ADOPTION OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES IN THE SEMI-ARID AREAS OF KENYA: THE CASE OF MACHAKOS, MAKUENI AND KITUI DISTRICTS

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DECLARATION

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

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To mothers; my beloved mum, Rusmelia Adhiambo Olale and my dear mother-in-law, the late Eunice Atieno Osewe.

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ACRONYMS AND DEFINITIONS

AFC	Agricultural Finance Cooperation
CAN	Calcium Ammonium Nitrate
CARMASAK	Collaboration on Agricultural/Resource Modeling and Applications in Semi-Arid Kenya
CIMMYT	International Maize and Wheat Improvement center
DAP	Diammonium Phosphate
GIS	Geographical Information System
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute in Semi-Arid Tropics
IN	Innovators
KARI	Kenya Agricultural Research Institute
KCB maize	Katumani Composite-B maize variety
Km	Kilometer
ln	Natural Logarithm
MOA	Ministry of Agriculture
NA	Non-Adopters
NGO	Non-governmental Organization
NPK	Nitrogen. Phosphate. Potassium
PA	Potential Adopters
UM	Upper Midland Zone

ABSTRACT

Agriculture is the main economic sector in Kenya and contributes significantly to national development. For the sector to play this central role in a sustainable way, rapid growth in output and productivity is critical. One of the major factors that continue to constrain agriculture is the low and declining fertility of land; the problem is even more pronounced in the semi-arid areas.

This study focused on developing strategies for improving adoption of soil fertility and water management technologies in the semi-arid areas of Machakos, Makueni and Kitui districts. Following the low adoption of soil fertility and water management technologies and consequent fall in yields in the semi-arid areas of Eastern province, there is need for technological recommendations that are specific to farm types. This is expected to take care of the differences between farm types.

A total of 228 farmers were interviewed during the period January/February 2004 using a single-visit survey approach. Geographical Information System (GIS) guided random sampling methodology was used to select farmers to be interviewed and the data obtained using semi-structured questionnaires.

The logistic regression model was applied and the results showed that off-farm employment, hired labour, maize output, agricultural extension and agro-ecological zone positively influenced fertilizer adoption, while the distance to the nearest market was negatively related to fertilizer adoption. Off-farm employment, livestock ownership, distance to the nearest market and agricultural extension positively influenced animal manure adoption, while education negatively influenced the adoption of animal manure. Hired labour use positively influenced compost manure adoption and the distance to the nearest market negatively influenced compost manure adoption. Maize output positively influenced the adoption of soil and water conservation structures, while the distance to the nearest market and agro-ecological zone were negatively related to the adoption of this practice. These factors should be incorporated in the design of policies and strategies for soil fertility improvement.

As a result of the need to design specific soil management strategies, three major farm types were identified in this study, using k-mean cluster analysis. Farmers/farms were classified as socio-economically unconstrained, resource and information constrained and socio-economically constrained. The identified farm types had varying technology adoption abilities that decreased with an increase in the group socio-economic constraints. To increase the adoption of improved soil fertility practices, short-term and long-term strategies were developed for each farm type. The short-term strategy was to improve on the use of what is adoptable and the long-term strategy was to relax the constraints associated with the respective farm types. These strategies are expected to ensure better soil fertility technology adoption and higher crop yields. The study also recommended that the strategies be implemented hierarchically, starting with the socio-economically constrained group, who were only able to adopt animal manure.

CHAPTER 1: INTRODUCTION

1.1 Background

Most countries in the Sub-Saharan Africa continue to grapple with problems of poor economic performance, widespread poverty and food insecurity. Past studies such as Haggblade (2004) have shown that agricultural growth is essential for improving the welfare of the vast majority of Africa's poor. In Kenya, agriculture is the main economic sector and contributes significantly to national development. For the sector to play this central role in a sustainable way, rapid growth in output and productivity is critical (Ouma *et al*, 2002). One of the major factors that continue to constrain agriculture is the low and declining fertility of land (Kenya, 2004). This constraint is more pronounced in the semi-arid areas of Kenya. As a result of the need to increase food production, this constraint should be addressed effectively.

According to Smaling *et al* (1997), soil nutrient depletion and declining crop yields are common in Sub-Saharan Africa. An increasing number of farmers report declining soil fertility to be a major constraint in farming. Kenya, Ethiopia, Malawi, Rwanda, and Lesotho have the highest nutrient depletion rates. Nitrogen, Phosphate, and Potassium depletion rates of over 40, 6.6 and 33.2 kg $ha^{-1}yr^{-1}$ respectively, have been reported (Smaling *et al*, 1997).

In the semi-arid areas of Eastern Kenya, a dominant feature of agricultural production systems is land degradation and low crop yields. Low settler population during the 1940s and 1950s permitted long fallow periods for land regeneration. The land emerging from such fallow periods was often capable of producing acceptable yields even under low inputs. As population increased, the fallow periods became shorter and less efficient in maintaining productivity (Okwach *et al*, 2004). The intensification of cultivation and lack of inputs under increasingly shorter fallow periods resulted into nutrient depletion, land degradation and, yield and income reduction. McCown and Jones (1992) described the situation currently evident in most farms in semi-arid Eastern Kenya as "poverty trap", in which the subsistent population living on degraded soils receive low income, afford low or no farm inputs, and consequently get low crop yields.

Farmyard manure has assumed increasing importance as a means of retarding soil fertility depletion under growing utilization intensity. Past studies such as Ikombo (1984) have revealed the potential of farmyard manure in maintaining soil fertility under intensive arable farming. However, low quality and quantity of manure limits its application as the sole source of nutrient. With such land exploitation pressures, and poor quality of manure, it's difficult to ignore the possibility of increased use of chemical fertilizers as a means to check productivity decline (McCown and Jones, 1992).

Physical structures and agronomic methods of soil and water conservation, along with combined use of farmyard manure, chemical fertilizers, and/or nitrogen fixing grain legumes are some of the key ideas disseminated to the local farmers over the years. But land degradation and crop yield decline persist as farmers have continued to ignore these recommendations. It is estimated that, about 40 percent of farmers in the semi-arid Eastern Kenya use chemical fertilizer (Omiti *et al*, 2000). The rates of application are commonly less than one-third of recommended levels. This lack of adoption of improved technology raises two major questions; why do farmers not increase their investment in improved technology for higher yields? What interventions would be effective in popularizing the improved technologies, and increasing the rate of adoption?

Omiti *et al*, (2000) found out that open recommendations for managing soil fertility, erosion control, and water conservation across soil types, climatic conditions and socio-economic scenarios are weak. There is therefore need for technological recommendations that target specific environments.

1.2 Problem Statement

Past studies (Smaling and Braun, 1996; Smaling *et al*, 1997) have indicated widespread evidence in land quality and productivity decline in Kenya. The evidence is even more pronounced in the semi-arid areas of Eastern Kenya (Sanchez *et al*, 1997; Omiti *et al*, 2000). One-year measurements in Machakos reveals that full nutrient balances at farm level are negative for nitrogen (-53 kg N/ha/yr) and to a lesser extent for potassium (-10 kg K/ha/yr) (Bosch *et al*, 1998). However, no specific measurements have been done for Makueni and Kitui districts. Up to four years ago, nutrient enrichment has been low and there is evidence that the main causes have been removal of crop residues, leaching and soil erosion, combined with low inputs of organic and mineral fertilizers (Jager *et al*, 1999). There is therefore need to eliminate these causes to improve crop yields.

To counter the low soil fertility phenomenon, a number of improved soil fertility and water management technologies (such as fertilizer, manure and soil and water conservation structures) have been disseminated to local farmers in the semi-arid areas over the past years. However, soil fertility and crop yields have declined as farmers continue to ignore these technological packages. The main questions that many scientists are still struggling with are- why are many farmers slow to adopt the options so attractive to researchers? What options are available for popularizing research innovations?

Farmers in the semi-arid areas of Eastern Kenya vary in their socio-economic characteristics and agro-ecological zones. Quite often, open technological recommendations are made which do not consider variations in farmers' biophysical and socio-economic environments. This may explain the evidence of slow adoption of improved technologies. Specific technological recommendations made in this study would take care of the differences in the technology adoption potential of the semi-arid areas, thereby improving adoption, crop yields and food security status of these areas.

1.3 Objectives of the Study

The overall objective of the study was to develop specific soil fertility and water management strategies for the major farm types of the semi-arid areas of Kenya. Specific objectives were:

- To describe the farmers' current practice in soil fertility and water management in the semi-arid ecosystems of Machakos, Makueni and Kitui districts.
- To determine the socio-economic and agro-ecological factors which influence adoption of the practices.
- To identify the major farm types of the study area and compare soil fertility and water management practices[1] across the farm types.

1.4 Hypothesis Tested

The following hypotheses were tested

- Socio-economic factors do not influence soil fertility and water management practices.
- Agro-ecological factors do not influence soil fertility and water management practices.

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[1] Soil fertility and water management practices considered were fertilizer use, animal manure use, compost manure use and soil and water conservation structure use.

- Adoption of soil fertility and water management practices does not differ across farm types.

1.5 Justification of the study

Justification for this study stemmed from the widespread evidence that land quality and crop productivity is steadily declining, while farmers continue to avoid those technologies such as fertilizer, manure and soil and water conservation structures that could ensure sustainability. It is evident that the issuance of open recommendations for the management of soil fertility, erosion control and water conservation across soil types, climatic conditions and socio-economic scenarios are weak and ineffective. There is need for technological packages that target specific environment and take into account farmers' socio-economic endowments. The ultimate goal of this study was to enhance food sufficiency in the upper Athi catchment of Eastern Province through increased rate of adoption of improved soil fertility and water management practices, leading to better and sustainable utilization of land and water resources. The identified socio-economic and agro-ecological factors affecting adoption of improved soil fertility and water management practices were incorporated in the design of specific technological recommendations, which are expected to improve adoption.

1.6 Limitations of the Study

The study was constrained by some factors experienced at the data collection stage. Due to the large area covered (5000 Km^2), data collection was difficult, but the GIS random sampling easened the process. Another problem was the absence of past farm records. However, the farmer responses were good indicators of the general pattern of behaviour. Regardless of these challenges, representative data was obtained from the sample farmers.

1.7 Organization of the Thesis

The thesis is organized in five chapters. Chapter one gives a background and introduction to the problem, declining soil fertility status in semi-arid areas, while Chapter two reviews literature related to the problem addressed. A methodology of tackling the problem is provided in Chapter three, followed by a presentation of the results in Chapter four. Finally, Chapter five gives the summary, conclusion and recommendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Theories of Adoption

Adoption may be defined as the decision to make full use of an innovation as the best course of action available (Rogers, 1983). Literature shows that peoples' adoption behaviours are specific to particular innovations, individuals and environments, although it also has some general characteristics. A technology on the other hand is defined as a means by which resources are combined to produce the desired output. An improved or a new technology can be referred to as an innovation. Rogers and Shoemaker (1971) defined innovations as ideas, practices or objects that are perceived as new by their recipients.

The choice to adopt an innovation is regarded as an outcome of a series of influences exerted by the change forces on the behaviour of the decision-maker through time (Lionberger, 1968). This therefore means that the choice to adopt a new technology is not made at once, but requires time.

Adoption should be viewed as a process that presents a change of behaviour on the part of the decision-making unit in the system. The adoption behaviour of farmers is dependent upon numerous influences from two major sources, internal (mental or symbolic) and external (physical and environmental). These influences can be translated into two classes as (1) Incentives (reasons for) (2) Disincentives (reasons against) adoption.

In order to facilitate the adoption process, a strategy would be required whereby the incentives are energized, while the disincentives are weakened. There is therefore need for identification and analysis of the factors that influence the adoption behaviour of farmers.

Several paradigms have been used to explain adoption decisions. These are the innovation-diffusion, economic constraint and adopter-perception models. In the innovation-diffusion model, access to information about an innovation is the key factor determining adoptions (Feder and Slade, 1984). The appropriateness of the innovation is taken as given, and the problem of technology adoption is reduced to communicating information on the technology to potential users. By emphasising the use of extension, media and local opinion leaders or the use of experimental station visits and on farm trial, the non-adopters can be shown that it is rational to adopt.

The economic constraint model contends that economic constraints reflected in asymmetrical distribution pattern of resource endowments are the major determinants of observed technology adoption behaviour. Lack of access to labour, land or capital could significantly constrain farmers' technology adoption decisions (Marra and Carlson, 1987; Nowak, 1987).

A third paradigm is termed the adopter-perception paradigm, (Adesina and Zinnah, 1993). This model proposes that the perceived attributes of innovations influence adoption behaviour. Studies that have dealt with farmers' perceptions in the context of adoption decisions have included a perception variable.

This study related the variables in the three paradigms to adoption of soil fertility and water management technologies. Furthermore, the study focused on how differences in farm types influence the decision to adopt the technologies in question. This helped give specific technological recommendations to specific farm types.

2.2 Qualitative Response Models

In regression analysis. there are cases where the dependent variable is dichotomous (i.e. take values of 0 and 1) while the independent variables are continuous and/or dichotomous. An example of such a case is technology adoption. where a value of 1 can be given for Adopters and 0 for Non-adopters. To analyze this regression, the simplest procedure is to use the ordinary least squares method (OLS). In this case, the model is called the *linear probability model* (Green. 1993; Maddala, 2001). The model is specified as follows:

$$y_i = \alpha + \beta_i + u_i \qquad (2.1)$$

$$Where\ y_i = \begin{cases} 1 \\ 0 \end{cases}$$

Because of a problem of heteroscedasticity, the OLS estimates of β from the above equation will not be efficient. This may lead to wrong conclusions based on the parameter estimates, hence the limitation in using this model.

In the quest for more efficient qualitative response models, other models have been developed. These are the *logit and probit models.* These models assume a variable y_i* which is not observed, commonly known as "latent" variable as expressed in the following equation (Pindyck and Rubenfield. 1991; Green. 1993; Maddala, 2001).

$$y_i* = \beta_0 + \sum_{j=1}^{k} \beta_i x_{ij} + u_i \qquad (2.2)$$

What is observed is a dummy variable y_i (e.g. technology adoption) defined by:

$$y_i = \begin{cases} 1 & if\ y_i^* > 0 \\ 0 & otherwise \end{cases} \qquad (2.3)$$

The *logit and probit models* differ in the kind of distribution followed by the error term u_i. If the cumulative distribution of u_i is logistic, we have the *logit model*. The model is expressed as follows:

$$\begin{aligned} P = F(Z) &= 1/(1+e^{-z}) \\ &= 1/(1+e^{-(\alpha+\beta x+u)}) \end{aligned} \qquad (2.4)$$

Where P is the probability that y_i is 1.

If the error u_i follows a normal distribution, we have the *probit model*. The model is expressed as follows:

$$P = F(Z) = \int_{-\infty}^{Z_i/\sigma} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt \qquad (2.5)$$

Where P is the probability that y_i is 1.

Suppose, however, that y_i* is observed if $y_i* > 0$ and is not observed if $y_i* \leq 0$. Then the observed y_i will be defined as:

$$y_i = \begin{cases} y_i* = \beta x_i + u_i & if\ y_i* > 0 \\ 0 & if\ y_i* \leq 0 \end{cases} \tag{2.6}$$

$$u_i \sim IN(0, \sigma^2)$$

This is known as the *tobit model.* It is also known as a *censored normal regression model* because some observations on $y*$ are censored (Green, 1993; Maddala, 2001). To estimate the logit, probit and tobit models, maximum likelihood estimation (MLE) is used.

The three models are used to solve different econometric problems. The tobit model is used to analyze factors influencing the probability and intensity of a qualitative phenomenon, while logit and probit are used to analyze the factors influencing the probability of a qualitative phenomenon. The interpretation of the logit and probit is similar, hence both can be used to solve the same problems.

Since the problem under study was to find ways of improving the probability of adoption of various soil fertility and water management technologies in the semi-arid areas of Kenya, the logit model, which is computationally easier than probit was selected and used.

2.3 Past Studies on the Socio-economic Factors Affecting Adoption of Soil Fertility Management Technologies

Many studies have been undertaken on the socio-economic factors affecting adoption of soil fertility management technologies in Kenya and Sub-Saharan Africa. Misiko (1976) conducted a study on the incentives and disincentives influencing farmers' adoption of agricultural innovations in Bungoma district of western Kenya. Misiko used a combination of methodologies that included cross tabulations, chi-square tests of statistical independence. Pearson's correlation and multiple linear regression to analyze data obtained from 240 farmers in three sub-locations of Bungoma district. The study found out that contact with extension officers, social participation, family size, income and endowment of economic resources significantly determined the decision to adopt improved technologies.

Factors that were identified as incentives in Misiko's study included crop yields, higher incomes, early maturity, use by neighbours and availability of technical guidance. The disincentives were lack of knowledge, lack of technical assistance, lack of credit, poor seeds, too expensive inputs, inability to supply inputs in time and complex technologies. The study by Misiko was however carried out in a high potential zone compared to this study, which targeted semi-arid areas of Machakos, Makueni and Kitui districts. The present study also looked at adoption in individual farm types, which was not the focus of Misiko's study.

Mwangi (1978) analysed the factors that constrained fertilizer use in western Kenya. These included lack of cash (capital), high transportation costs, lack of credit and low literacy levels of farmers. Similarly Mwangi's study was undertaken in a high potential zone. This study focused on a semi-arid zone. The focus on specific farm types by the present study gave adoption of the technologies in question a different approach.

Nadar and Faught (1984) undertook a study on the effects of legumes on the yields of associated and subsequent maize intercropping and rotation systems. They noted that while fertilizer use might have spread rapidly in Kenya, its spread is very low in the low potential zones. One of the factors that justified the low spread was the high risk associated with the use of the fertilizers. However, they did not explore on the use of integrated approach to soil fertility management (use of fertilizers, organic manure and soil and water conservation structures). This study analysed the integrated approach to soil fertility management and the socio-economic factors that affect their adoption.

Ongaro (1988) focused on the adoption of new farming technologies in western Kenya, particularly in Nandi and Kisii districts. Several conclusions emerged from the study among them the role of risk perception in affecting technological adoption. The study concentrated on the role of credit in providing a cushion against risk in the event of crop failure. His study found out that low fertilizer use among farmers in western Kenya was due to risk of rain-wash, uncertainty of input availability and payment for produce. This is different in the marginal areas where fertilizer use is made risky due to rainfall unreliability and moisture stress (Hassan et al, 1998). To address the rainfall problem in marginal areas, the study incorporated the use of soil and water conservation structures as a means of reducing runoff losses.

Muturi (1989) examined the factors influencing the use of fertilizers among small-scale farmers in Murang'a district. He used a lagged response model to analyse fertilizer use. The results of the analysis indicated that output price, credit availability and fertilizer prices were significant determinants of fertilizer use in maize, the main grain crop in the district. Muturi observed that farmers who got cash credit did not use it to purchase fertilizer because of the lack of willingness and therefore recommended the use of credit in kind. Muturi's work could not be generalized for the whole country (Kenya) because the study, which was carried out in a high potential zone, was based on a sample of 80 farmers from one division. The present study, which was undertaken in a low potential zone, focused on an integrated approach to soil fertility management in semi-arid areas to neutralize the element of risk in acquiring fertilizer in specific farm types.

Salasya *et al.* (1997) assessed the adoption of seed, fertilizer and role of credit among small-scale farmers in Vihiga and Kakamega and found out that lack of credit was an impediment to fertilizer adoption in maize production. Fourty two percent of the farmers refrained from acquiring credit for fear of default arising from poor harvest and consequent risk of having their farms, which were used as collateral, auctioned to recover unpaid loans. The authors concluded that the mere availability of credit does not mean that farmers would go for it, hence credit availability is a necessary but not a sufficient condition for fertilizer use. The fact that wealthier farmers (using livestock ownership as a proxy) used more fertilizer than less endowed counterparts is a clear indication that different farm types differ in soil fertility management, and therefore specific technological recommendations are required depending on farm types. The focus of this study on individual farm types is therefore justified. Furthermore, the study looked at a low potential zone.

Nabwile and Kilambwa (1997) analysed the economics of fertilizer use in moist and dry mid altitude zones. They drew the conclusion that, apart from one case, fertilizer use was sub-optimal and that yield gap could be bridged by the use of more fertilizers. However, in low potential areas, the problems faced range from high fertilizer prices, risk elements as a result of unreliable rainfall patterns, lack of knowledge on soil fertility management options, among many factors. This again implies that increased use of fertilizers is a necessary but not a sufficient condition for improved yields and farm incomes in semi-arid areas. There is need to employ an integrated approach to soil fertility management. This study focused on the use of soil fertility and water management technologies in the farm types of a low potential zone.

Omiti *et al*. (2000) undertook a survey on soil fertility maintenance in Eastern Kenya. Regression analysis was used to identify the factors that influenced adoption and intensity of use of fertilizers. The results indicated that improved technical knowledge about fertilizer use and with market orientation had a probability of achieving greater use of inorganic fertilizer on smallholder farms. The study indicated that a large number of farmers did not use fertilizers in semi-arid zones and even if they did, they applied in small amounts. However, they did not look at the adoption of soil fertility management technologies with a focus to individual farm types, which was the focus of this study.

Nzuma (2001) studied the adoption of improved seeds and inorganic fertilizers in maize productions systems of Machakos district. Nzuma used multi-stage sampling to select 121 farmers from Machakos district who were interviewed using pre-tested semi-structured questionnaires. Descriptive statistics were used to explain adoption of improved maize seed and inorganic fertilizer. He also estimated a simultaneous tobit model. Nzuma found out that major adoption limitations included recycling of seeds and high inputs costs. He also concluded that men were better adopters of improved technologies than women. This again illustrates that investment in new technologies differs with farm-family characteristics. However, Nzuma's study did not focus on specific farm types. Farm characterization and specific technological recommendations considering the differences in farm types is therefore justified.

Doss *et al.* (2003) synthesized the findings of 22 micro-level studies on technology adoption carried out by CIMMYT with national agricultural research systems in Ethiopia, Kenya, Tanzania and Uganda during 1996-1999. The authors found out that technology adoption especially that of fertilizer and seed was high in the high potential zones and low in the low potential zones. They also noted that research-extension linkages are weak and there is therefore need to tailor research to farmer circumstances. This study was aimed at addressing the research-farmer linkages by providing specific soil fertility management strategies to individual farm types in the low potential zones.

2.4 Past Studies that used Logit Models

Various adoption studies have been undertaken using logit models. Saito *et al,* (1994) analysed 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 major finding of the study by Saito and others was 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 analysing 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 exogenous variables considered included land, capital, education, age, gender, labour, risk, 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 considered how the socio-economic and agro-ecological factors influence adoption of soil fertility and water management technologies in the various farm types of the semiarid areas of Machakos, Makueni, and Kitui districts.

Adesina and Sirajo (1995) undertook a study on farmer's perceptions and adoption of new agricultural technology of modern mangrove rice in Guinea-Bissau. They used a logit regression model given as:

$$Q_{ik} = F(L_{ik}) = e^{Z_{ik}} / (1 + e^{Z_{ik}}) \qquad (2.7)$$

$$For\ Z_{ik} = X_{ik} B_{ik}\ and\ -\infty < Z_{ik} < \infty$$

Where, Q_{ik} is the dependent variable that takes the value of 1 for adopters and 0 otherwise. X_{ik} is a matrix of explanatory variables related to the adoption of modern mangrove rice varieties by farmers. B_{ik} is the vector of parameters to be estimated. L_{ik} is an implicit variable that indexes adoption. $F(L_{ik})$ is the probability that the i th farmer chooses to cultivate the modern mangrove rice over a local variety, zero otherwise.

The explanatory variables considered included farmer specific socio-economic variables as age, family size, farm size, contact with extension, education status, years of experience, access to non-farm income and commercialized farmer or subsistence orientation. Besides these, technology specific characteristics such as the shortness of crop cycle, yield on farmers fields, the ease of threshing, taste and starch content were considered. The present study covered the influence of agro-ecological characteristics, which was not the focus of Adesina and Sirajo (1995).

Jabbar *et al*, (1998) analyzed the factors affecting the adoption of the broad bed maker (BBM) in highlands of Ethiopia. The BBM, a manual drawn equipment was used for draining waterlogged vertisols. Logistic regression results showed that education, BBM training, cropland under vertisols, waterlogged area, distance to the market, number of work arrivals and access to credit significantly influenced the probability of adoption of BBM. The present study differs from the study by Jabbar *et al*, in that it considered a different technology, focused on the influence of agro-ecological characteristics on adoption and was done in a low potential zone.

Gamba *et al*, (2002) examined the factors that influence farmers' adoption of new wheat varieties in Narok, Nakuru, and Uasin Gishu Districts. The study used primary data collected from a sample of 80 wheat farmers from the three districts. The logit model was used to determine the factors affecting adoption of new wheat varieties. The study found out that, farmers in these districts neither knew nor grew wheat varieties, reflecting lack of seed and knowledge of the seed varieties. The logit model showed that experience in wheat farming had a positive impact on adoption of new wheat varieties. The influence of income variables (on-farm and off-farm) on adoption was not covered. This study addressed this research gap.

Makokha *et al*, (2001) studied the determinants of fertilizer and manure use for maize production in Kiambu District, Kenya. A multistage random sampling was used to select farmers for the survey resulting in a sample size of 97. Descriptive statistics were used to assess soil fertility practices in the study area. The logit model was used to determine factors influencing the use of fertilizer and manure. According to the study, extension contact and off-farm income significantly influenced the use of manure. Age of the household head, extension contact, membership in an organization, and off-farm income significantly influenced the use of fertilizer. The use of manure and inorganic fertilizer was significantly influenced by extension contact, membership in an organization, hired labour for manure application, livestock ownership and off-farm income. However, they did not assess the effect of agro-ecological characteristics on technology adoption, which was the focus of this study. Furthermore, the study was done in a high potential zone compared to this study, which was done in a low potential zone.

Okuro *et al*, (2000) assessed the factors affecting adoption of maize production technologies in Embu district-Kenya. They utilized a logit regression model to analyse the factors influencing adoption and found that gender, agricultural zone, use of manure, hiring of labour and provision of extension services significantly influenced adoption. These factors were important in the present study. However, the present study was based on a different agricultural zone and focused on specific farm types.

Ouma *et al*. (2002) reviewed the socio-economic and technical factors that affect adoption of improved maize and fertilizer in Embu district, Kenya and the role of credit in improved maize and fertilizer adoption. Specifically, the study described the socio-economic factors of the study area and the improved maize seed and fertilizer adoption practices. Factors that influence adoption were then determined. A total of 127 farmers were interviewed in this study during the long rain and short rain seasons of 1998 in Nembure, Runyenjes, and Keini divisions in Embu district. A multistage sampling approach was used to select the sample farmers. The logit model was used to determine the factors that determine maize seed adoption, while linear regression was used to determine the factors that influence amount of fertilizer used. The study found out that, agro-ecological zones, gender, manure use, hiring labour and extension were significant in explaining adoption of improved maize seed while.

hiring labour, education, age and membership of farmers' group were significant in determining amount of basal fertilizer used. The study differs from the present study since it was done in a high potential zone.

Asambu (1993) analysed the factors influencing maize enterprise performance and the adoption of an improved maize cultivar (Katumani composite B-KCB) among farmers in Mwala location of Machakos district. Maize enterprise performance was measured quantitatively in terms of output (yield) per acre, while adoption was qualitatively measured. Asambu found out that the selling price of maize, percentage of land under maize, farming experience, use of inorganic fertilizers and contact with agricultural extension agents, were the most important factors influencing farm level maize enterprise performance. The logistic regression results indicated that use of hired labour, family size and off farm employment were the most important factors influencing adoption of KCB. This study was however aimed at generating specific strategies for improving soil fertility management in specific farm types to increase crop yields in the semi-arid areas.

2.5 Past Studies that used Cluster Models

Small-scale farmers in the developing countries are not always homogenous, even within a community (Crossa *et al*, 2001). Ownership of resources such as land, labour and capital is not equal between households nor sharing of knowledge and information as well as access to markets. Soils and topography vary and seasons change. Consequently, goals and constraints differ between farming households. All these factors influence crop productivity.

Crossa *et al*, (2001) developed a method of classifying farm households into homogenous but distinct groups. The method allows the use of different types of variables, provides a systematic approach to decide the number of groups present in the data and assigns a probability that an individual belongs to a particular group. The Author used the method to divide a random sample of small-scale farmers in Mexico into homogenous groups, so as to evaluate specific technological requirements for each group. However, cluster models have not been used in a Kenyan situation and more specifically, in addressing soil fertility management problems. This study used a k-mean cluster model to define homogenous target groups and to give specific recommendations for managing soil fertility in the semi-arid areas.

CHAPTER 3: METHODOLOGY

Technology adoption is a discrete phenomenon. A form of qualitative response model is therefore required to analyze this phenomenon. Data on adoption of soil fertility and water management technologies were used to estimate the specified models.

3.1 Conceptual Framework

The study was conceptualised as a technology adoption study. Farmers were assumed to be consumers of agricultural technology inputs and were therefore categorised as adopters and non-adopters of improved soil fertility and water management technologies. If farmers are consumers of agricultural inputs, then according to the random utility theory, they will choose the alternative (technological package) that gives highest utility. Both descriptive and inferential statistical tools were used to analyse adoption of soil fertility and water management practices in the farm types of Machakos, Makueni and Kitui districts.

The decision to adopt an innovation is a behavioural response arising from a set of alternatives and constraints facing the decision maker as illustrated by Leagans (1979) in the behavioural differential model. The adoption decision can be related to a set of alternatives and constraints facing the decision-maker in the following theoretical model.

Decision = f (alternative, constraints)

Subject to welfare criterion (e.g. higher profitability or utility)

In this study, adoption was conceptualised as a function of farm and farmer's characteristics, institutional support services and agro-ecological characteristics.

3.2 Empirical Models

3.2.1 Logit Model

Background

Adoption behaviour, the phenomenon we seek to model is discrete rather than continuous. In this case, the dependent variable takes a limited set of values. These are cases where the dependent variable can be characterised as 0 or 1. The dependent variable 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 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 logit and probit models are often applied 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, don't 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. Another model is tobit, which is used to determine the factors influencing the probability and intensity of adoption (see chapter 2). For this study, the problem at hand was to determine ways of increasing the number of adopters of the diverse soil fertility management technologies. The study therefore used the logit model, which is computationally easier than probit, to evaluate the decision by farmers to adopt or not adopt improved soil fertility and water management technologies, and find ways of improving adoption potential of farmers.

In the Logit Model, the expectation of Y is a number P, which is related to the independent variables, (X) as follows (Pindyck and Rubenfield, 1991; Green, 1993; Maddala, 2001).

$$
\begin{aligned}
E(Y \mid X) = P = F(Z) &= (\alpha + \beta X + U) \\
&= 1/\left(1 + e^{-z}\right) \\
&= 1/\left[1 + e^{-(\alpha + \beta X + U)}\right] \qquad (3.1)
\end{aligned}
$$

Where P = Conditional probability of being adopter given the values of independent variables, (X).

e = Base of natural logarithm which is approximately equal to 2.718.

α = Constant

β = Regression Coefficients

U = Stochastic error term

The above expression P (equation 3.1) is referred to as the Logistic probability function. When the Logistic function is expressed in terms of odds, it is called the Logit and takes the following form.

$$\Pr ob(event)/(noevent) = [P/(1-P)] = e^{z} = e^{(\alpha + \beta X + U)} \qquad (3.2)$$

In order to estimate the Logit Model, the dependent variable is transformed by taking natural logarithm of both sides to yield "log odds" as follows.

$$\ln[P/(1-P) = Z = \alpha + \beta X + U \qquad (3.3)$$

In the present study, the Model (s) was estimated using the maximum likelihood method of the Statistical Package for Social Sciences (SPSS) software, version 10 and NLOGIT version 3. SPSS version 11 was found not appropriate for logistic regression analysis.

Model specification

The adoption models were specified using the following factors. The factors were derived from the adoption literature (Lionberger, 1968; Asambu, 1993; CIMMYT, 1993). Not all the factors in adoption literature were included in the regression analyses. Those included jointly maximized the predictability of each of the models, while factors which reduced the model predictability were excluded from the analyses. The factors represented household characteristics (age of household head/farmer, education, family size and off-farm employment), farm characteristics (hired labour use, yield and livestock ownership) institutional characteristics (distance to the nearest market, extension and group membership) and agro-ecological characteristics.

Dependent Variables

FERT: Probability of adoption of inorganic fertilizer (1/0).

ANIM: Probability of adoption of animal manure (1/0).

COMP: Probability of adoption of compost manure (1/0).

SOCST: Probability of adoption of soil and water conservation structures (1/0).

Independent (Explanatory Variables)

AGE: Age of the farmer in years. (+ or -).

FMLYSZ: Number of family members (+ or -).

EDUC: Formal education level in years (+).

OFFWRK: Off-farm employment. Dummy 1 for those with off-farm employment, 0 otherwise (+).

HRLB: Use of hired labour. A dummy 1 if farmer uses hired labour, 0 otherwise (+).

YIELD: Yield performance of maize crop. Measured in 90 kg bags in 2 seasons (+).

LVST: Livestock Ownership. A dummy 1 if farmer own livestock, 0 otherwise (+).

DTM: Distance to the nearest market in Km (-).

EXT: Extension: Dummy 1 for those who received extension, 0 otherwise (+).

GRME: Membership to a farmer's group. A dummy 1 for members, 0 otherwise (+).

AGRO: Agro-classification. A dummy 1 for those in UM zones, 0 otherwise (+).

Formation of the Models was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to either adopt or reject soil fertility and water management practices at any point in time is influenced by the combined effect of a number of factors related to farmers' objectives and constraints (CIMMYT, 1993). The variables in the model were hypothesized to influence the adoption of soil fertility and water management practices positively (+), negatively (-), or both positively and negatively (+/-). The hypothesized variables included:

Farmer's Age. A farmer's age (AGE) can generate or erode confidence. In other words, with age, a farmer can become more or less risk averse to a new technology. This variable can thus have positive or negative effect on a farmer's decision to adopt soil fertility and water management technologies. Age was measured in years.

Family Size. Larger households will be able to provide more labour that might be required to apply fertilizer and manure, as well as construct soil and water conservation structures. It was therefore hypothesized that the larger the family size, (FMLYSZ) the higher the probability of adoption of soil fertility and water management practices. It was measured in terms of the number of children.

Education. Farmers who have some years of schooling are easier to deal with when it comes to dissemination of agricultural innovations. Education level (EDUC) was therefore hypothesized to positively influence adoption of the technologies in question. The variable was measured as the number of years completed in school.

Off-farm Employment. Farmers with off-farm employment (OFFWK) are assumed to have higher total income than those who depend on farm output only. Higher income was hypothesized to positively influence adoption process. Farmers with off-farm income were given a dummy one and zero otherwise.

Hired Labour use. Hired labour use (HRLB) was hypothesized to positively influence the adoption of soil fertility and water management technologies. Farmers who hired labour for production were given a dummy one, while those who did not were given zero.

Yield of Maize (90 kg bags). Maize is a major food crop among majority of farmers. Farmers also grow maize partly for sale. Maize yield measured in 90 kg bags (YIELD) was hypothesized to be positively associated with adoption of soil fertility and water management technologies.

Livestock Ownership. Livestock ownership is an indicator of wealth. Livestock also provides manure. Therefore, livestock ownership (LVST) was expected to increase the likelihood of using manure and fertilizer. Those who had livestock were given a dummy one, zero otherwise.

Distance to the Nearest Market. Farmers who are closer to the market (input dealer) have better access to production inputs than the ones who are far from the market place. It was hypothesized that the distance to the nearest market (DTM) is negatively related to the adoption process. This variable was measured in kilometers.

Extension. Extension is a major source of agricultural information. It was hypothesized that contact with extension agents (EXT) positively influence adoption of soil fertility and water management technologies. Farmers who had received extension were given a dummy one, while those did not were given zero.

Membership of Farmer Organization. Members of an organization (farmer groups, Non-governmental organizations) are in a privileged position compared to other farmers in terms of access to information of agricultural innovations. Being a member of an organization (GRME) was hypothesized to be positively associated with adoption of soil fertility and water management technologies. Members of an organization were given a dummy one, while non-members were given zero.

Agro-classification. Farmers in Upper Midland (UM) zones receive higher rains than those in Lower Midland (LM) zones. It was hypothesized that UM farmers were better crop enterprise managers than LM farmers because of the reduced climatic risks. Farmers in the Upper Midland Zones were given a dummy one, while those in Lower Midland Zones were given zero.

3.2.2 Cluster Model

Farm characterization is the process of categorizing farmers (farms) into specific homogenous target groups. Each target group has associated constraints. Relaxation of these constraints in each group is expected to improve adoption of agricultural innovations.

In this study, the process of characterizing farmers proceeded in three stages. These included (1) Selection of statistically significant variables from logistic regressions (2) standardizing the variables in a standard normal (Z) distribution (3) clustering the variables in **K-mean cluster Model**. The variables were standardized to eliminate any spurious effects, which might result from unequal variances (Hair *et al*, 1992). The model minimizes the within-group variability and therefore maximizes the among-group variability. The model was estimated using the Statistical Package for Social Sciences (SPSS) software, version 10.

The standard normal distribution density function is expressed as follows.

$$F(Z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{Z^2}{2}} \qquad (3.4)$$

$$Z = \frac{X-\mu}{\sigma} \quad (\mu = O,\ \sigma = 1) \qquad (3.5)$$

Where,

X = observation

μ = Population mean

σ = Population standard deviation

The K-mean cluster model can be expressed as

Max between groups σ^2 given the values of Z_{X_1} ,..............., Z_{X_n}

3.3 Area of Study

The area of study was the upper Athi catchment of Machakos, Makueni, and Kitui districts (Figure 1). Upper Athi catchment spans an area of approximately 5,000 Km^2. The geographical location is described by coordinates of 1° to 3°S and 37° to 38°E. The geometry of the landscape is generally heterogeneous with hills and plateaus rising above the piedmonts and plains to an altitude of 1800-2100m above sea level (Okwach *et al.* 2004).

Agro-ecologically, the area is classified as arid and semi-arid lands of Kenya where dry land farming is practiced. The rainfall pattern is varied and erratic, ranging from 200-1300mm. The rains are normally concentrated in two short seasons of March-May and end of October-December, especially in the middle of Machakos district. The minimum and maximum temperatures are normally 12 ^{0}C and 27 ^{0}C, respectively (Jaetzold and Schmidt, 1983).

The major soil groups of the catchment area are dependent on relief and climate. Most of the underlying geology is composed of basement system rocks. These rocks are mainly *gneiss*, which outcrops in a number of hills including Mua, Machakos, Iveti, Kangundo and Mbooni. The soils of the mountains and hills have variable fertility and are well drained (Okwach *et al*, 2004).

The prevalent vegetation of the area is savanna grassland and woodlands. Stains of planted forest like eucalyptus are found mainly on the hill slopes of Mbooni and Kangundo. In areas with high agricultural potential, the native vegetation has disappeared, leaving patches of woodlands and shrubs enclosed in a matrix of planted crops. Semi deciduous forests are observed along Yatta plateau (Okwach *et al*, 2004).

The catchment is one of the poorest in terms of agricultural production. Unsuitable climate and poor soil fertility makes smallholder rain-fed agriculture difficult in more than 80 percent of the area. Most of the agricultural activities are concentrated on the hill slopes. In the Eastern slopes between 1650 and 1800m, is the Upper Midland (UM) zone which can support coffee (though with low to moderate yield), sunflower, maize and sorghum growing as well as ranching. The Lower Midland (LM) zone can support Cotton and millet growing as well as ranching to a lesser extent (Jaetzold and Schmidt, 1983). Other crops, which are agro-ecologically distributed within the catchment, include banana, cassava, potato, pigeon pea and some garden crops like Kales.

3.4 Data Sources

Data for the study was generated by the means of a semi-structured questionnaire that was administered to 228 farmers after a pre-testing process on ten farmers. The survey yielded information on soil fertility and water management practices of the area under study and the socio-economic factors related to their adoption. This information was based on the long-rain and short-rain seasons of the year 2003.

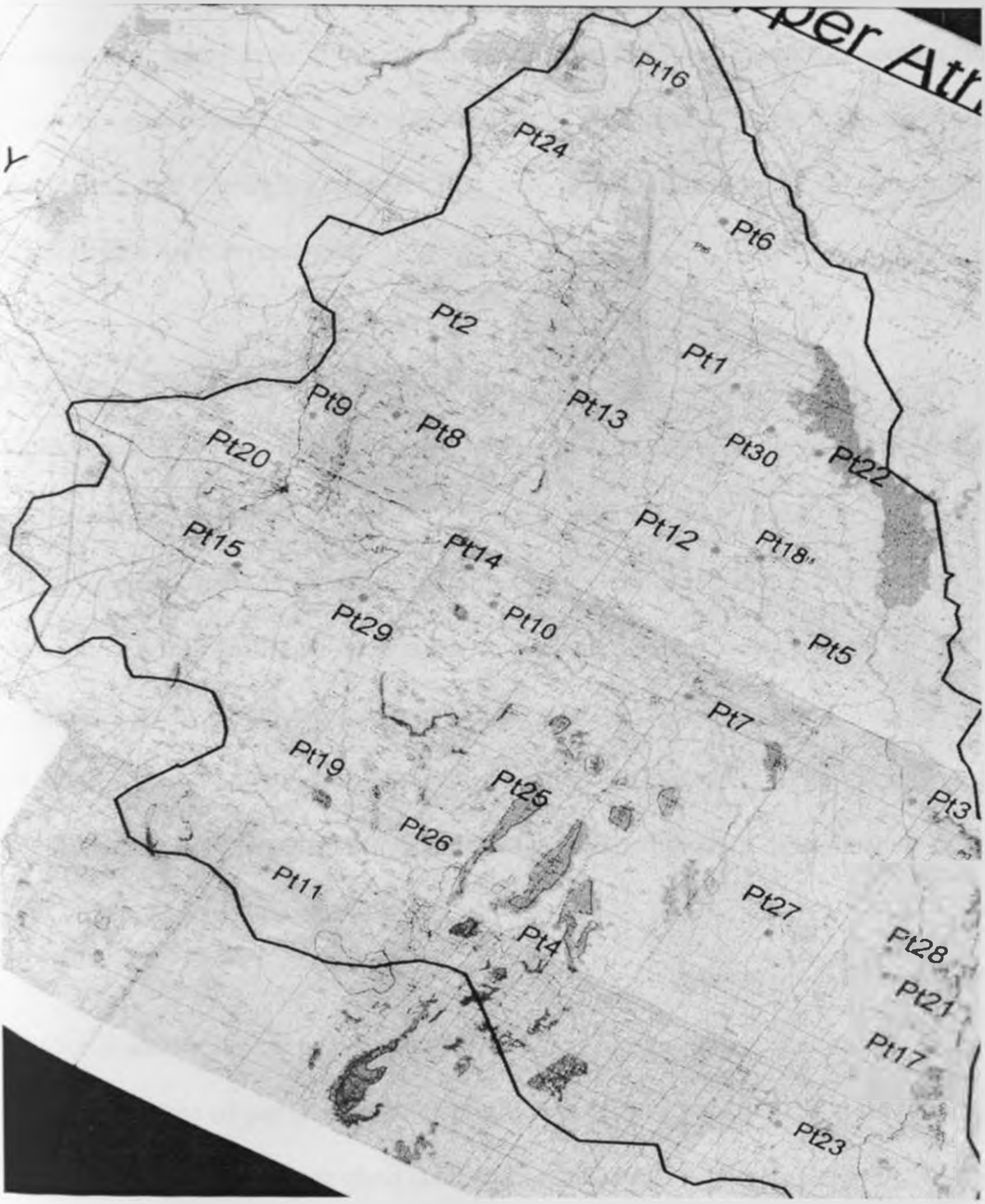
3.5 Sampling Procedures

A total of 228 farmers were interviewed in the study. In consultation with a team of Geographical Information System (GIS) experts from ICRAF, GIS program guided random sampling methodology was used to select farmers to be interviewed in the Upper Athi Catchment of Machakos, Makueni and Kitui districts. Using this procedure, 30 blocks (1 Km^2 each) were randomly selected as shown in Figure 1.

Eighteen blocks were in Machakos district, 11 blocks in Makueni district and 1 block in Kitui district, as determined by the catchment boundary. The study targeted 9 respondents per block. thus giving a total of 270 respondents. However, the 30 blocks only yielded 135 respondents in Machakos. 86 respondents in Makueni and 7 respondents in Kitui. a total of 228 respondents due to unavailability of farmers and sometimes low population within blocks. The farm household survey was undertaken in January/February 2004. using a single-visit survey approach.

A catchment is an area where run-offs and rivers drain into one outlet. In this case, the outlet was River Athi. The boundary of the Upper Athi Catchment is sketched in Figure 1 and reflects an area which was assumed to be heavily degraded. considering the catchment characteristic of uniform run-off flow.

Figure1: Sampling plan for the Upper Athi Catchment of Machakos, Makueni and Kitui



Source: Okwach *et al.* 2004

3.6 Problems Experienced in 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. Any number of problems will arise, even in the most carefully designed survey. In this section, the most commonly experienced data problems and their implications for estimation are discussed. The section also highlights measures that were taken to alleviate the consequences of data problems that were experienced.

3.6.1 Multicollinearity

Multicollinearity refers to the presence of linear relationships (or near linear relationships) among the explanatory variables (Koutsoyiannis, 1973). Since economic data is unexperimental, many econometric variables tend to move together in a systematic way and hence are termed 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.

Multicollinearity was examined through inspection of signs and magnitudes of the parameter estimates and use of partial correlation coefficient. 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 indicated that AGE and experience variable (EXP) were highly correlated (0.83), resulting into the removal of EXP from the logistic regressions. 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.

There is no easy solution to the problem of multicollinearity (Greene, 1993). On one hand, including the collinear variables will increase the variance of the estimator while exclusion of the variable will introduce bias in the estimator. For the case at hand, older farmers tended to have a higher farming experience. The experience variable (EXP) was therefore removed from the regressions because of its high correlation with age. Correlation matrix for all the included variables is in appendix (i).

3.6.2 Heteroscedasticity

One of the major problems with cross-sectional data is the tendency of the disturbances to vary with some or all of the explanatory variables (Kennedy, 1985). This violates the constant variance assumption of the disturbance term, resulting in heteroscedasticity. Heteroscedasticity renders the estimated ß's inefficient and thus invalid for use in making predictions about the dependent variables (Greene, 1993).

This study tested for heteroscedasticity in the four estimated models using the likelihood ratio (LR) statistic (Maddala, 2001). The null hypothesis was that the model in question is homoscedastic against the alternative that it is heteroscedastic. The LR statistic is similar to the F test in OLS. It is asymptotically distributed chi-square with k degrees of freedom, where k is the number of independent variables in the model. The LR statistic was calculated from:

$$LR = -2(Ln_{het} - Ln_{\text{hom}}) \qquad (3.6)$$

Where Ln_{het} and Ln_{hom} are the heteroscedastic and homoscedastic log-likelihood functions respectively. The computed LR value for the probability of fertilizer adoption model was 7.354, while the tabulated X^2 value, at $\alpha=0.01$ and $k = 11$ was 24.7250. On the other hand, the computed LR value for the probability of animal manure adoption model was 0.3054. The computed LR value for the probability of compost manure adoption model was 13.3112. The computed LR value for the probability of soil and water conservation structure adoption model was 1.246. Since the calculated LR values in the four cases were less than the tabulated X^2 value of 24.7250, the null hypothesis of homoscedasticity could not be rejected for the four models. These results are reported in appendix (ii).

3.6.3 Goodness of Fit

A goodness-of-fit measure is a summary statistic indicating the accuracy with which a model approximates the observed data. To measure the goodness-of-fit in qualitative response models, Greene (1993) and Maddala (2001) suggested use of likelihood ratio index (LRI). The LRI (also called McFadden R^2 or pseudo R^2) is analogous to the R^2 in a conventional regression. It was computed from the following formula:

$$LRI = 1 - LnL / Ln_0 \tag{3.7}$$

Where LnL is the log-likelihood function for the model having all the independent variables and Ln_0 is the log-likelihood function for the model computed only with the constant term. A zero LRI value indicates lack of fit while a LRI value of one indicates perfect fit. Empirical evidence suggests that LRI usually lies between 0.2 and 0.4 (Mbata, 1997). The LRI values for the model estimated in this study were 0.337 for the probability of fertilizer adoption model, 0.282 for the probability of animal manure adoption model, 0.134 for the probability of compost manure adoption model and 0.11 for the probability of soil and water conservation structure adoption model. The illustration of these results is in appendix (iii).

3.6.4 Measurement Errors

As is the case with many smallholder farms, reliable farm production data was lacking, as most farmers did not keep farm records. The author had to rely on the farmers' memory and approximation for information. This introduces measurement error and decreases the quality of data in general. Obtaining more reliable data from the small-scale farmers would involve spending longer periods in the field to collect data or mobilising farmers to keep records. This would necessitate mobilisation of huge financial budget, which cannot justify the value added to the data collected. However, the data obtained for this study was found to be good enough to make policy recommendations.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Soil Fertility and Water Management Practices

4.1.1 Definition of Adoption

Adoption may be defined as the decision to make full use of an innovation as the best course of action available (Rogers, 1983). The choice to adopt an innovation is regarded as an outcome of a series of influences exerted by the change forces on the behaviour of the decision-maker through time. However, this study was limited by adoption data in the past years. Following this limitation, it was assumed that adoption of soil fertility and water management technologies in the year of study (2003) is positively correlated with adoption behavior in the past years. The available data for the year of study (2003) was therefore used to explain the adoption behavior in the study area. Manure use and soil and water conservation structure use are long-term strategies for soil fertility management compared to fertilizer use. The positive correlation (Table 4.1) between soil and water conservation structure use and fertilizer use supports the assumption that farmers' current fertilizer adoption decisions are positively related to their past behaviours.

Table 4.1: Correlation Matrix for Dependent Variables

	Inorganic fertilizer use	Animal manure use	Compost manure use	Soil conservation structure use
Inorganic fertilizer use	1.000	-.027	.203**	.299**
Animal manure use	-.027	1.000	-.179**	-.034
Compost manure use	.203**	-.179**	1.000	.102
Soil conservation structure use	.299**	-.034	.102	1.000

** Correlation is significant at 1% level (2-tailed).

Source: Survey Results, 2003

4.1.2 Inorganic Fertilizer Adoption

About 40% of the farmers adopted fertilizer in the study area. Those who adopted fertilizer applied it on maize (81%), maize and coffee (19%). Farmers applied an average of 42 kg ha $^{-1}$ per season of fertilizer on maize. In terms of N and P, the average amount of fertilizer applied on maize was 8 kg N ha^{-1} and 12 kg P ha^{-1} per season. The recommended amount of N and P for KCB maize is 40 kg N and 20 kg P ha^{-1}. The amount of fertilizer applied was therefore far below the recommended levels.

Most of the farmers (40%) used a combination of DAP and CAN, while the rest used either DAP only (34%), CAN only (10%) or NPK only (8%). Those who did not adopt fertilizer gave many reasons with high cost (48%) recording the highest frequency. Twenty three percent preferred manure for fertilizer, while 17% said fertilizer destroys the soil.

4.1.3 Animal Manure Adoption

The study showed that, 76% of the farmers adopted animal manure. Of those who adopted animal manure, 46% adopted cattle and sheep/goat manure, 25% adopted cattle, sheep/goat and poultry manure, while 17% adopted cattle manure.

Those who did not adopt animal manure cited reasons including no livestock (60%), manure buying is expensive (17%), no means of transportation (9%), among other reasons. The study found a strong relationship between livestock ownership and animal manure adoption. Majority of those who owned livestock adopted animal manure (72%).

Table 4.2: Distribution of Respondents by Animal Manure use and Livestock Ownership

LIVESTOCK OWNERSHIP	ANIMAL MANURE USE		TOTAL
	No	Yes	
No	23*	8	31
	10.1%	3.5%	13.6%
Yes	32	165	197
	14.0%	72.4%	86.4%
Total	55	173	228
	24.1%	75.9%	100.0%

* = Number reporting

Source: Survey results, 2003

4.1.4 Compost Manure Adoption

Compost making is a natural process of turning organic material into valuable plant food called humus. It involves putting crop residues and other materials in a pit and allowing them to decompose. Twenty eight percent of the farmers adopted compost manure. A strong relationship was again observed between livestock ownership and compost manure adoption. Majority of the farmers who owned livestock did not adopt compost manure (63%). This is because the farmers who owned livestock had an access to animal manure. Animal manure therefore served as a cheaper source of manure because of its availability.

Farmers applied an average of 0.5 Ton ha^{-1} per season (0.4 Ton acre $^{-1}$ yr $^{-1}$)[2] of manure (animal manure and compost) on their crops during the study period.

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[2] 1 ha = 2.47 acres

Table 4.3: Distribution of Respondents by Compost Manure use and Livestock Ownership

LIVESTOCK OWNERSHIP	COMPOST MANURE USE		TOTAL
	No	Yes	
No	21*	10	31
	9.2%	4.4%	13.6%
Yes	144	53	197
	63.2%	23.2%	86.4%
Total	165	63	228
	72.4%	27.6%	100.0%

* = Number reporting

Source: Survey results, 2003

4.1.5 Soil and Water Conservation Structure Adoption

Soil and water conservation structure use is a long-term strategy for managing soil fertility and conserving water. According to this study, 74% of the farmers adopted soil and water conservation structures in their farms. The major types of structures constructed by farmers included terraces (bench) 76%, terraces and retention ditches (14%) and a combination of terraces, trash lines and retention ditches (4%). Farmers who did not adopt soil and water conservation structures cited reasons including lack of labour for construction (70%), lack of materials for construction (13%), lack of understanding of their relevance (8%) and lack of knowledge on about them (3%).

In terms of **strategies' combination**, 35% of the farmers adopted manure and soil and water conservation structures, 33% adopted fertilizer, manure and soil and water conservation structures, while 18% adopted manure only.

4.2 Sample Socio-economic and Agro-ecological Characteristics

4.2.1 Socio-economic Characteristics

Age of the farmer (years). According to the survey, the average respondent farmer in the study was aged 48 years, with a standard deviation of 15. The youngest respondent was 20 years old, while the oldest farmer was 89 years.

Formal education level (years). Respondent farmers had an average education level of 7 years, with a standard deviation of 4. The minimum education level was 0 years and the maximum was 23 years.

Gender of the respondent. About 70% of the respondent farmers were male, while 30% were female. A larger proportion of the respondent farmers were therefore male.

Size of the family. Respondent farmers had an average family size of 6 children, with a standard deviation of 3. The minimum family size was 0 children and the maximum family size was 26 children.

Farming experience (years). The farmers had an average farming experience of 22 years, with a standard deviation of 17 years. The minimum farming experience was 1 year and the maximum was 69 years.

Total farm size (acres). The survey showed that, the average total farm size owned by respondent farmers was 5.6 acres (2.3 ha), with a standard deviation of 4.2. The minimum total farm size was 1 acre (0.4 ha) and the maximum was 30 acres (12 ha).

Table 4.4: Descriptive Statistics for Some Continuous Variables

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
Age of the farmer	228	20.00	89.00	48.39	14.75
Formal education level (years)	228	0.00	23.00	6.43	3.96
Size of the family (no. of children)	228	0.00	26.00	5.45	3.12
Farming experience in years	228	1.00	69.00	21.51	15.48
Total farm size in acres	228	1.00	30.00	5.63	4.17
Farm size (under crops) in acres	228	.25	27.00	3.95	3.28
Output of the maize (90 kg bags)	228	.00	95.00	9.96	12.06
Distance to the nearest market in km	228	.20	19.00	4.89	4.74

Source: Survey results, 2003

Output of maize (90 kg bags). Respondent farmers obtained an average maize output of 10 bags in the year of study, with a standard deviation of 12. The minimum number of bags obtained was 0 bags and the maximum was 95 bags.

Distance to the nearest market (Km). The average distance to the nearest market was 5 Km, with a standard deviation of 5. The closest farm household unit was 0.2 Km from the nearest market, while the furthest household unit was 19 Km from the nearest market.

Hired labour use. Approximately 36% of the respondent farmers hired labour, while 65 % did not hire labour. This indicates that a larger proportion of the respondent farmers was not able to hire labour and hence used family labour.

Livestock ownership. About 86% of the respondent farmers owned livestock while 14% did not own livestock. Majority of the farmers therefore owned and kept livestock.

Access to production credit. The survey results showed that 18% of the respondent farmers had an access to production credit in the last four years, while 82% did not. This reflected the fact that production credit was a major constraint in production in the study area.

Access to on-farm agricultural extension. About 18% of the respondent farmers received on-farm extension, while 82% did not. This indicated that extension was a major constraint in the study area.

Membership of a farmers' group. The survey showed that 40% of the respondent farmers were members of a farmer group, while 61% were non-members. Majority of the respondents were therefore not members of farmer groups.

Attendance to field days/demonstrations. About 54% of the respondent farmers had attended a field day/demonstration while 46% had never attended any field day/demonstration. Information gap was clearly evident in the study area since many farmers did not have access to this source of information.

4.2.2 Agro-ecological Characteristics

Agro-classification. According to the survey results, 47% of the respondent farmers were in the Upper Midland (UM) zones, while 53% were in the Lower Midland (LM) zones. This is an indication that farmers were uniformly distributed across the two major agricultural zones in the study area.

Table 4.5: Descriptive Statistics for Some Discrete Variables

VARIABLE	CATEGORY	NUMBER REPORTING	PERCENT
Gender of the farmer	Female	69	30.3
	Male	159	69.7
Family members off-farm	No	62	27.2
	Yes	166	72.8
Hired labour use	No	147	64.5
	Yes	81	35.5
Livestock ownership	No	31	13.6
	Yes	197	86.4
Access to production credit	No	186	81.6
	Yes	42	18.4
Access to on-farm agricultural extension	No	185	81.1
	Yes	43	18.9
Membership of a farmers group	No	138	60.5
	Yes	90	39.5
Attendance to field days, demonstrations	No	105	46.1
	Yes	123	53.9
Agro-classification	Lower midland zones	120	52.6
	Upper midland zones	108	47.4

Source: Survey results, 2003

4.3 Factors Affecting Adoption of Soil Fertility and Water Management Technologies

4.3.1 Fertilizer Adoption

Model Properties

Table 4.6 shows the results of the logistic regression for fertilizer adoption. The logistic model correctly predicted 76% of the farmers' adoption practices and the pseudo R^2 was 0.337. The model parameter estimates were jointly significantly different from zero as shown by the chi-square statistic, which was significant at 1%. The maximum likelihood estimates of the logistic regression are shown in the table.

Hypothesis testing

Six out of the eleven variables included in the model were statistically significant at 10% level or better. These were the following:

Off-farm employment. Positively influenced the adoption of fertilizer. The result agreed with the set hypothesis. This meant that farmers who had access to off-farm income were better adopters of fertilizer.

Hired labour use. Positively influenced the adoption of fertilizer. The result agreed with the set hypothesis. This indicated that farmers who had an ability of hiring labour for farming were better adopters of fertilizer.

Maize output. Positively influenced the adoption of fertilizer. The result matched the set hypothesis. This meant that farmers who received a higher maize output had a higher incentive of adopting fertilizer.

Distance to the nearest market. Negatively influenced the adoption of fertilizer. The result matched the set hypothesis. This was an indication that farmers who resided near markets were better adopters of fertilizer compared to those who resided far from markets. Farmers near markets have a better access to other production inputs. They could also market their products aggressively.

Agricultural extension. Positively influenced the adoption of fertilizer. The result matched the set hypothesis. Farmers who had access to agricultural extension were therefore better adopters of fertilizer.

Agro-classification. Positively influenced the adoption of fertilizer. The result agreed with the set hypothesis. Farmers who resided in the Upper Midland (UM[3]) zones were therefore better adopters of fertilizer, compared to those in the Lower Midland (LM[4]) zones. This might be as a result of reduced farming risks brought about by the reliable rainfall they receive.

Some variables included in the regression analysis were insignificant in influencing the adoption of fertilizer in the study area. These were age of the household head, education, family size, livestock ownership and group membership. This could have been as a result of measurement errors in the respective variables.

In summary, farmers who had access to off-farm employment, used hired labour, received higher maize output, were nearer to the market, received extension and resided in the Upper Midland (UM) zones, were better adopters of fertilizer. The converse of this phenomenon is true.

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[3] UM Zones are good at Coffee, Sunflower, maize and Sorghum growing and Receive an annual rainfall of 400-1000 mm (Farm Management Handbook).

[4] LM zones are good at Cotton and millet growing and receive an annual rainfall of 200-400 mm (Farm Management Handbook)

Table 4.6: Results of Logistic Regression for Fertilizer Adoption

VARIABLE	B	S.E.	WALD	SIG.	EXP (B)	HYP-SIGN	OBS-SIGN
Age	-.010	.018	.333	.564	.990	+/-	#
Education level in years	.011	.060	.032	.859	1.011	+	#
Family size	-.063	.066	.898	.343	.939	+/-	#
Off-farm employment	.937	.424	4.890	.027**	2.553	+	+
Hired labour use	1.026	.415	6.122	.013**	2.790	+	+
Maize output (90 kg bags)	.040	.020	4.119	.042**	1.040	+	+
Livestock ownership	.356	.535	.444	.505	1.428	+	#
Distance to nearest market	-.283	.066	18.539	.000***	.753	-	-
Extension	1.028	.508	4.094	.043**	2.795	+	+
Group Membership	.131	.365	.129	.720	1.140	+	#
Agro-classification	2.397	.419	32.742	.000***	10.990	+	+
Constant	-1.855	1.147	2.614	.106	.157	+/-	#
Model chi-square	103.11***						
Percent correctly predicted	76.3						
Pseudo R^2	0.337						
Sample size	228						

Note: *** Sig. at 1%, ** Sig. at 5%, * Sig. 10%, # insignificant (two tailed test)

HYP-SIGN is hypothesized sign

OBS-SIGN is observed sign

Source: Survey results, 2003

4.3.2 Animal Manure Adoption

Model properties

Table 4.7 shows the results of the logistic regression for animal manure adoption. The logistic model correctly predicted 84% of the farmers' adoption practices and the pseudo R^2 was 0.282. The model parameter estimates were jointly significantly different from zero as shown by the chi-square statistic, which was significant at 1%. The maximum likelihood estimates of the logistic regression are shown in the table.

Hypothesis testing

Five out of the eleven variables included in the model were statistically significant at 10% level or better. These were the following:

Education level. Negatively influenced the adoption of animal manure. The result did not match the set hypothesis, which was positive. This might have been due to the fact that animal manure use is a relatively traditional technology, which does not require a lot of knowledge in terms of application methods, compared to other technologies such as fertilizer use. Farmers who had few to moderate years of schooling therefore preferred this technology, compared to other practices.

Off-farm employment. Positively influenced the adoption of animal manure. The result matched the set hypothesis. This indicated that farmers who had access to off-farm employment were better adopters of animal manure. These farmers could easily afford hired labour which is required for preparation, handling and application of animal manure.

Livestock ownership. Positively influenced the adoption of animal manure. The result agreed with the set hypothesis. This meant that farmers who owned livestock were better adopters of animal manure, since they could readily obtain animal manure from the primary source without necessarily buying.

Distance to the nearest market. Positively influenced the adoption of animal manure. The result did not match the set hypothesis which was negative. This might have been because farmers far from the market (in remote areas) do not have access to other soil fertility management strategies such as fertilizer, hence they tend to utilize the available strategies like animal manure.

Agricultural extension. Positively influenced animal manure adoption. The result matched the set hypothesis. It could therefore be interpreted that farmers who received agricultural extension were better adopters of animal manure, compared to those who did not receive. Agricultural extension brings hope to the farmers in terms of better knowledge on application methods.

Some factors were not significant in influencing animal manure adoption. These were age, family size, hired labour use, maize output in bags, group membership and agro-classification. This could have been as a result of errors in measuring the respective variables.

In summary, it was concluded that farmers who had off-farm employment, owned livestock, far from the market and received extension were better adopters of animal manure. The converse of this phenomenon is true.

Table 4.7: Results of Logistic Regression for Animal Manure Adoption

VARIABLE	B	S.E.	WALD	SIG.	EXP(B)	HYP-SIGN	OBS-SIGN
Age	.001	.021	.001	.976	1.001	+/-	#
Education level in years	-.116	.067	3.003	.083*	.891	+	-
Family size	-.109	.074	2.177	.140	.897	+/-	#
Off-farm employment	.889	.437	4.143	.042**	2.432	+	+
Hired labour use	-.684	.450	2.312	.128	.504	+	#
Maize output (90 kg bags)	.031	.024	1.732	.188	1.032	+	#
Livestock ownership	3.226	.575	31.446	.000***	25.182	+	+
Distance to nearest market	.123	.053	5.408	.020**	1.131	-	+
Extension	1.535	.687	4.983	.026**	4.639	+	+
Group Membership	.103	.427	.058	.809	1.108	+	#
Agro-classification	.543	.421	1.662	.197	1.721	+	#
Constant	-1.792	1.256	2.033	.154	.167	+/-	#
Model chi-square	70.947***						
Percent correctly predicted	83.8						
Pseudo R^2	0.282						
Sample size	228						

Note: *** Sig. at 1%, ** Sig. at 5%, * Sig. 10%, insignificant (two tailed test)

HYP-SIGN is hypothesized sign

OBS-SIGN is observed sign

Source: Survey results, 2003

4.3.3 Compost Manure Adoption

Model properties

Table 4.8 shows the logistic regression for compost manure Adoption. The logistic model correctly predicted 71% of the farmers' adoption practices and the pseudo R^2 was 0.134. The model parameter estimates were jointly significantly different from zero as shown by the chi-square statistic, which was significant at 1%. The maximum likelihood estimates of the logistic regression are shown in the table.

Hypothesis testing

Two of the eleven variables included in the model were statistically significant at 10% level or better. These were the following:

Hired labour use. Positively influenced the adoption of compost manure. The result matched the set hypothesis. It was therefore concluded that farmers who had access to hired labour were better adopters of compost manure. This reflected the fact that compost manure preparation requires a lot of labour.

Distance to the nearest market. Negatively influenced the adoption of compost manure. The result agreed with the set hypothesis. Farmers who resided near markets were therefore better adopters of compost manure, compared to those who were relatively far from the market. Farmers near markets have a better access to other production inputs. They can also market their products aggressively.

Some of the factors included in the regression analysis for compost manure adoption were insignificant. These were age, education level in years, family size, off-farm employment, maize output in bags, livestock ownership, Extension, group membership and agro-classification. This could have been as a result of measurement errors in the variables.

In summary, farmers who had a potential for hiring labour and were nearer the market were better adopters of compost manure. Labour is very essential for compost making, while farmers near the market have the ability to obtain information and market their products.

Table 4.8: Results of Logistic Regression for Compost Manure Adoption

VARIABLE	B	S.E.	WALD	SIG.	EXP(B)	HYP-SIGN	OBS-SIGN
Age	-.026	.018	2.060	.151	.975	+/-	#
Education level in years	.024	.054	.191	.662	1.024	+	#
Family size	-.014	.065	.045	.833	.986	+/-	#
Off-farm employment	.224	.376	.355	.551	1.251	+	#
Hired labour use	.611	.372	2.699	.100*	1.842	+	+
Maize output (90 kg bags)	.001	.015	.005	.945	1.001	+	#
Livestock ownership	-.350	.483	.525	.469	.704	+	#
Distance to nearest market	-.228	.061	14.104	.000*	.796	-	-
Extension	.019	.451	.002	.967	1.019	+	#
Group Membership	.038	.356	.011	.915	1.039	+	#
Agro-classification	.165	.341	.234	.629	1.179	+	#
Constant	.816	1.032	.626	.429	2.262	+/-	#
Model chi-square	36.01***						
Percent correctly predicted	71.5						
Pseudo R^2	0.134						
Sample size	228						

Note: *** Sig. at 1%, ** Sig. at 5%, * Sig. 10%, # insignificant (two tailed test)

HYP-SIGN is hypothesized sign

OBS-SIGN is observed sign

Source: Survey results, 2003

4.3.4 Soil and Water Conservation Structure Adoption

Model properties

Table 4.9 reports the results of the logistic regression for soil and water conservation adoption. The logistic model correctly predicted 75% of the farmers' adoption behaviour and the pseudo R^2 was 0.11. The model parameter estimates were jointly significantly different from zero as shown by the chi-square statistic, which was significant at 1%. The maximum likelihood estimates of the logistic regression are shown in the table.

Hypothesis testing

Three out of the eleven variables included in the model were statistically significant at 10% level or better. These were the following:

Maize output. Positively influenced the adoption of soil and water conservation structures. The result matched the set hypothesis. This meant that farmers who obtained higher maize output had an incentive for adopting soil and water conservation structures. Maize is a major crop among the farmers of Eastern province and is grown for subsistence or for sale. Farmers who received higher maize output were motivated to adopt strategies that would ensure higher yields.

Distance to the nearest market. Negatively influenced the adoption of soil and water conservation structures. The result was consistent with the set hypothesis. Farmers who resided near markets were therefore better adopters of soil and water conservation structures. compared to those who were far from the markets. Farmers near markets have a better access to production inputs. They can also market their products aggressively.

Agro-classification. Negatively influenced the adoption of soil and water conservation structures. The result did not agree with the set hypothesis, which was positive. It was therefore concluded that farmers in the Lower Midland (LM) zones were better adopters of soil and water conservation structures, compared to those in the Upper Midland (UM) zones. This could be due to the fact that LM zone farmers receive lower rainfall than UM zone and are likely to develop strategies for conserving soil and water.

Factors which were not significant in the regression analysis for soil and water conservation structure adoption were age, education level in years, family size, off-farm employment, hired labour, livestock ownership, extension and group membership. This could have been as a result of measurement errors in the variables.

In summary, farmers who received a higher maize output, were nearer to the market and resided in Lower Midland (LM) zones had a higher probability of adopting soil and water conservation structures.

Table 4.9: Results of Logistic Regression for Soil Conservation Structure Adoption

VARIABLE	B	S.E.	WALD	SIG.	EXP (B)	HYP-SIGN	OBS-SIGN
Age	.025	.016	2.315	.128	1.025	+/-	#
Education level in years	.048	.059	.664	.415	1.049	+	#
Family size	-.053	.066	.663	.415	.948	+/-	#
Off-farm employment	-.138	.378	.134	.714	.871	+	#
Hired labour use	.341	.414	.675	.411	1.406	+	#
Maize output (90 kg bags)	.051	.028	3.383	.066*	1.052	+	+
Livestock ownership	-.142	.458	.097	.756	.867	+	#
Distance to nearest market	-.104	.033	9.684	.002***	.901	-	-
Extension	.352	.494	.507	.476	1.421	+	#
Group Membership	.136	.361	.142	.706	1.145	+	#
Agro-classification	-.706	.356	3.928	.047**	.494	+	-
Constant	.348	1.057	.109	.742	1.417	+/-	#
Model chi-square	28.877***						
Percent correctly predicted	75.4						
Pseudo R^2	0.11						
Sample size	228						

Note: *** Sig. at 1%, ** Sig. at 5%, * Sig. 10%, # insignificant (two tailed test)

HYP-SIGN is hypothesized sign

OBS-SIGN is observed sign

Source: Survey results, 2003

4.4 Multivariate Farm Characterization

4.4.1 Definition of Farm Types

Table 4.10, reports the number of farmers in each cluster and the means of the standardized variables in clusters from k-mean cluster analysis. Three major farm types (clusters) were identified in this study. The delineation variables were identified as off-farm employment, hired labour use, maize output, distance to the nearest market, access to on-farm extension and agro-classification. These variables, which were significant in influencing the adoption of soil fertility and water management technologies, were selected from the logistic regressions in section 4.3. Analysis of variance for the variables is reported in Table 4.11. The variables were further grouped intuitively into productive resource variables (off-farm employment, hired labour use, maize output), information variable (access to on-farm extension), marketing variable (distance the nearest market) and agro-ecological variable (Agro-classification).

Table 4.10: Final Cluster Centers from K-mean Cluster Analysis

VARIABLE	CLUSTER		
	1	2	3
Z: Off-farm employment	.027	-.071	.150
Z: hired labour use	1.344	-.741	-.527
Z: maize output in 90 kg bags	.544	-.289	-.244
Z: distance to the nearest market	-.401	-.379	1.878
Z: access to on-farm extension	.148	-.117	.042
Z: agro-classification dummy	.066	.160	-.588
Number of cases in each cluster	77	112	39
Percent of cases in each cluster	34	49	17

Source: Survey results, 2003

Farm type (cluster) 1 Consisted of farmers who had access to productive resources (farm income, off-farm income and hired labour) and information (extension) and were nearest to the market. They were found in both UM and LM zones. The cluster size was 34%. The number of standard deviations from the means of individual variables for this cluster is shown in Table 4.10. Farmers/farms in this category were well endowed with resources, information and market access and were therefore classified as **socio-economically unconstrained farm type.**

Table 4.11: Analysis of Variance for Socio-economic and Agro-ecological Variables

VARIABLE	CLUSTER MEAN SQUARE	DF	ERROR MEAN SQUARE	DF	F	SIG.
Z: Off-farm employment	.748	2	1.00	225	.75	.475
Z: hired labour use	105.70	2	0.07	225	1524.15	.000***
Z: maize output in 90 kg bags	17.26	2	.86	225	20.17	.000***
Z: distance to the nearest market	82.99	2	.27	225	305.10	.000***
Z: access to on-farm extension	1.64	2	.10	225	1.65	.194
Z: agro-classification dummy	8.33	2	.94	225	8.91	.000***

Note: *** Sig. at 1% (two tailed test)

Source: Survey results, 2003

Farm type 2 Consisted of farmers who were near the market. However, they did not have access to productive resources (farm income, off-farm income and hired labour) and agricultural information (extension). They were found in both UM and LM zones. The cluster size was 49%. The number of standard deviations from the means of individual variables for this cluster is shown in Table 4.10. These farmers/farms were considered to be resource and information constrained. They were therefore classified as **resource and information constrained farm type.**

Farm type 3 Consisted of farmers who did not have access to productive resources (farm income, off-farm income and hired labour), information (extension) and markets. Most of them were found in LM zones (low midland zones). The cluster size was 17%. The number of standard deviations from the means of individual variables for this cluster is shown in Table 4.10. Farmers/farms in this category were considered to be resource, information and market constrained. They were therefore classified as **socio-economically constrained farm type.**

The above classification clearly demonstrated that farm types vary in their socio-economic constraints. This sample classification coupled with the estimated logistic functions can be used to predict the adoption behaviour in the unknown population clusters. This can be used to generate and prioritize short-term and long-term soil fertility and water management strategies for specific farm types in the semi-arid areas. A summary of the socio-economic and agro-ecological characteristics for each farm type is in Table 4.12.

Table 4.12: Means and Standard Deviations of Some Variables within Clusters

CLUSTER	1		2		3		TOTAL	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Age	48.97	14.63	47.63	14.19	49.41	16.73	48.39	14.75
Education level (years)	7.94	4.03	5.81	3.81	5.26	3.46	6.43	3.96
Family size	5.78	3.78	5.38	2.92	5.00	2.10	5.45	3.12
Farm size (acres)	7.39	5.33	4.39	2.68	5.73	3.92	5.63	4.17
Maize output (90 kg bags)	16.52	17.34	6.47	5.75	7.01	6.19	9.96	12.06
Distance to market (km)	2.99	2.34	3.10	2.19	13.78	3.32	4.89	4.74
Family members off-farm (a)	0.74	0.44	0.70	0.46	0.79	0.41	0.73	0.45
Hired labour use (b)	1.00	0.00	0.00	0.00	0.10	0.31	0.36	0.48
Access to extension (c)	0.25	0.43	0.14	0.35	0.21	0.41	0.19	0.39
Group member (d)	0.52	0.50	0.37	0.48	0.23	0.43	0.39	0.49
Agro-classification (e)	0.51	0.50	0.55	0.50	0.18	0.39	0.47	0.50
Livestock ownership (f)	0.94	0.25	0.81	0.39	0.87	0.34	0.86	0.34

Std. = standard deviation; a, b, c, d, e, f are dummy variables [0-1]

Source: Survey results, 2003

4.4.2 Soil Fertility and Water Management in Sample Farm Types

a) Actual cluster practices. Table 4.13 shows soil fertility and water management practices within the sample farm types (clusters). Fertilizer adoption decreased with an increase in group constraints, with the highest adoption rate of 62.3% experienced by the socio-economically unconstrained farm type and the lowest adoption rate of 2.6% experienced by the socio-economically constrained farm type. Animal manure adoption rate was uniformly distributed across farm types, while compost manure adoption rate was highest in the socio-economically unconstrained category (40.3%) and lowest in the socio-economically constrained group (5.1%). The socio-economically unconstrained farm type experienced the highest adoption rate for soil and water conservation structures (84.4%), while the converse was for the socio-economically constrained (53.8%). This clearly shows that technology adoption ability decreases with an increase in the group socio-economic constraints.

Table 4.13: Distribution of Respondents by Soil Fertility Management within Clusters

PRACTICE	RESPONSE	CLUSTER			TOTAL
		1	2	3	
Inorganic fertilizer adoption	No	29	71	38	138
		37.7%	63.4%	97.4%	60.5%
	Yes	48	41	1	90
		62.3%	36.6%	2.6%	39.5%
Animal manure adoption	No	21	29	5	55
		27.3%	25.9%	12.8%	24.1%
	Yes	56	83	34	173
		72.7%	74.1%	87.2%	75.9%
Compost manure adoption	No	46	82	37	165
		59.7%	73.2%	94.9%	72.4%
	Yes	31	30	2	63
		40.3%	26.8%	5.1%	27.6%
Soil conservation structure adoption	No	12	30	18	60
		15.6%	26.8%	46.2%	26.3%
	Yes	65	82	21	168
		84.4%	73.2%	53.8%	73.7%

Source: Survey results, 2003

b) Hypothesis testing for differences in soil fertility practices across farm types

Fertilizer adoption. Analysis of variance in Table 4.14 shows that fertilizer adoption was significantly different across the three farm types at 1% level. It was therefore concluded that farmers in the respective farm types or socio-economic groups differ in the level of adoption of fertilizer.

Animal manure adoption. Animal manure adoption was not significantly different across the three farm types (Table 4.14). Adoption behaviour for animal manure was therefore uniformly distributed across farm types or socio-economic groups.

Compost manure adoption. According to Table 4.14, Adoption of compost manure was significantly different across the three farm types at 1% level. It was therefore concluded that compost manure adoption differs across farm types or socio-economic groups.

Soil and water conservation structure adoption. This strategy was significantly different across the farm types at 1% level. It was therefore concluded that farmers in the respective farm types or socio-economic groups differ in soil and water conservation structure adoption.

Table 4.14: Analysis of Variance for Soil Management Practices between Clusters

PRACTICE		SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
Inorganic fertilizer adoption	Between Groups	9.430	2	4.715	23.55	.000***
	Within Groups	45.043	225	.200		
	Total	54.474	227			
Animal manure adoption	Between Groups	.610	2	.305	1.67	.191
	Within Groups	41.123	225	.183		
	Total	41.732	227			
Compost manure adoption	Between Groups	3.211	2	1.605	8.52	.000***
	Within Groups	42.381	225	.188		
	Total	45.592	227			
Soil conservation structure adoption	Between Groups	2.424	2	1.212	6.53	.002***
	Within Groups	41.786	225	.186		
	Total	44.211	227			

Note: *** Sig. at 1%

Source: Survey results, 2003

4.4.3 Prediction of Adoption of Soil Fertility Practices for the Population

a) Prediction models

Various models were used to predict the probability of adoption of soil fertility and water management practices for the farm types in the population. These models were derived from the logistic regressions in section 4.3. Means of the variables in the specific farm types were used to predict the probability of adoption of the practices. Only significant variables were included in prediction.

Model 1: Probability of fertilizer adoption

$$P\,(FERT) = 1/1 + e^{-[0.937\,(OFWK) + 1.026\,(HRLB) + 0.040(YIELD) - 0.283(DTM) + 1.028(EXT) + 2.397(AGRO)]} \qquad (4.1)$$

Where,

P(FERT)	is the probability of fertilizer adoption.
OFWK	is off-farm employment
HRLB	is hired labour use
YIELD	is output of maize in 90 kg bags
DTM	is distance to the nearest market in Km
EXT	is access to on-farm extension
AGRO	is agro-classification

Model 2: Probability of animal manure adoption

$$P\,(ANIM) = 1/(1 + e^{-[-0.116(EDUC) + 0.889(OFWK) + 3.226(LVST) + 0.123(DTM) + 1.535(EXT)]} \qquad (4.2)$$

Where,

P(ANIM)	is the probability of animal manure adoption
EDUC	is education level in years
OFWK	is off-farm employment
LVST	is livestock ownership
DTM	is distance to the nearest market in Km
EXT	is access to on-farm extension

Model 3: Probability of compost manure adoption

$$P(COMP)=1/1+e^{-[0.611(HRLB)-0.228(DTM)]} \tag{4.3}$$

Where,

P(COMP)	is the probability of compost manure adoption
HRLB	is hired labour use
DTM	is distance to the nearest market in Km

Model 4: Probability of soil and water conservation adoption

$$P(SOCST)=1/1+e^{-[0.051(YIELD)-0.104(DTM)-0.706(AGRO)]} \tag{4.4}$$

Where,

P(SOCST)	is the Probability of soil and water conservation adoption
DTM	is distance to the nearest market in Km
YIELD	is output of maize in 90 kg bags

b) Results of Prediction

Farm type 1 (Socio-economically unconstrained). According to the prediction for the population in table 4.15, farm type 1, which is the socio-economically unconstrained group, had a likelihood of adopting all the practices (fertilizer, animal manure and soil and water conservation structures) except compost manure. Farmers in this category were considered to be **Innovators (IN)** of soil fertility management innovations. This group was well endowed in adoption ability and only needed to improve on soil fertility management resource use so as to increase crop yields. This could be through better handling of manure during processing to reduce losses, better methods of manure and fertilizer application and frequent renewal and maintenance of soil and water conservation structures to reduce soil fertility losses through run-offs, infiltration and soil erosion.

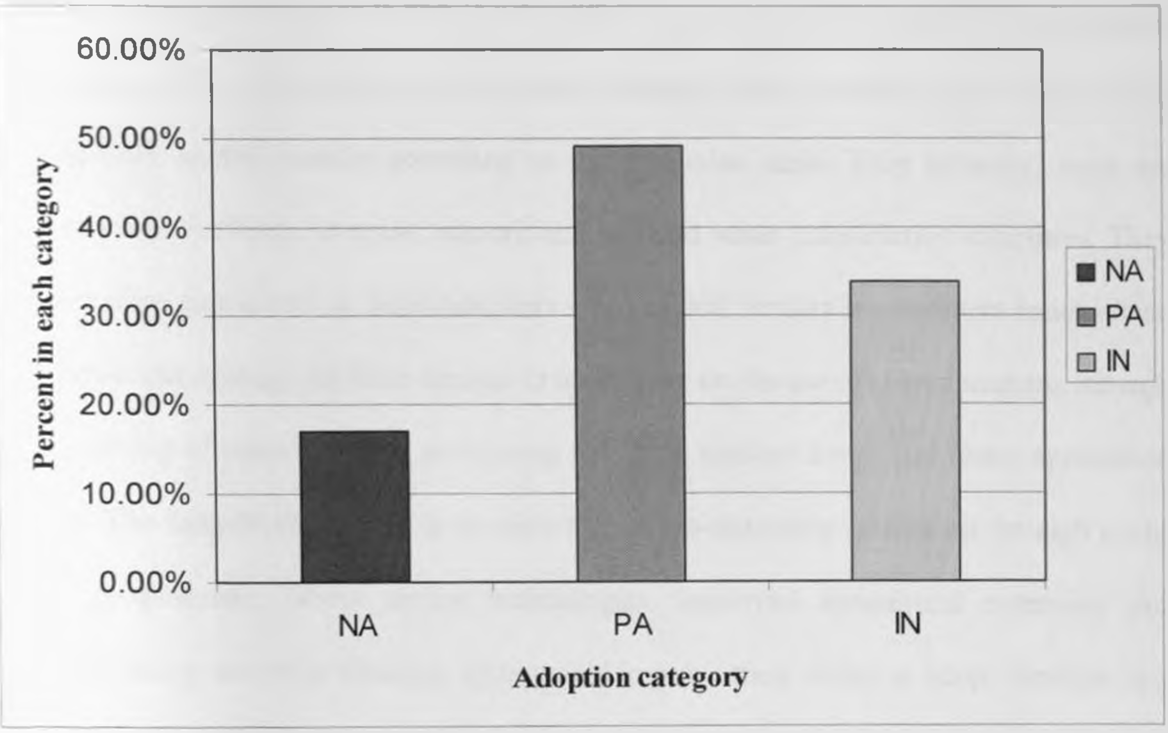
Table 4.15: Predicted Probabilities of Adoption for Population Clusters

CLUSTER	P(FERT)	P(ANIM)	P(COMP)	P(SOCST)
1	0.953179	0.971273	0.482327	0.54277
2	0.817525	0.959207	0.330306	0.405951
3	0.106294	0.992725	0.043909	0.230997
Total	0.800562	0.97263	0.290087	0.417652

$P \leq 0.5$ Not likely to adopt, $P > 0.5$ likely to adopt

Source: Survey results, 2003

Figure 2: Graph of Percentage of Farmers versus Adoption Category



Source: Survey Results, 2003

Farm type 2 (Resource and information constrained). This category consisted of resource (financial and labour) and information constrained farmers. Members of this category had a likelihood of adopting fertilizer and animal manure. However, they were not likely to adopt compost manure and soil and water conservation structures (Table 4.15). Farmers in this category were considered as **Potential Adopters (PA)** of soil fertility management innovations. The **short-term** strategy for these farmers is to improve on the use of animal manure and fertilizer, through better handling of animal manure during processing to reduce losses and better methods of manure and fertilizer application. The **long-term** strategy is relaxing their resource (financial and labour) and information constraints, through ensuring access to affordable credit, promoting labour saving technologies and improving agricultural extension services. This would improve their ability to adopt soil and water conservation structures.

Farm type 3 (Socio-economically constrained). These were the socio-economically constrained farmers. They did not have access to productive resources and agricultural information, and were furthest from the market. Farmers in this category had a likelihood of adopting only animal manure according to the prediction table. They however, were not likely to adopt fertilizer, compost manure and soil and water conservation structures. They were therefore considered as **Non-Adopters (NA)** of soil fertility management innovations. The **short-term** strategy for these farmers is to improve on the use of animal manure, through better handling of manure during processing to reduce nutrient losses and better application methods. The **long-term** strategy is to relax their socio-economic constraints through credit support programmes, labour saving technologies, improved agricultural extension and affordable timely access to fertilizer. This would improve their ability to adopt fertilizer and soil and water conservation structures.

In terms of **priority setting**, the socio-economically constrained category should be given more attention in the implementation of group recommendations as they had the lowest adoption ability. This would ensure equitable distribution of resources and information and better adoption of soil fertility management innovations.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusion

The study used frequency distributions to describe soil fertility and water management practices, identified the socio-economic and agro-ecological factors that influence soil fertility and water management practices using logistic regressions, and finally used the significant variables to characterize farmers into homogenous target groups. This characterization was important in giving recommendations for managing soil fertility in the specific farm types of the semi-arid areas of Eastern Kenya.

Results from descriptive statistics showed that about 40% of the sample farmers adopted fertilizer, 76% adopted animal manure, 28% adopted compost manure, while 74% had soil and water conservation structures in their farms. This justified the need to improve the adoption of soil fertility and water management technologies in the semi-arid areas.

The logistic regression indicated that off-farm employment, hired labour, maize output, agricultural extension and agro-ecological zone positively influenced fertilizer adoption, while the distance to the nearest market was negatively related to fertilizer adoption. Off-farm employment, livestock ownership, distance to the nearest market and agricultural extension positively influenced animal manure adoption, while education negatively influenced the adoption of animal manure. Hired labour use positively influenced compost manure adoption and the distance to the nearest market negatively influenced compost manure adoption. Maize output positively influenced the adoption of soil and water conservation structures, while the distance to the nearest market and agro-ecological zone were negatively related to the adoption of this practice. These factors should be incorporated in the design of policies and strategies for soil fertility improvement.

As a result of the need to design specific soil management strategies, three major farm types were identified in this study, using k-mean cluster analysis. Farmers were classified as socio-economically unconstrained, resource and information constrained and socio-economically constrained. The identified farm types had varying technology adoption abilities that decreased with an increase in the group socio-economic constraints. To increase the adoption of improved soil fertility practices, **short-term** and **long-term** strategies were developed for each farm type. The short-term strategy was to improve on the use of what is adoptable and the long-term strategy was to relax the constraints associated with the respective farm types. These strategies would ensure better technology adoption and higher crop yields.

In terms of **priority setting,** it was suggested that the socio-economically constrained category be given more attention in the implementation of group recommendations as they had the lowest technology adoption ability. This would ensure equitable distribution of resources and information and better adoption of soil fertility innovations.

5.2 Recommendations

In order to improve the adoption of improved soil fertility management practices in the semi-arid areas of Eastern Kenya, the following specific technological recommendations were made for the three identified farm types or socio-economic groups:

- **Socio-economically unconstrained farm type:** Had a likelihood of adopting all the practices (fertilizer, animal manure, and soil and water conservation structures) except compost manure. Farmers in this group should therefore improve on the use of soil fertility management resources so as to increase crop yields. This could be through better handling of manure during processing to reduce losses, better methods of manure and fertilizer application and frequent renewal and maintenance of soil and water conservation structures to reduce soil fertility losses through run-offs, infiltration and soil erosion.

- **Resource and information constrained farm type:** Had a likelihood of adopting fertilizer and animal manure. The short-term strategy for these farmers is to improve on the use of animal manure and fertilizer, through better handling of animal manure during processing to reduce losses and better methods of manure and fertilizer application. The long-term strategy is relaxing their resource (financial and labour) and information constraints, through ensuring access to affordable credit, promoting labour saving technologies and improving agricultural extension services. This would improve their ability to adopt soil and water conservation structures.

- **Socio-economically constrained farm type:** Had a likelihood of adopting only animal manure. The short-term strategy for these farmers is to improve on the use of animal manure, through better handling of manure during processing to reduce nutrient losses and better application methods. The long-term strategy is to relax their socio-economic constraints through credit support programmes, labour saving technologies, improved agricultural extension and affordable timely access to fertilizer. This would improve their ability to adopt fertilizer and soil and water conservation structures.

In order to achieve good results, the study recommended that the above strategies be implemented hierarchically, starting with groups that had the lowest technology adoption ability. Researchers who target these groups should therefore develop technologies which take care of the associated socio-economic constraints. Specifically, researchers who target the socio-economically constrained group, who were only able to adopt animal manure, should develop and recommend to the farmers ways of improving the quality and methods of application of animal manure. This would ensure improved soil fertility management and crop yields.

BIBLIOGRAPHY

Adesina, A. A. and Sirajo, S. (1995). Farmers' Perception and Adoption of New Agricultural Technology: Analysis of Modern Mangrove Rice Variety in Guinea-Bissau. Quarterly Journal of Agriculture 1995 vol.34 (4) PP. 354-371.

Adesina, A. A., Zinnah, M. M. (1993). Technology Characteristics, Farmer Perception and Adoption Decisions. A Tobit Model Application in Sierra Leone. Agric. Econ., 9; 297.

Amemiya, T. (1981). Qualitative Response Models. A Survey Journal of Economic Literature 19:1483-1583.

Asambu, F. K. (1993). Farmers' Perception and Economic Analysis of Factors Affecting Farm Level Maize Enterprise Performance and Adoption of Agricultural Technological Innovations in Semi-Arid South Eastern Kenya. MSc. Thesis, University of Guelph.

Bosch, H. Van den, Gitari, J. N., Ongaro, V.N., Maobe, S. and Vlaming, J. (1998). Monitoring Nutrient Flows and Economic Performances in African Farming Systems (NUTMON) III: Linking Nutrient Balances and Economic Performances in Three Districts in Kenya. Agriculture, Environment and Ecosystems 71:63-80.

CIMMYT. (1993). Adoption of Agricultural Technology. A guide for Survey Design. Mexico

Crossa, J., Bellon, M. R. and Franco, J. (2001). A Quantitative Method of Classifying Farmers using Socio-economic Variables. Mexico.

Doss, C. R., Mwangi, W., Verkuijl, H. and de Groote, H. (2003). Adoption of Maize Technologies in Eastern Africa: A Synthesis of Findings of 22 Case Studies. CIMMYT Economic Working Paper 03-06. Mexico, D. F.: CIMMYT.

Feder, G. and Slade, R. (1984). The Acquisition of Information and the Adoption of New Technology. American Journal of Agricultural Economics 66, 312-320.

Gamba, P., Ngugi, C., Verkuijl, H., Mwangi, W., Kiriswa, F. (2002). Wheat Farmers Seed Management and Varietal Adoption in Kenya. Mexico, D.F.; CIMMYT, Egerton University, Njoro, Kenya, and KARI, Nairobi.

Greene, W.H. (1993). Econometric Analysis. Second Edition. Macmillan Publishing Company, New York.

Haggblade, S. (ed) (2004). Building on Successes in African Agriculture (2020 Vision Focus) Washington, D.C.: International Food Policy Research Institute (IFPRI) 32 Pages. [EN]

Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C. (1992). Multivariate Data Analysis with readings.

Ikombo, B.M. (1984). Effects of Farm Yard Manure and Fertilizers on Maize in Semi Arid Areas of Eastern Kenya. Eastern Africa Agric. for. Journal 44 (special & issue): 266-274.

Jabbar, M. A., Beyene, H., Saleem, M. A. M., and Gabreselassie, S. (1998). Adoption Pathways for New Agricultural Technologies: An Approach and an Application to Vertisol Management in Ethiopia. Socio-economic and Policy Research Working Paper No. 23. International Agricultural Research Institute, Addis Ababa, Ethiopia.

Jager, A.D., Kariuki, I., Matiri, F.M., Odendo, M. and Wanyama, J. M. (1998). Monitoring Nutrient Flows and Economic Performances in African Farming Systems (NUTMON) IV: Linking Nutrient Balances and Economic Performances in Three Districts in Kenya. Agriculture, Environment and Ecosystems 71:81-92.

Jaetzold, R. and Schmidt, H. (1983). Farm Management Handbook for Kenya Vol. II. Nature Conditions and Farm Management Information. Ministry of Agriculture. Government Printer, Nairobi, Kenya.

Kennedy, P. (1985). A Guide to Econometrics. 2nd Edition. Basil Blackwell.

Kenya, (2004). Strategy for Revitalizing Agriculture 2004-2014. MOA. Government Printer, Nairobi

Koutsoyiannis, A. (1973). Theory of Econometrics. Macmillan Education Ltd.

Leagans, J. P. (1979). Adoption of Modern Agricultural Technologies by Small Farm Operators. Cornell International Agricultural Mimeograph No.69, Cornell University, New York.

Lionberger, M. F. (1968). Adoption of New Ideas and Practices. Iowa State University.

Maddala, G.S. (2001). Introduction to Econometrics. 3rd Edition. Cambridge University Press.

Makokha, S., Kimani, S., Mwangi, W. Verkuijl, H. and Musembi, F. (2001). Determinants of Fertilizer use for Maize Production in Kiambu Distrct, Kenya. KARI and CIMMYT.

Marra, M. and Carlson, G. (1987). The Role of Farm Size and Resource Constraints in the Choice between Risky Technologies. Western Journal of Agricultural Economics, 12(2), 109-118.

Mbata, J. N. (1997). Factors Influencing Fertilizer Adoption and Rates of use among Small-scale Food Crops Farmers in the Rift Valley Area of Kenya. Quarterly Journal of International Agriculture. Vol. 36 (3) pp. 229-230.

McCown, R.L and Jones, R.K. (1992). Agriculture of Semi-Arid Eastern Kenya. Problem and Possibilities. In: Probert, M.E. (Ed). A Search for Strategies for Sustainable

Dry Land Cropping in Semi-Arid Eastern Kenya, 10-11 December 1990. ACIAR Proceedings No.41.pp.8-14.

Misiko, P. (1976). Incentives and Disincentives Influencing Farmers in the Adoption of Agricultural Innovation: The Case Bungoma District, Kenya. Ph.D. Thesis, Cornell University, Ithaca, New York.

Muturi, W. M. (1989). Factors Influencing the use of Fertilizer among Smallholder Farmers: A Case of Murang'a district. M.A. Thesis, University of Nairobi.

Mwangi, S. M. (1978). Farm level derived responses for fertilizer in Kenya. Ph.D. thesis, Michigan State University.

Nabwile, S. M. and Kilambwa (1997). Economic Analysis Fertilizer use for Maize. Based on Fertilizer and Recommendations Project (FURP) Data Set. In: Waithaka M., (Eds.) KARI Proceedings of Second Socio-economic Conference (Nov 17th- 19th).

Nadar, H., and Faught, W. (1984). Effects of Legume on Yield of Associated and Subsequent Maize Intercropping in Rotational Systems. East African Agricultural and Forestry Journal 44, P127-136.

Nowak, P.J. (1987). The Adoption of Agricultural Conservation Technologies: Economic and Diffusion Explanations. Rural Sociology 52, 208-220.

Nzuma, J. M. (2001). Adoption of Improved Maize Production Technologies among Smallholder Farmers in Semi-Arid Zones of Kenya: The Case of Improved Seeds and Inorganic Fertilizer in Machakos District, M.Sc Thesis, University of Nairobi, Kenya.

Okalebo, J. R., Simpson, J. R., Probert, M.E, Okwach, E.G. and McCown, R. L. (1996). Maintenance of Soil Fertility under Intensive Maize Cropping in Machakos District Kenya, Submitted to the Eastern African Agriculture and Forestry Journal.

Okuro, O. J., Murithi, M. F., Verkuiji, H., Mwangi, W., Groote, H., and Gethi, M. (2000). An Assessment of Factors Affecting Adoption of Maize Production Technologies in Embu District, Kenya. Paper Presented at KARI Scientific Conference, November 2000, Nairobi, Kenya.

Okwach, E. G., Shepherd, K. D., Kwenah, K. M., Owiti, A. O. and Omuto, C. T. (2004). Assessment of Land Degradation in Machakos, Makueni and Kitui Districts. CARMASAK Technical Report Presented to Rockefeller Foundation.

Omiti, J.M, Freeman, H A, Kaguongo, W. and Bett, C. (2000). Soil Fertility Management in Eastern Kenya: Current Practices, Constraints and Opportunities, CARMASAK Working Paper 1 32PP KARI/ICRISAT.

Ongaro, W. A., (1998). Adoption of New Farming Technologies: A Case Study of Maize in Western Kenya Ph.D. Gothenburg (Sweden).

Ouma, J., Murithi, F., Mwangi, W., De Groote, H. (2002). Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya. Mexico, D. F.; CIMMYT.

Pindyck, R.S. and Rubenfield, D. L. (1991). Econometric Models and Economic Forecasts. New York

Rogers Everett, M. (1983). Diffusion of Innovations. The Free Press, New York.

Rogers, Everett, M., and Shoemaker, F. (1971). Communication of Innovations. 2nd Ed. The Free Press, New York.

Saito, A. K., Daphne S. and Hailu M. (1994). Raising the Productivity of Farmers in Sub-Saharan Africa. World Discussion Paper No. 230, Washington D. C.

Salasya, B. D. S., Mwangi, W., Hugo, V., Odendo, M. A., and Odenya, J. O. (1997). Assessment of Adoption of Seed and Fertilizer Packages and the Role of Credit in Smallholder Maize Production in Kakamega and Vihiga Districts. CIMMYT, Nairobi.

Sanchez, P.A., Shepherd, D.K., Soul, M. J., Place M.F., Buresh, R. J., and Izac A.M.N. (1997). Nutrient depletion in Sub-Saharan Africa. In Buresh J., Sanchez P.A. and Calhoun F. (Eds); Replenishing Soil Fertility in Africa. Soil Science Society of America and ICRAF. Special Publication. Madison.

Simpson, J. R., Okalebo, J. R. and Lubulwa, G. (1996).The Problem of Maintaining Soil Fertility in Eastern Kenya, a Review of Relevant Research. AC/AR Monograph No.4160p.

Smaling, E.M.A and Braun, A.R. (1996). Soil Fertility Research in Sub-Saharan Africa: New Dimensions, New Challenges. Communications in Soil Science and Plant Analysis 27:365-386.

Smaling, E.M.A, Nandwa, S.M., and Janssen, B.H. (1997). Soil Fertility at Stake. In Replenishing Soil Fertility in Africa. Special Publication No. 51.Madison, Wisconsin: American Society of Agronomy and Soil Science Society of America.

APPENDICES

Appendix (i): Testing for Multicollinearity

Pearson Correlation Matrix

	AGE	EDUC	FMLYSZ	OFFWRK	HIREDLB	YIELD	LIVOWN	DTM	EXT	GRME	AGROCLAS
AGE	1.000										
EDUC	-.621	1.000									
FMLYSZ	.547	-.355	1.000								
OFFWRK	.199	-.097	.184	1.000							
HIREDLB	.011	.268	.069	.021	1.000						
YIELD	.190	-.002	.176	-.014	.400	1.000					
LIVOWN	.151	-.057	.066	.016	.161	.221	1.000				
DTM	-.047	-.068	-.085	-.004	-.185	-.052	-.019	1.000			
EXT	.041	.092	-.081	-.159	.111	.182	.060	.056	1.000		
GRME	.124	.004	.038	-.011	.150	.120	.085	-.112	.299	1.000	
AGRO	.008	.085	-.002	-.012	.012	-.119	-.213	-.135	.149	.186	1.000

Source: Author's Survey

Appendix (ii): Testing for Heteroscedasticity

Likelihood ratio (LR) statistic

$LR = -2\,(\ln L_{het} - \ln L_{hom})$

Where LR = Log-likelihood ratio

$\ln L_{het}$ = log-likelihood of the model with heteroscedasticity

$\ln L_{hom}$ = log-likelihood of the model without heteroscedasticity (homoscedastic)

1. **Probability of fertilizer adoption (FERT) model**

$\ln L_{het} = -97.7128$

$\ln L_{hom} = -101.3898$

$LR = -2\,[-97.7128 - (-101.3898)]$

$= 7.354$

X^2 at 11 degrees of freedom and 0.01 significance level = 24.7250

$LR < X^2$ and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

2. **Probability of animal manure adoption (ANIM) model**

$\ln L_{het} = -90.3421$

$\ln L_{hom} = -90.4948$

$LR = -2\,[-90.3421 - (-90.4948)]$

$= 0.3054$

X^2 at 11 degrees of freedom and 0.01 significance level = 24.7250

$LR < X^2$ and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

3. **Probability compost manure adoption (COMP) model**

$\ln L_{het} = -109.7315$

$\ln L_{hom} = -116.3871$

$LR = -2\,[-109.7315 - (-116.3871)]$

$= 13.3112$

X^2 at 11 degrees of freedom and 0.01 significance level = 24.7250

$LR < X^2$ and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

4. **Probability of soil and water conservation structure adoption (SOCST) model**

$\ln L_{het} = -116.3429$

$\ln L_{hom} = -116.9659$

$LR = -2\,[-116.3429 - (-116.9659)]$

$= 1.246$

X^2 at 11 degrees of freedom and 0.01 significance level = 24.7250

$LR < X^2$ and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

Appendix (iii): Testing for Goodness of Fit

Log-likelihood ratio index (LRI = Pseudo R^2)

$LRI = 1 - LnL/LnL_0$

Where,

LRI = Log-likelihood ratio index

LnL = Log-likelihood function value for the model with all independent variables

LnL_0 = Log-likelihood function value for the model computed with only the constant term.

1. **Probability of fertilizer adoption (FERT) model**

$Ln L = -101.3898$

$LnL_0 = -152.9469$

$LRI = 1 - (-101.3898/-152.9469)$

$= 0.337$

2. **Probability of animal manure adoption (ANIM) model**

$Ln L = -90.4947$

$LnL_0 = -125.9680$

$LRI = 1 - (-90.4947/-125.9680)$

$= 0.282$

3. **Probability compost manure adoption (COMP) model**

$\text{Ln L} = -116.3871$

$\text{LnL}_0 = -134.3923$

$\text{LRI} = 1 - (-116.3871/-134.3923)$

$= 0.134$

4. **Probability of soil and water conservation structure adoption (SOCST) model**

$\text{Ln L} = -116.9659$

$\text{LnL}_0 = -131.4042$

$\text{LRI} = 1 - (-116.9659/-131.4042)$

$= 0.11$

Appendix (iv): Questionnaire

UNIVERSITY OF NAIROBI

DEPARTMENT OF AGRICULTURAL ECONOMICS

OLALE, E.K.

MSc. Student

(A56/7252/2002)

ADOPTION OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES IN SEMI ARID AREAS OF MACHAKOS, MAKUENI AND KITUI DISTRICTS

Farm level questionnaire

1.0 Identification

1.1 Name of the enumerator……………………………………………………………..

1.2 Name of the respondent……………………………………………………………...

1.3 District……………………….Division…………………………...

1.4 Location……………………..Sub-location………………………….

1.5 Date……………………..……Start time…………………………….

1.6 Farm ID ……………………..Easting……………..Nothing……….

Instructions

1. **This questionnaire should be administered to the household head or the person managing farm operations.**
2. **Tick or fill in the appropriate response**

2.0 Household characteristics

2.1 Age of the farmer…………

2.2 Gender (0) female (1) male

2.3 Marital status (1) Single (2) Married (3) Divorced (4) Widowed/Widower

2.4 Formal education level (years) ………………………………………………

(1) None (2) Primary (3) Secondary (O-Level) (4) Higher (A-Level)

(5) College/ University (6) Adult Education

2.5 Family size…………………….. (Number of children).

2.6 Number of children above 16 years……………………………...

2.7 Are there members of the family who work off-farm? (0) No (1) Yes.

2.8 How many?…………………

2.9 How much income has been earned off-farm in the last six months?……………..

3.0 Farm characteristics

3.1 How long have you been engaged in farming?……………….(years).

3.2 What is the size of your farm in acres? …………………

3.3 Do you own it? (0) No (1) Yes.

3.4 If yes, how did you acquire it? (1) Inheritance (2) Bought (3) Both

3.5 Tick the major activities present in the farm

(1) Crop cultivation (2) Livestock grazing (3) Both 1 and 2

(4) Fallow land (5) All the above (6) Other………………

3.6 Indicate the farm implements used on your farm

Implement	**Number**	**Value**	**Total**
1. Ox plough			
2. Ox donkey cart			
3.Wheelbarrow			
4.Bicycle			
5. Other			
Total			

Total value of farm implements in Ksh……………………….(at 2003 market prices)

3.7 Do you use hired labour on the farm? (0) No (1) Yes

3.8 If yes, what type? (1) Temporary (2) Permanent (3) Both

3.9 How many do you hire annually? (1) Temporary............ (2) Permanent ....

3.10 How much do you pay farm labour? (1) Temporary.......... (2) Permanent.........

3.11 Do you use improved seed varieties? (0) No (1) Yes

3.12 On which crops do you use improved varieties.................................

3.13 What was the yield of the major crop last year? Major crop.........yield......bags

3.14 What is the distance to the nearest water source?............................Km

3.15 Describe the nature of the water source (1) Permanent (2) Seasonal

3.16 Do you irrigate your crops? (0) No (1) Yes

4.0 Farm enterprise(s)

State farm enterprises by completing the table below.

4.1 Crop enterprise in 2003 (0) No (1) Yes

Long rains (March 2003-August 2003)

Crop	Intercrop or monocrop	Size of the farm in acres	Output (90 kg bags)	Price/bag	Total
1					
2					
3					
4					

Farm income in long rains in Ksh...........................

Short rains (September 2002-February 2003)

Crop	Intercrop or monocrop	Size of the farm in acres	Output (90 kg bags)	Price/bag	Total
1					
2					
3					
4					

Farm income in short rains in Ksh...........................

4.2 Livestock enterprise in 2003 (0) No (1) Yes

Type	Number	Value	Total
1. Local cow			
2. Exotic cow			
3. Oxen			
4. Sheep			
5. Goats			
6. Donkey			

Total value of livestock in Ksh....................

5.0 Soil fertility management/soil and water conservation technologies

5.1 Fertilizer use

5.1.1 Do you use inorganic fertilizer on your crops? (0) No (1) Yes

5.1.2 If yes, which crops do you fertilize?....................

5.1.3 If yes, what type and amount was used in 2003?

Type	Amount (Kg)		Total
	Long season	Short season	
DAP			
CAN			
NPK			
Other			

5.1.4 How long have you used inorganic fertilizer? .... (Years)

5.1.5 If yes in 5.1.1, how often do you use inorganic fertilizers?

(1) Every long season (2) Every short season (3) Both seasons (4) Occasionally

5.1.6 Have you ever used inorganic fertilizers then stopped? (0) No (1) Yes

5.1.7 If no in 5.1.1, what reason(s) do you give for non-use of fertilizer?

(1) High cost of fertilizer

(2) Unavailability

(3) Lack of knowledge on its use

(4) Fertilizer destroys the soil

(5) Alternatives like manure are available

(6) No crops were grown

(7) Other............................

5.2 Animal manure use

5.2.1 Do you apply animal manure in your farm? (0) No (1) Yes

5.2.2 If yes, what type was used in 2003? (1) Cow (2) Sheep/goat (3) Poultry (4) Other........

5.2.3 I f yes, what is the amount in wheelbarrows?

Long season	Short season	Total

5.2.4 How long have you been applying animal manure? .... (Years)

5.2.5 How often do you apply animal manure?

(1) Every season (2) once a year (3) Occasionally with no specific pattern

5.2.6 Have you ever used animal manure and stopped? (0) No (1) Yes

5.2.7 If no in 5.2.1, give reasons why animal manure is not applied?

(1) No livestock

(2) Manure buying is expensive

(3) No means of transportation

(4) Lack of labour

(5) Land is not ploughed

(6) No crops were grown

(7) Other...............................

5.3 Compost manure use

5.3.1 Do you use compost manure on your farm? (0) No (1) Yes

5.3.2 How long have you used it? ....(Years)

5.3.3 How often do you practice this?

(1) Every season (2) once a year (3) Occasionally with no specific pattern

5.3.4 Have you ever tried this practice then stopped? (0) No (1) Yes

5.3.5 If no in 5.3.1, what reason do you give for non-use of compost on the farm?

(1) Lack of labour

(2) Lack of materials.

(3) Other sources of manure like animal manure are available

(4) Other ……………………………………………

5.4 Soil and water conservation structures

5.4.1 Do you have soil and water conservation structures on your farm? (0) No (1) Yes

5.4.2 If yes, which ones?

(1) Terraces (Bench, Fanya Juu, Fanya chini)

(2) Tied ridges

(3) Trash lines

(4) Retention ditches

(5) Water ways

(6) Other……………………..

5.4.3 How long have you used them? ……………(Years)

5.4.4 If yes in 5.4.1, how often are they maintained?

(1) Every season (2) once a year (3) Occasionally with no specific pattern

5.4.5 If no in 5.4.1, give reasons why you don't have them?

(1) Lack knowledge about them

(2) Lack labour for construction

(3) Lack of materials for construction

(4) Not important)

(5) Other……………………………

5.5 Are there other soil fertility and water management practices? Which ones?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

6.0 Marketing and Institutional support

6.1 Market factors

6.1.1 What is the distance to the nearest market?…………….(Km)

6.1.2 What is the major means of transportation to the market?

(1) Vehicle (2) Motorcycle (3) Bicycle (4) Handcart (5) On foot

6.1.3 Are fertilizer and other soil fertility management inputs affordable? (0) No (1) Yes

6.2 Credit

6.2.1 Did you receive production credit in the last four years? (0) No (1) Yes

6.2.2 If yes, what form of credit? (1) In cash (2) In kind (3) Both (4) N/A

6.2.3 If yes, state how much you have received in 2003 from the following?

Source	**Amount**	**Type**	**Value**
AFC			
Co-operative			
Commercial Bank			
Friends			
Other			
Total			

Total Amount……………………………………

6.2.4 Are there occasions you fail to get credit when you need it? (0) No (1) Yes

6.2.5 If yes, why?

(1) Credit not available (2) Previous default (3) Fear of default

6.3 Extension

6.3.1 Has extension staff ever visited your farm? (0) No (1) Yes

6.3.2 If yes, what was the source of extension? (1) MOA (2) NGO (3) Church (4) Research (5) Other……………………

6.3.3 On average, how many times do they visit a year? (1) Once (2) Twice (3) Thrice

6.3.4 Are you a member of any farmers' group? (0) No (1) Yes

6.3.5 Have you ever-received extension through this group? (0) No (1) Yes

6.3.6 Have you ever attended any agricultural field day or demonstration on soil fertility management? (0) No (1) Yes

7.0 Closing comments

7.1 What assistance do you urgently require to improve soil fertility management and yields?

(1) Improved extension

(2) Increased credit availability

(3) Increased water supply

(4) Affordability of fertilizer and other inputs

(5) Other……………………………………..

7.2 Time at the end of the interview…………….

Thank you