# Rangeland Resource Management Technology Adoption among Agropastoral Households in South-Eastern Kenya: Its Influence on Factor Productivity and Poverty Alleviation

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## DECLARATION AND APPROVAL

This is my original work and has not been presented for a degree in any other university.

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## DEDICATION

This work is dedicated to God above,

My family below,

Morris and the family to be.

## ACKNOWLEDGEMENTS

I cannot take the credit for this work alone. I am indebted to several people who have contributed to the successful completion of this work in one way or another.

Firstly, I would like to thank God for the gift of life. Then I would like to thank the University of Nairobi for awarding me a scholarship to pursue my MSc. in Range Management. In doing this, they opened a door of opportunities for me. I also recognize the efforts of my supervisors, Prof. Dickson M. Nyariki and Prof. Nashon K. R. Musimba, who guided me throughout the study.

Secondly, I would like to thank the Agricultural Innovation in Dryland Africa (AIDA) for funding my research work. I extend my sincere appreciation to Florence Ngata (Assistant Chief Ngulu Sub-location) who made my stay there very comfortable despite the harsh climatic conditions. I cannot forget to thank Charles Ikutwa and my enumerators who assisted in data collection to ensure that the work was completed in time.

Thirdly, I would like to thank my family: My mother for moulding me into what I am and for believing in me always, my siblings, and my son Henry who cheerfully endured the emotional burden of being born by a student. Last but not least, I am highly indebted to my colleagues Mganga Zowe and Everlyne Kirwa for being a true brother and sister respectively.

May God reward you all.

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| | |
|---|---|
| AIDA | Agricultural Innovation in Dryland Africa |
| AMREF | Africa Medical Research Foundation |
| ASAL | Arid and Semi-Arid Land |
| CBO | Community Based Organisation |
| DHP | Dryland Husbandry Project |
| EPOS | Environmental Policy and Society |
| FAO | Food and Agriculture Organization |
| IPM | Integrated Pest Management |
| KARI | Kenya Agricultural Research Institute |
| KEFRI | Kenya Forestry Research institute |
| KES | Kenya Shillings |
| KWFT | Kenya Women Finance Trust |
| M &E | Monitoring and Evaluation |
| MOA | Ministry of Agriculture |
| MOLD | Ministry of Livestock Development |
| MOPND | Ministry of Planning and National Development |
| MPTs | Multipurpose Trees |
| NGO | Non-Governmental Organizations |
| OSSREA | Organization for Social Science Research in Eastern and Southern Africa |
| PH | Pioneer Hybrid |
| SHG | Self-Help Group |
| SPSS | Statistical Package for the Social Sciences |
| SHG | Sub-Saharan Africa |

## ABSTRACT

This study was motivated by the need to ascertain whether rangeland resource management technologies are suitable and relevant as alternative means to improved agro-pastoral production and livelihoods. Data were collected through formal interviews using a structured questionnaire in Ngulu Sub-location, Kikumbulyu Location in Kibwezi Division, from a systematically selected sample size of 80 agro-pastoral households.

Descriptive analysis revealed that there were differences in resource endowments between the adopters and non-adopters of rangeland resource management technologies. The adopters had larger pieces of land than the non-adopters. The adopters also had higher livestock numbers and more fixed assets than the non-adopters. A binary logistic regression was used to determine the factors that influence technology adoption. The analysis revealed that education level of household head, participation in project activities involved in the introduction of rangeland resource management technologies, type of information source, gender of household head and managerial skill requirement had significant effects on adoption.

The Cobb-Douglas production function was used to measure the effects of the factors of production among the agro-pastoral households. The results suggested that variable capital items, labour, land and farm implements have a significant contribution to output at 5% significance level. The results also implied that variable inputs and labour are profitable if expanded when compared to land and farm implements. The outcome showed that households in the study area and the non-adopters were experiencing increasing returns to scale while the adopters were facing a constant return to scale. The increasing returns to scale imply that the households in

general and non-adopters in the study area are producing at a very small scale, in other words, they apply too little of the variable inputs compared to fixed resource outlays. These farmers can make more output per unit if they increase the level of variable inputs or if they shift the fixed resource outlays to other types of production to match the variable inputs. For the adopters, constant returns to scale implied that by adopting these resource management technologies the farmers were operating at input efficiency locus and their output levels lie within the stage of rational economic production.

In conclusion, this study has demonstrated that grass reseeding, planting of multipurpose trees and water harvesting technologies adopted in the study area are suitable and relevant, and offer the means to improving agro-pastoral livelihoods by increasing earnings per unit area, food security and environmental conservation, thus leading to poverty alleviation. However, technology adoption is constrained by recurrent droughts, inadequate or non-existent framework of agricultural incentives, weak institutions and poor public services. The study therefore recommends the formation of farmer groups by farmers practising these technologies in order to access credit and stimulate their demand and adoption countrywide. There is also need to improve agricultural extension services through exchange visits, demonstrations and study tours. Furthermore, the study recommends the development of markets for the rangeland resource management outputs.

# CHAPTER ONE

# 1. INTRODUCTION

## 1.1 INTRODUCTION

There has been deepening crisis in Sub-Saharan Africa (SSA) with regard to its burgeoning human population and concomitant food insecurity, necessitating an increase in food production. Increasing food stocks in SSA would require that improvements be made in the efficiency of crop and livestock production, or the land area under cultivation be expanded. A large part of these endeavours will come from the drylands since opportunities for increased agricultural and livestock productivity in wet and fertile zones are getting fewer and land pressure in these areas is gradually pushing more and more people into the dryland zones. However, drylands are constrained by, among other things, their fragility and proneness to degradation (Musimba *et al.*, 2004; NEMA, 2005), the control of which would enhance agricultural production through the adoption of land-enhancing natural resource management technologies, in addition to other approaches.

Naturally, the productivity of the arid and semi-arid lands is low and its improvement may come less from technologies of the green revolution type (e.g., improved seed, fertiliser application, etc.) than from management innovations related to natural resource use, adapted to local circumstances (Nyariki, 1997). There is growing evidence that agricultural intensification in drylands is possible (Pinstrup-Andersen, 1994a) and development of improved agricultural technology through research, and the initiation of new land-use systems are some of the long term solutions to famine prevention, and the eradication of extreme poverty, associated food insecurity, and environmental protection (Pinstrup-Andersen, 1994b).

The adoption of new farming technologies is, therefore, essential if progress is to be made in turning agricultural activities into profitable ventures and enhancing farmers' abilities to overcome household food deficits. In some cases, however, introducing new technologies if poorly done may also cause undesirable impacts on resources. This will occur depending on the conditions under which the types of technology take place, existing land tenure system, as well as output and labour market conditions. Newly introduced technologies may lead to competition for resources between different enterprises. How farmers adapt to these changes, and how they ensure that improved agricultural production is realized, is ultimately dependent on the efficient use of the resources of production at their disposal in addition to the adoption of superior strategies in resource use to cope with the changes (Amara, *et al.*, 1998). Thus, sound resource use practices are an important aspect to consider in evaluating any newly introduced technologies and in designing public policies that increase farmers' chances of using resources efficiently in both the medium and long runs (Mwakalobo, 2000). What this implies is that any new strategies of resource utilisation and livelihood improvement in the dryland regions must be environmentally benign in terms of ecological sustainability, economically viable, technically feasible, and socially acceptable. They must also build on the best local, technical knowledge, and extend the previously existing livelihood systems (Safriel *et al*., 2002; Davies, 1996).

Three major land enhancing technologies were introduced in the mid 1990s in the study area by the Dryland Husbandry Project (DHP) of the University of Nairobi in collaboration with the Government of Kenya. These were reseeding of denuded land, tree planting and water harvesting. Reseeding involved sowing of locally growing perennial grasses—*Cenchrus ciliaris*, *Chloris roxburghiana*, *Enteropogon macrostachyus* and *Eragrostis superba;* tree planting involved establishment of multipurpose trees (MPTs); while water harvesting mainly entailed collecting and concentrating various forms of runoff from varying sources. These technologies enhance the land by reducing soil (or soil nutrient) loss through: the provision of ground cover and stabilising soils through the root system; increasing water retention thereby prolonging the cropping season; and reducing evaporation through the provision of shade. In addition to creating a suitable micro-environment for vegetable growing by improving the critical soil moisture supply, the establishment of trees, particularly MPTs, directly provides a source of food and feed; and the grasses increase biomass yield and composition beneficial to livestock production.

This study presents findings on resource access, productivity, and allocation efficiency among rangeland resource management technology adopter and non-adopter smallholder farmers in the study area. Specifically, it assesses the effect of technology adoption on resource access and utilization, compares the socio-economic conditions between adopter and non-adopter households, and, through the Cobb-Douglas production function analysis, determines the returns to scale and related factor productivity. The study also assesses the factors influencing adoption of the rangeland resource management technologies using a binary logistic regression. These findings should provide relevant insights into the guidelines of sustainable development and management of technologies in areas with similar conditions as the study area.

## 1.2 PROBLEM STATEMENT AND JUSIFICATION

A wide range of rangeland improvement technologies already exists and are being used successfully by farmers in Kenya. What is not evident is to what extent these technologies are influencing farmers' cultural, social and economic conditions. However, despite many promising technologies, some farmers often fail to adopt them (Knox and Meinzen-Dick, 1999). As a result, there is need to identify the determinants of technology adoption so that future projects and programs can address them properly. In addition to lack of adoption, the rangeland resource management technologies introduced in the study area have not been subjected to any impact assessment after the termination of DHP activities. Thus, there is need to assess whether existing technologies have had any impact on farmers' livelihoods. It is on this platform that this research was conceived, with special reference to resource management technologies adopted in one of the semi-arid areas of Kenya: Kibwezi District.

## 1.3 STUDY OBJECTIVES

### 1.3.1 Broad Objective

The overall objective of this study is to determine the factors influencing adoption of rangeland resource management technologies and economic impacts of using these technologies.

### 1.3.2 Specific Objectives

The specific objectives are to:

1. Investigate the contribution of grass reseeding, planting of multipurpose trees and water harvesting techniques to household factor productivity.
2. Determine the factors influencing adoption of rangeland resource management technologies.

3. Assess the contribution of rangeland resource management technologies to household income and food security and thus alleviation of poverty.

## 1.4 HYPOTHESES

The study tests the following hypotheses:

1. The productivity of resources used by adopters are higher than those used by non-adopters.
2. The rates of return from resources used by adopters are higher than those used by non-adopters.
3. An array of factors influence the adoption of range resource management technologies, including total land size, education level, household size, and access to information on available technologies.

## 1.5 SIGNIFICANCE OF THE STUDY

The social and economic analyses of rangeland improvement and rehabilitation technologies are important because African governments, non-governmental organizations (NGOs) and donors need information on the performance of these practices and how they contribute to household welfare in order to assess where and how they should continue investing in their development and dissemination. Data are needed on the financial and non-financial benefits of the practices, what works where and why, why some farmers within specific communities adopt and others do not, and who within the household reaps what levels of benefits.

Researchers and development practioners also need information on how farmers are using and modifying the practices and what problems they encounter, so that they can develop technologies and practices that better meet farmers' needs and circumstances. Similarly, policy makers need information on the influence of policy factors on the adoptability and performance of these technologies. For example, policy issues that constrain or enhance the provision of inputs that are required to carry out rehabilitation practices have a direct effect on how farmers react to these practices.

The conclusions drawn from this study will provide useful information to enhance the success of agricultural innovations in dryland Africa, and indeed any other related efforts that attempt to introduce practices for adoption in settings similar to those of the study area. Farmers themselves need information on the performance of rangeland improvement and rehabilitation practices in order to make informed decisions on whether to adopt them.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1 THE ECOLOGY OF KENYA'S RANGELANDS

The arid and semi-arid lands (ASALs) of Kenya comprise more than four-fifths of the country's total land surface and carry over 25% of the total human population and slightly more than half of the livestock population (Kariuki *et al.*, 1996). They are characterized by variable climatic conditions making the areas unsuitable for cultivation agriculture (Pratt and Gwynne, 1977). On the basis of moisture availability for plant growth, Kenya is classified as 88% arid to semi-arid (Milimo, 2004). Kenya's ASALs represent a very important socio-economic region.

Yet, in spite of the apparent potential socio-economic importance of the ASALs, they have been in the past marginalized due to lack of a clear understanding, by both policy makers and practitioners, about their ecological uniqueness. For example, past ASAL development plans were biased towards the cultivation of crops and since they inevitably failed, the region was perceived as unproductive. Although aridity is a major contributory factor to the special development challenges for the ASAL areas, recent research findings justify and support investment in the ASALs.

Land degradation and erosion are closely associated with human activities on rangelands through continuous population growth that accelerates degradation processes. This has especially occurred during the past 30 years with growing access to machinery to plough more rangeland or cut more trees. As the need for more food is growing, an increase of agricultural production and the number of livestock seems inevitable. Thereby, conversion of ecosystems such as forests and rangelands into productive land has resulted in loss of valuable rangeland. Ploughing of rangelands and their conversion into cropland has considerably increased. The soil condition and topographic status of these rangelands are not suitable for long-term agricultural production and are often abandoned after a short time.

Overgrazing due to excessive numbers of livestock in relatively small areas, adds to degrading management practices like untimely grazing. Taking into consideration the enormous extension of the rangelands, their ecological and economic value and their importance as means of improving standards of living of large numbers of people, it is obvious that improved management methods of rangeland resources are needed. These methods should consider conservation or restoration strategies, including reseeding of the range using grasses, water harvesting techniques and planting of multipurpose trees.

## 2.2 TECHNOLOGY ADOPTION

Adoption is a mental process through which an individual passes from hearing about an innovation to its adoption that follows awareness, interest, evaluation, trial, and adoption stages (Rogers, 1962). This five-stage model is called “the innovation-diffusion model”. Diffusion is defined in relation to the spread of an innovation at the aggregate level viewed over time. According to the economic constraints model (Aikens *et al.*, 1975), resource endowments are the major determinants of observed adoption behaviour, where lack of access to capital and inadequate farm size could significantly impede adoption decisions. The more technically complex the innovation, the less attractive it may be to many farmers. The decision of whether or not to adopt a new technology will be based on careful evaluation of a large number of technical, economic and social factors associated with the technology. The economic potential of a new technology in terms of yields, costs of production and profit is very important for the adoption decision. Typically, however, the economic impact of an innovation is not known in advance with certainty. Unfamiliarity with the new technology makes the initial impact on yields and input usage uncertain.

Concerning the situation of rural producers in developing and under developed countries like Kenya, the adoption of modern technology is urgently required to increase agricultural productivity so as to meet the increasing demand for food (cereals and animal products) for a rapidly growing population. The adoption of modern technologies, especially in subsistence farming, would be governed by a complex set of factors such as human capital, information, location, resource endowments and institutional support. Within this frame condition, farmers' decision depends on their needs, cost incurred and benefits accruing. These would be the major motivating factors for the acceptance or rejection of a particular technology (Karki, 2004).

## 2.3 DETERMINANTS OF ADOPTION

A variety of studies have attempted to establish the factors underlying the adoption of various technologies. As such, there is an extensive body of literature on the economic theory of technology adoption. Several factors have been found to affect adoption. These include government policies, technological change, market forces, environmental concerns, demographic factors, institutional factors, and delivery mechanism. *Market forces* include availability of labour, technology resource requirements, farm size, level of expected benefits, and level of effort required to implement the technology. *Social factors* may include age of potential adopter, social status of farmers, education level and gender-related aspects, household size, and farming experience. *Management factors* include membership to organizations, the capacity to borrow, concerns about environmental degradation and human health of farmers. *Institutional/technology delivery mechanisms* may include information access, extension services, and prior participation and training in resource management practices.

Some studies classify the above factors into broad categories: farmer characteristics, farm structure, institutional characteristics and managerial structure (McNamara *et al.*, 1991) while others classify them under social, economic and physical categories (Kabede *et al.*, 1990). Others group the factors into human capital, production, policy and natural resource characteristics (Wu and Babcock, 1998). Nowak (1987) brought in yet another category of classification. He categorizes factors influencing adoption as informational, economic and ecological. There is no clear distinguishing feature between elements within each category. Actually, some factors can be correctly placed in either category. For instance, experience as a factor in adoption is categorized under 'farmer characteristics' (McNamara *et al.*, 1991; Tjornhom, 1995) or under 'social factors' (Kabede *et al.*, 1990; Ghadim and Pannell, 1999) or under 'human capital characteristics' (Caswell *et al*., 2001). Perhaps it is not necessary to try and make clear-cut distinctions between different categories of adoption factors.

Besides, categorization usually is done to suit the current technology being investigated, the location, and the researcher's preference, or even to suit client needs. However, as some might argue, categorization may be necessary in regard to policy implementation. Extensive work on agricultural adoption in developing countries was pioneered by Feder *et al.*, (1985). Since then the amount of literature on this subject has expanded tremendously. Because of this extensive literature, this study has reviewed selected factors as they relate to rangeland resource management technology adoption.

## 2.4 MEASURING ADOPTION

The rate of adoption is usually measured by the length of time required for a certain percentage of members of a system to adopt an innovation. The extent of adoption on the other hand is measured from the number of technologies being adopted and the number of producers adopting them. The current study focuses on the rate of adoption of a specific number of technologies and the factors affecting it. Depending on the technology being investigated, various parameters may be employed to measure adoption.

Measurements also depend on whether they are qualitative or quantitative. For instance, in a study on factors affecting peanut producer adoption in Georgia, McNamara *et al.*,(1991) used the producer's decision to adopt or not to adopt and subdivided respondents into two groups: adopters and non-adopters. Similarly, farmers' perceptions have been examined in several studies including the study by Adesiina and Baidu-Forson (1995) and that by Tjornhom (1995). In the former, farmers' perception of characteristics of sorghum and modern varieties are taken into account. In the latter, farmer perceptions on harmful effects of pesticides on water quality, on health of individuals and on natural enemies of insects are sought. Baidu-Forson (1999) examined farmers' perceived utility from adopting half-crescent shaped earthen mounds - a land enhancing technology. While direct qualitative attributes are harder to measure, several studies have used estimates of probabilities (Shakya and Flinn, 1985; Harper *et al,* 1990; Green and Ng'ong'ola, 1993; Kabede *et al.*, 1990). In soliciting respondents' subjective perceptions, researchers capture the qualitative aspects that influence farmers' decisions probably because farmers' technology choices are based on their subjective probabilities (Feder *et al*, 1985). Farmers' perceptions are interpreted as perceived profitability of a technology and translate into more resources being devoted to it, hence adoption. The current study uses farmers' decisions to adopt or not to adopt and then subdivides respondents into two groups: adopters and non-adopters.

## 2.5 MEASURING IMPACTS OF ADOPTION OF NATURAL RESOURCE MANAGEMENT TECHNOLOGIES

Unlike traditional crop improvement research, where there is large documented evidence of impacts, there is a dearth of evidence of both overall and specific outcomes, intermediate and long-term impacts of natural resource management-based research. However, a lack of documented evidence does not necessarily imply lack of impact: it is often difficult in the short term to attribute the direct impacts/benefits of natural resource management research. As a consequence, M&E is now high on the agenda of many organizations, but few know how to generate relevant information for natural resource management-type initiatives (Thomas, 2005). While there are often cited valid reasons for not undertaking M&E within natural resource management research, such as complexity, it is essential to understand its contribution to enhancing agricultural productivity and sustainability, reducing vulnerability and ultimately alleviating poverty (Shiferaw *et al.*, 2005). In fact, Sayer and Campbell (2003) assert that M&E is the key to the adaptive project management, and reflective learning is required for successful natural resource management. Identification and development of an evaluation framework and appropriate impact indicators early in the research process is critical to ex-ante and ex-post assessment of progress and potential for impact (Douthwaite *et al*., 2003).

Impact assessment is seen as a tool for adaptation, learning and performance enhancement, providing data for further negotiation among stakeholders and for resource allocation decisions. Three types of assessment are required: ex-ante analysis to help set research priorities, continuous monitoring in order to make corrections during implementation and ex-post impact assessment to evaluate and attribute impacts. In the case of natural resource management, the latter involves substantial difficulties, as discussed in the literature (Shiferaw *et al.,* 2005). The current study is based on a ex-post impact assessment. A recent review of intergrated natural resource management research within the Consultative Group on International Agricultural Research (CGIAR) notes that it is increasingly clear to natural resource management programme evaluators that they must add appropriate indicators of both social and natural resource endowments and well-being to the limited, traditional economic indicators if they are to truly assess impacts (Harwood and Kassam 2003; Harwood *et al*., 2006).

## 2.6 METHODOLOGICAL APPROACHES FOR IMPACT EVALUATION

According to the Food and Agriculture Organization (FAO) (2000), impact refers to the broad, long-term economic, social and environmental effects resulting from intervention. Such effects generally involve changes in both cognition and behaviour. Casley and Lury (1985) defined impact as the determination of whether a program has desired effects on the individual, households and/or institution. There are two major approaches according to Pitt and Khandker

(1996), and Kerr and Kolavalli (1999) to evaluate the impact of a project intervention: (1) 'Before and After' approach. This approach compares the conditions of the same households before the project was introduced and after the termination of the project. (2) 'With and Without' approach which, compares the conditions of the farmers involved in the project with the conditions of the farmers without the project activities. The second approach is considered more appropriate in a situation where obtaining baseline data is problematic. Therefore, this approach was applied as a research methodology in this study.

## 2.7 PAST STUDIES THAT HAVE USED LOGIT MODELS

Various studies on adoption have been undertaken using logit models. Saito *et al.* (1994) analyses the factors that could raise the productivity of women farmers in Sub-Saharan Africa. The countries covered included Kenya, Nigeria and Burkina Faso. In Kenya, the study was undertaken in Kakamega, Murang'a and Kilifi. The findings of the study by Saito and others were that African farming was changing as women were growing crops, taking on tasks traditionally performed by men and making decisions on the daily management of the farm household.

In analyzing the factors influencing the adoption of improved technologies such as fertilizers, improved seeds and farm mechanization, their study made use of the logit model. The probability of adoption was used as the dependent variable while the explanatory variables considered included land, capital, education, age, gender, extension contact, ecological factors and infrastructural development. The results revealed that age, gender, education and extension contact significantly influenced the probability of adoption. The present study considers how the socio-economic factors influence adoption of rangeland resource management technologies.

In a study of maize technology adoption in the coastal lowlands of Kenya that covered Kwale and Kilifi Districts in 1998, Wekesa *et al.* (2003) defined adopters as those farmers who grew certified seed (coat composite, PH1, PH4 or pioneer hybrid) on at least one acre of land for the study year. They divided the sample population into adopters and non-adopters and compared them according to different variables using Chi-square tests. In their study, Wekesa *et al.* used logit models to study the effect of different factors on adoption, with the dependent variable being adoption of improved varieties and independent variables being farmers' resources (human and physical age of household head, education of household head and family size), external support systems (extension and credit), and technology and geographical characteristics. In their findings, adoption was negatively influenced by permanent labour and off-farm employment. Availability of cash, contact with extensionists, radio programs and credit were found to have a major impact on adoption. The study underscored the influence of institutional environment particularly extension and credit in adoption. The current study took a similar approach but did not consider geographical characteristics because the rangeland improvement technologies were introduced in the same area (Kibwezi Division) as opposed to the study by Wekesa *et al.* whereby the study concerned two districts.

Ouma *et al.* (2002) analysed the factors influencing adoption of improved maize and fertilizer use using maximum likelihood regression model and linear probability among three maize growing divisions in Embu District (Nembure, Runyenjes and Kyeni). The study covered two consecutive seasons in 1998. Fertilizer use was measured quantitatively while adoption was measured qualitatively. The logistic regression results suggested that gender, use of manure, agro-ecological zone and access to extension had significant impacts on adoption of certified maize seed. The age of a household head, education, farm size, group membership and credit did not have a significant impact on certified maize seed adoption. The linear model used to analyze the factors that influence fertilizer adoption concluded that hired labour, credit and education of household head had significant impact on adoption with education having a negative impact, for each increase in one year of schooling, fertilizer use declined by 7kg. For this study, the problem at hand was to determine the factors influencing the adoption of resource management technologies by agro-pastoralists. The study used the Logit model mainly because there was no reason to assume that cumulative normal distribution existed in the sample data, and also because the Logit model is computationally easier than the Probit to evaluate the decision by farmers to adopt or not to adopt rangeland resource management technologies.

## 2.8 PAST STUDIES THAT HAVE USED THE COBB-DOUGLAS PRODUCTION FUNCTION

The Cobb-Douglas production function (Cobb and Douglas, 1928) has been commonly used either singly (Donovan and Darroch, 1991, Bravo-Ureta and Evenson, 1994) or in combination with other functions (Fulgitini and Perrin, 1994; Widawsky, *et al.*, 1998) to analyze the efficiency of smallholder agricultural production. The Cobb-Douglas production function is linear in the logarithms, gives elasticities, permits calculation of returns to scale, is flexible, allows for the analysis of interactions among variables, and is empirically simple to apply (Byiringiro and Reardon, 1996; Kamanga, *et al*., 2000). The Cobb-Douglas production function provides the basis for estimating a log-linear regression model, in which the parameter estimates of the explanatory variables are their partial production elasticity coefficients, holding other variables constant (Gujarati, 2003). The parameter estimates (coefficients) indicate returns to scale (Parikh *et al*., 1995), which describe the output response to proportionate increases of all inputs (Bjorn and Salvanes, 1995). The Cobb-Douglas production function allows for the sum of these coefficients to be between zero and unity (Upton, 1979). Under these conditions, returns to scale are decreasing if the sum is less than one, constant if the sum is one and increasing if the sum is greater than one.

# CHAPTER THREE

# 3. METHODOLOGY

## 3.1 DESCRIPTION OF THE STUDY AREA

### 3.1.1 Geographical Location

The study area is in Ngulu Sub-location, located in Kibwezi Division of Makueni District (currently Kibwezi District after being cut off from Makueni District), Eastern Province of Kenya (see Figure 3.1). It is about 190km southeast of Nairobi (Rware, 2007). The area is located within Kikumbulyu Location and is about 12km to the North east of Kibwezi market. It is accessible through Kibwezi-Kitui road. This area was chosen because the rangeland resource management technologies (grass reseeding, planting of multipurpose trees and water harvesting) were introduced in this area by Dryland Husbandry Project.

### 3.1.2 Topography and Climate

The study area lies at an altitude of 900m above sea level and is classified as a semi-arid region. It receives bimodal rainfall with an average of 600mm annually and an average annual temperature of $23^0$C. Long rains are received in March to May and short rains from November to early January (Spaling *et al*., 2002). Short rains are more reliable in terms of time and spatial distribution than long rains, and are therefore more important.

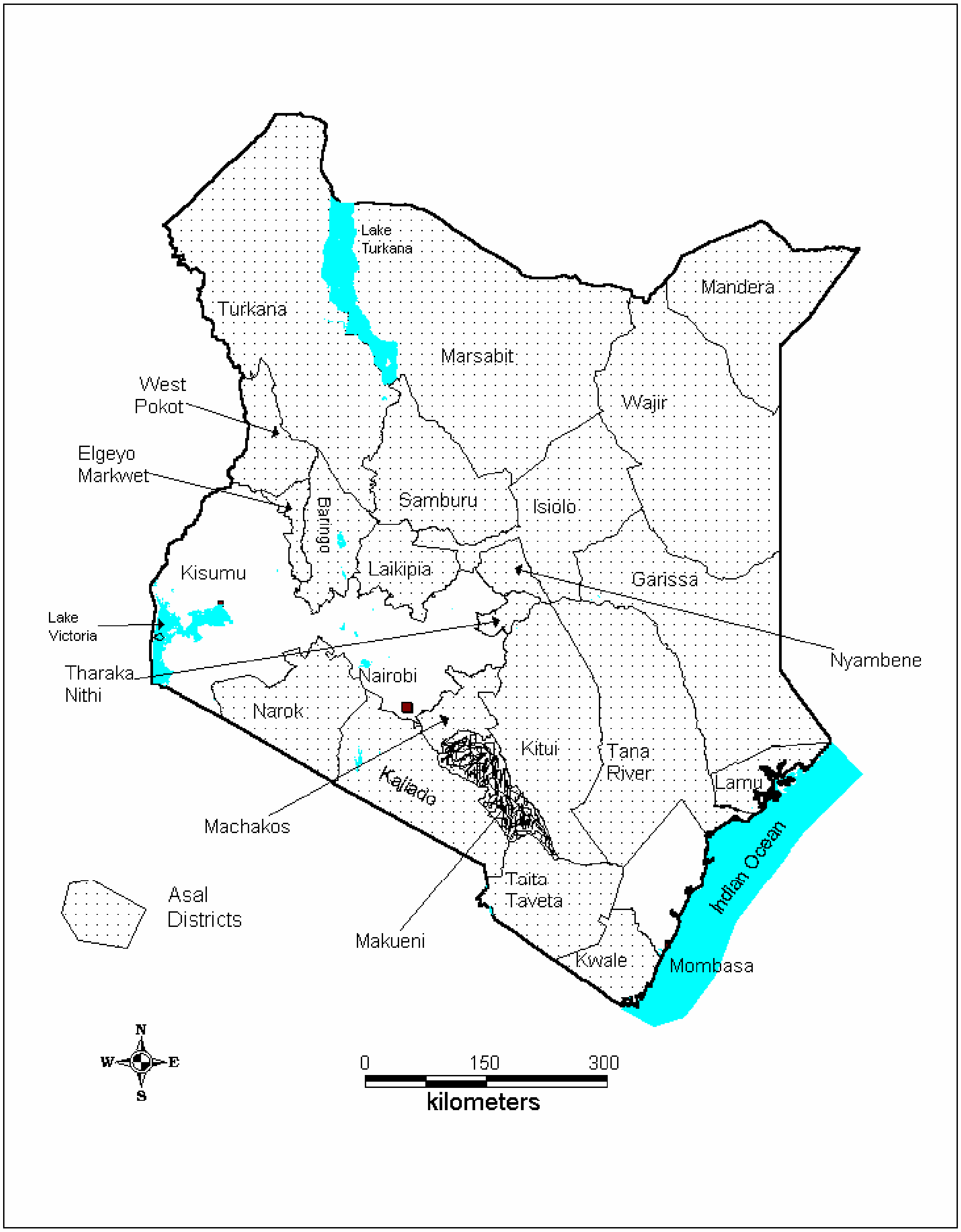



**Figure 3. 1: Location of Makueni District**

Source: Kenya ASAL Policy, 2004

### 3.1.3 Geology

Recent volcanic rocks and a basement complex system comprise the geology of the area. The rocks are broadly subdivided into basement system rocks, volcanic and superficial deposits

(Touber, 1983; Saggerson, 1963). Mostly low-lying plains, sloping gently eastwards toward the Athi River and broken by occasional hills and rivers, characterize the topography. Land rises slightly below 600m in the south to about 1,100m in the north (MDDP, 1993). Major land forms include the Chyulu hills in the southwest. The Kibwezi River drains in the project area as it flows into Athi River. The soils comprise ferrasols, nitisols, luvisols and cambisols (Michieka and Van Der Pouw, 1977; Touber, 1983). The ferrasols are found on flat interfluves and are well drained. Most of these soils are compact and have a massive structure with strong surface sealing which causes much runoff during heavy rains. Soils of floodplains and bottomlands range from calcareous to saline. On the south of Mombasa road, soils are of volcanic origin. These are shallow or very shallow, extremely stony to rocky and are highly permeable.

### 3.1.4 Vegetation

Vegetation in the area is influenced by a number of interrelated factors such as climate, geology, soil type and presence or absence of ground water. Kibwezi Division is a typical semi-arid savanna dominated by *Commiphora*, *Acacia* and allied genera, mainly of shruby habitat (Touber, 1983). Baobab trees (*Adansonia digitata)* are also common. Perennial grasses such as *Cenchrus ciliaris*, *Enteropogon macrostachyus* and *Chloris roxburghiana* can dominate but many succumb to continuous abuse over a long period. Bottomlands dominated by black cotton soils are characterized by *Pennisetum mezianum* at the lower storey and *Acacia drepanolobium* at the middle storey. Much of the original vegetation has been modified through cutting of trees, clearing, burning and grazing.

This study concerns Ngulu Sub-location within Makueni District. The exact study area is in Ngulu Sub-location, shaded in Figure 3.2.

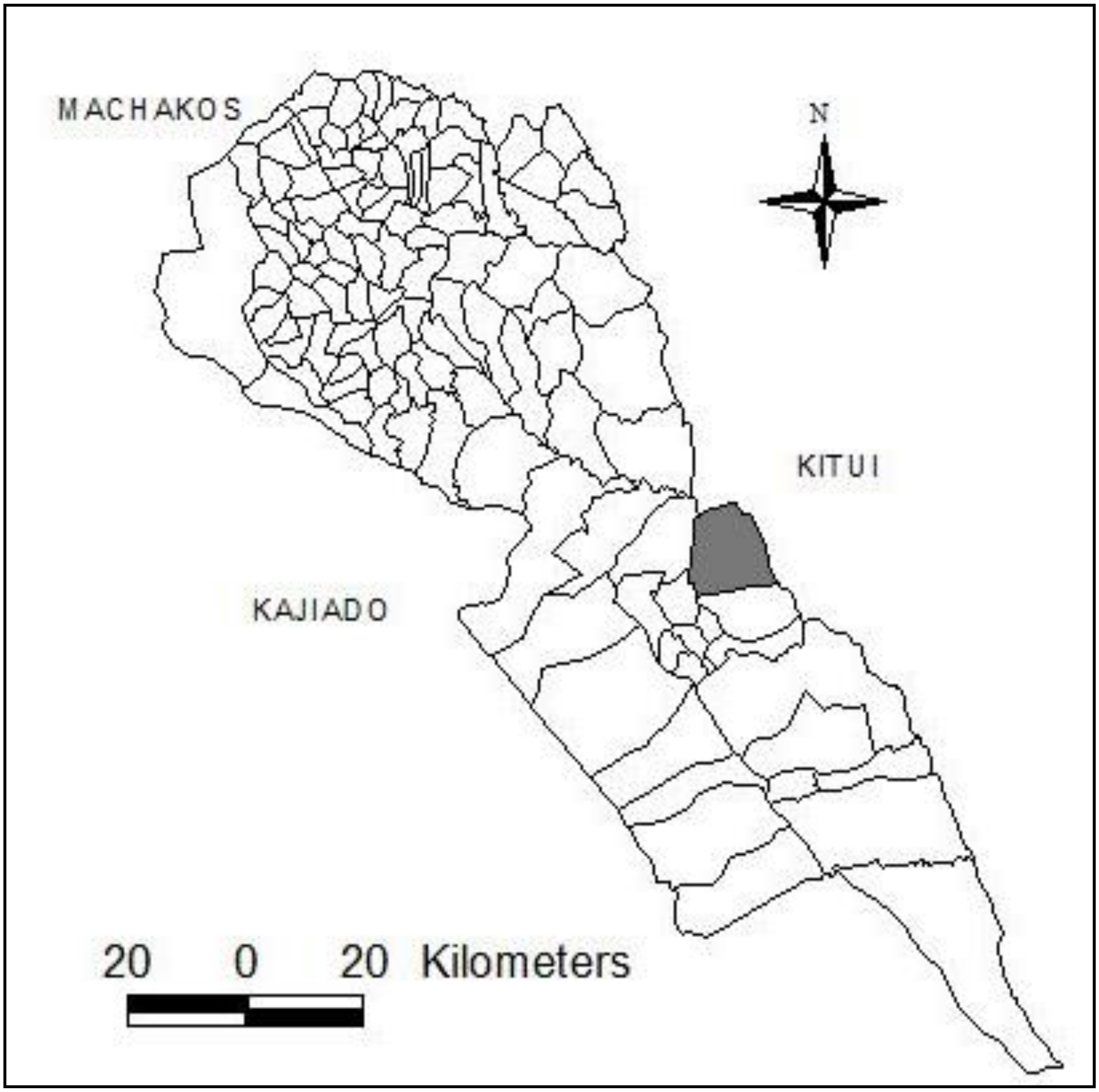



**Figure 3. 2: Location of study area in Makueni District (Shaded)**

Source: Kenya Bureau of Statistics, 1989

### 3.1.5 Main Land Uses and Potential

Land and soils have great potential for sorghum, millet, sisal and livestock production (Spaling *et al.*, 2002). Ranching and bee keeping are also present. The Athi River and its tributaries are used for some irrigation, notably at the University of Nairobi farm. The agro-climatic map classifies moisture availability as “V” (semi-arid), which means limited potential for plant growth and a high risk (25-75%) of maize crop failure (Spaling *et al.*, 2002). The study area also falls within temperature zones 1-2, implying warm to very hot temperatures. Rainfall and soil fertility are considered the main limitations for agriculture. Kibwezi forest is a local source of wood for building, fuel, carving and charcoal production, often without authorization from the Forestry Department. Sand harvesting and clay brick making are other important local economic activities. Umani Springs Camp, an ecotourism facility authorized by the Forestry Department, is also located in Kibwezi Forest Reserve.

## 3.2 DATA COLLECTION

### 3.2.1 Sources and Types of Data

Two main types of data sources were collected, primary and secondary data. These were both qualitative and quantitative. A questionnaire was administered by personal interviews in order to get responses with on-the-spot observations. Some respondents could not give quantitative information because it was not available. However, where it was felt there was need, qualitative data were also purposively gathered to describe the process. Additional data were collected from secondary sources such as previous research reports to complement the primary data.

### 3.2.2 Preparation of Questionnaire

Samples were selected and interviews were carried out using a questionnaire to provide cross-section data. A sample size of 80 households was chosen. This was done by taking into account the statistical requirement to have a minimum size of 30, the possibility of non-response and limited financial outlays and time. Further, the terrain in Kibwezi is difficult and the infrastructure is poor. Taking all these factors together, larger samples would have reduced the resources and as a result the quality of data collected would have suffered.

A draft questionnaire taking into account the objectives and the hypotheses was constructed before setting out to the field. The questionnaire took the 3 common forms: it contained dichotomous, multiple choice and open-ended questions. This was necessary because of diverse issues that were being investigated.

There was an effort to make each question simple and phrased in a manner that would imply the same meaning to all that were to be interviewed, that is, questions that would carry more than one meaning were avoided. Leading questions were avoided as they usually suggest the answer the interviewer wants to hear, and the respondent may agree with the interviewer simply because that is the expected response.

Sequencing of questions was such that the more sensitive ones such as those inquiring about family size, age and property ownership came later. These were held back until the time when the interviewer should have struck a rapport with the interviewee. Many questions were constructed in a way that allowed adequate room to make considered choices, so as to avoid forcing answers. The possibility for no response was borne in mind.

An effort was made to make the questionnaire as short as possible, including only the questions pertinent to the objectives of the study to avoid people becoming bored after answering an unending list of questions, which may also lead to incorrect answers (Nyariki, 1997). Most of the interviews took about one hour. (Further discussions on questionnaire preparation and other data collection tools and procedures can be found in Nyariki (2009).)

### 3.2.3 Pilot Survey

The questionnaire was tested in a pilot survey involving 15 households before it was used in the main survey. The 15 households belonged to the same area of survey but did not come from the main sample of 80. The main reasons for pre-testing the questionnaire were to decide on whether or not to exclude or modify some of the questions. This was done to ensure that the final questionnaire had only relevant and appropriately phrased questions to be put to the farmer. During the pre-testing exercise, informal gatherings were held to question them about mentioned operations.

### 3.2.4 Sampling Procedure

In Ngulu Sub-location, the sample of 80 households was interviewed. The preliminary survey procedures (informal discussions and a pilot survey) were carried out in February 2008 and the actual data collection was done in October, 2008. The villages were purposively selected based on the presence of adopters after which a sampling frame was prepared and systematic sampling was applied to the frame. This was done because Kibwezi Division is roughly homogeneous, large and has poor infrastructure and it was logistically difficult to reach all parts of the division. After the selection of villages was done, a list of 2,000 households was obtained from the area Assistant Chief. The names were numbered to form a sampling frame. Systematic sampling was then applied to the frame whereby every 25th farmer was selected to obtain 80 households. The starting number, which lay between 1 and 25, was randomly selected.

### 3.2.5 Aggregation of Output

This study involved aggregation of output. The main issue here was to determine the method and extent of output aggregation and the choice of a numeraire. Households grow a variety of crops and also keep livestock and therefore all output was converted to units of maize. This was done by applying the seasonal prices in the local markets of all goods, with respect to maize, to construct a known exchange rate as a means of conversion (see also Nyariki and Thirtle, 2000). Therefore, the output variable is a constructed series of maize equivalents. In the case of inputs, physical values included land area (in hectares) and household and hired labour (in adult-hours). The other inputs were expressed in terms of expenditures. These were variable capital costs (machinery hiring costs, fertilizers, seeds, and animal drugs) and farm implements. Managerial input was expressed as education level of the household head, which was used to rate the farmer’s skills by assuming that those with secondary education and above were skilled farmers while those with primary education and below were unskilled.

### 3.2.6 Identifying and Training of Enumerators

Data were obtained by personal interviews. This procedure usually requires the interviewer to ask prepared questions in a formal questionnaire and to record the respondent’s answers. The main advantage of this kind of interview is that people will usually respond when confronted in person. Further, the interviewer will be able to note specific reactions and therefore eliminate any misunderstanding that may arise from the questions being asked. The major limitations of personal interviews are the high costs involved. However, if the interviewers are not thoroughly trained and closely inspected, they may deviate from the required protocol, thereby introducing bias in the sample data collected.

Two enumerators with a minimum of an ‘O’ level certificate were recruited and trained in Ngulu Sub-location. These enumerators were, of necessity, recruited from the Akamba community due to the language barrier so that the information obtained would be as accurate as possible. As the enumerators were members of the villages surveyed, they were also useful in identifying the households selected.

### 3.2.7 Interviews

Interviews were done in the mornings and in the evenings, mostly for seven days a week. Three farmers were interviewed per day, that is, two farmers in the morning and one farmer in the evening. Initial visits were made with the intention of making appointments that were appropriate to the farmer. For those farmers who did not mind being interviewed on the first day, interviews were done. The interviews were taken in the local language (Kamba) and the questionnaire was filled in English.

### 3.2.8 Collection of Secondary Information

Secondary data were collected at the end of primary data collection because it was then that one could tell which important information had not been provided by the survey, and could be provided by secondary sources. The data were obtained from government departments in Makueni District and relevant ministries, such as, the Ministry of Agriculture (MOA), Ministry of Livestock Development (MOLD), and Ministry of Planning and National Development (MOPND). They were also collected from NGOs operating in the area surveyed such as Africa Medical Research Foundation (AMREF). Published sources also provided this information, which included climatic, administration and demographic data. Secondary information was also obtained by talking to organized groups of village elders through the assistance of the Assistant Chief.

## 3.3 METHODS OF DATA ANALYSIS

### 3.3.1 Descriptive Analysis

The data collected was analysed using Statistical Package for the Social Sciences (SPSS), a package that is mostly used for analysis of socio-economic data. Data collected through personal interviews and group discussions were subjected to descriptive statistical analysis. The information on general trends in social and economic status of the agro-pastoralists was summarized in terms of means, modes, frequency tables, charts and graphs and used to develop grass root indicators of technology adoption. The main objective for descriptive analysis was to have a detailed understanding of resource management technologies in the context of individual farmers and a diagnostic tool to analyse why problems occur and what potential exists for improvement.

### 3.3.2 Regression Analysis

Regression analyses were used to estimate a production function and to establish the factors that influence the decisions of agro-pastoralists so that appropriate policy evaluation could be undertaken depending on the regression coefficients. One of the objectives of the study was to investigate the adoption of rangeland resource management technologies and the factors that influence it. The Cobb-Douglas production function was estimated to establish the former while binary Logit model was used to establish the latter.

***3.3.2.1 Estimation of the Cobb-Douglas production function***

The Cobb-Douglas production function was used to test the hypothesis that "the productivity of and rates of returns from resources used by adopters were higher than those used by the non-adopters". A comparison was made of marginal (partial) productivity of the factors of production between the adopters and non-adopters of rangeland resource management technologies. The goal was to test for differences in returns to factors between adopters and non-adopters and find out if the adoption of rangeland resource management technologies leads to increased returns.

The Cobb-Douglas production function provides the basis for estimating a log-linear regression model, in which the parameter estimates of the explanatory variables are their partial production elasticity coefficients, holding other variables constant (Gujarati, 1995). The difference in marginal output between the two groups was computed from the production function. In addition, the costs and returns of production and productivity of the two groups (with- and without-technology) were determined. The Cobb-Douglas production function was also used to measure the effects of labour, farm implements, other variable inputs including seeds and agrochemicals (fertilizers, herbicides and insecticides), area of land under agricultural production, and managerial skills on output.

The non-linear Cobb-Douglas production function may be expressed as:

$$Q_i = \beta_0 X_i^{\beta_1} e^{\mu_i}$$

This model can be transformed into a linear model in the logs (ignoring the i and introducing more explanatory variables) as shown in the following specific equation:

$$\text{Ln Q} = \alpha + \beta_1 \text{Ln} X_1 + \beta_2 \text{Ln} X_2 + ... + \beta_5 \text{Ln} X_5 + \mu \qquad (1)$$

Where:

Q = household total/aggregate output in terms of maize-equivalents (in ‘000 kg per hectare per year).

$\alpha$ = intercept.

$X_1$ = amount of farm labour (‘000 Kshs per hectare per year) measured as the value of the number of mandays employed per household per year.

$X_2$ = value of farm implements owned at un-depreciated initial cost (‘000 Kshs per hectare per year).

$X_3$ = variable capital costs (machinery hiring costs, fertilizers, seeds, and animal drugs) used (‘000 Kshs per hectare per year).

$X_4$ = area of land used for agricultural production in hectares.

$X_5$ = managerial skills represented by the level of education.

$\beta_1, \beta_2, \ldots, \beta_5$ are the parameter estimates (coefficients) and represent the relative proportion of maize equivalents contributed by the various inputs, $X_1$ through $X_5$ ,defined above and indicate the elasticity of output with respect to changes in the input variables.

$\mu$ = error term.

*3.3.2.2 Description of variables included in the Cobb-Douglas production function*

In the Cobb-Douglas production function formulation shown in Equation (1), the factors of production were selected *á priori* taking into account the farming system in the study area. A preliminary correlation analysis of a number of variables for which data were available was carried out and an appropriate choice of the variables to be included in the model was made. These variables are briefly described below.

**Output** (the dependent variable) was measured in physical units of weight. As already noted, households grow a variety of crops and also keep livestock species. All output was converted to units of maize equivalents to construct an aggregate output. This was done by applying the seasonal prices in the local markets of all goods, with respect to maize, to obtain a known exchange rate as a means of conversion (see also Nyariki and Thirtle, 2000). The output was in '000 kg per hectare per year. The average market price paid in the study area was used in the conversion of all other outputs to maize equivalents.

**Labour** is an important factor of production, particularly in peasant agriculture which is labour-intensive. This factor is expected to influence the adoption of natural resource management technology since extra labour is required beyond what is needed for farming. Thus, if labour is limited, it is likely to discourage the adoption of these technologies. Labour was mainly provided by members of the farm family. For each enterprise, labour inputs were recorded for major operations such as planting, weeding and harvesting. Labour appeared to be a limiting factor only at harvesting time. The total value of farm labour used was considered.

**Variable capital costs** here refer to non-labour variable input costs. These were computed for all the enterprises per household. They included costs of seeds, animal drugs, pesticides especially for trees, and hiring of machinery. Fixed capital inputs, on the other hand, consisted of relatively simple farm implements such as an ox-plough, tractor drawn implements or hoes. As an index of a farmer's fixed capital inputs, the value of farm implements at un-depreciated initial cost was used.

**Land** is perhaps the single most important factor of farm production. The size of land is likely to affect the adoption of natural resource management technology in such a way that the smaller the land the higher the pressure to take up land-enhancing technologies that improve production to achieve household food security. Land was measured in terms of the area under agricultural production. This involved the farm size available for all the enterprises a household undertook. Land was assumed to be of the same quality, that is, the effect of soil type was not considered.

**Managerial skills** are known to be closely associated with formal education of individuals (Ngugi and Nyariki, 2005). Managerial skills were represented by the education level of the household head. This was used to rate the farmer's skills by assuming that those with secondary education and above were more skilled while those with primary education and below were less skilled.

#### *3.3.2.3 Logit model*

Adoption behaviour, the phenomenon we seek to model, is considered discrete rather than continuous in nature. In this case, the dependent variable takes a limited set of values. These are cases where the dependent variable can be characterised as binary, taking the value of 0 or 1. The dependent variable thus takes the value of 1 if technology has been adopted and 0 if not. The regressand in these circumstances is the decision to adopt a particular technology on the one hand and the decision not to adopt on the other hand.

A form of qualitative response model is required to analyse this phenomenon. Binary choice models such as the Logit or Probit are often used in modelling adoption decisions (CIMMYT, 1993). These are techniques for estimating the probability of an event (such as adoption) that can take one of two values (adopt or do not adopt). The basic difference between the two models is that Logit assumes a cumulative logistic distribution, while Probit model assumes cumulative normal distribution. Generally the interpretation of the two models is similar. A related model is the Tobit, which is used to determine the factors influencing the probability and intensity of adoption.

For this study, the problem at hand was to determine the factors influencing the adoption of resource management technologies by agro-pastoralists. The study used the Logit model mainly because there was no reason to assume that cumulative normal distribution existed in the sample data, and also because the Logit model is computationally easier than the Probit to evaluate the decision by farmers to adopt or not to adopt rangeland resource management technologies.

The following general equation represents the base model:

$$\mathrm{Y}_i = \alpha + \beta \mathrm{X}_i + \mu_i \qquad (2)$$

$i = 1, 2, \ldots, N$

Where:

$Y_i$ = the dichotomous (dummy) dependent variable for household i representing adoption or non-adoption.

$X_i$ = the $i^{th}$ observable explanatory variable.

$\alpha$ = captures the household specific unobservable explanatory variables.

$\beta$ = the estimation parameter.

$\mu_i$ = the error term ($\mu_i \sim (0, \sigma^2)$) of unknown effects on the dependent variable.

Because of the dichotomous dependent variable proposed in Equation (2), the Logit formulation is regarded as one of the most suitable model. In order to estimate the Logit model, the dependent variable is transformed by taking natural logarithms of both sides to yield ‘log odds’. The natural logarithm of the odds ratio is called the Logit (Gujarati, 1992; Pindyck and Rubenfeld, 1991).

The Logit model can be written as:

$$\mathrm{L_i} = \mathrm{Ln}(P_i / 1 - P_i) = Y_i = \alpha + \beta X_i + \mu_i$$

Where $L_i$, the log of the odds ratio, is the Logit;

$P_i$ is the probability of an event occurring; and

$1\text{-}P_i$ is the probability of the event not occurring.

In the present study, the Logit model was estimated using the maximum likelihood method through the use of the Statistical Package for Social Sciences (SPSS) software.

#### *3.3.2.4 Selection and measurement of variables used in the Logit model*

The variables used in the Logit model were derived from the adoption literature (Lionberger, 1968; Asambu, 1993; CIMMYT, 1993). Not all the variables in the adoption literature were included in the regression analyses. Those included maximized the predictability of the model, while those that reduced the model predictability were excluded. These variables represented household characteristics (education of household head, gender of household head, household size, off-farm employment, and management of the farm); and institutional characteristics (market availability, participation in project activities, and type of information source).

The formulation of the Logit model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to either adopt or reject rangeland resource management practices at any point in time is influenced by the combined effects of a number of factors related to farmer's objectives and constraints. The variables in the model were hypothesized to influence the adoption of resource management technologies positively or negatively. The hypothesized variables are briefly described below.

**Level of education of household head:** Farmers who have some years of schooling are easier to deal with when it comes to dissemination of agricultural innovations. Education level was therefore hypothesized to positively influence adoption of the resource management technologies. This variable was measured by ranking using ranges from 1-4 (1 = no education, 2 = primary education, 3 = secondary education and 4 = tertiary education).

**Off-farm employment:** Farmers with off-farm employment are assumed to have a higher total income than those who depend on farm output only. Higher income was hypothesized to positively influence the adoption process. Farmers with off-farm income were given a value of one while those without off-farm income a value of zero.

**Gender of household head:** Female and male farmers are likely to play different roles in technology adoption, depending on the nature of the technology. The effect of this variable may either be positive or negative. The variable was measured by allocating male-headed households a value of one and female-headed a value of zero.

**Type of information source:** Information from various sources may have a different impact on farmers' perception of farming practices. For 'exotic' practices such as grass reseeding, information from research sources such as Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI) and University of Nairobi may be more influential than information from neighbours and friends or from media sources. These latter sources however may be important in adoption of practices like water harvesting which are not new to the farmers. This variable was measured by ranking where (1 = DHP, 2 = Neighbours, 3 = KARI, 4 = KEFRI and 5 = MOA).

**Household size:** This variable represents the number of people who lived in the households for at least nine months during the year 2007/2008, the relevant period for the current study. Larger households are able to provide more labour that might be required to water trees as well as to construct water harvesting structures (see Nyariki *et al.*, 2002). It was therefore hypothesized that the larger the household size, the higher the probability of adoption of rangeland resource management practices. It was measured in terms of the number of residents present.

**Participation in project activities:** The farmers who had participated in DHP's project activities were likely to adopt the resource management practices because they were privileged with material and managerial support. This variable is assumed to have a positive effect on the adoption of resource management technologies. Farmers who had participated in the project activities assumed a value of one while those who had not a zero value.

**Managerial skill requirement:** The purpose of this variable was to test whether the uptake of rangeland resource management technologies required high or low managerial skills. It was hypothesized that managerial skills are directly related to the level of education. This variable was represented by a proxy where the high requirement was given a value of one and the low requirement a value of two.

**Market availability:** Farmers who had a ready market for outputs from resource management practices had a better opportunity to adopt these practices than those who did not have. It was hypothesized that market availability is likely to positively influence the adoption process. This variable assumed a value of one for those with a ready market and a value of zero otherwise.

### 3.3.3 Problems of Estimation

Greene (1993) noted that it is rare for data that a researcher has in hand for estimating a regression model to conform exactly to the theory underlying the model. A number of problems will arise, even in the most carefully designed surveys. The most commonly experienced data problem is multicollinearity.

Multicollinearity refers to the presence of linear relationships (or near linear relationship) among the explanatory variables (Koutsoyiannis, 1973). Since economic data are unexperimental, many econometric variables tend to move together in a systematic way and hence are termed as collinear. As a result, hypothesis testing becomes weak so that diverse hypotheses about parameter values cannot be rejected (Kennedy, 1985). The seriousness of its effect depends on the degree of intercorrelation as well as the overall regression coefficient. As such standard errors and the overall coefficient of determination ($R^2$) may be used for testing for multicollinearity. As noted by Greene (1993), the presence of high multicollinearity implies that the estimates of coefficients will be imprecise owing to large variances of the estimators.

In the current study, multicollinearity was examined through inspection of signs and magnitudes of the parameter estimates and use of partial correlation coefficient (see Appendixes II and III). Kennedy (1985) stated that a value of 0.8 or higher in one of the correlation coefficients indicates a high correlation between the two independent variables to which it refers. Based on this criterion, the Pearson correlation coefficient in the current study indicated that the age and education level of a household head were highly correlated. This necessitated the removal of the age variable, which had shown a lower significance level, from the logistic regression.

It should be pointed out that there is, however, no easy solution to the problem of multicollinearity (see for example, Greene, 1993 and Gujarati, 1995). On the one hand, including the collinear variables will increase the variance of the estimator while, on the other hand, the exclusion of the variables will introduce bias in the estimator.

# CHAPTER FOUR

# 4. RESULTS AND DISCUSSIONS

## 4.1 GENERAL DESCRIPTIVE ANALYSIS

This study covered Kibwezi Division, in Kibwezi District, South-eastern Kenya. The actual survey took one month, between the months of October and November, 2008. A baseline survey had been carried out for one week between March and April, 2008 to identify adopters and non-adopters. The final sample size of 80 agro-pastoral households was systematically selected.

### 4.1.1 Household Access to Land and other Basic Resources

A household was defined as all people who live under one roof and are subject to decisions made by the household head. A household head was defined as the person who is the owner of a major resource, notably land. Survey responses were obtained from 80 households (22 females and 58 males) from 8 villages in Ngulu Sub-location. The respondents were agro-pastoral with 100% crop cultivation and 99% livestock production. Total land area owned by producers was approximately 551 hectares. Majority of the respondents (58.8%) had bought their land while 41.3% had inherited the land they owned from their relatives. The results imply that the respondents had bought a large proportion of the land they used for farming. This is because this area was not settled until the late 1970s when squatters were settled in this area and majority of them bought their land (Musimba *et al.*, 2004).

The average household size was 7 people. The mean farm labour of 3 household members shows that about half of the household members worked on the farm. Ten percent of the producers borrowed to finance farming activities, while those who did not borrow cited credit unavailability as a major obstacle to credit acquisition. The agro-pastoralists obtained information on resource management technologies from a number of sources, including the Ministry of Agriculture (MOA) staff, friends, neighbours, and NGOs. Other information sources included self-help groups, newspapers and University of Nairobi researchers. Thirty eight percent of interviewed households belonged to self-help groups. Less than 50% of the farmers hired labourers to work on their fields. Payment for this labour took on many forms, including in-kind (live animals and/or part of farm produce), cash or exchange of labour. Tables 4.1 and 4.2 show and compare the means of the main household socio-economic characteristics for sampled households.

**Table 4. 1: Summary statistics of some continuous variables**

| **Variables** | **Total (N=80)** | | **Adopter (N=49)** | | **Non-adopter (N=31)** | |
|---|---|---|---|---|---|---|
| | **Mean** | **Std. Dev.** | **Mean** | **Std. Dev.** | **Mean** | **Std. Dev.** |
| Farm size (ha) | 6.9 | 3.9 | 8.4 | 4.2 | 4.5 | 3.2 |
| Variable capital costs | 8,452.5 | 4,407.6 | 8,477.6 | 4,444.8 | 8412.9 | 4421.0 |
| Total output in kg maize equivalents | 4,268.4 | 4115.3 | 4,710.2 | 4,511.3 | 3570.2 | 3348.6 |
| Family members available for work | 3.3 | 1.5 | 3.2 | 1.5 | 3.4 | 1.6 |
| Family members working off-farm | 1.4 | 1.1 | 1.3 | 1.3 | 1.4 | 1.0 |
| Household size | 7.3 | 2.3 | 7.3 | 2.5 | 7.4 | 3.1 |

**Table 4. 2: Summary statistics of some non-continuous variables**

| Variables | % Total (N=80) | % Adopters (N=49) | % Non-adopters (N=31) |
|---|---|---|---|
| Access to credit (% yes) | 10.0 | 88.0 | 12.0 |
| Access to extension services (%yes) | 15.0 | 75.3 | 24.7 |
| Participation in project activities (% yes) | 30.0 | 96.0 | 4.0 |
| Access to incentives (% yes) | 6.3 | 100.0 | 0.0 |
| Market availability (%yes) | 59.3 | 40.7 | 11.3 |
| Membership to SHGs (% yes) | 38.8 | 70.9 | 29.1 |

### 4.1.2 Participation in Project Activities

Thirty percent of the agro-pastoralists had participated in various DHP-Kenya project activities, which had been introduced in the study area. Among the 30% who had participated in these activities 96% were the adopters while 4% were non-adopters. This shows that participation in project activities had an influence on the adoption of resource management technologies. This is because farmers who were involved in the project had a higher probability of applying innovations. These farmers were privileged with material and managerial support, followed by timely availability of knowledge. The skills acquired during this process helped them apply the new technologies as innovators and early adopters. The results of the current survey were also supported by focus group discussion results where training offered by DHP officials was mentioned as the main driver for adoption of these resource management technologies.

### 4.1.3 Household Socio-economic Characteristics and Technology Adoption

The relationship between household socio-economic characteristics and resource management technology adoption was investigated with respect to characteristics such as age of household head, level of education of household head, farm size and off-farm income. Table 4.3 shows off-farm income by respondents. The results show that 64% of the respondents earned less than KES 5,000 per month, with 9% having over KES 15,000 per month. The results reveal that most of the low-income earners, those with less than KES 5,000 off-farm income, were the adopters. This shows that farmers with no off-farm employment are likely to adopt the resource management technologies so as to diversify their income sources. Another reason for this may be the high labour requirement of these technologies such that the adopters have no time for off-farm jobs. Non-adopters cited high labour requirement for multipurpose trees that was not compensated for by low returns and long waiting-time for these returns to be realized as the reasons for lack of adoption. Another likely reason for this is the recurrent drought that leads to drying up of plants before maturity. The results imply that off-farm employment may be playing an important role in the adoption of rangeland resource management technologies.

**Table 4. 3: Off-farm income by respondents (KES)**

| Income levels | Frequency (N=80) | % of total sample | % Adopters | % Non-adopter |
|---|---|---|---|---|
| 0-5,000 | 51.0 | 64.0 | 40.0 | 24.0 |
| 5,001-10,000 | 12.0 | 15.0 | 5.0 | 10.0 |
| 10,001-15,000 | 10.0 | 12.0 | 4.0 | 8.0 |
| Over 15,000 | 7.0 | 9.0 | 2.0 | 7.0 |

**Education level of household head:** Respondents had education level ranging from 1-4, with the larger being the higher. About 56.3% of the respondents had completed primary school. The household heads without formal education accounted for 13.8% of the sample while those with tertiary education were 2.5% of the total sample; all of these were non-adopter. Among the 56.3% who had acquired primary education, 66.6% were adopters of rangeland resource management technologies while 33.4% were non-adopters. For those without formal education, 54.3% were adopters while 45.7% were non-adopters. This implies that majority of the respondents had only basic education and the adoption of these technologies was based on their farming experience rather than their level of education.

**Age of household head:** According to the survey, majority of the respondent farmers' ages in the study area were in the age class of 31-50 years (57.5%). The youngest respondent was in the age class of 18-30 (10%) while the oldest farmer was in the age class of over 50 years (32.5%). Majority of the adopters were in the age class of 31-50 years, and accounted for 57.1% of all adopters. This could be due to the social norms on land ownership where only married sons are allowed to farm part of the land after marrying. Another likely reason may be that the younger people are more receptive and more ready to try new ideas/technologies. This finding is in conformity with the results of Olale (2006) who found out that the adoption of soil fertility management technologies in Machakos, Makueni, and Kitui Districts was by those who were in the age class of 31-50 years. Among the 32.5% of the respondents who were aged over 50 years, 61.5% were the adopters while 38.5% were non-adopters. This clearly shows that adoption was taken up by the people who were over 30 years of age, which is a relatively young age.

**Total farm size:** The survey showed that the average farm size owned by respondents was 6.9 hectares with a standard deviation of 3.9. The minimum farm size was 0.4 hectares and the maximum was 40.8 hectares. About 58.8% of the farmers had bought their land while 41.4% of them had inherited their land from their relatives. The major form of land tenure in the study area was individual ownership, meaning that there was secure land tenure and farmers could adopt the rangeland resource management technologies without fear of land tenure insecurity. This may be the reason why 61.3% of the respondents were adopters of resource management technologies. By grouping the agro-pastoralists into terciles based on their farm sizes, 47.5% of them were found in the lower tercile with less than 4 hectares. Among these, 63.2% were non-adopters while 36.8% were adopters. The upper tercile consisted of farmers with over 20 hectares of land (8.8%), and all these were adopters of rangeland resource management technologies. These results suggest that majority of non-adopters were natural resource poor farmers because they owned very small pieces of land. Thus, the adopters were relatively rich in natural resource endowment. Since land is an important production factor, land size is likely to have a significant influence on the adoption of resource management technologies.

**Gender of household head:** About 72.5% of the households were male-headed and the rest were female-headed. Among the male-headed households, 63.9% of them were adopters while 36.1% were non-adopters. However, in female-headed households, 54.5% were adopters while 45.5% were non-adopters. This shows that there is no much difference between the adopters and non-adopters among female-headed households while there is a clear difference between the adopters and non-adopters among male-headed households. A large proportion of the adopter farmers were therefore male-headed households. These results are similar to those of Volenzo (2006), whose study was dealing with the adoption of soil fertility improvement practices in a labour-intensive farming system, similar to the current study. The results suggest that the gender of the household head is likely to influence the adoption of rangeland management technologies.

**Household size:** The average household size in the study area was 7 people, with a standard deviation of 3. The minimum household size was 2 and the maximum was 13 people. The larger the household size the higher the availability of labour for farm activities. Among the adopters, the average household size was about 7 people, similar to the average among the non-adopters. This result implies that household size is likely to have no effect on the adoption of rangeland resource management technologies.

**Hired labour use:** Among the agro-pastoralists, 36% of the households hired labour, while the rest did not. Majority of those who were able to higher labour, 72%, were the adopters. This indicates that a large proportion of the agro-pastoral population was not able to use hired labour and they depended on family labour. Despite the higher labour requirement of the resource management technologies, majority of the adopters were not able to use hired labour on their farm. This was associated with low income levels (poverty) such that they cannot afford hired labour. These findings from the survey were also supported by the focus group discussion results. Inadequate labour availability may be a major hindrance to the adoption of rangeland resource management technologies.

The survey revealed that resource management technologies were labour intensive and on average required more labour than conventional farming. This is in agreement with Alexandra (2000) who in his study of organic vegetable growing in Vihiga found an increase in labour load. However, the results conflict with those of Hamilton (1997) who found no significant difference in labour use between conventional and the adoption of organic techniques in maize production.

**Livestock ownership:** About 99% of the farmers in the study area owned livestock. All the farmers grew crops, indicating that the farmers in the study area were agro-pastoralists. The largest ethnic group in the study area is the Kamba. According to Munro (1975), they depend partly on a pastoral and agronomic economy to meet most of their needs.

### 4.1.4 Institutional Characteristics

The relationship between institutional factors and adoption of resource management technologies was investigated with respect to access to extension services, credit access, availability of market and incentives. These relationships are discussed in the following paragraphs.

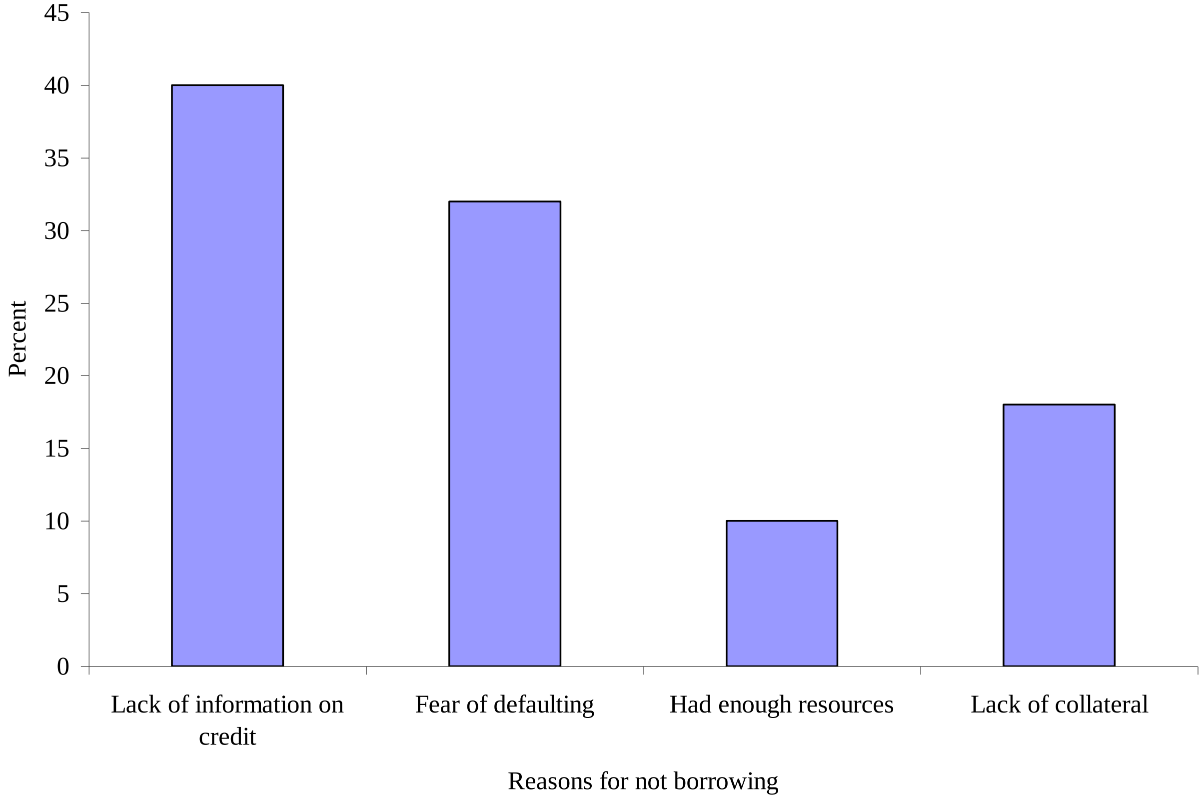
**Access to agricultural extension services:** From the survey results, 15% of the farmers received on-farm extension. Only one farmer in the study area had attended demonstration tours during the previous one year and this reflected lack of information dissemination tools in the study area. Among those who received extension services, 75.3% were adopters while the rest were non-adopters. A larger percentage of those who received extension services were the adopters. This implies that extension services are likely to play an important role in influencing adoption of resource management technologies (Semana, 2002). Extension service in the study area was provided by both public agencies and NGOs as shown by the survey results. There may be need for more extension services to be provided concerning the resource management technologies if adoption is to be increased.

**Membership to self-help groups (SHGs):** The survey results showed that 38.8% of the farmers were members of a self-help group. Of the total farmers who were members of these groups, 70.9% were adopters while the rest were non-adopters. This implies that membership to self-help groups could influence the adoption of the resource management technologies since most technologies are introduced through organized groups. Information gap on resource management technologies was clearly evident in the study area. The approach of working with groups rather than individual households is based on the assumption that farmers' groups promote the sustainability of innovations introduced (Mazur *et al.*, 2007).

Membership to self-help groups has helped farmers to participate in training and agricultural events, which have formed a major source of knowledge and skills applied in resource management technologies (Gichinga and Malevu, 2003). Through the same groups, the farmers make use of 'economies of cooperation', especially when they have activities which are labour intensive. Farmers who involved themselves in groups indicated that it enhances their interaction capability with other people outside their communities like the donors because of the exposure they get from the groups. These groups have assisted in improving the social welfare of the members through increased household goods such as utensils and through rules and regulations of the groups which enhance discipline among members.

**Access to credit:** The survey results showed that 10% of the respondent farmers had access to credit for farming activities in the previous one year, while the rest did not. The credit in this particular case was received from the Kenya Women Finance Trust (KWFT) (10%). Majority of those who received credit (88%) during the previous one year were adopters. Thus, only 12% of the non-adopters had received credit. This shows that credit might be a major production constraint in the study area and was likely to influence the adoption of the rangeland resource management technologies negatively. The low credit use was attributed to lack of information on credit sources and the need for collateral (58% of the respondents). Only 10% of the respondents claimed to have an adequate source of own funds and found no need to borrow (see Figure 4.1).

**Figure 4. 1: Households reporting reasons for not borrowing in percentages**




**Incentives:** Only 6.3% of the respondents received incentives in the form of free seeds, fully sponsored tours, field days and other forms of training on rangeland resource management techniques during the previous one year in the study area. Thus, 93.7% of the respondents did not receive any incentive. All the farmers who received incentives were adopters of rangeland resource management technologies, implying that incentives played a great role in influencing the adoption behaviour of farmers. The reasons given for adopting the resource management technologies by those who had not received incentives were the need to diversify sources of livelihoods, the need for continuous source of livestock feed, the availability of grass seeds locally, the fact that grasses can withstand drought more than crops, training, and curiosity.

**Type of information source:** Hypothetically, in the adoption of agricultural technologies, farmers pass through a series of stages, namely awareness, interest, trial evaluation and adoption (Rogers, 1983). The source of information for respondents is shown in Table 4.4. The DHP was named as the most used type of information source followed by neighbours and KARI respectively. The results suggest that the type of information source plays an important role in adoption. The study revealed that neighbours played an important role in dissemination of information about rangeland resource management techniques because 31.3% of the respondents heard about these techniques from their friends. This implies that farmer-to-farmer learning is important in dissemination of information about resource management technology adoption (see also Mazur *et al.,* 2007)

**Table 4. 4: Type of information source**

| Sources | Frequency | Rank | % |
|---|---|---|---|
| DHP | 28.0 | 1 | 35.0 |
| Neighbours | 25.0 | 2 | 31.2 |
| KARI | 11.0 | 3 | 13.8 |
| KEFRI | 8.0 | 4 | 10.0 |
| MOA | 8.0 | 5 | 10.0 |

**Marketing of produce:** Marketing plays an important role in agricultural production and adoption of technology. Market access depends on many factors such as marketing channels, marketing infrastructure and information availability to consumers and producers alike. Literature shows that poor marketing and low prices act as a disincentive towards the adoption of technology and vice versa. The poor marketing strategy of resource management produce acts as a disincentive and was said to be a reason for lack of adoption in some households. About 71% of non-adopters cited poor marketing as the reason for lack of adoption while 73.5% of the adopters cited lack of markets for the outputs from the rangeland resource management technologies as a major drawback to adoption. According to the survey results, organizations promoting resource management technologies such as KARI had initially assisted in marketing but later withdrew forcing some farmers to lose interest in these techniques.

### 4.1.5 Summary Characteristics of Adopters and Non-adopters

Within the final sample of 80 households, 49 households were adopters of the rangeland resource management technologies while the rest were non-adopters. This accounts for 61.3% adopters in the sample. Most of the adopters (57.1%) were in the age class of 31-50 as it was the case in the sample population. Among the adopters, 61.2% had acquired at least primary education. The characteristics of the adopters and non-adopters are summarized in Table 4.5.

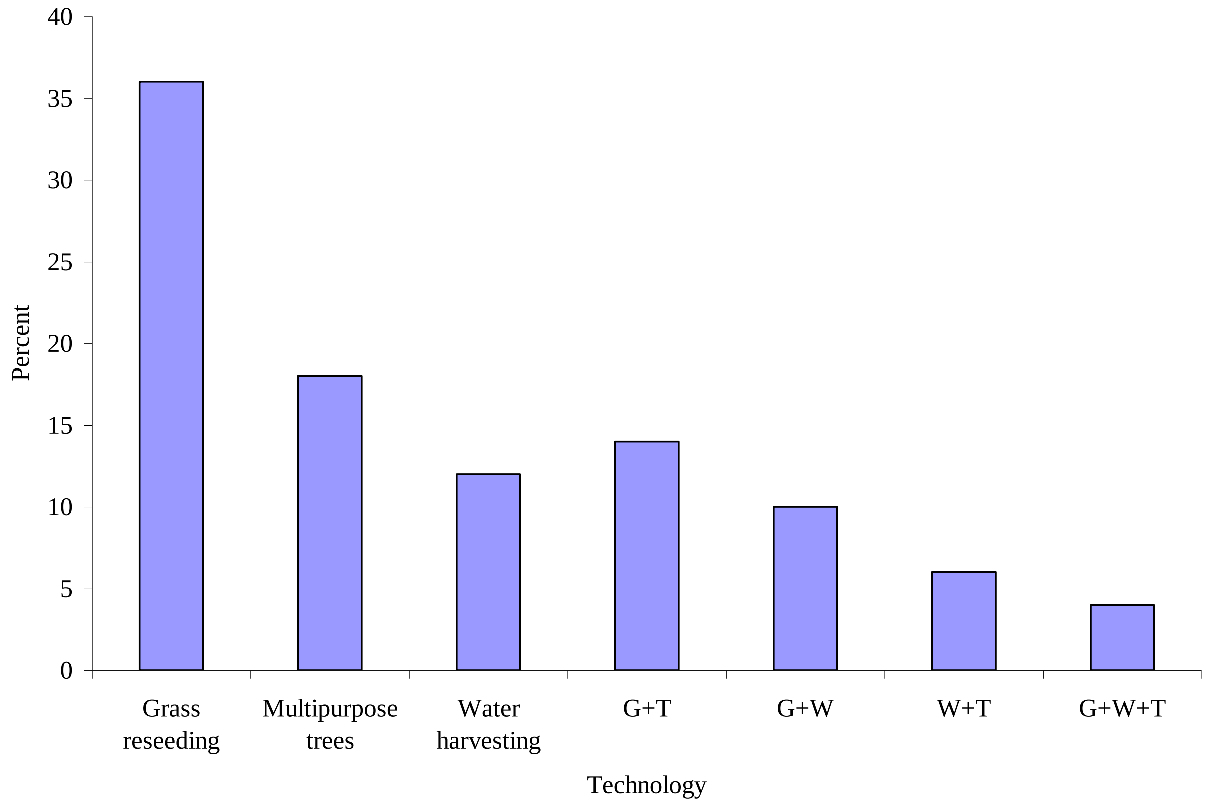
**Table 4. 5: Summary statistics on adopters and non-adopters**

| Variables | % Total sample | % Adopters | % Non-adopters |
|---|---:|---:|---:|
| Access to extension (% yes) | 15.0 | 75..3 | 24.7 |
| Membership to SHGs (% yes) | 38.8 | 70.9 | 29.1 |
| Access to credit (%yes) | 10.0 | 88.0 | 12.0 |
| Food secure (% yes) | 32.7 | 76.5 | 23.5 |
| Participation in project activities (% yes) | 30.0 | 96.0 | 4.0 |
| Access to incentives (% yes) | 6.3 | 100.0 | 0.0 |
| Market availability (% yes) | 27.5 | 59.3 | 40.7 |

### 4.1.6 Resource Management Technologies Used

Though there were many rangeland resource management technologies that were introduced in the study area by DHP-Kenya project, this study focused on only three technologies, that is, grass reseeding, planting of multipurpose trees and water harvesting. The last included both roof-top and run-off water harvesting for crop production. Among the 49 adopters, 61.2% were practicing grass reseeding, 42.9% were planting multipurpose trees, and 32.7% had water-harvesting structures. This shows that there were some farmers who were practicing more than one technology, with the aim of diversifying their sources of income. The adoption of various rangeland resource management technologies is shown in Figure 4.2.

**Figure 4. 2: Percent adoption of various rangeland resource management technologies**




Note: G+T = Grass reseeding + Multipurpose trees, G+W = Grass reseeding + Water harvesting, W+T = Water harvesting + Multipurpose trees, and G+W+T =Grass reseeding + Water harvesting + Multipurpose trees

### 4.1.7 Area Planted with Trees and Grass

The area planted with grass for all the adopters was ranging between 0.2 and 3.2 hectares with a mean of 0.8 while that under multipurpose tress was ranging between 0.2 and 10 hectares. The area planted is low and reflects the small land holdings, and labour input constraints. The area under trees is larger because, as per the survey results, multipurpose trees are more profitable than grass reseeding in the long term. For multipurpose trees the income was ranging between KES 3,000 and KES 100,000 while for grass reseeding the income ranged between KES 360 and KES 7,000. This implies that if all constraints were removed multipurpose trees would be preferred to grass reseeding. This is because, in the study area, livestock production is secondary to crop production. As a result, the grass which was intended for livestock feed is currently used for other purposes such as thatching of houses and granaries.

### 4.1.8 Income Generating Activities

Various income-generating activities were examined as summarized in Table 4.6. Crop farming was found to be the main source of income for households, contributing 65% of the total income of the adopters. Charcoal burning and livestock keeping which had contributed 12% and 9% to income respectively followed. Other sources were non-farm wages, sale of resource management produce (fruits, grass, water and milk) and farm labour. The comparison of the average income of adopters and non-adopters of resource management technologies showed that the sale of resource management produce was an additional source of income for adopters unlike the non-adopters.

The total household income generated from all activities was found to be higher among adopters (KES 45,000) compared to non-adopters (KES 29,000). Income from livestock was also found to be higher among the adopters. Thus as income rises, households can be expected to invest in more livestock. With increased and stable incomes (in other words, reduced poverty) through product sales and wages, and with the availability of markets for exchange, improved food access is possible (Nyariki *et al*., 2002). Comparatively, therefore, the non-adopters are poorer than the adopters, implying that the adopters are more food secure by having higher total income.

**Table 4. 6: Respondents' average income in KES**

| **Activities** | **Adopters** | | **Non-adopters** | |
|---|---|---|---|---|
| | **Income (KES)** | **%** | **Income (KES)** | **%** |
| Crop farming | 29,250.0 | 65.0 | 17,400.0 | 60.0 |
| Livestock keeping | 4,050.0 | 9.0 | 1,740.0 | 6.0 |
| Charcoal burning | 5,400.0 | 12.0 | 4,930.0 | 17.0 |
| Non- farm wages | 1,350.0 | 3.0 | 2,030.0 | 7.0 |
| Bee keeping | 900.0 | 2.0 | 290.0 | 1.0 |
| Farm labour | 1,350.0 | 3.0 | 2,610.0 | 9.0 |
| Sale of resource management products | 2,700.0 | 6.0 | - | - |
| **Total** | **45,000.0** | **100.0** | **29,000.0** | **100.0** |

### 4.1.9 Explaining Differences in Household Characteristics by Resource Endowment

This section investigates differences in a number of household characteristics in the study area based on the level of output. All output was converted to units of maize. Households were subdivided into three groups (terciles) based on the output per household (kg of maize equivalents) in the previous one year. The lower tercile included those households with 0-2,590 kg maize equivalents, middle tercile fell within households with 2,591-5,180 kg and the upper tercile with 5,181-7,770 kg maize equivalents. The mean values of the various variables were then computed and compared. The variables were used as indicators of differences in resource endowment between the households in the lower and upper terciles. These differences are shown in Table 4.7.

The table shows that the two groups of households had no difference in terms of education level of the household heads. Majority of the household heads had only acquired primary education. The households with low output (lower tercile) had less farm sizes than the households in the upper tercile. This indicates that the size of the farm was likely to have an influence on the output a household could get. Both the value of variable capital costs and the value of farm implements were higher in the upper tercile than the lower tercile. This shows that for a household to get high output, it had to invest more on variable inputs as well as fixed resources. This is also supported by the higher number of livestock (units) kept by the households in the upper tercile than the lower tercile. Households with low output had higher household sizes than those with more output. This indicates that although larger households imply more labour availability, their labour was not reflected in the output they got during that year. The likely reason is that the larger households are likely to offer their labour for sale. This result implies that household size is likely to have no effect on the household output. About 62.5% of the adopters were in the upper tercile while the rest were in the lower tercile. These results on the whole show that the adopters were better endowed than the non-adopters.

**Table 4. 7: Differences in household characteristics by resource endowment**

| Characteristics | Lower tercile | Upper tercile |
|---|---|---|
| Output (kg maize equivalents/household) | 1,043.8 | 6,633.8 |
| Education level of household head | 2.0 | 2.0 |
| Farm size (hectares) | 0.7 | 1.3 |
| Value of farm implements | 9,500.4 | 12,629.5 |
| Value of variable capital costs | 7,479.7 | 19,200.0 |
| Livestock units/household | 2.5 | 6.3 |
| Household size | 5.0 | 3.0 |

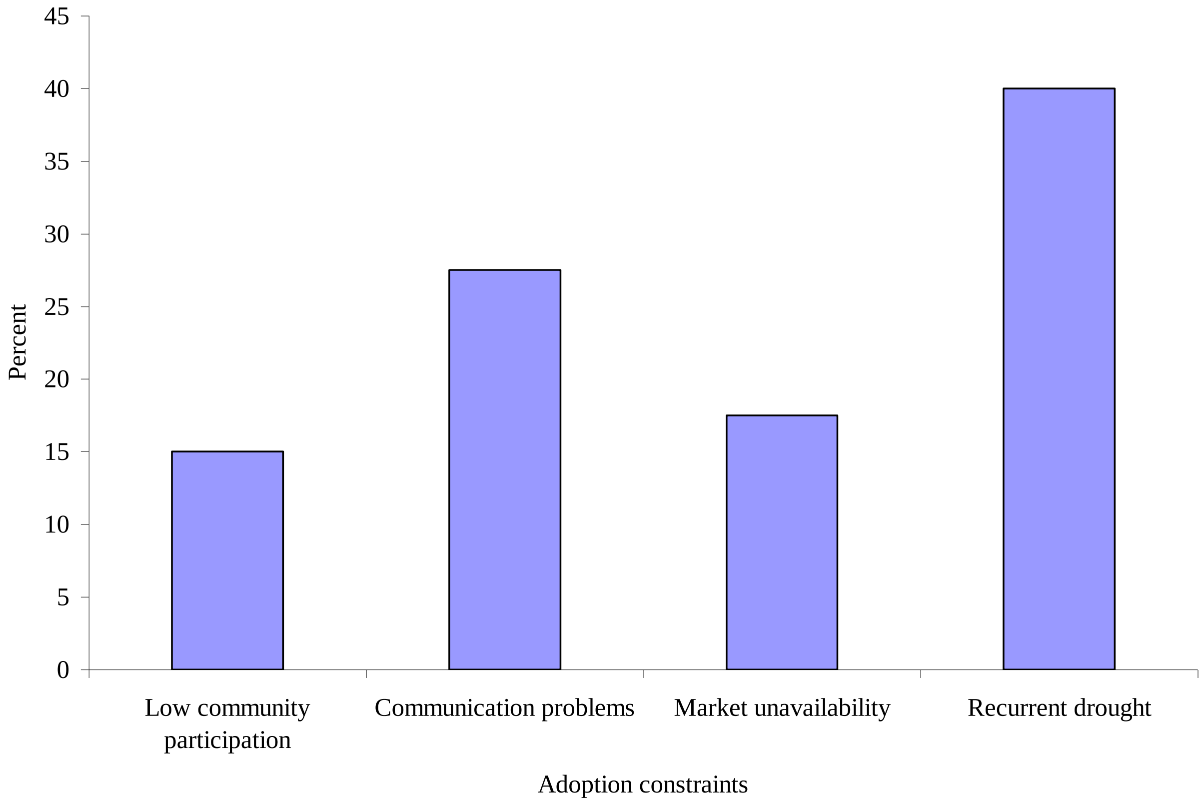
### 4.1.10 Constraints to Adoption of Rangeland Resource Management Technologies

Significant progress has been made towards improving the livelihoods of the people in the study area against a background of a wide range of challenges and constraints; some of which are unique to ASALs. They include climatic, infrastructural, economic and technical constraints that hinder them from adopting the resource management technologies. Figure 4.3 represents these constraints as reported by the households.

#### *4.1.10.1 Communication problems*

Communication infrastructure in the study area is generally poor and ranges from poorly maintained roads to poor or non-existent postal and telecommunication services. This has led to insufficient contact time between the research scientists and technology end-users. It has also had a negative impact on market availability because of poor roads, leading to middlemen exploiting the farmers due to high transportation costs involved. Lack of farm inputs in shopping centers and at the farm level is also attributable to communication problems.

**Figure 4. 3: Households reporting adoption constraints (in percentages)**




#### *4.1.10.2 Low community participation*

In spite of the great enthusiasm shown by the DHP officials in the dissemination of rangeland resource management technologies, community participation in technology development, adoption and up-scaling is still wanting. The community in the study area has been exposed to a wide range of donors and seems unwilling to participate in activities that do not have immediate benefits. This dependency syndrome serves as a hindrance to sustainable participatory development efforts (Karanja *et al.*, 2004).

#### *4.1.10.3 Recurrent drought*

The ASALs of south-eastern Kenya are characterised by poor rainfall, high temperatures, strong winds, sandy soils and sparse vegetation (Swanepoel, 2002; Tadecha, 2003). Droughts vary in scale and intensity, and are likely to become more frequent and more intense given the predictions of climate change. Drought frequency in the study area has increased from once after every ten years to once after every two years, according to the survey results. These frequent droughts discourage the farmers from adopting the rangeland resource management technologies. This is because, even if they adopt them, the moisture content in the soil is too low to support the trees or grass to maturity, leading to a loss because the returns are always lower than the cost of inputs. This implies that there is need for irrigation infrastructure in this area in order for these technologies to be sustainable in the long run and to help improve the livelihoods of the people living in this area.

The recurrent droughts are also associated with scarcity of water for domestic use and also the emergency of termites which cause the drying up of trees. The farmers indicated the need to exploit underground water sources such as boreholes in addition to piped water. With this water, it would be easier for them to diversify their sources of livelihoods through the adoption of resource management technologies and also to try and grow vegetables for home consumption as well as for sale.

#### *4.1.10.4 Marketing of rangeland resource management products*

Marketing is closely associated with infrastructure. Even when the farmers had adopted these resource management techniques, it was evident that there was no market for grass seed, hay, timber and fruits in the study area; and when they found a market, the prices offered were very low. The lack of effective demand for the commodities the farmers produce is a major problem affecting the ability to pay for technological innovations (Deuson and Day, 1990). This is a major disincentive to the adoption of rangeland resource techniques.

#### ***4.1.10.5 Low income levels***

It was clear that the agro-pastoralists in the study area are low income earners from the focus group discussion results. This was a major hindrance to the adoption of rangeland management technologies. There were some farmers who were interested in trying these technologies but they were constrained by their incomes. There were also those who had adopted some of these techniques such as planting of trees but could not afford to hire labour or buy farm inputs such as pesticides, leading to drying up of the trees. In addition to the low income, the culture of the Kamba community also discouraged some of its members from adopting these techniques. This is where some members were ignoring changing land tenure systems, for example, and continued to operate as if land was communally owned. Because of their ignorance, they have often allowed their animals to destroy the improved pastures and planted trees.

### 4.1.11 Summary Differences between Adopters and Non-adopters

From the survey and focus group results, it was clear that adoption of the resource management technologies had led to specific differences between the adopters and non-adopters. The adopters had diverse sources of income through the sale of timber, hay, grass seed and fruits. Their animals were also healthier than those of the non-adopters because they had access to enough feed despite the current drought. This was because those farmers who had improved pastures on their farms were able to harvest hay and grass seeds as opposed to crops where there was total crop failure in the 2008 short rains.

The adopters also were said to have a higher number of bee hives that were occupied by bees because there was enough bee forage on their farms. This was an additional source of income for the adopters because they could sell the honey or use it for their own consumption. Through the adoption of the rangeland management technologies, the adopters' degraded land had been restored and there was improved soil fertility through leaf fall which provided organic matter. This had led to increased crop yields on their farms in years of reliable rainfall amounts. Through water harvesting techniques, the adopters were able to save on time wasted on long queues in water kiosks at the nearby Kathyaka market. These results are supported by those obtained by Rware (2007) who studied the social impacts of Kisayani community water projects in Kibwezi Division.

From the differences between the adopters, and non-adopters it is reasonable to conclude that the adopters are better endowed and are more food secure than the non-adopters. This is because of their increased incomes as well as the output per unit area. Their healthy animals can produce products which are readily consumed or exchanged in order to purchase food.

#### 4.1.12 Why Continue Planting Maize despite Failures

The participants in focus group discussions cited the major reason for continuing to plant maize despite frequent failures. They averred that maize was their staple food and there was no reason for abandoning it. The respondents being agro-pastoral indicated that agronomy was their way of living and could not change from it. The aftermath of the maize crop was a source of livestock feed. So, even if there was no crop harvest, their animals were able to get some feed. The past successes also drive the farmers to remain optimistic that one time the harvest will be good. It was also clear that farmers needed to be convinced that new technologies promised better returns so that they would adopt them and change from their way of living.

## 4.2 RESULTS OF REGRESSION ANALYSES

### 4.2.1 Cobb-Douglas Production Function Estimates

The estimates of the Cobb-Douglas production function are presented in Table 4.8. As shown by the corresponding t-values, four out of the five explanatory variables were significant. The adjusted $R^2$ value was high and indicated that 64.7% of the total variation was explained by the variables. The F-statistic was significant at 5% level and therefore indicated that the variables as a group had a significant influence on the output. Substituting the coefficients in Table 4.8 in Equation (1), the Cobb-Douglas production function can be expressed as:

$$LnQ_{Sample} = 2.843 + 0.464\,LnX_1 + 0.177\,LnX_2 + 0.578\,LnX_3 + 0.272\,LnX_4 + 0.020\,LnX_5$$

**Table 4. 8: Estimated coefficients of Cobb-Douglas production function (whole sample n=80)**

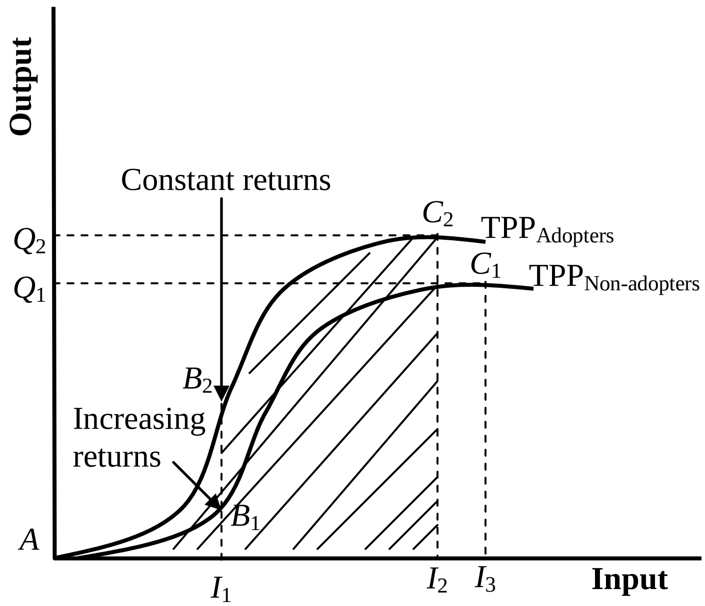
| Variables | β | SE | t |
|---|---|---|---|
| Constant | -2.843 | 1.038 | -2.740* |
| Value of farm labour, $X_1$ | 0.464 | 0.099 | 4.665* |
| Value of farm implements, $X_2$ | 0.177 | 0.091 | 1.944* |
| Variable capital costs, $X_3$ | 0.578 | 0.141 | 4.110* |
| Area of land under production, $X_4$ | 0.272 | 0.140 | 1.938* |
| Managerial skills, $X_5$ | 0.020 | 0.191 | 0.103 |

Notes: * Significant at 5%, F=29.900,* $R^2$=0.669, Adj. $R^2$=0.647, Returns to Scale= IRS=1.5

The parameter estimates represent the relative proportion of output in terms of maize equivalents contributed by unit increase in the respective variables (Urama and Mwendera, 2005). The results showed that labour costs, costs of farm implements, variable capital costs and land had a significant contribution to the output at 5% significance level. This implied that a percentage increase in investment on these variables by farmers would increase farm output by 46.4%, 17.7%, 57.8% and 27.2% respectively. The results suggested that variable inputs and labour inputs were profitable if expanded when compared to implements and land. This finding supports that obtained by (Urama and Mwendera, 2005) who assessed rice output from irrigated and rain fed fields in Swaziland. The difference in their study was that they used three inputs to assess the output. In the current study, the return to management was low and statistically insignificant, although management is an important production factor. This might have been as a result of the method of measurement, using education level as a proxy for skills.

The agro-pastoral system in the study area was experiencing increasing returns to scale because of the sum of elasticity coefficients of 1.5. This implied that these agro-pastoralists were operating in stage one of their production function (see Figure 4.4), which is an irrational stage of production. They were operating at a very small scale relative to available bundle of resources, and there was room for them to increase their production by making more efficient use of their variable inputs. In other words, the agro-pastoralists were using too little of the variable inputs in relation to fixed resource outlays and could get more output per unit if they increased the use of variable inputs. Another option would be to shift the fixed resources to other types of production to match the variable input.

**Figure 4. 4: Production Functions Illustrating Returns to Scale for Adopters and Non-Adopters of Natural Resource Management Technologies**




***4.2.1.1 Comparing factor productivity between adopters and non-adopters***

The Cobb-Douglas production function was used to measure the effects of labour costs ($X_1$), costs of farm implements ($X_2$), variable capital costs ($X_3$), area of land under production ($X_4$) and managerial skills ($X_5$) used on output. The following results were obtained from the data collected from the survey in Kibwezi. By substituting the coefficients in Tables 4.9 and 4.10 in Equation (1) the Cobb-Douglas production functions for adopters and non-adopters can be expressed as shown in Equations (3) and (4):

$$LnQ_{Adopters} = -2.690 + 0.306\,LnX_1 + 0.006\,LnX_2 + 0.891\,LnX_3 + 0.006\,LnX_4 - 0.191\,LnX_5 \qquad (3)$$

$$LnQ_{Non-adopters} = -6.653 + 0.325\,LnX_1 + 0.696\,LnX_2 + 0.536\,LnX_3 + 0.049\,LnX_4 - 0.003\,LnX_5 \qquad (4)$$

The parameter estimates represent the relative proportion of output (in maize equivalents) contributed by unit increases in the respective variables. The results showed that for adopters of rangeland resource management technologies in Kibwezi, only the value of labour and variable capital costs had significant contributions to output at 5% significance level, with production elasticities of 0.306 and 0.891 respectively. This implied that a percentage increase in investment on labour and variable inputs by the adopters would increase farm output by 30.6% and 89.1% respectively.

**Table 4. 9: Estimated coefficients of Cobb-Douglas production function (Adopters n=49)**

| **Variables** | **β** | **SE** | **t** |
|---|---|---|---|
| Constant | -2.690 | 1.943 | -1.384 |
| Value of farm labour, $X_1$ | 0.306 | 0.128 | 2.389* |
| Value of farm implements, $X_2$ | 0.006 | 0.063 | 0.101 |
| Variable capital costs, $X_3$ | 0.891 | 0.221 | 4.031* |
| Area of land under production, $X_4$ | 0.006 | 0.239 | 0.025 |
| Managerial skills, $X_5$ | -0.191 | 0.316 | -0.604 |

Notes: * Significant at 5%, F=9.364*, $R^2$=0.521, Adj. $R^2$=0.466, Returns to scale=CRS=1.0

**Table 4. 10: Estimated coefficients of Cobb-Douglas production function (Non-adopters n=31)**

| **Variables** | **β** | **SE** | **t** |
|---|---|---|---|
| Constant | -6.563 | 2.407 | -2.727* |
| Value of farm labour, $X_1$ | 0.325 | 0.158 | 2.062* |
| Value of farm implements, $X_2$ | 0.696 | 0.312 | 2.234* |
| Variable capital costs, $X_3$ | 0.536 | 0.240 | 2.333* |
| Area of land under production, $X_4$ | 0.049 | 0.333 | 0.148 |
| Managerial skills, $X_5$ | -0.003 | 0.384 | -0.007 |

Notes: * Significant at 5%, F=8.734*, $R^2$=0.636, Adj. $R^2$=0.563, Returns to scale=IRS=1.6

The results suggested that variable inputs were profitable if expanded when compared to labour inputs (Upton, 1973). The returns to farm implements, land and management for the adopters were rather low and statistically insignificant. For the non-adopters three out of the five variables were significant at 5% level. These were labour cost with a production elasticity of 0.325, cost of farm implements with a production elasticity of 0.696, and variable capital cost with a production elasticity of 0.536. Compared to the production function representing the adopters, the elasticity of production for labour costs had increased while that of variable capital costs had reduced. The pattern of significance of variables had changed from that of the adopters, but the return to variable costs was higher for the adopters than for the non-adopters. These findings were of special importance to farm credit policy targeting and other farm management policies for the affected technologies. Increasing access to variable inputs was central to improved productivity to both the adopters and the non-adopters in similar systems and areas to Kibwezi.

The independent variables of the model specified ($X_1$-$X_5$) explained 46.6% of the total variation in the dependent variable (output Q), for the adopters and 56.3% of the variation for the non-adopters. This implied that the model did not capture 53.4% and 43.7% of the total variation in the adopters and the non-adopters respectively. These were subsumed in the stochastic variable ($\mu$). The implication was that there was still more to the productivity problems that could not be explained in the present analysis.

It may be interesting to note that, in the present analysis, land costs and managerial skills were not significant for both the adopters and the non-adopters though they are important factors of production. This outcome suggests that land and skills are not limiting factors compared to other factors of production. It implies that too much land, for example, is used compared to other resource outlays. On the other hand, the influence of variable costs and labour costs were positively significant at 5% level for both the adopters and the non-adopters. One imminent policy intervention that could boost productivity for both the adopters and the non-adopters, would therefore be improving the access to variable inputs (seeds, drugs, insecticides and fungicides) and labour by farmers.

This study further adopted the Cobb-Douglas production function in order to find the returns to scale and the impacts of factors of production on output. The sum of the elasticities of response was one for the adopters, thus suggesting constant returns to scale. However, the sum of elasticities was 1.6 for the non-adopters, which implied increasing returns to scale. The results support the set hypothesis, thus the hypothesis that "the productivity of and rates of returns from resources used by the adopters were higher than those used by the non-adopters" failed to be rejected.

The constant returns to scale for the adopters implied that doubling inputs would double the output, suggesting that by adopting the rangeland resource management technologies the adopter farmers were operating within the input efficiency locus and their output was optimal. Thus, by using more of the factors of production, they could not increase their scale of production because they had reached an optimal level (Sridhar, 2007). For the non-adopters, increasing returns to scale suggested that doubling of inputs would more than double the output, meaning that they were producing at a very small scale compared to a fixed bundle of production resources, and they could make more efficient use of the variable factors of production so as to produce at the optimal level. The non-adopters were operating in stage one of production function while the adopters were operating at the border between stage one and stage two.

Assuming one factor of production, and holding everything else constant, this could be illustrated as shown in Figure 4.4. With higher output per unit factor of production, the adopters' production function is shifted upwards compared to that of the non-adopters. The non-adopters lie between the region represented by A-$B_1$ and the adopters $B_2$-$C_2$, but close to the border at $B_2$. Thus, with $I_1$ factor of production, the non-adopters produce at $B_1$ and are operating at a point of increasing returns to scale (stage one) on their production function, $TPP_{Non\text{-}adopters}$; whilst with the same quantity of input, the adopters are producing at $B_{2,}$ which is at a point of constant returns to scale (border between stages one and two) on a superior production function, $TPP_{Adopters}$. Furthermore, as illustrated in the figure, the adopters' total physical product function reaches its peak with a lower quantity, $I_2$, of input compared to that for the non-adopters, $I_3$; and at a higher level of output, $Q_2$, instead of the lower output $Q_1$ for the non-adopters. Comparatively, then, the non-adopters are involved in wastage of variable resource $I_3$–$I_2$, whose use could be rearranged with fixed bundles of resources to produce more output. These results generally imply that land-enhancing environmental management technologies could be adopted to optimize the use of labour, farm implements, and variable physical capital.

The results in Table 4.11 show that primary level of education was the most common in the agro-pastoral households and the education level was likely to influence the adoption of rangeland resource management technologies. Forty seven households had off-farm employment while the rest did not. Off-farm employment provided income for the household and was likely to influence the adopting behaviour of the households. Majority of the households (58) were male-headed and the household head was the controller of the major resource (land). The results showed that male-headed households were likely to be adopters, since they were the majority.

Household participation in project activities was low because only 22 households had participated in project activities involved in the introduction of rangeland resource management technologies. The average household size in the study area was seven people. This showed that household labour was likely to be available for farm activities in the agro-pastoral system. In the study area, the most used information source on resource management technologies was DHP. This implied that the more the agro-pastoralist got information from DHP the higher the probability of adoption. Markets for resource management technology outputs was still lacking because only 22 households had access to a ready market.

**Table 4. 11: Summary of explanatory variables affecting resource management technology adoption**

| Variables | Unit, definition | Average recorded in Kibwezi |
|---|---|---|
| Education of household head | Scaled 1-4: the larger the higher | Primary (mode=2) |
| Off-farm employment | Binary: 1 for yes, 0 for no | 47 hhs had off-farm* |
| Gender of household head | Binary: 1 for male, 0 for female | 58 male-headed |
| Type of information source | Scaled 1-5: the smaller the most used | DHP (mode=1) |
| Household size | Residents present | 7 |
| Participation in project activities | Binary: 1 for yes, 0 for no | 24 hhs had participated |
| Managerial skill requirement | Coded: 1 for high, 2 for low | Low (mode=2) |
| Market availability | Binary: 1 for yes, 0 for no | 22 hhs had a ready market |

* hh=households

### 4.2.2 Binary Logistic Regression Analysis

Table 4.12 presents the results of a logistic regression analysis for the Kibwezi data. The regression predicts household resource management technology adoption or lack of it from a number of continuous and indicator (dummy) variables. The model parameter estimates were jointly significantly different from zero as shown by the Chi-square statistic, which was significant at 5%. The maximum likelihood estimates of the logistic regression are shown in the table. The significance of individual variable was tested by the Wald statistic. From Table 4.12, which gives results for the logistic regressions, gender of household head, participation in project activities involved in the introduction of rangeland resource management technologies, type of information source and education level of household head were significant at 5% level. Managerial skill requirement showed influence at a significance level of 10%. According to the results, the highest change was realized when there was change in participation in project activities, given the large value of Exp (β). This was followed by changes in gender of household head and managerial skill requirement.

**Table 4. 12: Maximum Likelihood Estimates for resource management technology adoption model**

| Variables | β | SE | Wald | Exp (β) |
|---|---|---|---|---|
| Constant | -27.500 | 74.239 | 0.137 | 0.000 |
| Gender of household head | 2.946 | 1.355 | 4.729** | 19.037 |
| Managerial skill requirement | 2.404 | 1.471 | 2.669 * | 11.037 |
| Participation in project activities | 3.242 | 1.586 | 4.181** | 25.583 |
| Type of information source | -0.677 | 0.350 | 3.731** | 0.508 |
| Off-farm employment | -0.454 | 0.331 | 1.879 | 0.635 |
| Market availability | 1.208 | 0.998 | 1.466 | 3.347 |
| Education of household head | -1.627 | 0.670 | 5.905** | 0.196 |
| Household size | -0.140 | 0.139 | 1.011 | 0.869 |

Notes:** Significant at 5%, * Significant at 10%, -2 Log likelihood=44.314, Model Chi-square=62.505*

#### *4.2.2.1 Hypothesis testing*

Five out of the eight variables included in the model were statistically significant at 5% and 10% levels. The significant variables are described below:

**Education level of household head** influenced the adoption of rangeland resource management technologies negatively. The result did not support the set hypothesis, which was positive. This might have been due to the fact that these resource management technologies and especially planting of multipurpose trees and water harvesting are relatively traditional technologies, which do not require a lot of knowledge in terms of application methods, compared to grass reseeding which is an exotic technology. The results were inconsistent with the findings of Adhikary (1994), which showed that the education coefficient was positive because in their study they were assessing improved breeds of farm animals, hybrid poultry, plantation of fodder trees and cultivation of improved cultivars of forage crops to reduce risk aversion. Their study required high education level in order for the farmer to adopt these technologies which were exotic in origin. However, in the adoption of IPM insect sweep nets in Texas, education was negatively related to adoption (Harper *et al.*, 1990), and thus their results were similar to the findings of the current study.

**Participation in project activities**' sign of the coefficient was as expected. This was because those farmers who were involved in projects had a higher probability of applying innovation. It was presumed that they were privileged with material and managerial support, followed by timely availability of knowledge, which apparently helped them apply new technologies as innovators and early adopters. Its largest positively significant coefficient indicated a positive impact of project interventions in technology adoption. This finding was in conformity with other studies (Karki and Bauer, 2004; Mazuze, 2004; Wabbi, 2002).

**Type of information source** influenced the adoption of rangeland resource management practices negatively. The sign of the coefficient on the type of information source suggested that the more the information was obtained from DHP the higher the probability of adoption. There was an inverse relationship between the type of information source and the adoption behaviour. This is because in the measurement of this variable which was ranked with a range of 1-5, the smallest value represented the most used type of information source. Thus, the results implied that when farmers received information from DHP officials, they were likely to adopt the resource management technologies.

**Gender of household head** had a positive coefficient, indicating that male-headed households were likely to adopt the rangeland resource management technologies than female-headed households. This might have been due to the high labour requirements of these technologies that males would provide. Consequently, a technology like planting of trees would require secure land tenure, because their benefits are expected after a long-waiting time. Thus, male-headed households are likely to adopt such technologies because they are the owners of land, which is the most important resource in production. These results were consistent with the findings of Volenzo (2006) who assessed the adoption of soil fertility improvement practices in Vihiga District. To change this, programs that target both gender groups would be necessary to ensure equitable adoption of practices between male-headed and female-headed households.

**Managerial skill requirement** influenced the adoption of rangeland resource management technologies positively. The managerial requirement was represented by a proxy where the highest requirement was allocated the lowest value. Therefore, the interpretation of this result is that the more the introduced technology required high skills the less likely that it would be adopted. Thus, the sign of the coefficient was as expected. This suggested that low managerial skills required in these technologies may increase their adoption. High managerial skills may hinder technology adoption because managerial skills are directly related to level of education (McNamara, Wetzstein and Douce, 1991; Waller *et al.*, 1998). In the present study, with the low level of education in the study area (primary education), managerial skills required for rangeland resource management technologies were low.

Some factors were not significant in influencing rangeland resource management technology adoption. These were off-farm employment, market availability and household size. Thus the logit model confirms that the variables with positive significant coefficients enhance technology adoption. Lack or inadequacy of any of these variables could hamper the adoption decision (Karki and Bauer, 2004).

# CHAPTER FIVE

# 5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 5.1 SUMMARY

This study analysed social and economic factors influencing adoption of rangeland resource management technologies by agro-pastoral households in Kibwezi, Kenya. The study was conducted in Ngulu Sub-location, Kikumbulyu Location in Kibwezi District. Data were collected through formal interviews using a structured questionnaire between the months of October and November, 2008. Descriptive analyses were done, a binary logistic regression was estimated, and a Cobb-Douglas production function estimated to capture partial factor productivity, and returns to resources used by the agro-pastoralists.

The results of descriptive analysis indicated that majority of the adopting farmers had participated in DHP project activities, were members of self-help groups, and had borrowed to finance their farming activities. The survey findings revealed that there were differences in resource endowment between the adopters and the non-adopters of rangeland resource management technologies. The adopters of rangeland resource management technologies had larger pieces of land than the non-adopters. The adopters also had higher livestock numbers and more fixed assets than the non-adopters. Thus, the adopters were better endowed than the non-adopters. These results were supported by the focus group discussions, where the adopters were said to have higher incomes from the sale of hay, grass seed and tree products.

With the current crop failure in the study area, the adopters were said to be more food secure because they were able to get some harvest from these resource management technologies as opposed to crop farming. Through selling of these products, the adopters were able to purchase food using the earned income. The fruits were also used directly as a source of food.

Even though the three types of rangeland resource management technologies were being practised, grass reseeding was preferred to the rest because it was the cheapest in terms of labour requirement. Planting of multipurpose trees was the most profitable practice though it was constrained by lack of water and other inputs such as pesticides, to control attacks by termites. All the three rangeland resource management technologies required high labour input per unit area in comparison to conventional agricultural practices suggesting high employment potential. Majority of the non-adopters cited intensive labour requirements, poor marketing infrastructure, lack of extension services, lack of credit, and recurrent droughts as the major constraints. On the other hand, adopting farmers cited soil fertility improvement through leaf fall, increased income, training, food security, and incentives given as the reasons for adopting rangeland resource management technologies.

The results of binary logistic regression showed that participation in project activities, gender of household head, and managerial skills had a positive significant effect on adoption. The type of information source and education level of household head had a negative significant effect on adoption, on the other hand. There would thus be a remarkable influence on transferring technology, alleviating food insecurity and increasing household economy if the determinants of adoption are properly addressed in future projects and programs. Thus, the binary logistic model confirms that the variables with positively significant effects enhance the adoption of these technologies. Lack or inadequacy of any of these variables could hamper the adoption decision.

The Cobb-Douglas production function was used to measure the effects of the factors of production on output of the agro-pastoralists. The results suggested that variable capital costs, labour costs, land, and costs of farm implements all had significant contributions to output at 5% significance level. The results implied that the application of variable inputs and labour are profitable if expanded when compared to land and farm implements. The outcome showed that households in the study area and the non-adopters were experiencing increasing returns to scale while the adopters were facing a constant return to scale. The increasing returns to scale imply that the households in general and non-adopters in the study area are producing at a very small scale (or inefficient level), in other words, they apply too little of the variable inputs compared to fixed resource outlays. These farmers can obtain more output per unit if they increased the level of variable inputs or if they shifted the fixed resource outlays to other types of production to match the variable inputs. For adopters, constant returns to scale implied that by adopting these resource management technologies, the farmers were operating within the input efficiency locus and their output levels lie within the stage of rational economic production, but can still do better by increasing the use of idle variable resources.

## 5.2 CONCLUSION

Farmers used the improved diversity of practices to avoid risk, increase food security and generate income. They also did this to optimize land use and help adapt to changing conditions such as increased drought frequencies. Rangeland resource management technologies can contribute economically and environmentally to sound agricultural production, thereby improving livelihoods through increased incomes, food security, and thus reducing poverty among the agro-pastoral households. However, the actual impact, particularly on the environment, will much depend on management practices of individual farmers and whether policy in favour of rangelands is formulated and implemented.

The findings imply that rangeland resource management technologies adopted in the study area are suitable, relevant and could offer the means to improving agro-pastoral livelihoods by increasing earnings per unit area and environmental conservation, thus leading to poverty alleviation. However, technology adoption is constrained by recurrent droughts, inadequate or non-existent framework of agricultural incentives, weak institutions and poor public services. The results suggest that extension and research support could enhance adoption of rangeland resource management technologies.

In a broad perspective, future projects should focus on encouraging farmers to participate in project activities This will enhance the competency and problem solving capacities of beneficiaries and other stakeholders. This will enable them to apply the acquired knowledge and skills in selecting and running enterprises independently even after the termination of project activities to solve food insecurity problem and raise living standards.

## 5.3 RECOMMENDATIONS AND POLICY IMPLICATIONS

Arising from the aforementioned findings and conclusions, a number of recommendations are made as follows:

- There is need for a concerted effort to heighten awareness about the rangeland resource management technologies through demonstrations, exchange visits and study tours. These approaches were found to have a significant impact on adoption of the technologies introduced in the study area. This is because the participatory research methods and the associated tools increase farmer confidence and self-organization. Thus, policies that influence farmer's access to agricultural information on the availability of technically viable land use options, either through research and extension services or indirectly through improving the level of literacy and education of farmers, should be strengthened.
- There is need for the promotion of collective action (farmer groups) by farmers practising these technologies in order to stimulate their demand and adoption countrywide. Through these groups, farmers will be able to access credit, ease logistics involved in training and access markets for their outputs as a group.
- Encouraging farmers to diversify their production by not only engaging in farm production but also in non farm income generating activities in order to improve farm-non farm linkages that are known to boost cash earning opportunities that can be used to purchase farm inputs.

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# APPENDICES

**Appendix I: Survey questionnaire**

**Rangeland Resource Management Technology Adoption among Agro-pastoral Households in South–Eastern Kenya: Its Influence on Factor Productivity and Poverty Alleviation**

1. Date of interview ____________________ Questionnaire No: _________________
2. Name of enumerator_________________________________________________
3. Name of respondent ________________________________
4. Division __________________________ Location________________________
5. Sub-location _______________________ Village __________________________
6. Relationship of the respondent to the household head ____________________________
7. Sex of the respondent: (1) Male (0) Female
8. Age of respondent: (1) 18-30 (2) 31-50 years (3) 51 years and above
9. Education level of the respondent: (1) None (2) Primary (3) Secondary (4) Tertiary
10. What is total size of your farm? __________ Acres.
11. What is the form of your land acquisition? (1) Inheritance (2) Bought (3) Others, specify _______
12. Who manages your farm? (1) Myself (2) Wife (3) Others, specify _________________________
13. What were the major activities in the farm last year? (1) Crop cultivation (2) Livestock grazing (3) Fallow land (4) Others ____________________________________________
14. What farm implements did you use on the farm last year?

| Implement | Number | Value KES. |
|---|---|---|
| Ox-plough | | |
| Wheelbarrow | | |
| Bicycle | | |
| Others | | |

Total value of farm implements in Kshs.__________________at 2008 market prices.

15. What crops did you grow during the Long rains? (March 2008-August 2008)

| Crop type | Area (Acres) | Harvest in bags | Price per bag (KES.) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

16. What crops did you grow during the short rains? (September 2007- February 2008)

| Crop type | Area (Acres) | Harvest in bags | Price per bag (KES.) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

17. What kind of animals did you keep last year?

| Animal Type | Breed | Number | Value KES. |
|---|---|---|---|
| Cattle | | | |
| Goats | | | |
| Sheep | | | |
| Poultry | | | |
| Others, specify | | | |

Total value of farm animals in KES. __________________at 2008 market prices.

18. How much did you get last year from the livestock enterprise?

| Animal Type | Product | Amount | Price per unit(KES) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

19. How many permanent farm labourers did you have last year? _____________
20. How much did you pay each month? _________________
21. How many casual labourers did you employ last year? _______________

| Months of activity | No. Employed | Pay per day or month | No. of days worked |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

22. Among the family members who was available for work last year?

| Member | No. of days | Hrs/day | Months/year |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

23. Did the extension staff visit your farm last year? (1) Yes (0) No
24. If yes what was the source of extension? (1) MOA (2) NGO (3) Church (4) Other _________
25. Are you a member of any farmers' group? (1) Yes (0) No
26. If yes did you receive extension through this group last year? (1) Yes (0) No
27. What did the group deal with concerning resource management technologies last year?
28. How did you benefit from the group last year? _______________________
29. Did you borrow any money or inputs last year? (1) Yes ______ (0) No _____
30. If yes state the source ___________________________________________
31. For which farming activity did you borrow last year? _________________________________
32. If you did not borrow what were the reasons? _________________________________
33. How much food did your household consume last year? (Amount of staple food in bags) ________
34. Did you harvest enough food that could last up to the next harvest? (1) Yes Ask Qn 35
 (0) No Ask Qn 37
35. If yes, did you sell the surplus? (1) Yes (0) No
36. If yes how much income did you get last year? _____________________KES.
37. How did you acquire the deficit? (1) Purchase from the market (2) Donation from friends
 (3) Relief (4) Other_______________________________________________
38. What was the source of income for purchase of food? _____________________________________
39. Was the income enough for your food requirements last year? (1) Yes (0) No
40. Were you employed on other people's farms last year? (1) Yes (0) No

41. If yes, did it affect your own farm activities? (1) Yes (0) No
42. If yes, how________________________________________________________________________
43. Did you participate in DHP-Kenya activities? (1) Yes (0) No
44. If no why not?______________________________________________________________
45.If yes are you still continuing with the practices they introduced? (1) Yes (0) No
46. If no why not?______________________________________________________________
47. If yes, fill the table below:

| Technology/practice | Source of information | When | By whom? |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

48. Of the resource management techniques you know, did you apply any of them last year? (1) Yes (0) No
49. If no, why not? _______________________________________________________

50.If yes, fill the table below:

| Technique/Method | Extent (acres) | Benefit |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

51. For techniques above when did you carry them out? (1) Long rains season (2) Short rains seasons (3) both
52. Give reasons for answer in on 51 ______________________________________________
53. Did you experience any problems in applying the various techniques above? (1) Yes (0) No
54. If yes, list the problem for each technique and suggest ways of solving the problems?

| Technique | Problem | Suggest ways of solving |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

55. If no problems were experienced in applying the techniques, why was this so? ___________________________
56. Where did you get the forage/tree germplasm/seed? (Fill the table below)

| Forage species | Source | Quantity (Kg) | Cost (KES/Kg) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

57. Did you harvest forage and forage seeds in your farm last year? (1) Yes (0) No
58. If no, why not? ______________________________________________________________

59. If yes in Qn 57fill the table below

| Forage species | Area (Acres) | Harvest in bags | Price per bag (KES.) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

60. What was the income and level of input use for the various techniques last year?

| Technique | Input type | Unit cost KES | Income KES |
|---|---|---|---|

61. What is your view on the requirements of practicing resource management techniques compared to the natural unimproved conditions? It involves

| Requirement | More | Less | Equal |
|---|---|---|---|
| Mgt time | | | |
| Cost | | | |
| Knowledge | | | |
| Land | | | |
| Labour | | | |
| Others, specify | | | |

62. How many household members were working off-farm last year? _______________
63. How much income was earned off-farm last year? _____________________
64. Did you receive any incentive to go into resource management activities last year? (1) Yes (0) No
65. If yes, what type of incentive? ________________________________________
66. If no, what motivated you to still continue? _____________________________________
67. What is your opinion on resource management technologies and its future? ____________________ 68. Which are the factors, which have led to successful resource management practices in your farm?
69. Did you have an organised market for your products such as tree products and grass last year? (1) Yes (0) No
70. If no what do you think was the problem?________________________
71. Who makes decisions about farming? (1) husband (0) wife
72. What is the age of the head of the family (decision maker)/? (1) 18-30 (2) 31-50 years (3) 51 years and above
73. What is the education level of the decision maker: (1) None (2) Primary (3) Secondary (4) Tertiary
74. Where would you most like to be assisted in order to continue practicing various resource management techniques? (Rank according to priority) (1) Technical advice (2) Credit facility (3) Input supply (4) Other____________________________________________

**Appendix II:** Partial correlation matrix for variables used in Cobb-Douglas production function

| | Farm size | Value of farm implements (KES) | Variable capital costs (KES) | Value of farm labour (KES) | Education level of decision maker |
|---|---|---|---|---|---|
| Farm size | 1 | | | | |
| Value of farm implements(KES) | .325 | 1 | | | |
| Variable capital costs (KES) | .403 | .425 | 1 | | |
| Value of farm labour (KES) | .263 | .251 | .477 | 1 | |
| Education level of decision maker | -.085 | -.022 | .020 | -.048 | 1 |

**Appendix III:** Partial correlation matrix for variables used in binary logistic regression

| | Gender of household head | Participation in .project activities | Type of information source | Off-farm employment | Market availability | Education level of household head | Household size | Managerial requirement |
|---|---|---|---|---|---|---|---|---|
| Gender of household head | 1 | | | | | | | |
| Participation in project activities | .019 | 1 | | | | | | |
| Type of information source | -.021 | -.478 | 1 | | | | | |
| Off-farm employment | -.133 | .050 | -.296 | 1 | | | | |
| Market availability | -.014 | -.098 | .229 | .045 | 1 | | | |
| Education household head | .360 | .072 | -.014 | -.152 | .088 | 1 | | |
| Household size | .177 | -.008 | -.005 | .071 | .112 | .023 | 1 | |
| Managerial requirement | -.587 | -.035 | .066 | -.006 | -.224 | -.263 | -.141 | 1 |