DECLARATION

I Paswel Phiri Marenya, confirm that this thesis is my original work and has not been submitted for any degree or any other qualification in any University

Signed____________________ 20 NOV. 2001

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This thesis has been submitted for examination with our approval as the University Supervisors

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The kind of work presented in this document is usually accomplished, not in isolation, but with collaborative efforts from others. However, may I say at the outset that any errors remaining in this thesis are solely mine and I share them with no one.

I wish to acknowledge the enabling administrative and academic framework provided by the Department of Agricultural Economics within which my entire graduate programme has been conducted.

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DEDICATION

This work is dedicated to my mother, Esther Asala, for reasons that may or may not be obvious to those who read this document.

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ABBREVIATIONS

ASL	Above Sea Level
BCR	Benefit Cost Ratio
CAN	Calcium Ammonium Nitrate
CBS	Central Bureau of Statistics (Kenya)
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	*Centro Internacional de Mejoramiento de Maiz y Trigo* (International Maize and Wheat Improvement Center)
CM	Crop management
DAP	Diammonium Phosphate
GM	Gross Margin(s)
Ha	Hectare
K	Potassium
KARI	Kenya Agricultural Research Institute
Kshs.	Kenya shillings
MLE(s)	Maximum likelihood estimate (s)
N	Nitrogen
OLS	Ordinary least Squares
P	Phosphorous
TA	Technical Assistant

Conversions

1US$	**=**	**Kshs 78.0**
1 Ha	**=**	**2.50 acres**

ABSTRACT

This study focused on the adoption of CM techniques on maize crop considering that CM issues, apart from fertilizer adoption, have hitherto received scanty attention in Kenya. The CM practices considered were: Weeding frequency, use of organic manure versus fertilizer and fertilizer-manure combinations as well as timely planting. The overall objective of this study was to make an appraisal of the status of CM technologies in the area of study in order to identify and analyze the major socioeconomic constraints to the adoption of CM practices and identify possible policy options that can foster their adoption.

Limited dependent variable models were used to assess the factors influencing the adoption of the relevant practices. The model results showed that factors that are related to farmers' resource endowments such as farm size and livestock ownership and factors that reflect costs of production such as use of animal traction or tractor equipment in farming operations impact on the adoption of capital and labour intensive practices such as multiple weeding. Profitability as indicated by per hectare gross margins was found to positively affect the use of inorganic and organic fertilizers. Human capital factors such as number of years of education and fulltime family labour also represent important factors influencing the adoption of the CM practices considered. The major policy implication was that there is need to find ways of reducing the costs of the CM techniques considered and also raising farm level yields to improve returns to their application.

CHAPTER 1

1.0 INTRODUCTION AND BACKGROUND

1.1 Background

The modern economic growth that has taken place on the global scene since the industri revolution has been characterized by the conscious and systematic application of basic scientifi discoveries to problems of economic production as the major precursor to sustained increases i the productivity of resources. While the application of science had established itself by the firs half of the 20th century as a major source of growth in agricultural output in more develope countries, it had bypassed Third World agriculture (Hayami and Otsuka, 1994). Vast areas o sub-Saharan Africa are still characterized by technological stagnation. This is the case in th face of existence of technological innovations within the continent itself and from Internationa Agricultural Research Centers (Byerlee, 1994).

In Kenya the challenge of modernization of the agriculture sector via the generation o technological innovations and application of such in the production and other processes remains great since the need still exists to put this vital sector on a high productivity path beyond what is currently attained. Kenya's experience of maize research and technology development is a powerful illustration of the above fact. Maize arrived in East Africa with the Portuguese in the sixteenth century (Miracle, 1966), but several centuries passed before it became established as a major food staple in East Africa. The First World War created a considerable export market for maize to which East Africa's white settlers and smallholders responded by expanding their production. By the end of the Second World War, the role of maize as a major food and cas crop in Kenya was consolidated.

Due to this growing importance of the maize crop, the government initiated a maiz improvement research program in 1955 at Kitale. By mid-1970's ten hybrid-maize varieties an three composites had been released. This first generation of technical change in Kenyan maiz production followed the Green Revolution path fairly closely. Farmers' yields increased largel because they used improved varieties supplemented by purchased inputs, especially fertilizer.

Despite the progress achieved, this maize revolution has yet to fulfill its early promise. Farmer have not seen sustained growth in maize yields. Maize yields grew at an average rate of 7.1% annually over the 1963-91 period, but was significantly lower after the mid-1970's, falling fron 10.9% in 1963-74 period to 4.4% during 1985-91 (Lynam and Hassan, 1998). The declin experienced after 1970's in maize yield growth rates was the result of a number of key factors such as the deteriorating macro-economic environment in the 1980s, which weakened public financial support for research, extension and credit. Additionally, this has meant the collapse of the favorable scientific and institutional co-operation that created the maize success story of the 1960s and 1970s. The outcome from all these has been a general decline in overall maize production as the number of new technical innovations has dropped and the rate at which farmers adopt current technologies has fallen (Hassan and Karanja, 1997).

Hassan and Karanja (1997) reported that by 1997, in most maize growing regions average farm yields were about half of KARI's experimental yields and 25-50% lower than yields recorded for researcher managed trials in farmers' fields. The gaps between potential and actual yields wei even wider in low potential areas. What this implies is that there exists considerable potential fc increasing maize production in Kenya. Exactly how this is to be done is a matter of tremendou concern to researchers and policy makers and all stakeholders in the maize sub-sector (Hassa and Karanja, 1997). Agricultural research in Kenya must intensify its research on cro management (CM) and at the same time inject new energy into its breeding program to ensur future improvements in maize yields (Hassan and Karanja, 1997).

It is evident that one of the major factors behind the current yield gaps between what farmers ge and what has been demonstrated by researcher managed on-farm trials is the low adoption rate of CM technologies among maize farmers especially smallholders. Allan (1971) asserted that i is insufficient to recommend the use of expensive fertilizer in the absence of high levels o husbandry. A 'second best' formula is implied in which improved seed genotype is combinec with improved husbandry practices for low-cost, high return solutions. Evidence emerged fron Allan (1971) which showed that improvements in yield of up to 16% could be achieved undei optimal agronomic conditions. Mugunieri (1997) indicated that losses of between 475-515 Kg per hectare of maize yield result from *poor weed management* and 432 Kg per ha are lost due to *late planting*.

The present study sought to determine the salient factors that condition CM adoption and provide policy options for enhancing their adoption (For the purposes of this study, crop management (CM) refers to all those husbandry practices in maize production apart from use of improved varieties). Focussing on CM is of critical importance if it is considered that a major reason for low returns to fertilizer use and consequently low adoption of the same has been reported to low levels of agronomic management (Allan, 1971; Mugunieri, 1996; and Hassan, Murithi *et a* 1998).

1.2 Problem Statement

Conscious efforts on the part of the extension system to extend seed and fertiliz recommendations in tandem with complimentary CM technologies are indispensable in seekir ways of reversing the decline in the growth rate of maize productivity in Kenya. A survey ‹ current literature on maize technology issues in Kenya shows that a part from fertilizer use the is a dearth of studies that clearly document other CM technology status in maize production i Kenya and which quantify the impact of these technologies - or lack of such - on maiz productivity.

As has been posited above, the maize sector now seems to have entered a period of technologica stagnation as evidenced by low yield growths and existence of considerable gaps betwee potential and actual yields on farmers' fields. (Potential yields being those obtained unde research trials in various maize production zones (Lynam and Hassan, 1998). Exactly how thi gap can be closed is a matter of tremendous concern for researchers, policy makers and al stakeholders in the maize sub-sector. Evidently, a major factor behind these gaps is the low levels of adoption of CM practices among small-scale farmers in Kenya as in other countries (Mugunieri, 1997; Hassan and Karanja, 1997; Kumwenda *et al.*, 1997; Salasya *et al.*, 1997; Hassan and Murithi, *et al.*, 1998; Lynam and Hassan, 1998). One way of narrowing this gap is by enabling farmers to adopt better crop management technologies. The crucial question that mus be answered, however, is what lies behind this scenario of low adoption of CM practices.

The present study sought to delineate the factors that determine the adoption or non-adoption o crop management practices. The study focused on three areas of crop management namely: **(a** Frequency of weeding **(b)** Use of organic manure, fertilizer and fertilizer-manure combination and **(c)** Timely planting. Research and extension policy inferences were made regarding way: that may help enhance adoption of CM technologies on the part of small-scale farmers. This wil be important in closing the current yield gaps.

1.3 Justification

The intensification of agricultural production in Kenya via the development of modern technologies is necessary if the current technological stagnation is to be halted and reversed. Yet, in doing this, an integrated approach is paramount. No single method or technology can stand on its own from whatever branch of science - be it Genetics, Chemistry or Engineering or even from Nature itself (Dellere and Symoens, 1991). Such a holistic strategy to technology generation and dissemination holds out great promise in the attainment of higher and sustainable levels of productivity (IITA, 1992). This is especially so if, at the current levels of fertilizer and seed use, greater yields can be obtained by improvements in crop management. In view of the considerable capital outlays needed for purchased inputs, such a process would be most desirable for smallholder producers who face severe capital limitations (Ackello Ogutu, 1987). It is important that while intensification of production is being pursued through use of fertilizers and improved seeds, adequate attention must be paid to complimentary CM issues as part of the package. These CM issues include; soil degradation *vis a vis* the use of organic resources in soi fertility management, increased incidence of pests and weeds and hence the need for better weec management, the general decline in natural resource productivity and the importance of ensurin timeliness of farming operations. Such efforts will be most crucial if it is considered that maize is the major staple food for the majority of households in Kenya as well as a source of income and employment in vast areas of the rural sector (KARI, 1997). The focus on small-scale farmers is justifiable when it is considered that over 70 percent of the area under maize in Kenya is cultivated by farmers who own 20 acres and below (CBS, 1990). The results generated from this study will be important in providing indications where necessary, for research and extension policy realignment with regard to CM technology development and dissemination to enhance adoption of the same. The relevance of the present study must be seen in that light.

1.4 Objectives of the Study

The overall objective of this study was to make an appraisal of the status of CM technologies in the area of study in order to identify and analyze the major constraints to the adoption of CM practices. Specific objectives were:

1.To determine the levels of adoption of the CM practices among the sample farmers and characterize the farmers who have adopted them.

2.To determine the factors that influence the adoption of CM practices in the study area.

3. To establish mechanisms and policies for enhancing adoption of the CM practices to narrow farm level yield gaps.

1.5 Hypotheses tested

- Age, education, gender, family size, ownership of extra non-maize crop enterprises, livesto ownership, farm size, mechanization, credit access, extension contact, fulltime family labo perception of correct planting time and gross margins per hectare *do not influence* tl adoption of organic manure, inorganic fertilizer and fertilizer-manure combinatio respectively.
- Age, education, gender, family size, ownership of extra non-maize crop enterprises, livestoc ownership, farm size, mechanization, credit access, extension contact, fulltime family labou perception of correct planting time and gross margins per hectare *do not influence* th adoption of Timely planting.
- Age, education, gender, family size, ownership of extra non-maize crop enterprises, livestoc ownership, farm size, mechanization, credit access, extension contact, fulltime family labou perception of correct planting time and gross margins per hectare *do not influence* th adoption of Multiple weeding

1.6 Area of study

This study was carried out in Kakamega district which lies within the moist mid altitude agro-ecozone characterized by elevation of 1200-2000m above sea level and March-August rains greater than 550mm. The district is part of the Western Province of the Republic of Kenya. It is reputed to have the highest population density in the country. Many soils are very old and therefore poor or leached (Jaetzold and Schmidt, 1982). The major annual food crop is maize, coffee, sugar and tea are some of the important cash crops grown. The district houses the KARI regional research center mandated to carry out public agricultural research in the western regio of this country.

Kakamega district has been selected since large portions of this district represent the maiz production zone called the moist mid-altitude zone. This zone is ranked third by KARI in it prioritization scheme of the six different maize production areas in Kenya in terms of potentia returns to research (as indicated by consumer surplus) (Lynam and Hassan, 1998).

1.7 Organization of the Thesis

The thesis is organized into five chapters. Chapter 1 provides the introduction and th background setting of the research theme, objectives of the current study, the research problem hypotheses tested, justification and relevance of this study and description of the area of study Chapter 2 is the literature review covering the major conceptual frameworks on CM technology issues, current maize technology status in Kenya as well as methodological issues in the context of adoption studies. An overview of current adoption studies in Kenya and elsewhere has been provided. Chapter 3 describes the methodology used in the current study covering major adoption paradigms and the analytical models used. The theoretical underpinnings of the models and their appropriateness for the analyses carried out have been discussed in Chapter 3 as well. The results of the descriptive summaries, binary and multinomial logit as well as probit model regression analyses have been presented and discussed in Chapter 4. The economic and policy inferences are also drawn in the discussion of the results. A summary of the main findings, conclusions and policy recommendations that can be drawn from the results as well as directions for further research are the subject of chapter 5 which is the last Chapter of the study.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Agronomic information on the Selected Crop Management Practices

This section provides brief explanations on the importance of the CM practices covered in thi study from an agronomic perspective. The aim being to show why the application (adoption) o these practices as conceptualized in the present study forms an important issue in maiz production.

2.1.1 Timely Planting

Among the most important CM practices that influence maize yield is date of planting, plant population and weeding. At the time of germination, maize roots have a high demand for oxygen and plant growth can be severely limited if soils are soaked by a succession of rainy days so that air is largely replaced by water and soil temperatures decline. It is for this reason that early planting, particularly in heavier soils, is a major factor in determining maize productivity. There is also the phenomenon referred to as nitrogen flush. Following a dry spell, it has been observed that there occurs an upsurge of soil nitrogen (brought about by an increase in soil microbial activity) upon onset of rains. This then decreases soon thereafter. Planting should be done within such a time as to make use of this initial nitrogen accumulation (Carr, 1989). The foregoing factors coupled with other favorable physical, microbial and chemical changes brought about by the onset of rains, provides a strong case for emphasis on timeliness of planting operation.

2.1.2 Weeding

Weed control in maize is important to reduce competition for water, soil nutrients and light. has a positive effect on yield performance. Studies done in Ethiopia showed that yield losse caused by weeds ranged between 30% and 88% of potential yield (Carr, 1989). It i recommended to weed at least twice using hand hoes, cultivators or herbicides. Weeding o maize remains a major problem in many smallholder situations due to labour scarcities. Car (1989) suggested that the problem of labor scarcities can be studied in terms of the whol farming operation to ascertain whether there is a possibility of making a profitable change ir cropping patterns which can ease the bottleneck on early maize weeding. Mugunieri (1997 showed that maize yield is reduced by 515 Kg per ha and 475 Kg per hectare by poor anc average (as measured by agronomic indices) weed management respectively.

2.1.3 Soil fertility

One important characteristic of maize is its high and relatively rapid nutrient requirement. Maize grain generally contains up to 2% (nitrogen) N. This means that 100kg of harvested grain contains 2 Kg of N. It has been estimated that up to 25Kg of nitrogen is removed when 1 ton of maize grain is harvested in a hectare. In spite of recommendations of about 60 to 120 kg N per ha for maize, actual use of fertilizer by farmers in sub-Saharan Africa is very low estimated at 10kg of nitrogen per hectare. These recommendation levels though agronomically sound are economically sub-optimal under the farmers' resource, management and market conditions (Carsky and Iwuafor, 1998; Mugunieri 1997).

Carsky and Iwuafor (1998) thus suggest several strategies to reduce excessive reliance o chemical fertilizers to alleviate soil nutrient depletion in maize production ecosystems. Thes include; targeting maize to those environments with greater native N supply and inclusion in th rotation leguminous crops or planted fallows of herbaceous legume cover crops, forages o woody species. The study by Carsky and Iwuafor (1998) provided evidence that showed that th recommendation rate of N-fertilizer could be reduced sharply by incorporating legume base cropping systems into maize agronomy. Use of animal manure can also reduce chemica nitrogen fertilizer requirement. Carsky and Iwuafor (1998) therefore pointed to future researcl strategies that may be used to achieve the above, namely; maximizing benefits of legumes t maize and developing systems of fallow, manure management and breeding of low-nitroger tolerant varieties that are acceptable to farmers.

2.2 General Conceptual Framework on CM Technology Issues

In most situations of technological advancements in agriculture, improvements in CM account for a significant share of increments in crop production and productivity and this share can be as much as 50% in some cases as has been observed in some developed countries (Byerlee, 1994). Byerlee (1994), focusing on CM technology transfer, concluded that CM issues take center stage during later stages/periods in the sequence of agricultural development. The author conceptualized several stages through which the intensification process passes namely:

A Pre-Green Revolution Phase when increased production results largely from expanding land area or improvement in resource base, Phase (I). *A Green Revolution Phase* when a technological breakthrough in the form of new, high yielding, input responsive varieties provides the potential to dramatically increase the productivity of land, Phase (II). *A first post Green Revolution Phas* beginning after widespread adoption of improved varieties, when intensification of input usє especially fertilizer and water, substitute for increasingly scarce land for agriculture, Phase (III) *A second post-Green Revolution Phase* beginning after input use has reached relatively higl levels. In this stage farmers' experiences with the new technology together with suppor institutions and policies have evolved to allow improved managerial and information skills tı increasingly substitute for input use, Phase (IV).

From the above conceptual framework, it can be seen that the successful adoption of agricultural technologies results from the interplay of an array of factors as indicated by developments in Phase IV. The present study is based on the same premise. Nevertheless, it is postulated that rather than the seemingly discreet sequence described above, improvements in crop management are important at all stages, more so starting with Phase (II). As such, concurrent adoption of improved varieties and better management practices are essential for long term productivity gains. The current study is, therefore, envisaged to come up with findings that will help determine the important factors that explain the reported low levels of crop management among the smallholder maize farmers in Kenya.

In a paper discussing the future of agricultural technology in developing countries, Plucknett (1994) provides cogent arguments for paying attention to issues of sustainability in agriculture. In that paper, sustainability was linked to adoption of crop and resource management technologies. Thus, sustainable agriculture as defined by the Consultative Group on International Agricultural Research (CGIAR) is: "the successful management of resources for agriculture to satisfy changing human needs, without degrading the environment or the natural resource bas on which agriculture depends". Improved crop varieties with increased adaptability to abiotic an biotic constraints such as resistance to pests and diseases are essential. In addition, research t improve soil and water management, fertilizer use, crop management and related topics ar needed. Sustainable agriculture will require a strong scientific knowledge base to make i effective. This study was an endeavor at illuminating CM issues that must be complimentary t the use of improved germplasm in agriculture.

Writers such as Pierce (1990) and Dellere and Symoens (1991) have called for an integrated approach to agricultural intensification given the complexity, diversity and heterogeneity of many agricultural productivity problems. These studies with their focus on crop and resource management issues validate the concept upon which the current study is based. The present study will seek to determine to what extent such an approach has been recognized in the Kenyan maize system by looking at the adoption patterns (and reasons thereof) of CM technologies among small-scale maize farmers in the study area.

The CGIAR Annual Report for 1987-88 (CGIAR, 1988) presented three challenges for agriculture in the future:

- Globally, can yields be brought up to and maintained at their technical and economic potential?
- Can productivity be improved in less-favored areas, which of necessity have become the last frontier of agricultural expansion?

Will production technologies maintain soil fertility and other vital resources upon which futur production depends?

The third challenge finds expression in this study. It can be seen that resource managemen issues are now central in discussions on agricultural technologies worldwide. There is nc gainsaying that increases in productivity are indispensable especially in third world countries ir view of burgeoning population with its increasing demand for greater food supplies. However, such productivity gains must be sustained into the future. It is difficult to see any other way of doing this apart from adopting a composite approach to technology generation and dissemination. The role of crop and resource management technologies in ensuring this happens is crucial. It is worth pointing out at this stage that the valid concerns with CM technology do not by any means imply that research resources should now be shifted from plant improvement to CM research. Lipton (1994) has emphasized this fact in a World Bank policy paper on agricultural research investment issues. The author argued that the possibility exists that there are resource management innovations with decent rates of return but which only need explanation and local adaptive modifications to foster their adoption. The present study will endeavor to shed light along similar lines to provide indications whether extra efforts are warranted in the Kenyan maize sector as far as research and extensions of crop/resource management technologies are concerned.

Eicher and Byerlee (1997) in a study that focused on the need to revitalize maize research in Africa, contended that Africa's maize experience over the past two decades strongly vindicates the assertion that improved varieties alone are not enough to increase and sustain high rates of growth in maize production. This can be seen from the fact that adoption of improved varietie has been relatively remarkable in African maize systems yet low productivity persists. The therefore, argued that varietal improvement research must be complimented with strong researc programs on crop and resource management. This capacity is still generally weak in Afric Previous gains in yields are unsustainable due to declining soil fertility and the failure on the pa of farmers to adopt soil fertility related practices. Monoculture and weed infestation problem also loom large as the salient issues to be tackled in ensuring sustainable yield increases Reliance on fertilizer alone to tackle the issue of declining soil fertility is insufficient and henc the need to explore complimentary CM technologies to ensure that a sustainable maize system i put in place.

What emerges from the study by Eicher and Byerlee (1997) is the need to place adequate emphasis on CM technology in the African maize production systems. Studies that seek to analyze and document the adoption of these technologies in maize production in Africa will be important in ensuring that conditions are put in place that will enable the extension and research institutions in Africa to generate and extend viable CM technologies. This will provide a basis for sustained productivity achievements in the maize sector. The present study, by seeking to determine the major factors that influence adoption of CM technologies in maize production in the selected study area, is an important contribution in this regard.

In a review of past impacts of and future prospects for maize research in Africa, Byerlee *et al.* (1994) provided evidence for the existence of differences between the high adoption rates of improved maize varieties and hybrids against the relatively limited adoption of resource management technologies. They therefore suggested the following strategies:

(a) Tailored fertilizer recommendations to take into account agro-climatic and resource constraints in order to increase the returns to fertilizer amounts currently used by farmers and therefore encourage greater adoption are crucial.

(b) Intensifying availability and use of organic fertilizers since current levels of organic matter management are insufficient.

(c) Exploiting interactions between soil fertility weed control, and fertilizer responsive varieties is also critical.

Evidence was provided in that study showing that use of organic supplements with fertilizer has enhanced fertilizer response in Kenya and Nigeria. These authors also cited evidence from Malawi showing that farmers who carried out double weeding could achieve higher yields with only half of the fertilizer than those who weeded only once.

From Byerlee *et al.* (1994), clear indications emerge regarding the crucial importance of CM issues in maize productivity in Africa. Why CM technologies have not found widespread application in vast portions of African maize systems including that of Kenya should be a matter of interest to all stakeholders in this sub-sector. The present study determined the major factors influencing adoption of selected CM practices. This may help reveal the factors responsible for this (low adoption) in the Kenyan case as noted by Mugunieri (1997) and Hassan and Mwangi (1997).

On the issue of the constraints that may hamper the adoption of CM technologies, Byerlee an Jevell (1997) concluded that labour appears to be a major limiting factor in the adoption of thes technologies. The labour constraint arises out of the fact that many CM practices are labou intensive. They, therefore, asserted that research on CM should pay attention to the need t overcome labour constraints and maximize returns on cash inputs. This must be done within context of maintaining soil fertility in the long run. Otherwise, due to the failure on the part o farmers to adopt appropriate CM practices, yield gains from hybrids and other improved varietie will invariably be lower than the potential. As far as the present study is concerned, labour i among the factors that were hypothesized to influence farmers' adoption decisions of CM technologies. However, labour may not be the only factor in this scenario. This study therefore included other variables such as extension, farm size, household size, education, credit, age and gender. The aim was to isolate the important factors that explain the current adoption patterns of CM innovations in Kenya.

Smale and Heisey (1997) unequivocally identified poor CM as responsible for the low and declining trends of smallholder maize productivity in Malawi. They also concluded that solving soil fertility problems might be the greatest maize research priority in Malawi in the near future. They did not however mention the socio-economic dynamics behind the poor management levels among smallholders in that country. Hassan and Karanja (1997) and Hassan, Karanja *et al* (1998) made similar findings in Kenya as those made by Smale and Heisey (1997) in Malawi, Tripp and Marfo (1997) in Ghana and Smith *et al*. (1997) in Nigeria. For instance Tripp and Marfo (1997) pointed out that although more research was needed on developing new varieties suitable to Ghana's agro-climatic conditions, increased attention needs to be placed on soil fertility and crop management research. Since fertilizer is only marginally profitable, efficient methods o improving its returns by combining fertilizer recommendations with other CM practices ar called for. Concerted efforts have to be made in clearly deciphering the exact reasons behind th poor management levels in maize production in Africa. So far, the diagnosis is generally correct That low productivity in the maize sector in Africa is attributable, at least in part, to poor CM Nevertheless, no concrete prescriptions to remedy the situation seem to be forthcoming Understandings of the major factors behind poor adoption of CM practices deemed to increas productivity are indispensable in African maize systems.

2.3 Current Maize Technology Status in Kenya and other Recent Adoption Studies.

The maize sector in Kenya has experienced major technological breakthroughs especially in th spheres of varietal development and fertilizer technologies. The need to carry out comprehensiv studies that analyze the extent of adoption of available technologies and explain the rational behind farmers decisions remains an important research concern (CIMMYT, 1993). Such effort have been rare in Kenya. This can be seen from the fact that prior to 1998, the only nationwid survey that had been carried out on maize technology adoption had been in the 1970's (Gehar 1975, Mwangi, 1998). However, several adoption studies focusing on maize-based systems i different countries of sub-Saharan Africa have become available in the recent years.

Ongaro (1988) carried out an adoption study that sought to delineate factors that influence maiz technology adoption in Western Kenya. A major finding was that risk considerations wer critical determinants of fertilizer use and that input and output price variability played a majo role in this. The author recommended tailored information delivery targeted at specific farmer and provision of credit to provide cushions against such risks. Nevertheless, the author did no say much on yield gaps and issues of CM are not mentioned. The present study sought to identify the factors that underlie the adoption of CM technologies in the smallholder maize sub-sector ir parts of Western Kenya.

The Kenya Agricultural Research Institute (KARI) undertook a comprehensive project (the Kenya Maize DataBase Project - MDBP) with the aim of providing the basis for maize research planning and evaluation in Kenya (Hassan, 1998). Under this project, data on such issues as agro-climatic zonation of maize production systems, relevance of maize research in Kenya in relation to problems perceived by farmers and on the patterns of maize technology diffusion and impact of research were gathered and conclusions made on what should be priority areas for maize research policy in Kenya.

Among the major conclusions drawn from the MDBP was that farmers in certain agro-ecozones (especially the moist and dry mid altitude areas) plant maize varieties different from those recommended by the extension personnel (Hassan *et al.*, 1998). This suggests that other environmental and socioeconomic considerations affect farmers' decisions in this regard. The existing varieties may not be attuned to these conditions. The recommendation given in that study is for breeding research to fine tune germplasm targeting meant for different zones. Lynam and Hassan (1998) writing on the need for a new approach to securing sustained growth in Kenya's maize sector concluded that those responsible for planning Kenya's future research strategy must address two central questions:

(i) Should the balance of objectives change within the breeding program itself?

(ii) What should be the relative balance between breeding and crop management research? Thi is especially crucial due to declining returns to breeding purely for higher yield and the high cos of breeding for resistance. The present study will look into ways of encouraging adoption of CN technologies in addition to fertilizer-seed technology. This will come out clearly once the salien factors that influence farmers' decisions to adopt the selected CM practices are identified.

Factors such as soil moisture, timing and method of application of fertilizer, weeding anc cropping systems have been identified by Hassan and Karanja (1997), Hassan, Muriithi *et a* (1998) as influencing crop response to fertilizer. These authors identified returns to fertilizer a: an overriding factor in promoting demand for fertilizer among small-scale farmers. The need foi breeding and crop management research and proper targeting of appropriate germplasm anc fertility management technologies that can enhance returns to fertilizer (higher yield gains) has been highlighted in these studies. The authors went on to stress that farmers, especially smallholders, can increase yields significantly with changes in crop management and adoption ol modern varieties. These studies do not, however, shed much light on the specific factors that need to be addressed in the process of CM development and transfer, neither do they identify the potential constraints to adoption of specific CM technologies as was done in the present study.

Mugunieri (1996), in a study entitled "Economics of Fertilizer Use In Maize Production among Smallholder Farmers in Kisii District" made the conclusion that emphasis be placed on improvement of field management practices before encouraging farmers to apply fertilizer recommendations obtained from response estimations (experimental data). From that study, the observation was that crop response functions to fertilizer differ between experimental and farm conditions. Given farmers' low levels of management and the environmental and economic circumstances they face, their fertilizer rates are optimal even if these are below recommende levels. The major recommendation derived from Mugunieri's (1997) study is the need t emphasize better crop management in the field as part of the package accompanying fertilize recommendations. The study showed that maize yield response to Nitrogen and Phosphate unde well-managed (experimental) crop was higher than that under farm conditions. Thus, th continual emphasis of use of fertilizer at the recommended levels without sensitization to th need for proper management will lead to losses on the part of farmers. If, on the other hand, th level of management by farmers remains the same, that study established that fertilize recommendations derived under farm conditions would be better than those derived unde experimental situations. The need to emphasize overall crop/resource management comes ou clearly in Mugunieri's study. For example, the study indicated that losses of between 475-515 Kg per hectare of maize yield result from poor weed management and 432 Kg per ha are lost due to late planting. However, the need to understand the factors behind the seemingly low management levels in the maize sector has not been addressed in Mugunieri's study.

A survey of literature on maize technology adoption in Kenya shows that fertilizer and seed technologies have received exclusive attention and there have been virtually no efforts to study the factors affecting the adoption of other CM technologies. Studies such as Gerhart (1975), Ongaro (1988), Nabwile and Kilambya (1997), Hassan, Njoroge *et al* (1998), Hassan, Njoroge *et al* (1998), Murithi *et al.* (1998) and Salasya *et al* (1998), have basically dwelt on adoption issues having to do with fertilizer and seeds. None of them provides any attempt at analyzing the factors that affect the adoption patterns of CM practices.

In all the studies referred to in the previous paragraphs in this section, mention is made of the need to go beyond merely looking at seed-fertilizer recommendations. However, no concrete attempt has been made in these cases to look at the seed-fertilizer technology issues from a systems perspective. What the survey of current literature on maize technology in Kenya reveals is that majority of researchers analyze either adoption of seed and/or fertilizers in isolation without factoring in other complementary crop and resource management practices. Even the MDBP report only makes passing mention of the need for greater focus on crop management research especially in the moist mid-altitude zones. The report, which is arguably, the most comprehensive so far regarding maize technology status in Kenya, provides an overview of the of the adoption patterns of current seed and fertilizer technologies in the country's maize sub-sector. It is not equally specific in enunciating the status of CM technology adoption in Kenya. While factors that underlie the adoption of fertilizer and seeds are given considerable treatment, similar studies were not made for CM techniques. This is evident from portions of the report such as Hassan, Njoroge *et al* (1998), Hassan, Murithi *et al* (1998), Lynam and Hassan (1998) and Murithi et al. The present study was a contribution towards filling this gap.

Bisanda *et al* (1998) also confirmed that fertilizer use is positively related with wealth. Cash producing enterprises such as dairy farming enable farmers to purchase fertilizers. A similar hypothesis was developed in the present study where ownership of an extra crop enterprise apart from maize was used as a variable to assess its impact on adoption of fertilizers and the selected CM practices. Bisanda *et al* (1998) in studying adoption of maize production technologies in the Southern highlands of Tanzania have a variable that is similar to the use of machinery variable in the present study. Use of ox-plough was included as a variable in explaining adoption of the present study sought to examine the adoption of multiple weeding and timely planting. This, it is hoped, may provide a useful reference point for similar studies in maize based cropping systems in Kenya and elsewhere in Africa, especially in those areas where the major challenges of maize productivity remain not only lack of purchased inputs, but also poor CM.

Akpoko and Arokoyo, (1999) also provide an intriguing aspect of adoption of maize technologies in Kaduna state (Nigeria). In a study that examined proportion of farmers who had adopted among others fertilizer use *per se*, correct fertilizer type and correct fertilizer rate, it was found that 100% of the farmers in the sample of 1050 respondents had used (adopted) fertilizer. However, only 0.9% were using the correct fertilizer type and 0.4% had adopted the right fertilizer rate. This may provide confirmation to the interpretation presented previously that adoption per se does not guarantee that farmers have acquired all the information about the new practice. This fact may be one reason behind insufficient adoption of divisible technological packages. Use of perception variables that help indicate the level of farmers' understanding of the practices they have adopted are important in determining what remedies can be proffered by the extension system to help farmers improve in their in application improved practices.

2.4 CM Adoption Studies in Western Kenya

Ojiem *et al* (1997) in a maize agronomy report at KARI's Kakamega center showed that maize yields in Western Kenya are still much below the potential demonstrated by research. The average yield at farm level is 1.5 t per ha. In western Kenya yields of up to 7t/ha have been demonstrated by research trials. In that report it was shown that timely planting had been well improved seed and fertilizer in Bisanda *et al* (1998). The present study endeavored to provide economic reasons underpinning the influence of machinery as well as other factors on adoption outcomes.

Carr (1989) in an analysis of the technological options for small-scale farmers in sub-Saharan Africa argues that increased and sustainable food production under conditions of burgeoning population and consequent land scarcity requires corresponding increases in nutrients brought in from outside the production eco-system. Of interest to the present study is the assertion by Carr (1989) that a great impediment to the maintenance of soil fertility among smallholders is that much of the produce of smallholder systems in many parts of Africa is basically meant to meet subsistence requirements, and this does not generate cash with which to purchase external inputs such as fertilizers. It is essential in such areas for farmers to have access to cash crops with particularly high returns to land from which income can be derived to pay for fertilizer for use on food crops. This fact was recognized in the present study and variables reflecting enterprise diversification were used.

In a study that assessed maize technology adoption among farmers in Kaduna, Akpoko and Arokoyo (1999) identified the major agronomic practices which are critical to maize production and among these were planting dates, spacing and seed rates, fertilizer application as per recommendations, fertilizer type, and weeding. The range of practices covered is wide and is similar to the argument in the present study. The present study took cognizance of the fact that adoption of these practices is conditioned by specific socio-economic circumstances of farmers. While the study of adoption of cultural practices has found scanty attention in adoption literature, adopted, but fertilizer use and weed control lagged behind recommendations. This shows that th examination of adoption of multiple weeding in the present study is a valid research issue.

In another locality within the Western Kenya agro-ecozone, surveys done by KARI have shown that maize production in the area stands at a low 225-450kg/ha while research trials have showr that up to 4000kg/ha can be realized (Achieng *et al* 1999). The reason behind this was found tc be low soil fertility accompanied by low or non-use of fertilizers as well as non-adoption o improved varieties. The economic base of the majority of farmers in the study area was such tha most of them cannot afford to purchase the required amounts of fertilizers. The project, upor which the study by Achieng *et al* (1999) was based, entailed the provision of credit to farmers ir Yala area. The productivity boost was up to 2925kg per ha from a maximum of 450kg/ha as a result of increased application of fertilizer at the rate of 250Kg DAP (Diammonium Phosphate) fertilizer per hectare at planting and 250 Kg CAN (Calcium Ammonium Nitrate) per hectare foi top dressing. The study illustrated that there exists huge potential for increased fertilizer use in vast regions of western Kenya. Credit was provided in the form of fertilizers, which was repaid in kind in the form of a fraction of the harvested grain. The recovery rate was indicated at 90%. The current study focused on credit availability and its impact on fertilizer adoption as well as its impact on the other CM practices.

KARI (1994) in a Maize Research Plan document at KARI center in Kakamega has argued that while it is possible to group farmers into recommendation domains (a group of farmers who will adopt the same recommendation given equal access to information) characterized by similar enterprise patterns, husbandry practices, resource endowment and similar opportunities for development, this need not be defined by geographical delimitation. The KARI center at

Kakamega is mandated to carry out research in western Kenya and has endeavored to demarcat target groups based on socio-economic factors. The concern of the present study with the impac of socio-economic factors on technology adoption fits in with this focus. Previous efforts a fertilizer and other CM recommendations have been too broad and based on agro-climatic factor while insufficient attention has been placed on socio-economic factors. This concern has beei raised in other studies in Kenya such as Lynam and Hassan, (1998).

KARI has in the past six years come up with maize research prioritization scheme in its westeri Kenya mandate region. Prominent issues that need attention have been summarized in the Tabl 2.1 below. Use of farmyard manure, inter-cropping with leguminous crops and alley croppin are some of the solutions suggested to tackle soil fertility problems. Noteworthy also is th concern with problems to do with moisture deficits and droughts in some of the locales in thi region (Siaya and Busia on the littoral region experience semi arid conditions frequently).

On the issue of cultural (CM) practices, KARI, (1994) identified the major problems and corresponding research strategies for the maize system in western Kenya as the carrying out of adoption studies and generation of information on various CM aspects. This recommendation is a tacit recognition that CM issues have not been examined to the extent desirable in the context of their adoption. The present study has been conceptualized to fill part of this gap. Table 2.1 below summarizes the key problems and strategies for overcoming them (relevant for western Kenya) as identified in KARI (1994).

Table 2.1: Common Constraints to Maize Production in Western Kenya and Possible Solutions

Constraint	Possible Solutions
1. Low Soil Fertility	1. Use of Fertilizer and FYM 2. Inter-cropping with leguminous crops 3. Alley cropping
2 Lack of suitable bimodal rainfall crop varieties	1. Development of suitable crop varieties for different environments.
3. Striga infestation	1. Prevention of striga seeding to new areas 2. Use of tolerant crop varieties 3. Improvements in soil fertility 4. Use of trap crops
4. Labour scarcities	1. Timely and proper land preparation 2. Use of herbicides in weed control 3. Development of labour saving technologies
5. Crop pests and diseases	1. Use of tolerant crop varieties 2. Use of chemicals 3. Crop rotation
6. Drought/moisture deficits	1. Use of early maturing crops 2. Timely planting 3. Mulching

Source: Adapted from KARI (1994)

The review presented in the foregoing paragraphs shows the relevance of the present study in view of the production constraints and research strategies for solving these that have been designed in the western Kenya region. It is clear from this review that major challenges to research and extension still remain in the need to find profitable ways of enhancing soil fertility management and adoption of other cultural practices. This can only happen when the technical, social, economic and environmental factors that affect the adoption of specific practices, innovations or technologies are clearly delineated. Adoption studies such as the present one form an important aspect of such a process.

2.5 Adoption Paradigms and Methodological Issues

This section presents an overview of the current adoption paradigms to provide a conceptual grasp of the intricate processes involved in farmers' decision-making as far as adoption of agricultural techniques is concerned. Smale *et al* (1994) provided a review of several paradigms that may explain adoption behavior among smallholder farmers especially the common phenomenon of partial adoption of fertilizer-hybrid technologies. This scenario can be explained by four theoretical explanations namely; input fixity or rationing, portfolio selection, safety first behavior and farmer experimentation and learning.

Input fixity occurs due to the fact that in agricultural economies, where the supply of inputs or credit is rationed, inputs normally regarded as variable such as fertilizer can be considered as quasi fixed allocable input in the short run. This illustrates why low levels of fertilizer use or partial adoption of improved varieties (only a proportion of total maize area planted to improved varieties) is a common phenomenon in smallholder maize systems.

The other paradigm is called portfolio selection. According to this paradigm, risk attitudes and the stochastic relationships between the yields realizable from different technology options determine the extent of adoption of new agricultural technologies. The shape and relative position of per hectare net returns distributions for hybrids and local varieties suggest that farmers may be able to reduce overall riskiness of returns by choosing a portfolio of technologies such as a mix of crop varieties. The distributions may also cross at lower net return levels, indicating that farmers who seek to avoid downside risk may choose to grow only local varieties even though improved varieties are more profitable in the higher net returns range.

The third paradigm is called safety first behavior. This paradigm postulates that the probability of failing to achieve producer goals constrains producer choice. The decision-makers goals are expressed in terms of a targeted level of a random variable (output, income, or subsistence production). In most smallholder systems, sufficient production to meet subsistence requirements is the foremost goal of most farm households.

The fourth paradigm concerns farmer experimentation and learning. It has been observed that farmers may test an innovation even when it is unprofitable to do so because of the value they attach to the information gained through such experimentation. Learning from experience has been hypothesized to reduce allocative errors. Most models that examine learning and farmer adoption decisions emphasize the role of farmer beliefs about the technology, the initial skill level or human capital of the operator and costs of information gathering in determining the time lag to initial adoption (Feder and Slade, 1984).

Other paradigms that have been used to explain adoption decisions as found in the literature dealing with the issues are the economic constraint, innovation-diffusion and "adopter-perception" models (Adesina and Zinnah, 1992;). In the innovation- diffusion model, access to information about an innovation is the key factor determining adoption decisions. The appropriateness of the innovation is taken as given, and the problem of technology adoption is reduced to communicating information on the technology to the potential users. By emphasizing the use of extension, media and local opinion leaders or the use of experiment station visits and on-farm trials the non-adopters can be shown that it is rational to adopt.

The economic constraint model (Aikens *et al.*, 1975) contends that economic constraint reflected in asymmetrical distribution patterns of resource endowments are the majc determinants of observed adoption behavior. Lack of access to capital or land could significantl constrain adoption decisions (Havens and Flinn, 1976; Yapa and Mayfield 1978). A thir paradigm is termed the adopter perception paradigm. This model proposes that the perceive attributes of innovations condition adoption behavior. Studies that have dealt with farmers perceptions in the context of adoption decisions have included a perception variable. Th foregoing provided a conceptual framework that lent justification to the use of a variety o economic, human capital and social variables in the present study.

Regarding analytical procedures, relevant models have now been developed to facilitate th investigation of the effect of various institutional, farm and farmer specific socioeconomic a well as of technology attributes on dichotomous/polychotomous adoption dependent variables The most common models presently are the logit and probit models. These models specify a functional relation between probability of adoption and various explanatory variables. Whil Feder *et al* (1985) contend that few adoption studies seem to account for the qualitative nature o the dependent variable, a survey of more current literature shows that this weakness has largel been rectified. Regression analysis represents one of the most common analytical tools in econometrics and the use of ordinary least squares methodology is the most common estimation technique. However, OLS finds little application in the type of regression done in adoption models. The inappropriateness of OLS in estimating qualitative discrete choice models such as adoption of a particular agricultural technology can be appreciated if it is considered that the assumption of normality of disturbances is obviously inappropriate for assessing the hypotheses concerning the impact of various factors in the adoption process (Ben Akiva and Lerman, 1985; Kennedy, 1985; Amemiya,1981). Moreover, when the dependent variable is dichotomous, the assumptions of the Ordinary Least Squares (OLS) estimation method concerning the distribution of the error term such as multivariate normality and independence of regressor and error terms do not hold. The OLS procedure becomes inappropriate under these conditions (Maddala, 1983). Since discrete choice models are best analyzed as probabilistic models, the usual linear regression framework does not apply since in this case (of linear regression framework), the probability cannot be restricted to the 0-1 interval. Linear regression leads to unrealistic probability values hence the use of continuous probability distribution models (such as the logit procedure which relies on the logistic probability distribution) to estimate the parameters of concern (Kennedy 1985). These outcomes are technically implausible and it is impossible to conduct usual hypothesis tests on the estimates.

However, since the early 1970s important progress has taken place in econometrics concerning qualitative response models. The range of economic phenomena in which qualitative response models have been applied is wide including labour force participation, choice of occupation, union membership, housing, use of seat-belts and farming techniques among others (Amemiya 1981).

A major limitation of the above models is mainly that other than providing a statistical evaluation of the directional impact of the variables on the probability of adoption, they fail to provide quantitative information on the economic importance of these variables. Nevertheless, the parameter estimates from the models should isolate the important factors that condition adoption behavior. The next step would be to carry out further analysis concerning the econom importance of those variables that have been isolated as statistically important in influencir adoption. This would mean the application of other models to achieve the foregoing.

Several adoption studies have used the logit model to analyze a variety of factors that affect tl decision to apply a particular technology. In a study of the adoption patterns of improved maiz seed in Kenya, Hassan, Njoroge *et al.* (1998) made use of Maximum Likelihood Estimatic technique to estimate the parameters of the logit model.

Salasya *et al.* (1997) undertook a study in Kakamega and Vihiga districts meant to assess th adoption of seed and fertilizer packages and the role of credit. They used the logit model i which the maximum likelihood technique was used as the estimation procedure to study th pertinent factors that were *a piori* expected to affect the adoption of improved maize seed an fertilizer in those districts. The factors considered included age of household head, educatior credit, extension, and farm size. The logit estimation technique has been used in diverse adoptio studies. These include those by Putler and Zilberman (1988) and Batte *et al* (1990) on the use o microcomputers in agriculture, Harper *et al* (1990) on the factors affecting adoption of insec management technology and by Rahm and Huffman (1984) on the adoption of reduced tillag Kaliba *et al* (1998) employed probit model to analyze factors that influence fertilizer use. Th reason given was lack of data on rate of use of fertilizer. Extension was the only factor found tc influence adoption of fertilizer. The present study used binary and multinomial logit as well a ordered probit in examining the factors that affect the adoption of CM technologies in the stud area.

CHAPTER 3

3.0 METHODOLOGY

3.1 Conceptual Models and Hypotheses

3.1.1 Conceptual Models on Adoption

When farmers are faced with multiple technological options, which they can apply in their farm operations, the outcome can be modeled within the framework of theories that explain individual choice behavior. Any choice is made from a non-empty set of alternatives. The environment of the decision-maker will determine what can be referred to as the universal set. Any single decision-maker considers a subset of this universal set, which subset is commonly referred to as the choice set (Ben-Akiva and Lerman, 1985). The choice set includes alternatives that are both feasible to the decision-maker and known during the adoption process. The feasibility of any alternative is defined by a variety of constraints such as physical availability, monetary resources and informational constraints.

In discreet choice situations, the mathematical techniques and assumptions applied in classical consumer choice/demand theory do not apply. For example, in classical consumer theory, a continuous space of alternatives is assumed and as such these models lend themselves to the use of calculus to derive demand functions whose arguments express the factors conditioning consumer demand and preferences. Because technology adoption deals with discrete choices, it is impossible to use the maximization techniques of calculus to derive demand functions. Thus, a discrete representation of alternatives necessitates a different analytical approach. The types of problems considered in adoption studies are better described as a selection of one of a finite set of discrete bundles of attributes. For these problems, discrete choice models based on random utility theory are a more appropriate basis for analyses. In particular, probabilistic choice theory that specifies the probability with which an individual will select any feasible alternative provides an appropriate framework for analyzing discrete choice situations of which technology adoption is an example. A major assumption used in probability models is that the outcomes from farmers technology choice decisions are basically stochastic (not known with certainty) as opposed to being deterministic.

3.1.2 Random Utility Theory

Generally, decisions of the farmer in a given period are assumed to be derived from the maximization of expected (random) utility subject to various socio-economic, institutional and other constraints. The utility maximization framework allows the discreet choice models to take into account a variety of objectives such as subsistence production or profit maximization. Profit for instance is a function of the farmer's choices of crops and technology in each time period. In the case of technology adoption, therefore, a particular technological alternative will be adopted if and when it possesses those attributes that will maximize the utility of the farmer in the sense that it best minimizes the cost of production, maximizes profits or ensures achievement of a threshold level of subsistence or any other objective as the case may be. The utility function depends on the farmer's discrete selection of a technology from a set that includes traditional and a set that contains components of a modern technology package (Feder *et al.*, 1985). Given the farmer's discrete choice, income is modeled as a continuous function of land allocation among crop varieties, the production function of these crop varieties, the variable usage inputs, the prices of inputs and outputs and the annualized costs associated with discrete technological choice.

It is clear from the foregoing that the farmer as an economic agent endeavors to solve a complex optimization problem in each production period consistent with his objective function (utility maximization). This solution determines the type of technology a farmer will employ. It follows then that any technological choices must be consistent with the farmer's objective function. The utility that each decision-maker seeks to maximize is a function of the attributes of the technologies in the choice set, external economic and institutional factors and farmers' own socio-economic circumstances. The implication from this is that while specific technologies can technically contribute to a farmer's objectives, the farmers' own specific socio-economic circumstances and the unfavorable institutional and macro-economic environment in which they operate make the adoption of these techniques infeasible. This provided the motivation for the use of socio-economic and institutional variables in the present study to determine their influence on the adoption of the CM techniques considered in the present study.

The random utility approach is more in line with consumer theory. The individual is always assumed to select the alternative with the highest utility. However, the utilities are not known to the analyst with certainty and are therefore treated by the analyst as random variables. From this perspective the choice probability of an alternative is equal to the probability that the utility of that particular alternative is greater than or equal to the utilities of all other alternatives in the choice set. The choice probabilities are interpreted as the analyst's statement of the probability that for any decision-maker, the utility of an alternative will exceed the utilities of all other feasible alternatives. The utility functions can therefore be broken down into deterministic and random components as follows:

$$U_{in} = V_{in} + e_{in}$$

$$U_{jn} = V_{in} + e_{in}$$

V_{in} and V_{in} are the systematic components of the utility of *i* and *j* respectively and e_{in} and e_{in} are the random parts and are called disturbances (or random components). The systematic component comprises of the choice attributes and characteristics of the decision-maker. The random components take account of observational deficiencies resulting from unobserved attributes, unobserved taste variations, measurement errors and the use of instrumental (or proxy) variables (Ben-Akiva and Lerman 1985). Due to lack of data on technology specific attributes, the present study made use of the individual specific attributes and institutional factors. These factors hypothesized to affect adoption of fertilizer, manure, fertilizer-manure combinations, multiple weeding and timeliness of planting operations are presented in the following sub-section.

3.1.3 Factors Hypothesized To influence adoption of Fertility Options on Maize (Choice of inorganic Fertilizer alone, Manure alone or Combinations of both); Multiple weeding and Timely Planting.

Age (AGE)

The influence of age on adoption decisions cannot be predicted unequivocally. The directional impact of age of decision-makers on the adoption decision is in many cases difficult to sign *a priori*. Different studies have come up with different signs for this variable (Feder and Slade, 1985). In this study, it is hypothesized that older farmers will exhibit higher adoption levels for multiple weeding and fertilizer, and manure and combinations thereof. This is based on the postulation that older rural farmers may have accumulated more experience and capital resources than their younger counterparts. Capital constraints constitute the single greatest impediment to technology adoption in developing countries (Byerlee1994; Byerlee et al 1994; Feder et al 1985). Regarding the timeliness of planting, older farmers may be better adopters. Older farmers are likely to have longer experience in farming and therefore are more familiar with the weather patterns in their locations. Hence the age variable is expected to have positive impact on the timeliness of planting operations.

Education (EDUC)

Education constitutes an important human capital variable. In an environment of technological change characterized by the introduction of new technologies and practices, farmers are faced by new disequillibria precipitated by the adoption of the new techniques. Thus, it becomes incumbent that decision-makers exhibit clear capabilities to perceive, interpret and respond to these diequillibriating changes in the context of risk (Schultz, 1981). The importance of human capital factors as expressed in the level of education may be attributed to its impact on allocative ability. Formal schooling is hypothesized to play an important role in determining allocative ability. Congruent with the foregoing, Gehart (1975) found that the likelihood of adoption of hybrid maize in Kenya was positively related to education.

Huffman, (1977) showed that the use of nitrogen fertilizers by maize farmers in the United States is affected by their educational attainments. Farmers with better education showed superior ability to adjust their nitrogen use in response to a decline in price ratio, and that their input use levels approached optimal rates faster than did those of their less educated counterparts. According to Schultzian hypothesis, education is likely to make a more substantial contribution to agricultural productivity in a rapidly changing environment. Education increases a person's awareness of his environment and his ability to acquire and process information about his environment and to detect changes in it. It also enhances his ability to identify alternatives and to assess and compare the benefits and costs associated with each of the alternatives possibly under different states of nature. Education also in general increases the facility and speed with which new skills and techniques can be learned and new alternatives, when judged desirable, can be adopted and implemented. Thus, other things being equal, it is immensely reasonable to expect that education will enhance the probability of adopting a new presumably superior technology. In this study, more education was hypothesized to increase the adoption of multiple weeding, timely planting and the three fertility options under question.

Gender (GEND)

Previous studies on adoption have shown certain differences in adoption patterns that are related to gender (Hassan , Njoroge *et al* 1998, Hassan, Murithi *et al* 1998, Nkonya *et al* 1997, Omiti *et al* 1999). These differences in adoption between male and female decision-makers arise from differential access to productive resources; land, labour, capital, credit and information.

The hypothesis presented here is that owing to various socio-cultural factors present in various rural African communities and sometimes even in contemporary urban settings- female farmers tend to have poor access to productive resources and information, and consequently, are expected to exhibit low adoption rates for the practices considered in this study.

Household Size (FMLY)

Larger households may have more labour available from the members who are able to work on the farm. Evidence exists from previous adoption studies confirming the fact that shortages of family labour explain non-adoption of improved rice varieties in India. Greater availability of family labour may remove labour bottlenecks and labour supply uncertainty facing individual households hence greater adoption. The position taken in this study departs from the above postulates. The impact of household size on adoption arises, not necessarily due to greater labour availability, but possibly more importantly, due to its impact on the overall household disposable income and allocative behavior. The size of the household determines the household income distribution; non-farm expenditures such as education, health care and clothing. Larger households may experience greater capital limitations than smaller ones. This is because larger households have greater subsistence and other needs, which tie up available financial resources, leaving proportionately less cash to finance the purchase of fertilizers and other tradable inputs as well as the hiring of labour for labour intensive operations such as weeding and planting. Larger households, therefore, have clearly greater allocative problems in the face of resource limitations and the diverse non-farm (non-subsistence) and subsistence requirements that compete with farm operations for limited resources available to the household. Household size is therefore postulated to negatively influence adoption of timely planting and multiple wedding and the three fertility options. This hypothesis is plausible considering that corroborative evidence is currently emerging from studies carried out is the study area which shows that larger households exhibit relatively poor soil fertility management on their farms (Rotich *et al,* 1999).

Livestock Ownership (LVSTK)

This is hypothesized to be important in the use of organic manure. Availability of farmyard manure is almost assured by ownership of livestock although the herd size will determine how much is available. For instance, manure from cattle and other animals is very important for many farmers in Zimbabwe but rarely available in Malawi where animals are scarce (Kumwenda *et al*, 1994). It is also possible to surmise that livestock ownership may be a proxy for greater managerial capabilities. This is especially so if improved breeds are used in dairy enterprise. Such enterprises require higher management skills (Ervin and Ervin 1982). It is hypothesized that from this perspective, livestock ownership might positively influence adoption of the entire CM practices at hand.

Farm Size (FMSZ)

Feder *et al*, (1985) point out that the incidence (as opposed to intensity) of adoption of improved crop varieties is positively related to farm size. This is because even though it might be taken for granted that seed-fertilizer technologies are scale neutral, they nevertheless may entail significant set up costs in terms of learning, locating and developing markets and training hired labour.

When these factors are considered as fixed expenses, they tend to discourage adoption by small farms. In the present study it is postulated that larger farms will be more likely to adopt fertilizer and less likely to adopt manure (as well as combinations with fertilizer), timely planting and multiple weeding. The reason for this hypothesis is that operators of larger farms will tend have greater labor constraints since their absolute labour outlays are higher than for those with smaller farms, a fact that may impede the adoption of labor intensive practices such as manure application.

Use of Machinery (MACH)

One of the chief objectives of farm mechanization is to alleviate labour bottlenecks. Use of ox power or tractor equipment can make possible more timely farming operations and allow increased production and reduced labour demand (Feder *et al,* 1985). CM technologies are patently labour intensive. Mechanization of some of the farm operations will release extra labour for the more labour-intensive operations. For example, use of oxen plough might mean cash (labour) saving that can be used for prompt planting or weeding. However, this outcome is contingent on mechanized processes being efficient enough as to allow for sufficient cash and labour saving. This calls for competitive and properly functioning markets for the hire of animal traction or tractor services.

It is hypothesized, based on the foregoing arguments, that those farmers who employ some form of mechanization in their maize growing operations will be more likely to weed more often, plant on time as well as use manure and fertilizer.

Extension contact (CONTACT)

Diffusion of technology related information and measures that expedite this diffusion can have a positive effect on adoption intensity by reducing the uncertainty associated with the new technology. Contact with extension programs through farm visits by extension staff, participation in field days and demonstrations have all been proved as important in promoting adoption of new technologies by farmers (Goodwin and Shroeder, 1994; Adesina and Seidi, 1995; Nkonya *et al*, 1998; Ongaro, 1988 and Salasya et al 1998). However, evidence exists in some recent studies such as Omiti *et al,* (1999) where extension contact has been shown to have no influence on adoption of fertilizers. While it is widely acknowledged that the impact of extension on farmers' production decisions has been minimal in many areas of Africa, continued efforts to evaluate the role of extension in fostering agricultural change in specific locations are called for.

This variable has been included in the models used in this study to assess its impact on the adoption of technologies being considered here. It was hypothesized that exposure to extension will positively influence the adoption of the CM practices under consideration in this study.

Credit (CRDT)

Lack of credit may be an important factor in explaining farmers' reactions to innovations. Capital in the form of either accumulated savings or access to capital markets is necessary to finance the uptake of new agricultural technologies. Differential access to capital is often cited as a factor in differential rates of adoption. This is especially so when adoption of a particular technology calls for considerable capital outlays that constitutes a significant proportion of the total amount of capital available to the farmer (Feder and Zilberman, 1985).

Although it is considered debatable in some quarters whether lack of credit alone does inhibit adoption of innovations, several studies have shown that lack of credit does significantly limit adoption of scale neutral hybrid technology. Sufficient evidence exists to show that a majority of small farms reported shortage of funds as a major constraint on adoption of divisible technology such as fertilizer use (Frankel 1971, Wills, 1972 and Khan, 1975). Ongaro (1988) focused on the role of credit in providing cushions against crop failure and other adversities. This could provide farmers with access to resources needed to apply input intensive recommendations. The hypothesis presented here is that farmers who have access to credit will be better adopters of the CM practices considered in this study.

Enterprise Diversification (ENTPRS)

Agricultural diversification is defined broadly as the increased variety of agricultural commodities produced, achievable either, by planting new crops in newly opened lands beyond the lands used for traditional crops and/or adding new crops to traditional crops in the same lands through more intensive crop rotation or inter-cropping. Diversification of agricultural production in less developed countries has been confirmed as a necessary requisite for economic development in these areas (Hayami and Otsuka, 1994). The livelihood of the poor in these environments vitally depends on incomes from diverse sources including production of cash crops. In order to increase incomes in agriculture as well as earn foreign exchange, diversification of agricultural resources to production of commercial crops and livestock products with high-income elasticities becomes necessary in the course of economic development. It is hypothesized here that farmers who operate an extra crop enterprise apart from maize are likely to realize the benefits of diversification discussed above. Thus, such farmers should be able more readily adopt the CM technologies being studied.

Number Of Family Members Working Fulltime on the Farm (FLTIME)

As has been posited before, labour constraint constitutes the single greatest impediment to the adoption of CM technologies (Feder and Zilberman, 1985; Byerlee and Jewel, 1997). Observations have been made that smallholders in much of Africa plant maize late because of labour constraints among others (Low and Waddington, 1990). The present study looked at the impact that the number of family members working full time will have on the adoption of the CM practices studied. The hypothesis is that families with more of their members working full time will achieve better adoption of these practices.

While it might be argued that the household size is a sufficient proxy to labour availability, this is not necessarily the case. Availability of family labour especially on full time basis is conditional on such factors as availability of off farm employment (both farm and non-farm), agricultural *vis a vis* non agricultural wage rates, the household demographic characteristics and human capital endowments. In the absence of empirical evidence to show strong correlation between household size and amount of available full time family labour, this study looked at the impact of available full time family labour on the farm on the adoption of the CM technologies being studied separate from household size *per se.*

Farmers' Perception Of Correct Planting Time (PLTIME)

Crop management practices are by their nature knowledge intensive. It is paramount that farmers gain accurate appreciation of these practices and the principles behind them. Akpoko and Arokoyo (1999) explored the relationship between farmers' correctness of knowledge of the principles underlying recommended maize production practices and their willingness to adopt these practices. The conclusion was that adopters of recommended practices also had accurate knowledge of the principles embodied in such practices. Agronomic recommendations in Western Kenya suggest that the best planting period is no more than two weeks after onset of rains. The study explored the degree of confluence of farmers' perception of the right planting period after onset of rains with the agronomic recommendation. It is expected that those farmers whose perceptions are more in line with recommended practice will more likely plant on time.

This variable was also used as a proxy for overall knowledge of the broader principles of good maize husbandry. As such its impact on adoption of the fertility options and multiple weeding was also examined. The expectation being that those farmers whose perceptions are correct in this regard are more likely to adopt all the CM practices.

Gross Margin Per hectare (GRMGN)

In attempts to encourage adoption of improved varieties the issue of returns to adoption ought to be seen as an important determinant of the up-take of improved techniques. The data used in estimating the gross margins were from the season preceding the season for which adoption data was collected. The theoretical basis for this follows from Feder *et al* (1985). In Feder *et al* (1985) farmers are assumed to solve a temporal optimization problem at the beginning of each production period. The solution to the temporal optimization problem at the beginning of each period determines the type of technology the farmer will use in the period, his allocation of land among crops and his use of variable inputs. At the end of each period, the actual yields, revenues and profits are realized, and this added information, as well as experience accumulated during the period and information on outcomes obtained by other farmers, tends to update the parameters the farmers will use in their decisionmaking for the next period. The impact of per hectare profitability (as indicated by gross margins) on the application of the various techniques was examined. Higher levels of returns are hypothesized to positively affect the probability of adoption of the CM choices considered in the present study. While resource constraints may be regarded as the overriding impediments to adoption of improved farm practices, it is also entirely plausible to hypothesize that farmers will adopt those techniques or aspects of them, which yield the highest returns to their resource expenditures. However, it must be borne in mind that improvements in crop husbandry practices also entail extra costs. Farmers will only apply the recommendations if doing so will be profitable as conditioned by extra returns generated. Nkonya (1997) showed that since cash is a major limiting factor in African smallholder farming systems, the return that farmers receive from their cash outlays after adopting a technology is likely to be an important decision criterion.

3.2 Analytical Models

This section provides a description of the models that were used in the actual analysis of the data set to test the statistical significance of the various factors hypothesized to influence adoption of the various techniques included in this study. The models used were the binary logit, multinomial logit and ordered probit models. Additionally, descriptive statistical summaries were computed to describe the data set.

3.2.1 Descriptive Statistics

Descriptive statistics focusing on frequencies and means were used to characterize adopters of the various CM options. This was done by carrying out cross tabulations on the data set. Characterization was done on the basis of input use and credit access and extension contact

3.2.2 Binary Logit

Adoption behavior, the phenomenon modeled in this study, is discreet rather than continuous. In this case, the dependent variable takes a limited set of values. These are cases where the dependent variable can be characterized as 0 or 1. The dependent variable takes the value 1 if technology has been adopted and 0 if not. This numerical designation has no particular economic significance but is a formulation meant to facilitate econometric estimation. The dependent variable in these circumstances being the decision to adopt a particular technology on one hand and the decision not to adopt on the other (Maddala, 1983). A form of qualitative response model is required to analyze this phenomenon. Binary choice models such as the logit model (as was used in this study to determine the factors that influence the frequency of weeding) are often applied in modeling adoption decisions.

The decision to weed only once or not at all versus the decision to weed more than once is therefore modeled in the equation below:

$$y_j = 1/1+e^{z_j} \text{..................}(3.1)$$

Where;

y_j = Probability that the technology *j* under investigation is adopted.

Z_j = $X'\beta i$ (Coefficient- regressor matrix associated with y_j

X = A set of regressors

β_i = vector of model parameters

j= 1……n where n is the number of choices available

In the present study y_j= WEED= Probability that farmer weeds more than once.

Equation 3.1 is non-linear and Maximum Likelihood Estimation (MLE) procedure is used. The e^z measures the odds of adoption of multiple weeding where the odds of adoption change with

X_i. When βi (coefficient of regressor i) is equal to zero then Z is zero indicating regressor i has no effect (does not change the odds of adoption). On the other hand when βi is greater than zero then ez will be greater than one indicating that the odds of adoption increase with X_i. The reverse is true when βi is less than zero (Hassan, Murithi *et al* 1998). The coefficient regressor matrix can be represented as follows:

$$Z_1 = \beta_0+\beta_1 \text{ AGE} +\beta_2 \text{ EDUC} +\beta_3\text{GEND} +\beta_4\text{FMLY}+\beta_5 \text{ ENTPRS} +\beta_6 \text{ LVSTK} +\beta_7 \text{ FMSZ} +$$

$$\beta_8 \text{ MACH} + \beta_9 \text{ CRDT} +\beta_{10} \text{ CONTACT} + \beta_{11} \text{ FLTIME} + \beta_{12} \text{ PLTIME} +\beta_{13} \text{ GRSMGN} +\mu$$

The μ is the stochastic term

3.2.3 Multinomial Logit

This model was used to analyze the factors affecting choice of the fertility options considered in this study. Derivation of the multinomial logit model is based on the random utility theory of choice behavior. The utility to an adopter of an alternative is specified as a linear function of the characteristics of the adopter and the attributes of the alternative and a stochastic component.

The model that results from the utility maximization is determined by the nature of the distribution assumed for the error term. If the random utility error terms are assumed to be distributed as a Weibull distribution, the multinomial logit results. The great advantage of this model is its computational ease, the probability of an individual selecting a given alternative is easily expressed and a likelihood function can be formed and maximized in a straightforward manner. The random utility model upon which the multinomial choice model is derived can be modeled in three ways (Ben-Akiva and Lerman 1985):

The first specification involves the assumption that the utility that an individual derives from a particular alternative is a linear function of the *M* number of *attributes of that particular alternative*. Choice of fertilizer versus manure for example may be based on the price per unit of each alternative and effect on soil properties among others. In this specification it is possible to predict the probability that an individual will select a certain alternative given attributes of that particular choice and not the decision-maker's characteristics.

The second specification is where the utility of a choice to an individual is a linear function of that *individual's (decision-maker's) own socio-economic and farm specific characteristics* with a different set of parameters for each alternative. If the model is specified in this manner, it is possible to predict the probability of an individual selecting a particular alternative given the characteristics of the individual.

The third specification involves a combination of both individual specific characteristics and technology specific attributes. This yields different sets of parameters for the individual characteristics (but not technology attributes) for each alternative.

The present study has used the second specification. This is because this study proceeds on the premise that smallholder farmers' individual socio-economic circumstances play a more important role in their technology choice rather than on the technical attributes of available agricultural practices. Following a formulation similar to that employed by Greene (1994), the overriding assumption in the present study is that the primary determinants of the alternative chosen is a set of the characteristics of the individual. The greatest impediments to the adoption of inorganic fertilizer for instance lies, not in the fact that available fertilizers have undesirable properties (attributes), but in farmers' own socio-economic limitations. This is not to suggest that such attributes as per unit price of different fertility options may not influence farmers' choices. However, in the context of smallholder farming systems of Kenya, it is farmers' own specific socio-economic constraints that may present the most important constraining factors in technology adoption. The majority of studies that have used multinomial logit model to study adoption such as Batte *et al* (1994), Baker (1992) and Putler and Zilberman (1998) have all used the specification involving use of individual specific characteristics alone to determine factors that influence adoption of alternatives under question. Due to lack of farm level data on technology specific attributes that can be useful in a regression model the present study used institutional and individual specific variables. Gathering or generating data that contain both types of variables (individual characteristics and choice attributes) would be a costly undertaking. Due to this limitation, data sets typically analyzed by economists do not contain mixtures of both types of variables (Greene 1993).

It is important to mention at this point that the use of per hectare GMs as a variable in the adoption models should be able to capture the attributes of the CM techniques considered. However this variable, can only be included in the regression model as a farm specific variable.[1]

Following Greene (1994), Ben-Akiva and Lerman (1985) and Kennedy (1985), the discreet choice models are derived from the random utility model of choice behavior. An individual is

[1] Observations on per hectare GM for any particular period for a particular farmer can only be made for one alternative at a time precluding any observation on the other alternatives (in the choice set) not chosen by that farmer. Under these circumstances, the technology-specific configuration of the data set is not possible. Inclusion of per hectare returns as a farm specific variable in a discreet regression model has been made by Ervin and Ervin (1982).

assumed to have preferences defined over a set of alternatives (fertility options). The utility of each alternative on the other hand is a linear function of either individual characteristics, choice attributes or combination of both. In the present study use has been made of individual and farm specific characteristics (X_0).

$$U(alternative\ 0) = \beta_j X_0 + e_j$$

$$U(alternative\ 1) = \beta_j X_0 + e_j$$

$$U(alternative\ j) = \beta_j X_0 + e_k \text{------------------------------------} 3.1$$

Suppose the observed outcome (dependent variable) = choice *j*

If $U(alternative\ j) > U\ (alternative\ k) \quad \forall j \neq k$

$$\beta_j X_j + e_j > \beta_k X_k + e_k$$

Alternatively

$$\beta_k X_0 + e_k < \beta_j X_0 + e_j$$

$$e_k - e_j < X_0(\beta_j - \beta_k) \text{------------------------------------} 3.2$$

Assuming the type 1 extreme value (Weibull) distribution for e_k and e_j ; the probability that the above choice (*j*) is made is given by the cumulative density of $e_k - e_j$ to the point $X_0\ (\beta_j - \beta_k)$. Since the cumulative density is given by the logistic function we have:

$$Prob\ (Choose\ option\ j) = \frac{(e^{X_o(\beta_i - \beta_j)})}{(1 + e^{X_o(\beta_i - \beta_j)})} \quad \text{------------3.3}$$

This shows for the binary logit case, the relationship between the random utility function and the logit model. The generalization to the multinomial case can be made in the following fashion. Suppose we have several alternatives, the ratio of the probability of taking the *kth* alternative to the probability of taking some standard alternative is given by $e^{X\beta_k}$ where β_k is a vector of individual characteristics in the present case then:

$$Prob\ (Choice\ j) = \frac{e^{\beta_j X_o}}{\Sigma_j e^{\beta_j X_o}} \quad j = 0, 1 \text{---------} J \quad \text{------------3.4}$$

From the above it is clear that the effect of the explanatory variables on the probability of adoption is via their effect on the utility associated with each alternative. The problem now is that of assessing this impact by inferring the parameters β_1 ---- β_k from a sample of observations. The other major problem becomes that of finding parameter estimates that possess at least some if not all of the desirable properties of statistical estimators. The most widely used estimation procedure is maximum likelihood (ML). The ML procedure yields estimates that are consistent and are both asymptotically efficient and normal. The MLE are derived from maximization of equation 3.4. The likelihood function from such maximization then becomes

$$\ell = \prod \frac{e^{x_i \beta_j}}{1 + e^{x \beta_j} + e^{x \beta_k}}$$

$$\ell = \prod \frac{e^{x_0 \beta_j}}{1 + e^{x_i \beta_j} + e^{x_i \beta_j}} \prod \frac{e^{x_j \beta_k}}{1 + e^{x_j \beta_j} + e^{x_j \beta_k}} \prod \frac{1}{1 + e^{x_k \beta_j} + e^{x_k \beta_j}}$$

The maximum of ℓ is solved by differentiating it with respect to each of the β's

3.2.4 Ordered Probit

The ordered probit belongs to a class of limited dependent variable models called ordered probability models. According to Amemiya (1985) the ordered model can be conceptualized as a case where the dependent variable values, though discreet, correspond to successive partitions of the real number line. Certain multinomial choice variables are inherently ordered. Diverse examples can be cited such as the following: Results of taste tests, opinion surveys, level of insurance coverage by a consumer (none, part or full) and employment (unemployed, part time employed or full time employed). It is thus clear that ordered probability models are applicable in those scenarios where the choice variable lends itself to a form of ranking (gradation). In the present study use was made of ordered probit model in assessing the factors that affect timeliness of planting by sample farmers. As has been defined in table 3.1, the dependent variable in this case will be the time lapse between onset of long rains (in the 1999 – 2000 season) and the date of planting. The dependent variable PLANT in this case lends itself to a form of ranking and three partitions have been used in this study namely planting done within one week of onset of rains (PLANT=2), planting done beyond one week but within two weeks of onset of rains

(PLANT=1) and planting done beyond two weeks of onset of rains (PLANT = 0). The discrect values assigned to the dependent variable therefore may be viewed as representing degree of timeliness of planting.

In situations described above, although the outcome is discreet, the multinomial probit (or even multinomial logit) model would fail to account for the ordinal nature of the dependent variable. The consequence of using unordered models when the true model is ordered is a loss of efficiency in the resultant probability estimates (Amemiya 1985; Greene 1993). The ordered probit model has come into fairly wide use as a framework for analyzing such responses. The ordered probit is built around a latent regression as in the binary and multinomial probit models.

$y^* = \beta' X + e$ As usual y^* is not observed what is observed is y = 0 if y < 0 .

$y = 0 \text{ if } y^* \leq 0$

$= 1 \text{ if } 0 < y^* \leq \mu_1$

$= 2 \text{ if } \mu 1 < y^* \leq \mu_2$

$= J \text{ if } \mu_{j-1} \leq y^*$

The μ's are unknown parameters representing the threshold values and are estimated together with β. As in the binary situation, e is assumed to be normally distributed across observations. When the distribution of e is assumed to be normal (mean 0 and variance 1), we have ordered probit model. When the logistic distribution for e is assumed the model becomes ordered logit. The difference between the two models has been observed to be trivial and appears to make no difference in practice, between the results from the two models (Greene, 1994). Given the normal distribution we have the following probabilities:

$Prob\ (y = 0) = \Phi\ (-\beta' X)$

$Prob\ (y = 1) = \Phi\ (\mu_1 - \beta' X) - \Phi\ (-\beta' X)$

.

$Prob\ (y=J) = 1 - \Phi\ (\mu_{j-1} - \beta' X)$

In order for all probabilities to be positive, we must have

$0 < \mu_1 < \mu_2 < \text{--------} < \mu_{j-1}$

For the above probabilities, the marginal effects of changes in the regressors are:

$$\frac{\partial prob(y = 0)}{\partial X} = - \emptyset(\beta' X)\beta$$

$$\frac{\partial prob(y = 1)}{\partial X} = (\emptyset(- \beta' X) - \emptyset(\mu - \beta' X))\ \beta$$

$$\frac{\partial prob(y = 2)}{\partial X} = \emptyset(\mu - \beta' X)\ \beta$$

Generally speaking, *prob (y = 0)* will have opposite sign from β while *prob (y = J)* in the general case has the same sign as β. The sign of the marginal effect in the middle cell is rather ambiguous (Greene 1993). An ordered model has been used by (Nannyonga *et. al.* 2000) to examine the factors that affect timeliness of loan repayments among clients of a micro finance bank in Uganda. This formulation is similar to the one used in the present study, the only difference being that Nannyonga *et. al.* (2000) used an ordered logit model.

3.3 Variables used in the Present Study

As was shown in section 3.1.1, adoption of a technology or an agronomic recommendation falls under discreet choice phenomenon, which borrows from classical consumer theory albeit employing a different analytical approach. In developing the probabilistic choice models the decision to adopt any particular technology from a set of feasible alternatives forms dependent variable. The dependent variables used in the present study were as follows:

Multiple weeding: WEED

This refers to a farmer's choice to weed once or not at all versus weeding twice. The variable name being WEED. It was coded as a binary variable having value 0 where a farmer has weeded only once or not at all and 1 where a farmer has weeded at least two times.

Timeliness of Planting Operation: PLANT

The variable name here is PLANT. This was coded as a three level choice taking the values 0 when planting was done beyond two weeks after onset of rains, 1 if it was done beyond one week but within 2 weeks upon onset of rains and 2 if planting was done within one week of onset of rains. The onset of rains for the 1999-2000 planting seasons was ascertained from the meteorological records at the Kakamega Agro-meteorological station housed at the KARI's Kakamega Regional Research Center. Once the date of onset of rains for that season was established farmers were asked to reveal what date they started their planting operations for the 1999-2000 season. Comparison of the data of onset of rains and the data when a farmer planted showed how much time had elapsed between the two events.

Soil Fertility Management Choice: FERT

The variable name here is FERT. It was configured as a four level choice variable which was coded 0 where a farmer did not use any fertilizer or manure on the maize crop during 1999-2000 season, 1 where a farmer used only inorganic fertilizer on the maize crop, 2 if the farmer used only manure on the maize crop and 3 if manure and fertilizer have been combined. The definition of the rest of the independent variables used in the study is presented in table 3.1 below.

Table 3.1: Descriptions of Variables used in the Regression Models

VARIABLE DEFINITIONS	
Dependent Variables	
FERT	Fertility options used on maize crop between 1999-2000. Takes the following discree values: 0 if no fertilizer or manure was used, 1 if fertilizer alone was used, 2 if manure alone was used and 3 if inorganic fertilizer was combined with manure
PLANT	The timeliness of maize planting during the 1999-2000 seasons. Variable take discreet values of 0 if planting was done beyond two weeks after onset of rains, 1 i planting was done beyond one week but within two weeks after onset of rains and 2 i planting was done within one week after onset of rains.
WEED	Farmers practice of multiple weeding during the 1999-2000 seasons. A variable take discreet value of 0 if weeding was done once or not at all and 1 if weeding was don more than once.
Independent variables	
AGE	Continuous variable. Age of decision-maker in years
EDUC	The level of formal education of decision-maker expressed in number of years spen in educational institutions.
GEND	Refers to sex of decision-maker. Takes discreet values of 0 if decision-maker i female and 1 if decision-maker is male
FMLY	The household size of farm household expressed as number of persons.
ENTPRS	Enterprise diversification. Takes value 0 if farmer has another crop enterprise thai maize on the same farm and which generates some marketable output.
LVSTK	Livestock ownership. Takes value 0 if farmer has no livestock enterprise and 1 i farmer has livestock enterprise
FMSZ	Total farm size owned by respondents measured in hectares
MACH	Use of tractor or animal traction in land preparation. Takes the value 0 if lan preparation is done manually and 1 if tractor or animal traction is used in lan preparation.
CRDT	Availability of credit in the two years prior to 2000. Takes value 0 if no credit wa received and 1 if any credit was received from commercial banks, co-operatives an other informal sources during the period under question
CONTACT	Decision-makers contact with extension through such avenues as visits by extensio staff, farmers' field days and visits by farmers to extension offices. Takes value 0 i farmer responded to have had no contact with extension and 1 if they responded t have had contact with extension through the various avenues
FLTIME	Fulltime family labour expressed as number of family members who worked fulltim on the farm during the 1999-2000 season
PLTIME	Farmers perception of right planting time upon onset of rains. Takes value 0 i perceived as more than two weeks after onset of rains and 1 if perceived as two weeks or less after onset of rains.
GRSMGN	Total revenue from maize enterprise in the 1998 to 1999 season (prior to 1999-20(season) *less* total variable costs both quoted in Kshs per hectare.

3.4 Data Sources

Data for this study was generated by means of a structured questionnaire that was administered on 120 farmers after a pre-testing and refinement process. This yielded information on such issues as the yield in the previous production season, frequency of extension visits, years of education and application of agronomic practices among other variables of interest. Additionally data on potential maize yields, optimum fertilizer rates and available crop management technologies were gathered from secondary data sources at KARI regional research center in Kakamega.

3.5 Sampling Procedure

A total of 120 farmers were included in this study upon which the questionnaire was administered. This is in line with a CIMMYT recommendation that a sample size of between 80-130 farmers is generally adequate in adoption studies (CIMMYT 1993). A stratified sampling procedure was used to select the divisions, locations and work units (villages) upon which the questionnaires were administered. Two divisions, Shinyalu and Lurambi were selected on the basis of their importance in smallholder maize production in the Kakamega district. In each division, two locations were selected at random. Ilesi and Khaega locations were selected in Shinyalu. Similarly, Bukura North and Bukura South locations were selected in Lurambi division. Two work units in each of the four locations were randomly picked giving a total of eight work units. Fifteen farmers were interviewed in each work unit. These farmers were randomly picked from an inventory of farmers maintained by the TA in each village. The interview process achieved one hundred per cent response by making return calls in cases where respondents were unavailable for interview during the initial calls.

In summary, the methodological approach to analyzing discreet choice problems are the probabilistic choice models of which binary and multinomial logit as well as ordered probit have been used in this study. The underlying behavior assumed in building these models is that of maximization of random utility conditioned by technology choice and other constraints such as physical availability, monetary resources and information access. The major premise regarding factors that affect adoption is that farmers own socio-economic circumstances reflected in resource endowments, human capital as well as institutional parameters such as existence of agricultural extension programs and credit facilities represent the most important factors in determining farmers' technology choices.

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics on Adoption of Soil Fertility Management Options

Table 4.1 provides a summary of the adoption patterns among maize farmers. A striking observation is that only 9 per cent (11 farmers) of all the respondents did not apply any manure or fertilizer on their maize crop during the 1999-2000 season. Thirty-three farmers (28%) applied fertilizer alone. Forty-seven farmers (39%) used manure alone and twenty-nine farmers (24%) used fertilizer in combination with manure. .

4.1.1 Input Use Patterns among Adopters of different Soil Fertility Management Options

Awareness of the need for soil fertility intervention is relatively high as shown by the fact that 91% of the farmers in the sample applied fertilizer, manure or combinations thereof (Table 4.1). Fifty two per cent of respondents used fertilizer either alone or in combination with manure. Nutrient application however, remains below recommended rates among fertilizer adopters. Those who use fertilizer alone applied an average of 30Kg N per hectare and 36.5Kg P per hectare. Those who used fertilizer and manure combined applied 38.1Kg of nitrogen per hectare and 46Kg P per hectare. The recommended nutrient application in the region is 55Kg of nitrogen per hectare and 57.5Kg P per hectare. Only about 15% of sample farmers applied over 45Kg of nitrogen. Seventy per cent of farmers applied 15Kg or less of nitrogen per hectare (Appendix 4e). Since awareness of the importance of fertilizer application is high, it is reasonable to surmise that farmers are also aware of the right amounts of fertilizer to apply and that they are limited either by scarcities or high prices of fertilizers. The low application may therefore be attributed to low purchasing power among the majority of farmers. However, those who use manure either alone or in combination with fertilizer seem to use more labour in both operations than th who use fertilizer alone. This is because manure use is more labour intensive than fertili application. Those who used manure alone used 47.8 and 20.7 man days, respectively in a sin weeding and planting operation compared to 43.7 and 22.0 for those who used manure-fertili combination (p = 0.02 and p = 0.1 respectively). The mean cost of land preparation among th who use fertilizers alone was Kshs 1827 per hectare. Those who use manure alone used, average Kshs 2230. This is due to higher labor expenditures for manure application requir more cash for the hiring of labour. (Table 4.1).

Table 4.1: Input Use Patterns among Adopters of the various Soil fertility Management Optio

Input Use	Soil Fertility Category			
	None used	Fertilizer alone	Manure alone	Fertilizer-Manure Combined
Overall percentage of farmers in various categories	9.0	27.0	39.0	25.0
Weeding labour (Mean)- Man-days/ha	62.0	39.2	47.8	43.7
Planting labour (mean) –Man-days/Ha	26	17.7	20.7	22.0
Land preparation cost (mean)-Kshs/Ha	2093	1827	2230	2242
Inorganic Nitrogen applied per hectare (Kg/ha)		30.0		38.1
Inorganic phosphorous applied per hectare (Kg/Ha)		36.5		46.0

4.1.2 Extension contact and Credit access among adopters of the various soil management options

With regard to extension contact, those who used manure alone or in combination with fertili and had never had extension contact constituted 26.7 per cent of the entire sample. Additiona those who used fertilizer alone and had not had extension contact constituted 5 per cent of entire sample. This shows that a greater percentage of those who had never had extension cont are found among those who use manure either alone or in combination with fertilizer. Only 1

of all respondents had obtained credit in the two years before 2000. This shows a low cre[illegible]
access rate among smallholders in the study area.

Table 4.2: Extension contact and Credit Access among Adopters of the various Soil Fertility Management Options

Extension and Credit Access	Soil Fertility Category			
	None used	Fertilizer alone	Manure alone	Fertilizer-Manure Combined
Extension contact (% of total)	5.8	22.5	14.2	12.5
No extension contact (% of total)	3.3	5.0	25	11.7
Credit received in the 2 years prior to year 2000 (% of total)	0.8	4.2	5.0	6.0
No credit received in the 2 years prior to year 2000 (% of total)	8.3	23.3	34.2	18.2

4.2 Descriptive Statistics on Timely Planting among Sample Farmers

The results presented in Table 4.3 show that 30.3 per cent of all the farmers interviewed plant[illegible] beyond two weeks after the rains, 23.8 per cent planted within two weeks and 45.9 per ce[illegible] planted within one week of the onset of the rains. Roughly 70 per cent planted within the fi[illegible] two weeks after onset of rains. This result may show that adoption of timely planting may [illegible] high in the region.

However 58% of farmers who plant at least within the first two weeks of onset of rai[illegible] responded that in their view the right planting time could be beyond two weeks of onset of rai[illegible] This means that there are those who plant in time but whose perceptions of the right plantin[illegible] time after onset of rains is somewhat incorrect. This can lend weight to the conclusion th[illegible] farmers might adopt certain practices but fail to fully understand the principles behind them. Th[illegible] could explain the apparent discrepancy between the proportion of farmers who planted in time and the proportion whose perceptions of the right planting time are correct.

4.2.1 Input use patterns according to timeliness of Planting among sample farmers

Farmers who plant within one week appear to be using more labour (48 man days per hectare) to carry out a single weeding operation than those who plant beyond two weeks after onset of rains, who use 41.7 man days per hectare. While labour constraint represents an important impediment to the timeliness of farming operations, cross sectional analyses such as the present one may not reveal sufficient variability in labour use patterns. What this means is that smallholders generally face similar external economic and environmental constraints. However, major differences occur in their managerial and resource capabilities in dealing with these constraints (Table 4.3).

Table 4.3: Input Use Patterns according to Timeliness of Planting Operations among Sample Farmers

Input Use	Planting time Category		
	Beyond two weeks	Beyond one week but within two weeks	Within one week
Overall percentage in various categories	30.3	23.8	45.9
Weeding labour (Mean)- Man-days/ha	41.7	43.2	48.0
Planting labour (mean) –Man-days/Ha	18.8	23.2	21.0
Land preparation cost (mean)-Kshs/Ha	2022	2311	2048
Inorganic Nitrogen applied (Kg/ha)	20	11	19
Inorganic phosphorous applied (Kg/Ha)	22	22	21

Those who plant within at least two weeks of onset of rains used slightly more labour than those who plant beyond two weeks with those who plant within one week expending 21 man-days/ha compared to 18.8 man-days/ha for those who plant beyond two weeks ($p = 0.1$). This shows that timeliness of planting operation is contingent upon availability of adequate amount of labour to expedite this operation. This tend is also seen in the amount of labour employed in cost of tillag where those who plant within two weeks expend on average Kshs 2311/ha compared to Ksh 2022 for hose who planted beyond two weeks (p= 0.05) (Table 4.5).

4.2.2 Extension contact and Credit access according to timeliness of planting operations

The farmers who had never had extension contact but planted at least within the first two week (two last columns of Table 4.4) constituted 33.5 per cent of the entire sample. Contact wit extension seems not to be an important factor in determining the timeliness of farmers' plantin operations. This is a plausible assertion since farmers' own experience, weather patterns an availability of cash and labour are more important in this regard.

Table 4.4: Extension Contact and Credit Access according to Timeliness of Planting Operations

Extension and Credit access	Planting time Category		
	Beyond two weeks	Beyond one week but within two weeks	Within one week
Ever had extension contact (% of total)	23.3	8.3	24.1
Never had extension contact (% of total)	10.8	12.5	21
Received credit (% of total)	3.3	2.5	10.0
No credit received (% of total)	30.8	18.3	35.1

4.3 Descriptive Statistics for the Adoption of Multiple Weeding among Sample Maize farmers

From Table 4.5 the results show that 82% of the farmers surveyed weeded at least twice. Thi compares favorably with the 70% who planted in time (at least within two weeks of onset c rains). These results show that adoption of CM technologies per se is relatively high amon smallholders. This however says little about the effectiveness with which these practices ar being applied.

4.3.1 Input Use among Adopters of Multiple Weeding

Those weeding two or more times use on average 46.4 man-days per hectare in a single weedi operation compared to 39.9 man-days for those weeding only once. Similarly, those weeding tv or more times apply more labour during planting (21 man-days per hectare) compared to man-days per hectare for those who weed only once ($p = 0.1$). Those weeding more than on may have greater ability to hire more labour than those weeding only once. Hence, the high labour use per hectare in planting and weeding. However, it is apparent that those who we once incur higher costs in land preparation than those who weed two or more times (Table 4. Another result was the apparent incongruency between fertilizer application and multip weeding. Those weeding more than once applied 19Kg of nitrogen per hectare (compared 55Kg of nitrogen per hectare and at least two rounds of weeding as recommended by ministry agriculture extension staff).

Table 4.5: Input Use among Adopters of Multiple Weeding.

Input Use	Number of weedings
Overall percentage in the two categories	
Weeding labour (Mean)- Man-days/ha	
Planting labour (mean) –Man-days/Ha	
Land preparation cost (mean)-Kshs/Ha	
Inorganic Nitrogen applied (Kg/ha)	
Inorganic phosphorous applied (Kg/Ha)	

4.3.2 Extension contact and Credit access among adopters of multiple weeding

The farmers who have never had extension contact and who weeded at least twice constitut 35.8 per cent of the sample. This is another indication that farmers' awareness of improv practices does not necessarily result from contact with the extension service. Information abo improved practices can diffuse through other channels than the extension system even if the original source of that information was the extension system. Of the 16 per cent of farmers who had credit in the two years prior to the survey, 13 per cent weeded twice or more times. This confirms that cash constraint reflected in lack of credit is an important impediment to the adoption of multiple weeding (Table 4.6).

Table 4.6: Extension Contact and Credit Access among Adopters of Multiple Weeding

Extension and Credit Access	Number of weedings	
	One or None	Two or more
Ever had extension contact (No of respondents)	10.0	45.9
Never had extension contact (No of respondents)	8.3	35.8
Received credit (2 years before 2000) (No of respondents)	2.7	13.3
No credit received (2 years before 2000) (No of respondents)	16.7	67.3

4.4 Gross Margin Analyses for Farms using the various CM techniques

The gross margin calculations (Table 4.7) show that those who use fertilizer obtained higher gross margins than those who did not use fertilizer. Those using fertilizer realized a mean gross margin of Kshs 18120 per hectare compared to a loss of Kshs. 4240 per hectare for those not using fertilizers (p = 0.1). Those using manure alone realize a gross margin of Kshs 11240 and those using manure combined with fertilizer have a mean gross margin of Kshs 14492 per hectare which is about 20% less than that of those using fertilizer alone. The figures presented in Table 4.7 show that those who planted at least within two weeks had a higher gross margin of Kshs 11481 which is 26% higher than those who planted beyond two weeks who realized a gross margin of Kshs 8443 (p = 0.05). This again shows that timely planting as suggested by agronomic recommendation (no more than two weeks after onset of rains during planting period) makes economic sense in view of the higher gross margins. Therefore, those planting late do so, not because it yields higher returns than planting more promptly as recommended, but apparently because of specific constraints (lack of cash or labour) to facilitate timely operations or other factors such as poor health. Those weeding two or more times had a gross margin of Kshs 13426 per hectare compared to Kshs 3625 of those weeding only once ($p = 0.02$). The implication of the result is that any labour savings[2] from avoiding extra weeding operation do not compensate for the extra losses incurred from weeding only once.

Table 4.7: Gross margin (GM) calculations* among sample farmers by adoption Categories

Category of adopters	GM (Kshs/ha)
Overall sample	761
No fertilizer or manure used	-4240
Fertilizer alone Used	18120
Manure alone used	11240
Fertilizer-manure combination used	14492
Planting done within two weeks of onset of rains	11481
Planting done beyond two weeks of onset of rains	8443
Weeding done once or not at all	3625
Weeding done two or more times	13426
0-15	8539
16-30	783
31-45	25413
Over 45	22018

- For the actual figures and variables involving costs and revenues used in these computations see appendix 4a - 4d.

On the other hand, the two gross margins may also show that the overall returns to multiple weeding or even specifically, the returns to labour expended in multiple weeding are positive. (The weeding operation is largely done by hand hoeing and labour costs are the only variable costs in this operation. Chemical weed control is virtually non-existent in the area of the study). Gross margins as categorized by the level of inorganic nitrogen use shows that as the level of

[2] Estimates presented in appendix 4b show that the average cost of a single weeding operation per hectare was Kshs 1993. This means that to carry two or three weeding operation would cost two and three times that amount respectively. This is because the initial and subsequent weeding operations cost the same as confirmed by on farm research trials and farmers' own responses during the present survey (see appendix 4d).

inorganic nitrogen application approaches the recommended rate of 55Kg per hectare, the gross margin increases. The highest gross margin is in the 31 – 45Kg range (Kshs 25413). Since the application of inorganic fertilizers under proper CM increases gross margin per hectare (implying increased profitability and returns to fertilizer), the pervasive sub-optimal application of inorganic fertilizers must be explained by lack of resources. This may confirm that low returns to fertilizer use seem to arise from poor application of complimentary CM practices (Tripp and Marfo 1997). According to Ojiem *et al* (1997), the mean gross margins calculated for researcher managed on farm trials in the area was Kshs 31705 per hectare. This shows that the highest gross margin level in the present sample of Kshs 25413 per hectare (among those applying 31-45Kg of nitrogen per hectare) is about 20% lower than what is possible under near-optimum management conditions.

The GM results presented above provide important policy challenges to extension and research efforts. Maize production is possibly a profitable enterprise (as shown by on farm researcher managed trials) but farmers are unable to realize potential returns to maize production due to resource constraints. Developing alternative low cost maize production techniques should now receive emphasis from research and extension systems. This will help farmers to achieve higher returns at the current levels of resource endowments without incurring extra production costs.

4.5 Multinomial logit Model Estimates of the Factors Affecting Choice of Soil Fertility Management Options on Maize.

The results of the multinomial logit model have been presented in Table 4.8. The estimates are significant in 27 instances for the entire model, at significance levels of between 1 – 10 per cent.

The *age* of the decision-maker was positively related to adoption of manure. This may be due to the fact that older farmers may have longer experience in farming, a fact that may have convinced them of the benefits of manure use. Additionally older farmers may have accumulated more capital resources reflected in such enterprises as livestock ownership. These two factors may mean greater ability to hire needed labour for manure application and also ready availability of manure from the livestock enterprise.

Education had a positive influence on the use of all the three options considered. This outcome is congruent with the hypothesis presented earlier. More educated farmers are likely to benefit more from technical information received from extension departments and other sources on different fertility management options. Previous studies seem to provide mixed results as far as the influence of education on adoption of improved techniques is concerned. Salasya *et al (*1998) found that attainment of secondary education had a negative impact on adoption of hybrid seed and number of years of primary education had no impact on adoption of improved seed. Omiti *et al* (1999) found that formal education has no significant impact on fertilizer adoption. On the other hand, Nkonya *et al* (1997) found that education positively influenced adoption of fertilizer and hybrid seeds. The implication of the present result is that extension system must seek to compensate for lack of formal education on the part of the farmers (Byerlee 1994, Feder *et al* 1995, Saha *et al* 1994). To the extent that extension emphasizes a prescriptive role, farmers receiving information may use it more effectively if schooling helps them to understand more effectively the rationale behind the recommendations. Extension system should thus move beyond its role of prescriptive communication to emphasis on education and skill enhancement.

Table 4.8: The maximum likelihood estimates for the multinomial Logit Model of the factors Affecting Choice of Soil Fertility Management Options on Maize.

VARIABLE	COEFFICIENT ESTIMATES											
	Fertilizer Alone Chosen				Manure Alone Chosen				Fertilizer -Manure Combination			
	Estimate	SE	t	p-value	Estimate	SE	t	p-value	Estimate	SE	t	p-value
Constant	0.04	3.00	0.01	0.99	2.90	2.80	1.02	0.30	-0.20	3.07	-0.06	0.95
AGE	0.05	0.04	1.13	0.26	0.07	0.04	1.70	0.09*	-0.07	0.05	1.44	0.15
EDUC	0.67	0.24	2.80	0.005***	0.60	0.23	2.40	0.02**	0.70	0.23	2.80	0.0045***
GEND	-3.7	1.60	-2.30	0.02**	-3.50	1.60	-2.30	0.02**	-3.20	1.60	-2.00	0.04**
FMLY	-0.90	0.30	-2.90	0.004***	-0.80	0.30	-2.62	0.01***	-0.90	0.30	-2.90	0.003***
ENTPRS	-1.20	1.50	-0.80	0.42	-1.20	1.44	-0.80	0.40	-1.75	1.50	-120	024
LVSTK	4.50	1.90	2.35	0.02**	5.00	1.90	2.60	0.01***	5.30	1.96	2.70	0.007***
FMSZ	2.07	0.84	2.50	0.01***	1.90	0.80	2.30	0.02**	2.20	0.80	2.63	0.008***
MACH	-0.27	1.4	-0.20	0.84	-1.60	1.40	-1.20	022	-0.12	1.50	0.09	0.94
CRDT	7.90	4.00	1.90	0.05**	8.10	4.06	2.00	0.04**	8.96	4.00	2.20	0.03**
CONTACT	0.45	1.30	0.40	0.7	-2.30	1.16	-1.95	0.05**	-1.10	1.30	-0.85	0.70
FLTIME	0.90	0.50	1.70	0.09*	1.07	0.53	2.01	0.04**	0.74	0.56	1.33	0.18
PLTIME	2.71	1.40	1.94	0.05*	1.19	1.40	0.90	0.40	2.50	1.40	1.80	0.08*
GRSMGN	0.0003	0.0001	2.31	0.02**	0.0003	0.0001	2.40	0.01**	0.0003	0.0001	2.40	0.02**

Notes

Unrestricted Log Likelihood –115.0 Restricted Log Likelihood –157.0 McFadden's R^2 0.27

Chi Squared 82.80 Degrees of freedom 45 Significance Level 0.01

The asterixes *, **,*** refer to significance at 10%, 5% and 1% respectively

The *gender* variable had a negative sign and is significant at 5 per cent level for all the soil fertility management options. This is contrary to the hypothesis presented earlier on the effect of gender on adoption. It may be surmised that since female decision-makers are likely to be fulltime operators of their farms without off farm employment, they may tend to exhibit greater adoption of fertility options on their maize plots. It was explained that due to previously observed differences in access to information and productive resources between men and women, with women being at a disadvantage, it is expected that adoption of new agricultural technologies and practices will be lower among women decision-makers. The present result shows that the reverse may be true. Deciphering the reasons behind this may be important in understanding ways to speed up the uptake of agricultural technologies across the gender divide. It is possible that female farmers are more inclined to apply fertility options on their farms since farming may represent their major, if not the only source of livelihood. This fact may be attributable to the lower educational attainments on average among female decision-makers in the study area (Rotich *et al.*1999). Male farmers are therefore likely to have off farm formal employment since greater education may mean a higher opportunity cost of engaging in farming, a fact that may mean that their farming activities are basically secondary part time undertakings. Reduced application of some farm practices in such a case is entirely plausible. The foregoing argument seems to be corroborated by Moock (1976) who in studying the efficiency of female farm managers in the neighboring Vihiga district showed that more educated male are more likely to be employed in off farm activities.

Family size had a negative impact on adoption of the three soil fertility management options considered, suggesting decreased adoption for larger families. This confirms the hypothesis presented previously that larger families might be less likely to use fertilizer due to greater resource limitations that such families may have. Rotich *et al* (1999) in a survey in the same location where part of the present data set was derived, showed that larger households tend to exhibit poor soil management characterized by low or no use of fertilizer and/or manure. Soil fertility management options developed and promoted by extension must therefore take into account the specific demographic and other socio-economic characteristics of target households.

Omiti *et al* (1999) found similar results for adoption of chemical fertilizers among smallholders in Machakos district (Kenya). In that study they showed that family size (total number of family members resident on the farm) had a negative impact on adoption of fertilizer. The explanation offered was that smaller households show preference for inorganic fertilizer, which utilizes less labour. However, it is cash constraint rather than labour constraint argument that may explain this scenario. In the absence of cash limitations for the purchase of fertilizer, larger families are likely to apply more fertilizer especially if more family labour is available. It might be deduced from the labour constraint argument that larger families employ more labour intensive rather than capital (cash) intensive soil fertility management options. However, contrary evidence is presented here which shows that family size has a negative impact on manure adoption as well. The upshot is that the influence of family size on adoption is more via its relationship to disposable household income rather than labour availability. This can be expected if it is considered that the application of sufficient amounts of manure (which often may be available further from the maize field) requires more labour than application of fertilizer for example. In the face of cash limitations it is less likely that manure and combinations thereof will be applied. Similar conclusions have been reached by Kumwenda et al, (1997); Byerlee (1994); Low and

Waddington (1990); and Byerlee and Jewell (1997). In any case availability of family labour appears not to be straightforwardly dependent on household size. The current study shows a low correlation coefficient of 0.16 between household size and family members working full time on the farm.

Farm size was positively related to use of all the options studied at a significance level of 5 per cent. Owners of larger farms may be more likely to have livestock enterprises ensuring ready supply of manure. Considering that dwindling farm sizes has been shown to limit livestock herd sizes, ownership of a small parcel of land certainly militates against livestock ownership and availability of manure and the adoption of the same. Operators of larger farms will likely adopt chemical fertilizer. Operators of larger land parcels might have greater enterprise diversification hence a more diverse income base. This may improve the farmers' ability to acquire purchased inputs. Salasya *et al* (1998) in a study that examined factors affecting adoption of improved maize varieties and fertilizer in Kakamega and Vihiga districts found no significant influence on adoption by the farm size variable. In a study carried in the marginal agro-ecological zone of Eastern Kenya, Omiti *et al* (1999) report that farm size has no significant influence on fertilizer use. However, Nkonya *et al* (1997) reported that farm size positively influence adoption of improved seed and fertilizer in Northern Tanzania. As noted before, there does not exist any clear consensus on the directional impact of farm size on adoption. This is because farm size is a proxy for a large number of factors such as access to credit and capacity to bear risks. Operators of large farms are likely to be able to bear risk by allocating portions of their farms to the new technology while at the same time hedging against the stochastic outcome of the new technology by maintaining another portion of the farm under traditional technology (Smale *et al,* 1994).

Credit had a positive influence on adoption of all the fertility options. This is consistent with expectations that availability of credit to smallholder farmers will help alleviate capital and labour impediments to adoption of soil fertility management options. Noteworthy too is the fact that credit availability has a positive impact on use of manure. Ordinarily, it might be expected that adoption of manure can proceed even in the absence of credit since these materials are locally available and can be acquired from own sources or at lower prices and on easier terms from neighboring farms. The result from this study shows that the labor requirements for manure application represents an important impediment that can be overcome if credit is available to farmers.

The number of family members working fulltime on the farm is positively associated with fertilizer use and use of organic manure at 10 and 5 per cent significant levels respectively. Application of manure has been shown to be a labour intensive operation. It is likely then, that those households with more members working on fulltime basis on the farm will find it easier to apply manure due to greater availability of family labour. The positive influence on fertilizer application may arise from the fact that those households with more family labour available may rely less on hired labour for their farm operations hence realizing some cash savings which may be used in purchasing fertilizer. As shown by Delgado (1979) and Delgado and Mcintire (1982) the return to family labour is an appropriate criterion in technology choice from farmers' viewpoint in Africa's labor constrained systems. Lack of an elastic supply of hired seasonal labour forces most farmers in Africa to rely on family labour to overcome peak labour demands.

The model results showed that *livestock ownership* was positively related to fertilizer adoption as well as use of manure and fertilizer-manure combination. The implication here is that only livestock owners may have sufficient organic fertilizer. Research and extension need to look at alternative sources of organic fertilizer or new techniques of crop residue management or legume-maize rotations as alternative ways of soil organic matter management. Since livestock is important in adoption of manure, the implication is that developing manure markets will be important in enabling those without livestock enterprises to buy the organic materials (Omiti *et al* 1999). Results presented in Table 4.3 show that of all the 77 users of manure either alone or in combination with fertilizer, only 11 did not own livestock. In the face of population pressure and dwindling farm sizes, there may not be enough livestock herds to provide sufficient quantities of organic fertilizer and even those who own livestock enterprises currently may, in future, opt out of it due to lack of land (Kumwenda *et al* 1997). As has been noted in previous sections of this study, livestock ownership may be indicative of greater resource endowment and management skills. These factors are important in adoption of chemical fertilizer. Okuro *et al*, (2000) showed that use of manure by maize farmers in Embu district (Kenya) improved fertilizer adoption.

Agronomic evidence exists which shows that combining small amounts of inorganic and organic nutrient sources has synergistic effects especially due to the soil ameliorating properties of the latter (Kumwenda *et al*, 1997; Ladd and Amato 1985). Livestock owners who have readily available manure are likely to have noticed this benefit and thus have come to be more inclined to add at least some fertilizer to their manure applications. If availability of organic manure is likely to encourage use of inorganic nutrient sources, then this provides a useful reference point for research and extension. Finding acceptable combinations of these materials that can be promoted among smallholders is important in soil fertility management in smallholder maize systems of Kenya. The advantage of this approach is that it would be cost effective, as it is likely to reduce the amount of either inorganic or organic manure applied per hectare.

Farmers' perception of correct planting time positively influenced use of fertilizer alone and fertilizer-manure combinations. As was explained in the hypothesis concerning the influence of this variable on adoption of the three options, a farmer's perception in this regard may be indicative of his/her overall correct understanding of CM issues. If this is true, then the positive influence on fertilizer use as well as use of manure-fertilizer combination arises from the fact that these farmers have acquired basic understanding of soil fertility management. The policy implication from this is that since CM techniques are knowledge and skill intensive (Byerlee 1994), extension efforts should seek ways of improving farmers' knowledge of crop production and agronomic principles rather than offering prepackaged suggestions on CM.

The variable for *extension contact*, though significant, is negative for the adoption of manure. This result may look counterintuitive. The negative significant estimate for manure adoption might be interpreted to mean that extension exposure has discouraged use of this fertility management option. A closer examination may reveal that the negative influence of extension on manure choices may be valid. Omiti *et al* (1999) found that extension contact had no significant influence on adoption of fertilizer. This may derive from the fact that the few farmers who have some contact with extension become discouraged in using manure since extension messages on fertility management are neither practical nor relevant for large numbers of farmers. Byerlee (1994) argued that extension credibility may suffer in situations where their recommendations to farmers are unsuitable for their (farmers') conditions. This process has the potential to precipitate dis-adoption of these packages. Jamison and Lau, (1982) found that extension had a negative impact on productivity and profitability of Thai farms. The reason forwarded for this observation was that farmers might have adopted extension recommendations before they are technically ready for them. In Kenya, extension and research efforts have in the past emphasized fertilizer-seed technologies more than alternative soil fertility management strategies. This might explain the negative relation between extension and the adoption of manure in the present sample.

Byerlee (1994) contends that the impact of training and visit (T and V) extension approach in different parts of the world have been mixed. While T and V extension system seem to have led to a 7% increase in productivity in Haryana State (India); in an almost identical agro-ecological environment in the Pakistani Punjab, and where T and V was also implemented, the objectives of widespread adoption of improved practices and productivity increases have not been achieved. Despite investment in extension and farmers' extension contact having increased, there was little evidence of any effect on farmers' knowledge or adoption of improved practices. Lack of effective adaptive research to formulate useful recommendations and poor research- extension linkages partly explain lack of success of extension systems with potential negative impacts as the present study seems to imply.

Gross margins per hectare positively influenced adoption of fertilizer alone, manure alone and fertilizer-manure combinations. This shows that the higher the returns (profits) farmers expect or get from investing in improved techniques and in their overall farming operations, the greater will be the adoption of these techniques. This outcome can also be interpreted to mean that financial constraints are less for farmers that get higher profits from their maize operations (Erwin and Erwin 1982). It can thus be said that profit maximization is an important criterion in farmers' adoption decisions. As such, any techniques developed or recommended to maize farmers must be critically evaluated in terms of their potential contribution to increased profits. As has been shown in the section for descriptive analyses on GMs among different categories of farmers, the overall GM of Kshs 761 per hectare is way below the potential (being only 2.4%) of Kshs 31705 per hectare. Those not using any soil fertility option actually incurred losses apparently due to poor yields, which could not even cover the labor and cash expenses. In view of the foregoing, research and extension institutions are thus faced with the double pronged problem of simultaneously seeking ways of increasing maize yields and reducing per hectare costs of maize growing operation. This is because the low GMs observed above are also accompanied by low absolute yields[3]. Reducing costs alone without concomitant increases in yields apparently will not translate into farmers' yields approaching potential levels.

[3] On-farm research trials in this region show a potential yield of from 4 to 7t/ha. Data collected in the current sample showed farmers' yield averaged 1.8t/ha comparable to a similar estimate of 1.5t/ha by Ojiem *et al* (1997).

4.6 Ordered Probit Model Estimates of the Factors Affecting timeliness of planting operations

The coefficient estimates of the factors affecting timeliness of planting have been presented i

Table 4.9 below.

Table 4.9: The Maximum Likelihood Estimates for the Ordered Probit Model of the Factors Affecting Timeliness of Planting Operations

Variable	Estimate	SE	t-ratio	P value	Marginal effect on Planting within one week
Constant	0.35	0.92	0.38	0.7	0.140
AGE	-0.011	0.01	-0.88	0.38	-0.004
EDUC	**0.11**	**0.07**	**1.70**	**0.09***	**0.012**
GEND	**-1.26**	**0.74**	**-1.70**	**0.08***	**0.2**
FMLY	0.003	0.04	0.08	0.93	0.001
ENTPRS	0.44	0.31	1.42	0.16	0.170
LVSTK	**0.18**	**0.11**	**1.67**	**0.09***	**0.0005**
FMSZ	0.06	0.06	0.86	0.34	0.022
MACH	-0.28	0.38	-0.72	0.47	-0.120
CRDT	**0.63**	**0.35**	**1.81**	**0.07***	**0.250**
CONTACT	**-0.45**	**0.25**	**-1.76**	**0.08***	**-0.180**
FLTIME	0.02	0.12	0.23	0.81	0.004
PLTIME	**1.84**	**0.80**	**2.53**	**0.01****	**0.110**
GRSMN	-0.1E-05	0.12E-04	-0.11	0.91	0.00
μ_1	0.65	0.12	5.49	0.00	

Notes
Unrestricted Log likelihood -113.0 Restricted Log likelihood -129.0
Chi Squared 31.60 Degrees of Freedom 17 Significance level 0.05
McFadden's R^2 0.12
The asterixes *, ** refer to significance at 10% and 5% respectively.

Number of years of education of decision-maker was positively related to planting within o week of onset of rains. The results show that an extra year of education increased the probabili of planting within one week by 1%. This illustrates the importance of formal schooling enabling decision-makers to appreciate more fully the underlying principles of agricultu practices. It is therefore plausible that formal schooling should positively influence timeliness of planting operations.

The *gender* variable was negatively associated with probability of timely planting showing that male farmers were less likely to weed more than once than female farmers. This shows that female farmers are likely to adopt improved farming techniques similar to their male counterparts. As was noted under soil fertility options, previously observed lower adoption of improved farm techniques among female farmers is attributable not to lower management skills among women farmers but as has been correctly pointed out, due to resource limitations among women.

Credit availability was positively related to timely planting with the variable increasing the probability of planting within one week of onset of rains by 25%. Availability of credit should relax any cash or labour constraints a farmer faces. Given the importance of labour in ensuring timeliness of planting operations, availability of credit should enhance adoption of improved techniques and promptness of farm operations. This appears validated by the positive CRDT coefficient in the present model.

The impact of *extension contact* on timeliness of planting is negative from the negative reducing the probability of planting within one week by 18%. Jamison and Lau, (1982) showed a negative effect of extension on both productivity and profits of Thai farms. As has been posited in the discussion on the effect of extension on manure use, the negative influence of extension on timely planting may be the result of extension recommendations being unrealistic from the point of view of farmers' objectives. The experience of farmers with extension recommendations, which fail to work, may eventually discourage application of such practices. This phenomenon may have a ramifying effect so that the negative influence in one aspect of production is reflected in other related areas. This may explain the negative impact of extension for manure choice and timeliness of planting. The negative association between extension and timeliness of planting can be understood from the foregoing perspective.

The correctness *of farmers' perception of the right planting time* after onset of rains is, as expected, positively related to timely planting. The probability of planting within one week is increased by 10% when the farmer's perception of right planting time matches the technical recommendation from extension. The adoption of any innovation, technology or agricultural practice will be accelerated if farmers have an accurate understanding of the principles underpinning the recommendations (Byerlee 1994; Akpoko and Arokoyo 1998). It should not be taken for granted that those adopting specific recommendations understand fully the principles behind them. This fact may be responsible for incomplete adoption (such as inconsistent or staggered timing of planting operations) since farmers take time in experimenting and getting more information about the new innovation (Smale *et al* 1997).

Livestock ownership was positively related to probability of timely planting. When taken to be indicative of greater wealth, then the positive association here is easy to explain. Livestock enterprises also have the potential to improve the farm cash flow arising from sale of livestock and livestock products. This improves the ability to acquire the needed labour for weeding. The implication for research and extension policy is to pay greater attention to the issues of diversification and farm enterprise dynamics as a means of ensuring modernization of smallholder farm sub-sector through the adoption of improved farm techniques (Hayami and Otsuka 1994).

4.7 Binary logit Model Estimates of the Factors affecting the decision to carry out multiple weeding

The ML estimates of the factors influencing the frequency of weeding have been presented in Table 4.10 below.

Table 4.10: The Maximum Likelihood Estimates for the Binary Logit Model of the factors Affecting Choice of Multiple Weeding.

	Coefficient Estimates				
Variable	Estimate	SE	t	p-value	Marginal Effect
Constant	**7.50**	**2.60**	**2.90**	**0.004*** **	**0.44**
AGE	-0.03	0.03	-1.12	0.26	-0.002
EDUC	-0.24	0.09	-0.30	077	-0.0007
GEND	-0.30	0.76	-0.35	0.72	-0.02
FMLY	-0.01	0.10	-0.10	0.91	-0.0003
ENTPRS	**2.07**	**0.80**	**2.60**	**0.01*** **	**0.12**
LVSTK	0.74	0.80	0.88	0.38	0.045
FMSZ	0.02	0.21	0.10	0.91	0.0001
MACH	**-2.90**	**1.20**	**-2.40**	**0.02** **	**-0.1799**
CRDT	1.60	1.17	1.40	0.17	0.09
CONTACT	-0.80	0.75	-1.06	0.30	-0.045
FLTIME	**0.60**	**0.36**	**1.70**	**0.09***	**0.03**
PLTIME	**-2.50**	**0.81**	**-3.04**	**0.002*** **	**-0.14**
GRSMGN	**0.0001**	**0.00005**	**2.70**	**0.02***	**0.7E-05**

Notes:
Unrestricted Log likelihood Function (–36.60)
Restricted Log likelihood Function (-57.6) McFadden's R^2 0.36
Chi Squared (42.02) Degrees of Freedom 15 Significance Level (0.01)
The asterixes *, **,*** refer to significance at 10%, 5% and 1% respectively

Ownership of an extra non-maize crop enterprise on the same farm is positively associated with weeding more than once. As shown by the marginal effect, the probability to weed more than once increases by 12% as a result of operating an extra enterprise. An extra enterprise may be a source of cash income. This is likely to improve the farm cash flow and the ability of the decision-maker to hire the needed labour for extra weeding.

Use of machinery was negatively associated with multiple weeding and probability to weed more than once is reduced by 17% due to machinery ownership. It may have been expected that those farmers who employ machinery in land preparation realize savings on labour costs, which would mean greater ability to carry out multiple weeding. The possible reason for this outcome is that since oxen and tractor hire services tie up a substantial amount of cash, this impinges negatively on the ability to carry out multiple weeding. This may confirm the qualifier presented under the hypothesis on effect of machinery on adoption of CM practices. It was observed that labour savings from mechanizing some farm operations will only be significant if, the use of machinery is efficient enough as to lead substantial cash/labour savings to be employed in non-mechanized operations. As observed by Celis *et al* (1991); the use of oxen for example introduces new activities to cultivation, such as leading oxen, harrowing and clearing the land of trees, roots and stumps. This means greater labour requirements. Delgado and Mcintire (1982) made similar observations in a study on adoption of oxen cultivation in the Sahel. They showed that use of animal traction increases per hectare labour requirements on small farms. Use of machinery *per se* does not necessarily guarantee sufficient labour/cash savings unless intrinsic inefficiencies in farm operations are removed. Until that happens, the negative impact of machinery on multiple weeding is a plausible outcome.

Number of family members working full time on the farm positively affected probability of weeding twice. The probability to weed more than once increases by about 1% as a result of an extra person being available to work fulltime on the farm. This is a straightforward outcome in the sense that the more family labour is available full time the less labour problems a farmer may face hence greater probability of multiple weeding.

Perception of correct planting time had a negative impact on probability of multiple weeding with a 15% reduction in probability to weed more than once. This looks implausible in view of the argument presented previously on the effect of perception on correct planting time on choice of the techniques considered in this study. .The negative relation between perception on correct planting time and probability of multiple weeding may nevertheless arise from the fact that those farmers whose perceptions of the right planting time are correct do plant early and may experience fewer weed infestation problems. They may perhaps be less inclined to weed more than once especially if they experience cash shortages for hiring labour.

Gross Margins per hectare also important in the adoption of multiple weeding at 5% level. GM results presented in Table 4.7 showed that those who carry out multiple weeding had higher gross margins. Improving the returns to labor expended in the weeding operation is an important way to foster the adoption of multiple weeding. This provides an important criterion for evaluating agronomic recommendations involving multiple weeding and other cost-increasing techniques.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Major Findings

This study set out to determine the level of adoption of fertilizer, manure and combinations of manure and fertilizer as well as the level of adoption of timely planting and multiple weeding. It also sought to determine the factors that significantly influence adoption of these practices and to finally come up with policy recommendations that would encourage their adoption.

Limited dependent variable models namely multinomial logit, binary logit and ordered probit were used to isolate the socio-economic factors that significantly influenced the adoption of soil fertility management options, decision to carry out multiple weeding and timeliness of planting, respectively. The multiple choice scenario as far as soil fertility management options available for smallholder farmers are concerned justified the use of multinomial logit to determine the factors that influenced adoption of these options. The ordered probit model was relevant for studying adoption of timely planting given that the variable for timeliness of planting lent itself to a form of ordinal ranking. The decision to weed once or not at all versus the decision to weed more than once was modeled as a binary variable hence the use of binary logit to model this decision. Descriptive statistical summaries were used in determining the level of adoption of the CM practices considered as well as to describe salient trends in input use, resource endowment, extension contact and credit access for the farmers falling in various adoption categories. An overriding assumption that individual farmer's own and perhaps unique socio-economic circumstances constitute the greatest determinants (constraints) in the adoption of farm techniques was adopted in this study. This provided the rationale for the inclusion of various factors reflecting farmers' human capital and resource endowments as well as institutional access in the adoption models.

Descriptive statistics computed from the current data set showed that 91 per cent of all the farmers interviewed applied at least one soil fertility management option on their maize during the season under consideration. The results also showed that only 52 per cent of the farmers applied fertilizer in one way or the other. Sixty-four per cent applied manure either alone or in combination with fertilizer. The study also found that 70 per-cent of all sample farmers applied 15Kg or less of nitrogen per hectare, 7.4% applied between 31 to 45Kg per hectare and 15% applied over 45Kg per hectare. The recommended rate of nitrogen application in the area of the study is 55Kg of nitrogen per hectare. Seventy per cent of all the farmers interviewed planted at least within two weeks of the onset of rains and 82% of all the farmers interviewed weeded at least twice. The gross margin computations revealed that those not applying fertilizers were actually incurring losses to the tune of Kshs 4240 per hectare. Those using fertilizer alone realized gross margins of Kshs 18120 per hectare. Those using manure alone realized Kshs 11240 per hectare and those combining fertilizer with manure realized Kshs 14492 per hectare. This shows there are incentives for use of fertilizer since its use is associated with higher gross margins.

The multinomial logit analysis showed that the following factors significantly influenced the use of fertilizer alone, manure alone and fertilizer-manure combinations. Age and extension contact were positively related to adoption of manure. Formal schooling as indicated by the number of years of education, size of the farm owned, availability of credit, livestock ownership and gross margin per hectare were positively related to use of the three options. The number of family members working fulltime on the farm positively influenced use of fertilizer alone and manure alone. Farmers' correct perception of the right planting time positively influenced use of fertilizer and fertilizer-manure combinations. Male farmers and farmers with larger household size were less likely to use all the three options considered. Farmers' extension contact was negatively related to use of manure alone.

Binary logit coefficients showed that operation of an extra crop enterprise, number of family members working fulltime on the farm and gross margin per hectare positively affected probability to weed more than once. Use of tractor or ox-plough and farmers' correct perception of the right planting time, were found to negatively affect the probability to weed more than once. The ordered probit model regression coefficients showed that formal schooling, credit access, farmers' perception of the right planting time and livestock ownership were positively associated with timeliness of planting operation. Male farmers were less likely to plant in time. Extension contact negatively influenced timeliness of planting.

5.2 Conclusions

From the foregoing, it can be concluded that the awareness of the need for soil fertility intervention is relatively high. Ninety-one per-cent of all farmers either applied some fertilizer, manure or their combination. It can also be seen that at 52%, fertilizer adoption lags behind adoption of timely planting and multiple weeding whose adoption stand at 70% and 82% respectively. Since the awareness of the need for soil fertility intervention is high, it can also be concluded that the sub-optimal application of fertilizer is clearly attributable to lack of cash for the purchase of fertilizers, and in the case of manure lack of labour for its application. Contrary to what current literature seem to suggest, the incidence of adoption of timely planting and multiple weeding among smallholder farmers in this region appear relatively high. Poor CM levels (including fertilizer use) among farmers apparently does not result from low incidence of adoption among farmers. Rather, this study leads to the conclusion that the main problem of poor CM among farmers is the sub-optimal (incongruent) combination of the rate of fertilizer application, timeliness of planting and frequency of weeding.

The regression results show that factors that are related to resource endowment such as farm size and livestock ownership are important in conditioning adoption behaviour. Factors that reflect costs of production such as per hectare costs of land preparation and weeding as well as use of animal traction or tractor equipment in farming operations impact on the adoption of capital and labour intensive practices such as the ones considered in this study. Human capital factors such as number of years of education and fulltime family labour also represent important factors influencing the adoption of the CM practices considered.

The overall conclusion is that the most prominent constraints to improvements in CM levels among smallholders remain the scarcity of cash and labour as well as lack of understanding of the principles embodied in the recommended CM practices.

5.3 Recommendations

5.3.1 Research and Extension Policy Recommendations for Enhancing Adoption of CM Practices

Based on the above findings and conclusions, research and extension policy thrust should focus on the following:

- Policy interest should be rekindled in the search for ways of providing sustainable credit support to smallholders in view of the importance of credit in fostering the adoption of fertilizer, manure, fertilizer-manure combinations and multiple weeding.
- Macro-economic and marketing policies that will encourage widespread availability of fertilizer are needed if farm level application of fertilizer is to be increased beyond the current low levels that stand at 27 per cent of the recommended rates.
- Since gross margins per hectare are important in fostering the adoption of the different soil fertility management options considered as well as multiple weeding, the implication is that techniques that increase gross margins/returns per hectare will be more readily adopted. Research and extension policies should concentrate on simultaneous cost reduction and yield enhancement in smallholder maize systems. This can be achieved through efforts meant to modify current recommendations or developing new ones, which require less per hectare labour expenses than the current practices. This combined with simultaneous increases in yield from greater nutrient application will improve farmers' gross margins and encourage the uptake of improved practices.
- More efficient methods of small farm mechanization need to be developed since use of animal traction or tractor equipment was shown to reduce the probability of multiple weeding. Extension efforts meant to increase and improve the use of animal traction among

smallholder farmers are needed so that the costs of the use of animal traction can be lowered. Macro economic policies that are aimed at improving tax incentives to fabricators and/or importers of animal traction equipment can be an important policy effort in improving the availability of these implements at lower costs to small-scale farmers.

- Due to low levels of formal schooling among smallholder farmers and due to the fact that formal schooling has been shown to be important in ensuring the effective uptake of improved farm practices, extension policy should now focus on efforts meant to make up for the low educational attainments in rural farming communities. This can be done by pursuing a policy of educating farmers on the scientific principles of good farming techniques and focusing on training activities meant to impart and improve management skills among the farmers. This will involve shifting from the current policy of promoting specific recommendations to farmers who neither fully understand the reasons behind these techniques nor have the skills to apply them.
- Soil fertility management research policy should pay greater attention to the search of alternative sources of organic fertilizers other than livestock (which was shown to positively influence adoption manure and combination of fertilizer and manure) and to developing markets for organic fertilizers much the same way as there are markets for inorganic fertilizers. Developing markets for manure (organic fertilizers) will entail developing appropriate means and units of quantity measurement, quality determination and dissemination of prices. This also presupposes that availability of organic fertilizers will increase to satisfy increased demand occasioned by improved manure markets.

5.3.2 Recommendations for Future Research

The present study dwelt on isolating the significant factors that affect positively or negatively the probability of adoption of the various CM practices considered. These factors reflect farmers' resource endowments, human capital, and costs of operation as well as institutional support available to decision-makers. However as was noted in section 2.5 of this thesis, the type of analyses such as the one done in the present study is useful in providing information on directional (qualitative) impact of the factors included in the regression models on the adoption decision. This study has therefore laid the groundwork for further quantitative analyses on the economic importance of the various variables found to be significant in influencing adoption of the CM practices. Such analyses will also help determine whether the economic significance of individual variables should warrant policy attention. The foregoing analyses can be implemented by developing optimization models over time and carrying out stochastic production frontier analyses. Such analyses will allow for the study of the impact of the various socio-economic factors so far isolated on yield gaps, risk perceptions and related issues.

Since the present study dwelt on only three areas of CM namely soil fertility management options, timely planting and multiple weeding, similar adoption studies can in future focus on other CM areas such as; soil moisture management, maize-legume rotations, alley cropping, fallowing, soil conservation and other alternatives to animal manure in soil organic matter management.

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APPENDICES

Appendix 1. Marginal Effects of the Multinomial Logit Estimates of the factors affecting Fertility choice on Maize

VARIABLE	MARGINAL EFFECTS														
	None chosen				Fertilizer Alone Chosen				Manure Alone Chose				Fertilizer -Manure Combination Chose		
	Estimate	SE	t	p-value	Estimate	SE	t	p-value	Estimate	SE	t	p-value	Estimate	SE	t
Constant	-0.002	0.01	-0.2	0.82	-0.12	0.39	-0.3	0.76	0.38	0.39	0.99	0.32	-0.27	0.36	-0.75
AGE	0.00002	0.001	0.19	0 84	-0.004	0.005	-0.78	0.44	0.005	0.005	1.03	0.3	-0.001	0 004	-0 34
EDUC	-0.0004	0.002	-0.2	0.81	0.003	0.02	0.20	0.83	-0.02	0.01	-1.12	0.2	0.01	0.01	1.08
GEND	0.003	0.01	0.2	0.82	0.06	0.12	0.49	0.62	-0.13	0.12	-1.1	0.26	0.07	0.1	0.68
FMLY	0.001	0.003	0.22	0.82	0.002	0.02	0.14	0 89	0.01	0.02	0.56	0.57	-0.01	0.02	-0.89
EXTFAM	-0.0002	0.002	-0.11	0 90	0.14	0.12	1.13	0.25	-0.15	0.13	-1.18	0.23	0.01	0 11	0 13
ENTPRS	0.003	0.01	0.23	0.81	0.2	0.13	1.48	0.13	-0.01	0.13	-0.09	0.92	-0 18	0.11	-1.6
LVSTK	-0.005	0.02	-0.22	0.80	-0.18	0.15	-1.19	0.23	0.02	0.16	0.11	0.91	0.16	0.15	1.12
FMSZ	-0.002	0.008	-0.23	0.81	0.01	0.03	0.43	0.66	-0.04	0.03	-1.46	0.14	0.03	0.02	1.5
MACH	0.0005	0.002	0.2	0.83	0.85	0.15	0.54	0.59	-0.26	0.15	-1.74	0.08*	0.17	0.15	1.12
CRDT	-0.006	0.03	-0.2	0.81	-0.16	0.16	-0.98	0.32	0.01	0.16	0.08	0.93	0.15	0.13	1.10
CONTACT	0.002	0.007	0.22	0.82	0.29	0.12	2.5	0.01***	-0.39	0.12	-3.11	.001***	0.07	0.10	0.70
FLTIME	-0.001	0.004	-0.24	0.81	0.02	0.04	0.46	0.65	0.02	0.03	0.58	0.56	-0.04	0 04	-0.95
PLTIME	-0.002	0.01	-0.23	0.81	0.14	0.12	1.18	0.23	-0.200	0.12	-1.65	0.09*	0.06	0.11	0 56
HYBRID	-0.002	0.01	-0.22	0.82	0.02	0.15	0.13	0.89	0 09	0.15	0.60	0.55	-0 11	0.12	-0 86
GRSMGN	-0.00001	0.001	-0.19	0.85	-0.004	0.005	-0.75	0.45	-0.001	0.005	-0.3	0.80	0 01	0.004	1.27

Appendix 2 Marginal Effects for the ordered Ordered Probit Model

Variable	Time Lapse between onset of rains and date of Planting: More than two weeks	More than one week but within two weeks	No more than one week
Constant	-0.120	0.020	0.140
AGE	0.004	-0.0005	-0.004
EDUC	-0.020	0.002	0.012
GEND	-0.160	0.020	0.180
FMLY	-0.001	0.0001	0.001
ENTPRS	-0.155	0.020	0.170
LVSTK	0.005	-0.0006	-0.005
FMSZ	-0.020	0.003	0.022
MACH	0.100	-0.012	-0.120
CRDT	-0.220	0.028	0.250
CONTACT	0.160	-0.020	-0.180
FLTIME	-0.003	0.0004	0.004
PLTIME	-0.101	0.012	0.110
GRSMGN	-0.004	0.0005	0.005

Appendix 3 Effects of the Binary Logit Model:

Variable	Marginal Effect	S E	t- ratio	P-value
Constant	0.44	0.19	2.2	0.03
AGE	-0.002	0.002	-0.9	0.37
EDUC	-0.0007	0.006	-0.13	0.90
GEND	-0.02	0.05	-0,43	0.67
FMLY	-0.0003	0.007	-0.05	0.96
ENTPRS	0.12	0.05	2.27	0.02**
LVSTK	0.045	0.05	0.82	0.41
FMSZ	0.0001	0.01	0.007	0.99
MACH	-0.17	0.08	-2.09	0.04**
CRDT	0.09	0.07	1.23	0.20
CONTACT	-0.045	0.04	1.03	0.30
FLTIME	0.007	0.02	0.41	0.68
PLTIME	-0.14	0.06	-2.5	0.01***
GRSMGN	0.002	0.002	1.14	0.25

*** refer to significance at 10, 5 and 2% respectively

Appendix 4a. Per hectare Gross Margin calculations for adopters of different soil fertility options

Cost Revenue Items	No fertilizer/manure	Fertilizer	Manure alone	Fertilizer manure combined
COSTS				
Seed	1295	1790	117	1706
Fertilizers(Planting and top dressing)	0	1799	0	2278
Planting labour costs	1185	952	990	1088
First weeding labour costs	3293	2041	2252	2075
Second weeding labour costs	3293	2041	2252	2075
Land preparation (Initial and harrowing)	4000	3750	2170	2260
Harvesting costs (including shelling. costs of gunny bags and transpot)	690	954	596	910
TOTAL VARIABLE COSTS(TVC)	**13756**	**13327**	**8377**	**12392**
Revenues				
Mean maize yield (Kg per Ha)	732	2423	1509	2068
TOTAL REVENUE in Kshs per(TR)	**9516**	**31499**	**19617**	**26884**
GROSS MARGINS (TR-TVC)	**-4240**	**18172**	**11240**	**14492**

Appendix 4b. Per hectare Gross Margin calculations for adopters of timely planting and multiple weeding

Cost Revenue Items	Weeding done once	Weeding done two or more times	Planting done at least within two weeks of onset of rains	Planting done beyond two weeks of onset of rains
COSTS				
Seed	1747	1403	1441	1485
Fertilizers(Planting and top dressing)	842	885	1116	999
Planting labour costs	898	1048	1048	1015
First weeding labour costs	1993	1993	2084	2282
Second weeding labour costs		1993	2084	2282
Land preparation (Initial and harrowing)	4400	4400	4040	4360
Harvesting costs (including shelling, costs of gunny bags and transport)	931	748	769	792
TOTAL VARIABLE COSTS(TVC)	**12804**	**12470**	**12470**	**13215**
Revenues				
Mean maize yield (Kg per Ha)	1102	1992	1851	1666
TOTAL REVENUE in Kshs per(TR)	**10811**	**25896**	**24063**	**21658**
GROSS MARGINS (TR-TVC)	**3625**	**13426**	**11481**	**8443**

Appendix 4c Gross margin calculations for different nitrogen application categories(Kg per Ha)

Cost Revenue Items	0 to 15	16 to 30	30 to 45	Over 45
Costs				
Seed	1471	1708	1790	1190
Fertilizers(Planting and top dressing)	184	1672	2150	4405
Planting labour costs	969	1337	800	1219
First weeding labour costs	2276	2054	1450	2581
Second weeding labour costs	2276	2054	1450	2581
Land preparation (Initial and harrowing)	2062	4990	2742	4834
Harvesting costs (including shelling, costs of gunny bags and transpot)	785	911	982	601
TOTAL VARIABLE COSTS(TVC)	**11494**	**14726**	**11364**	**17411**
Revenues				
Mean maize yield (Kg per Ha)	1541	1193	2829	3033
TOTAL REVENUE in Kshs per(TR)	**20033**	**15509**	**36777**	**39429**
GROSS MARGINS (TR-TVC)	**8539**	**783**	**25413**	**22018**

Appendix 4d Gross margin calculations from on- farm research trials (Kshs per Ha)

Cost Revenue Items	Researcher Achievement
Seed	1725
Fertilizers(Planting and top dressing)	5420
Planting labour costs	1020
First weeding labour costs	1200
Second weeding labour costs	1200
Top dressing labour	60
Harvesting costs (including shelling, costs of gunny bags and transpot)	3760
TOTAL VARIABLE COSTS(TVC)	14475
Revenues	
Mean maize yield (90 Kg bags per Ha)	41
TOTAL REVENUE in Kshs per(TR)	46150
GROSS MARGINS (TR-TVC)	**31705**

Source Ojiem *et al* (1997)

Appendix 4e: Rate of Nitrogen application among sample farmers

Nitrogen application (Kg per Ha)	**Per-cent of farmers applying**
0 to 15	70.5
16 to 30	7.4
31 to 45	7.4
Over 45	14.8

Appendix 5. Farm level Questionnaire

UNIVERSITY OF NAIROBI

Department of Agricultural Economics

The Socio economic Factors affecting the Adoption of Crop Management Technologies among Smallholder Maize Farmers: Evidence from Western Kenya.

FARM LEVEL QUESTIONNAIRE

1.0 FARM IDENTIFICATION

1.1 Questionnaire Serial Number------------------------------------Start Time---------------------------

1.2 Name of enumerator---

1.3 Name of respondent--

1.4 Division--

1.5 Date of interview--

2.0 BACK GROUND INFORMATION:

2.1 Farmers Name---

Age (years)------------------- Gender: **M / F**

2.2 Education level: (A) Standard------------Year completed19------ (B) Form-----------------Year completed 19------ (C) College certificate (D) College diploma (E) Degree

2.3 Size of family (persons)--

2.4 What is the size of your farm---acres

2.5 What year did you start operating this farm 19---

2.6 Do you own the tittle to this land? **YES/NO** *if NO go to 2.7*

2.7 On what terms do you operate the farm?

(A) Rented **(B)** Temporary Grant **(C)** Other specify--

2. 8 When will the present tenure expire?

2.9 Do you operate any land elsewhere? **YES/NO** *if YES* acres--------------------------------------

3.0 SOIL FERTILITY MANAGEMENT

3.1 How do you usually ensure your soil remains fertile? ***(Tick all options mentioned)***

(A) Fertilizer **(B)** FYM **(C)** Stover **(D)** Green Manure **(E)** Any other (Specify)---

3.2 Did you use any fertilizer last production year (1999)? Season 1 **YES / NO** Season 2 **YES / NO** *If YES fill out table below, if NO go to 3.3*

TYPE	AMOUNT (Kg or Bags)		PRICE/COST *(Kshs per Kg or Bag)*	
	Season 1	Season 2	Season 1	Season 2

3.3 If **NO** why don't you use fertilizer?

(A) Unavailability **(B)** High purchase cost **(C)** High transport cost

(D) Other reasons (Specify)

Organic fertilizer

Note: *Organic fertilizers refer to farmyard manure (including compost) as well as green manure from legume trees e.g.* Crotalaria. *(Green manure on the other hand refers to the incorporation of fresh or green plant materials into the soil to maintain soil fertility).*

If farm yard or green manure or stover **IS USED**

3.4 Why is it beneficial to use the materials you mentioned (in 3.1 above) on your farm? **(A)** Leads to higher yields **(B)** Not enough fertilizers are available **(C)** Advised by extension staff **(D)** Readily available **(E)** Any other reasons---

----

3.5 Did you use any of the organic materials you mentioned in **3.1** above in 1999? **YES/NO**

3.6 Do you plant any legume trees/shrubs (e.g Crotalaria) on your shamba? **YES/NO**

3.7 What reasons make you **NOT TO USE** Organic manure (FYM, Compost, or Green manure): ***(Tick reason (s)). In the blank spaces remaining, fill in the other reasons mentioned by farmer and tick as appropriate***

	Not available	**Lack of labor**	**No Cash for hiring labor**	**Not aware of benefits**		
FYM/Compost						
Green manure						

4.0 CROP MANAGEMENT INFORMATION

Definitions:

Timely Planting: If planting was done by the end of march.

Multiple weeding: Wedding done more than once on the maize crop.

Planting

4.1 What date did you plant last year **(1999)**? Tick as appropriate

Season1 (A) In January **(B)** In February **(C)** Early March **(D)** Mid March **(E)** Late March**(F)** April

Season2 (A) In January **(B)** In February **(C)** Early March **(D)** Mid March **(E)** Late March**(F)** April **4.2** Do you receive any announcements about the correct planting dates? **YES/NO**

4.3 What date was announced last year? ---

4.4 If the rains arrive at the end of February what period would **you consider late** for planting maize? **(A)** Mid-March **(B)** Late March **(C)** Early April **(D)** Mid April **(E)** Late April

4.5 Why do you think this is important? **(A)** High yield

(B) Other reasons (Specify)---

4.7 If planting was late (*Planting done after end of March*), why were you unable to plant *before* end of March?

(A) Lack of Labor **(B)** Lack of seeds **(C)** Lack of cash to hire labor **(D)** Lack of cash for seeds **(E)** Any other reasons

---

Multiple Weeding

4.8 How many times did you carry out weeding on your maize crop in 1999?

Season 1-- **Season 2**--------------------------------

4.9 If you had enough cash and labour how many times would you weed your maize crop?----------

4.10 What are the benefits of weeding more than once **(A)** Higher yields **(B)** Other reason (s)--

--------**4.11** What area of your crop did you weed more than once?

Season 1(A) Whole **(B)** Half **(C)** Less than Half **Season 2 (A)** Whole **(B)** Half **(C)** Less than Half

The following is for those who weed only once:

4.12 Why do you weed only once? **(A)** Do not have enough labor **(B)** Makes no difference in yields **(C)** Not aware of importance **(D)** No cash to hire labor

(E) Any other reason(s) --

Intercropping

4.13 Do you plant maize as **(A)** Pure stand **(B)** Intercrop (Tick as appropriate)

4.14 Which crop(s) do you intercrop with maize?

Season 1--

Season 2--

4.15 What area under maize did you intercrop?

Season1 **(A)** Whole **(B)** Half **(C)** Less than Half

Season 2 **(A)** Whole **(B)** Half **(C)** Less than Half

4.16 Why do you intercrop maize as you have shown in **4.13** above?

(A) Higher maize yield **(B)** Suppresses Weeds **(C)** Limited land

(D) Other reasons--

4.17 For how long have you been carrying out the following activities?:

Note:

1. ***Mark √for YES in the table if activity was carried out at least in one or both seasons of 1997 and 98 and X for NO if they did not car y out the activity at all.***

ACTIVITY	1997	1998
Weeding more than once		
Planting by the end of March		
Use of FYM, Green manure or Stover		

5.0 IMPROVED SEED.

Note: Improved seed refers to those seeds supplied by certified seed companies such as the Kenya Seed Company.

5.1 From where do you get your planting materials? **(A)** Purchase **(B)** From previous crop

(C) Other sources---

5.2 If seed was purchased, which variety/varieties did you plant in 1999?

Season1 ____

Season2 ____

5.3 How frequently do you buy fresh seeds?(A) Each planting season

(B) Any other (Specify)---

5.4. Why did you choose to plant the particular variety you mentioned in 5.2 above?

(1) Superior taste

(2) Yield advantage

(3) Cheap seeds

(4) Superior storage quality

(5) Early maturing

(6)Other specify____

NB. Insert number in the reason column below.

Variety	Reason	Cost/kg (Kshs)

5.5. At which market do you buy your seed?------------------------------------Distance------------km.

5.6 If NO improved seeds are used why didn't you use improved seeds?

(A) Seed unavailability

(B) Lack of cash to purchase seed.

(C) Did not know the right variety to use

(D) Never heard of improved varieties.

(E) Other (specify)---

6.0 FARM ENTERPRISES

6.1 What area of your farm was under maize in 1999? --

6.2 What was your maize output last year (1999) Season 1------------bags/kg Season 2-----------Bags/Kgs?

6.3 Apart from maize, name four other major crops enterprises you had on your farm in 1999?

CROP	ACREAGE	YIELD Bags/Kgs/Tins *(Show units)*	TOTAL REVENUE

6.4 Do you have "Grade" dairy cattle? **YES/NO**

6.5 For how long have you kept "Grade" dairy animals? Since19-----------------------------------

6.6 How many "Grade" dairy animals do you have--(number)

6.7 How many of these were in milk on average per month last year?----------------------------------

6.8 What is the average milk production per day in litres/bottles?------------------------litres/bottles.

6.9 Other than "Grade" dairy cattle, Do you keep any other livestock? **YES/NO** ***(If yes tick as appropriate)***

TYPE	NUMBER	PURPOSE
CATTLE		
SHEEP		
GOATS		
OTHER		

7.0 FARM LABOR

7.1 How many of your family members work on the farm full or part time?

PROFILE OF FAMILY LABOUR	
Number working full time	
Number working part time	

Note: *Those working full time are those who are not engaged in any off farm activity.*

Those working part time engage in other off farm activities or for any reason do not spend the whole week/month working on the farm.

7.2 How much time and labor do you require for the following activities?

ACTIVITY	**No of days required to complete**	**LABOUR** (*Number of people involved*)			**MACHINERY** *Indicate type eg plough/Tractor*
		FAMILY LABOUR	**HIRED LABOUR**		
			Casual	**Permanent**	
Land preparation 1					
Land preparation 2					
Planting					
Application of manure					
Weeding 1					
Weeding 2					
Weeding 3					

NOTE: *Include other activities not listed but mentioned by the farmer by filling the blank spaces under* ***'Activity'*** *column and complete the rest of the columns as appropriate.*

7.3 For those members who work full and /or part time on the farm, how many are:

Below 18-------------------------------------- above 18---

7.4 For those who work **full time** how much time do they spend actually working?

Days per week---------------------------------Hours per day--

7.5 How much do you pay for *casual* labor per day? Kshs---

7.6 How much do you pay *permanent* labor per month Kshs--

7.7 Do you always have enough people for planting, weeding, or harvesting etc? **YES / NO**. If **NO** during which operations do you experience such shortages? ***Mark X where shortage occurs and leave blank where No shortage occurs.***

Activity	**Labor Shortage** *Mark X if shortage occurs*	**Extra Labor Required**	
		Casual	**Permanent**
Land preparation			
Planting			
Weeding 1			
Weeding 2			
Weeding 3			
Manure application			

8.0 INFORMATION ON CREDIT:

8.1 Did you get any credit in the last two years? **YES/NO**

8.2 If **YES** how much and from where?

Source	Amount	Year received	Enterprise on which credit was used
A F C			
Co-operative			
Commercial Bank			
Friends			
Others specify			

8.3 If Credit was used on maize, on which operation was it used (tick as appropriate).

(A) Land preparation **(B)** Planting **(C)** Weeding **(D)** Purchase of seed and fertilizers. **(E)** Others specify: --
----

9.0 ACCESS TO INFORMATION

9.1 Has your farm ever been visited by extension staff to talk to you about any improved farming methods **YES /NO If yes ask 9.2**

9.2 Was your farm visited last year (1999) **YES / NO.** If yes how many times-----------------------

9.3 If the farm was not visited last year when was it last visited? 19-------------------------------------

9.4 Have you ever come into contact with agricultural Extension staff *outside* your farm?

YES / NO **If yes where:** (A) **Chief's Baraza** (B) **FTC** (C) **Farmer's field day** (D) **I visited their offices** (E) **Other places (specify)**--------------

----

9.5 Who normally gets in contact with the extension officers when they visit your farm?

(A) Respondent **(B)** Respondent's Spouse **(D)** Other (specify)--------------------------------------

9.6 Have you ever received advice on Timely planting, Weeding more than once, Use of manure, or '*Crotalaria*' YES/ NO

If YES from what source (s)?

Source of advice	*Tick if advice has been received*	Year
Agricultural extension staff		
Farmer Training Center (FTC)		
Farmers Field day		
NGO		
Co-operative		
Magazines		
Radio/TV		

10.0 GENERAL CONCLUSIONS:

10.1 Do you think there is anything else you can do to increase your yields from current levels? YES / NO. What else:

(A) Start to use / Use more fertlizer **(B)** Start to use / use more manure **(C)** Start to use/ use more green manure **(D)** Use improved seed **(E)** Others (specify)

10.2 What problems do you face in maize production and which we have not mentioned?

(A) Low producer prices
(B) High cost of fertilizers
(C) High cost of seeds
(D) High cost of labor
(E) Other problems
(Specify)____

____

____

10.3 What solutions do you suggest?

____

Thank you very much for your co-operation and finding time to answer my questions.

End Time------------------------------