AN ECONOMIC ANALYSIS OF THE DETERMINANTS OF FERTILIZER USE IN SMALL MAIZE FARMS IN WESTERN KENYA

BY

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DECLARATION

I, Lawrence Obae Mose, declare that this thesis is my original work and has not been presented for a degree in any other university

Mose 18/7/97

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This thesis has been submitted for examination with our approval as university supervisors

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ABSTRACT

A major objective of the National Food Policy for the government of Kenya is the attainment of Household and National food security. One of the methods recommended is through land use intensification such as use of fertilizers to increase crop yields. However, previous studies have shown that fertilizer use in maize production by smallholder farmers who form the bulk (in terms of area and production) of maize producers is sub-optimal. This study was thus formulated with the objectives of describing the fertilizer use patterns and identifying the major determinants of fertilizer use in Kisii, Kakamega and Trans Nzoia Districts in Western Kenya.

Data on fertilizer use were collected from a random sample of 120 farmers using a pre-tested structured questionnaire over the 1995 main maize production season. The data collected were analysed by use of descriptive statistics to show the fertilizer use patterns and factors responsible for inter-farm differences and by regression analysis to establish the major determinants of fertilizer use.

The descriptive analyses results indicated that fertilizer use in maize varied within the three districts studied according to resource base, liquidity position of the farmers, access to extension services and markets. The highest level of fertilizer nutrient use was 87.3 kg/ha in Trans Nzoia District while the lowest average was in Kisii District estimated at 35.5 kg/ha. The estimated mean amount of nutrient fertilizer use in Kakamega District was 54.3 kg/ha. It was also reported that in the striga prone areas notably Khwisero and Mumias Divisions in Kakamega

District, the weed impacts negatively on the rate of fertilizer use and growing of hybrid maize.

While it is widely acknowledged that availability of credit enhances the liquidity position of farmers and hence increases the farmers' ability to purchase fertilizer and other complementary inputs, the study revealed that of the 120 farmers interviewed, none of them got institutional credit for maize production in 1995. Thus, it was not possible to determine the effect of formal credit on fertilizer use.

The results of the regression analyses indicated that the fertilizer - maize price ratio was the only important determinant of fertilizer use which cut across all the three districts, though it was not highly significant in Trans Nzoia District. The study found a strong linear relationship between fertilizer use and total farm sales in Trans Nzoia district, a commercial maize dominant area. The other important determinants of fertilizer use were use of FYM in Kisii District, land size in Kakamega District, initial soil fertility in Trans-Nzoia District and extension contact in Kisii and Trans-Nzoia Districts.

Based on the above findings, it is recommended that research should be intensified in an effort to control striga before any advances are made to farmers to use fertilizer in the affected areas. It is further recommended to the government to strengthen the agricultural extension programme to ensure that the necessary information on fertilizer use is availed to the farmers in time in order to increase maize production. Finally, the AFC should revise its credit eligibility criteria which limits farmers' access to fertilizer so as to make credit more available to farmers. It is anticipated that this will improve the liquidity

is anticipated that this will improve the liquidity position of the farmers and hopefully increase fertilizer use in maize production.

CHAPTER ONE

1.0 INTRODUCTION

This chapter contains the background information on importance of agriculture to the economy of Kenya, the role fertilizers play in enhancing production of maize, the problem statement, objectives and hypotheses of the study. It also gives an account of the justification of the study and organisation of the thesis.

1.1 Background information

Agriculture forms the backbone of Kenya's economy. It contributes about 30 percent to Gross Domestic Product and supplies almost all the domestic food requirements. Besides, it is a major source of raw materials for the domestic industries and a source of employment for 75 percent of the total labour force. The sector is also expected to generate farm family incomes and stimulate the growth of productive off-farm activities in the rural areas, so that off-farm jobs can grow at the rate of between 3.5 percent and 5 percent per year (Kenya, 1994a, 1994b).

Thus, provision of food security, generation of farm family incomes, employment creation, supply of export crops to earn foreign exchange and growth of productive off-farm activities in rural areas form the development goals for agriculture. Seven commodities have been identified as being central to achieving the development goals established for agriculture. Coffee and tea expansion is the foundation of growth of both agricultural incomes and exports. Maize, wheat, milk and meat production must be adequate for food security. Food security refers to access to good and adequate food to all people at all times. Horticultural crops will serve both goals. However, given the rapid population growth estimated at 3.34 percent annually and the increasing demand for food, food security remains a key priority in the agricultural sector (Kenya, 1994a). This therefore calls for appropriate strategies of food production to meet the anticipated demand for food in the near future. For instance, in the year 2000; national maize, wheat and potato requirements are projected at 3676, 401 and 737 thousand tonnes respectively. One of the strategies the government recommends is increased research in the production of these major food crops. Maize production is a major farming activity in medium and high potential regions of Kenya and the crop is a staple food for about 95 percent of the people. It accounts for more than 75 percent of the total cereal area and over 60 percent in value terms, of the total cereals marketed (Hassan et al, 1994a). Seventy five per cent of Kenya's maize is produced by small scale farmers who cultivate about 85 percent of the total land area under maize, and account for about 70 percent of Kenya's population (Ongaro, 1988; Kenya, 1994a). This explains the dominant position maize holds in Kenya's agriculture and its role both as a source of food and income to the producers. Research in maize production has therefore been given first priority among the food crops (Kenya, 1994b).

Increase in maize production can be achieved by expansion in area under maize production or through increase in yield or through a combination of the two. Expansion of maize production by increasing the area under production is, however, limited because most of the arable land has been utilised. It has been estimated that even if all irrigable land were put under production, total crop and dairy land could be expanded by only 10 percent (Kenya, 1986). Some of the ways of expansion in area involved maize production in marginal areas where traditionally maize did not have a comparative advantage. In these areas, the production risks such as crop failure are quite high. Areas around Naivasha are a case in point. Production through irrigation could be another option of expansion of area under maize. However, in his study on "Diffusion of maize hybrid in Western Kenya", Gerhart (1974) reported that irrigation potential in Western Kenya is very limited and is extremely expensive ruling out this alternative approach to maize production. Alternatively, maize production could be increased by encroaching on lands currently occupied by export crops. But because these crops are essential to economic growth, to rising farm incomes and to foreign exchange earnings, this approach would lead to conflicts in agricultural development goals. This then leaves maize production to be concentrated on the existing medium and high potential areas. Maize production in 1992 was estimated at about 2.2 million tonnes and to attain self-sufficiency it was estimated that 2.6 million tonnes was required by the year 1996 (Kenya, 1994a). This required an annual growth of 2.5 percent per annum.

Leaving out increase of maize production through area expansion, long-term growth in maize production necessarily depends on increased yields from land already under food crops. This could be achieved through use of hybrid maize seed, increased and efficient use of fertilizers and improvements in cultural practices (Kenya, 1994b). However previous studies have shown that use of hybrid maize is quite high unlike use of mineral fertilizers among the purchasable inputs of maize production (Gerhart, 1975; Ongaro, 1988; Chege, 1992). This then implies that increased use of chemical fertilizers and improved maize cultural practices such as timely planting, weeding, pest and disease control remain as the only possible ways of increasing maize yield.

Fertilizers are the most dominant purchasable farm input used in Kenya (Kenya, 1989). Fertilizer use patterns in Kenya are marked by a concentration on major cash crops . For instance, in 1982/83, coffee, tea and sugarcane accounted for about two-thirds of total fertilizer use while maize accounted for only 19 percent (World Bank, 1986). This trend has not changed even in recent years. Average returns to fertilizer use is higher in cash crops than in food crops and this partly explains why more fertilizer is used in cash crops. Besides, cash crop farmers are provided inputs such as fertilizers in contractual arrangements by the monopsonist of the respective crop marketing boards (e.g. case of tea and sugarcane). There is also a clear divergence between large and small farmers. It is estimated that large farms and estates account for about 58 percent of the total fertilizer consumption, although its share of total land under crop production is only 30 percent. Of the total fertilizers used by small farmers, 20 percent go into maize production (World Bank, 1986).

All fertilizers used in Kenya are imported. Table 1 shows the quantities (tonnes) and the value (K£'000) of the imported fertilizers between 1982 and 1990. It is clear from the table that the single most important fertilizer types imported are the nitrogenous fertilizers. Phosphatic fertilizers are the second major category. Total consumption varied greatly over the years with no discernible regular pattern. This partly can be explained by the availability of foreign exchange. This is because it is foreign exchange availability that determines the effective demand for fertilizer at the national level.

Table 1: Fertilizer imports (quantity) in tonnes and value of imports (K£'000), 1982-1990

Year	Imports in tonnes			Value in K£'000		
	N	P	Other	N	P	Other
1982	70808	28200	30600	7341	3855	15605
1983	72272	12780	65625	11857	1979	25087
1984	36339	2001	35996	6255	290	13893
1985	111532	10263	146302	16414	1756	52027
1986	120813	21496	176073	16090	2875	50014
1987	52681	4524	168780	7315	520	38959
1988	66173	22041	138064	13223	4965	49180
1989	50206	7500	244040	15711	1611	69407
1990	27100	4000	12051	5236	902	33276

Source: CBS, 1991.
where N and P refer to Nitrogenous and Phosphatic fertilizers respectively.

The fertilizer price per tonne varied over the years. This was partly due to the changing patterns of the prevailing exchange rates. During the period, 1982-1990, the Kenya shilling had not been floated but was pegged to the dollar and hence prices could change based on the strength of the Kenya Shilling as compared to the American Dollar.

The major types of fertilizers used on maize are Diammonium Phosphate (DAP), and Calcium Ammonium Nitrate

(CAN). For instance, Murithi and Shiluli (1993) in a study of the effect of liberalisation of fertilizer marketing on fertilizer consumption conducted in Embu and Meru districts found out that DAP and CAN were the most popular fertilizer types stocked by traders (Table 2). Further analysis of the data indicated that the majority of the traders (65.2 percent) considered the demand for the fertilizers to be the main factor influencing the amounts and types of fertilizers stocked.

Table 2: Type of fertilizer stocked by traders.

Fertilizer type	Percent traders selling (n=23)
DAP	100.0
CAN	52.2
20:20:10	43.5
20:20:10	21.7
Foliar	8.7
Others (e.g. 17:17:17)	8.7

Source: Murithi and Shiluli, 1993.

Before 1990, fertilizer marketing was controlled by the government, which not only issued licences for fertilizer imports but also fixed prices at the various levels in the marketing channel. However in 1990, the government liberalised the marketing of fertilizers in the country. This was expected to increase competitiveness in the fertilizer market as more importers and retail suppliers entered the market. It was also expected that unavailability of fertilizers at rural retail outlets could be eased. However, the rapid devaluation of the Kenya Shilling relative to foreign currencies resulted in high domestic prices and a downward trend of fertilizer use was experienced after the fertilizer market liberalisation (Kenya, 1994b).

1.2 The problem statement

The role of fertilizer in increasing yield in maize ceteris paribus has been observed not only in Kenya but in other countries as well (Shaw and Durost, 1965; Auer and Heady, 1967; Allan, 1971; and FURP, 1994). However, studies by Ruigu and Schulter (1990) indicated that the amounts of chemical fertilizers that small scale farmers used on maize production in Kenya were below levels recommended by research centres. Similar trends have also been observed (Chege, 1992; FURP, 1994; Ongaro, 1988). The levels of these fertilizers applied also vary from region to region and year to year. For instance, it has been documented that the highest levels of nitrogen and phosphorus use are estimated at about 43 percent and 70 percent respectively of the research station's recommendations for Trans Nzoia District while the lowest is less than 5 percent for both nutrients for Nyanza province (Kenya, 1986; Chege, 1992).

Further, a study by the World Bank (World Bank, 1986) estimated that the difference between the actual amounts of fertilizers applied and those recommended for crop production in Kenya was 150,000 metric tonnes. The study further estimated that 100,000 metric tonnes of this fertilizer gap would be filled by increasing fertilizer use in maize production. This means that the increase must be borne by the small farmers who form the bulk of the maize producers but use low levels of fertilizers. However, factors that determine low levels of fertilizer use by these farmers are not well documented. Therefore, there is need to identify the main determinants of fertilizer use on maize so that its use by smallholder farmers who produce about 75 percent of the total maize in Kenya (FURP, 1994) can be increased in order to attain food self sufficiency.

1.3 Objectives and hypotheses of the study

The broad purpose of this study was to identify the main determinants of fertilizer use on smallholder maize farms. The specific objectives were:

a) Describe the fertilizer use patterns by smallholder maize farmers in Western Kenya.
b) Determine the most important determinants of fertilizer use in maize in Western Kenya.
c) Determine factors responsible for inter-farm differences in fertilizer use in maize.

Generally, the hypotheses of a study are a means by which the questions raised in the study are answered and the objectives of the study are realised. The following hypotheses were tested for these purposes.

a) The rate of application of nutrients is not influenced by total farm size.
b) Location does not influence the rate of nutrient use.
c) Value of total farm sales does not influence the rate of

fertilizer use positively.

d) Presence of off-farm employment does not influence the rate of fertilizer use positively.

1.4 Justification of the study

The government of Kenya (Kenya, 1994a) emphasizes that due to the importance of maize as a major staple food, all efforts should be made to ensure that its rate of production at least keeps pace with the rapid increase in population growth estimated at 3.34 percent annually, if food self sufficiency is to be achieved. The strategy is to concentrate research efforts on the crop and the priority is given to maize grown by small scale farmers. One such area of research is on fertilizer use.

Fertilizer Use Recommendation Project (FURP) showed that if optimal rates of fertilizer use are applied by farmers, maize yields will increase by 1400-2900 kg/ha from 4000 kg/ha in Kisii District, 300-800 kg/ha from 2500 kg/ha in Kakamega District and about 2000 kg/ha from 4500 kg/ha in Trans Nzoia District (FURP, 1994). FURP has thus shown that increases in fertilizer use can lead to increased food production and hence food self sufficiency. However, only a few descriptive analyses on fertilizer use in Western Kenya are available. No quantitative study has been carried out to generate information on determinants of fertilizer use per se in the area. Thus, this study aims at filling up this information gap by providing information on the determinants that influence fertilizer use at farm level which has been regarded as sub-optimal. The information will be used to draw inferences regarding appropriate research, extension and credit policy interventions which will augment the use of fertilizers.

An increase in fertilizer use, ceteris paribus, will lead to increased agricultural productivity with several positive effects. First, achievement of food self sufficiency will save the country of foreign exchange earnings which could have been used for food imports. The foreign exchange earnings will instead be used to purchase goods necessary for the development of the economy which cannot be purchased locally. Second, the development of smallholder agriculture will lead to employment creation in the rural areas and hence an increase in rural incomes. The rising farm incomes will generate demand for many consumer goods, some of which can be made in local workshops, and for the construction of housing, water supplies and other farm improvements. These developments which are essential to agriculture, will also provide opportunities for rural entrepreneurs and the self employed to create new jobs at satisfactory incomes. This in turn will at least decelerate rural urban migration. High rates of urban migration have strained the physical and social facilities in urban centres such as hospitals, schools and housing leading to increased crime. Finally, improving productivity of rural agriculture will even out the regional and personal income distributions which has been observed in Kenya (Kenya, 1994b).

1.5 Organisation of the thesis

The thesis is organised into five parts. Chapter one covers the introduction. The introduction includes background information about the economy, recent fertilizer use trends in Kenya, problem statement, objectives and hypotheses to be tested, justification for the study and organisation of the thesis. Chapter two contains a review of theoretical aspects of fertilizer use and some relevant empirical work on the subject both outside Kenya and in Kenya. Chapter three gives an account of the methodology used in the study. This includes the sources of data, area of study, data collection procedures, data analysis and organisation. Chapter four contains descriptive and regression analyses results and a discussion of the major findings of the study. Chapter five contains a summary of the research objectives, methodology, results, conclusions and recommendations of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW.

This chapter reviews the theory and empirical work that has been done on fertilizer use. The review intends to provide an understanding of what has been done concerning fertilizer use in general.

2.1 Factors affecting fertilizer use.

Mineral fertilizers are a purchasable input. Ruthenburg (1985) pointed out that at farm level, this is translated as a form of cash burden to the farmer. Fertilizer use decisions are complex and are affected by many factors. He broadly grouped these factors into four sets; financial, technical, supply and other socio-economic factors.

First, financial factors include the price of fertilizers, price of output and credit availability. For economical rational farmers, fertilizer usage must be profitable. Lower fertilizer prices could normally increase fertilizer use unless the presence of certain constraints prohibit such increase. Some of the suggested ways of lowering price of fertilizer include offering direct subsidies to farmers or indirectly by subsidising credit to purchase fertilizers, and increasing efficiency in distribution of fertilizers. An increase in output prices will also make it profitable for the farmer to increase fertilizer usage. However, lack of credit is frequently mentioned by most farmers as a constraint to fertilizer use (Pinstrup-Anderson,1982). Access to credit by farmers enhances their liquidity position and this in turn increases fertilizer usage.

However, a large proportion of farmers who state that lack of credit is the reason for not using, or increasing the use of fertilizers could probably not utilise it for this purpose, even if provided. Pinstrup-Anderson (1980) and Ongaro (1988) pointed out that lack of knowledge, risk and uncertainty, and unwillingness to risk the consequences of being unable to repay credit from the income generated from the sale of maize are some of the reasons why credit is not sought by farmers. In Kenya, fertilizer prices were liberalised since 1991 and maize price were liberalised in 1993. Thus, the prices quoted at any one given time depend on the supply and demand situation in the country of either the fertilizer or maize respectively. On the other hand, credit continues to be available to eligible farmers from the commercial banks and Agricultural Finance Corporation (AFC).

Second, technical factors include crop response to fertilizer application and farmers' knowledge of fertilizer. Presence of crop varieties that are fertilizer responsive encourages fertilizer use among farmers. Similarly, knowledge of the right kind and quantity of fertilizer to use, how and when it should be applied, influences its use. Thus, to enhance fertilizer usage, adequate information should be available to farmers on types of fertilizers required, optimum quantities to use and timing, placement etc. under various climatic, environmental, economic and soil conditions. In Kenya, knowledge of the type and rate of fertilizer usage is made available by the agricultural extension staff or through public media. Hybrid maize grown by most farmers in Western Kenya are fertilizer responsive.

Third, supply factors involve mainly availability of the fertilizers to farmers. Unavailability of fertilizers to farmers may be occasioned by disruptions in national supplies (due to foreign exchange constraints and/ or lengthy procurement procedures) or local impediments such as poorly developed and/ or inefficient distribution network. Long distances between distribution outlets and difficult transportation facilities make it difficult or practically impossible for many farmers to obtain the desired fertilizer. At times, because of lengthy procedures, even if the fertilizer outlets are within the reach of the small farmer, the fertilizer needed may arrive too late in relation to the cropping season or the kind of fertilizer available may not be that which is needed. Thus, fertilizer unavailability can be a major constraint to fertilizer use. After the 1990 fertilizer marketing liberalisation, lengthy fertilizer procurement procedures have been eased and fertilizers have presumably been available at all fertilizer market outlets in the country.

Finally, socio-economic factors that influence fertilizer use include land tenure systems, risk and uncertainty of fertilizer use. In freehold tenure systems, fertilizer use tends to be larger than in cases of tenant / landlord and communal land tenure systems (Pinstrup-Anderson, 1982; Shiluli, M.C., 1988). This is because farmers have knowledge of residual effects of fertilizers applied now and hence are more willing to invest in it if they are assured of cultivating the same piece of land in future years. Thus, ceteris paribus, land reform policies that result in a shift from tenancy to ownership by the farmer, would expand fertilizer use. Farmers in Western Kenya, who have a freehold land tenure system, ceteris paribus, are expected to use fertilizer to the maximum. The freehold tenure system assures the farmers of the need to maintain high soil fertility if they have to sustain crop production in the future. Farmers who are risk averse use little or no fertilizers because of risk and uncertainties in farming which could be due to natural (weather, pest and disease incidence) or market factors (fluctuations in price of fertilizers and other input, and product prices).

According to Ruthenberg (1985), risk aversion, problems of fertilizer and credit availability and price of mineral fertilizers certainly contribute to an explanation of the main factors explaining sub-optimal rates present and impending expansion of fertilizer use in future.

With over 18 years experience in over 40 countries worldwide, the Food and Agriculture Organisation (FAO) has shown that at farm level, constraints to fertilizer use include lack of knowledge of modern agricultural techniques, ineffectiveness of extension staff, insufficient credit facilities, inadequate supply facilities and restricted possibilities of marketing farm products (FAO, 1985). FAO further concludes that once a demand has been created in a certain area for fertilizer, the input must be available to farmers at the right time and place in sufficient quantities.

2.2 Empirical studies from outside Kenya

According to Feder and O'Mara (1981), the Green Revolution technology which consists of the use of hybrid seeds, chemical inputs (fertilizers, pesticides) and special practices is a technology that is divisible and neutral to scale. Thus one may expect that adoption patterns will not be affected by farm size. But facts from a number of regions across the world have shown that the adoption rates and the time pattern of adoption are related to farm size. One obvious reason for differential adoption rates in many regions is the credit constraint. Working capital requirements associated with the new technology are substantially higher (fertilizers, pesticides and hybrid seeds are cash inputs). For instance studies of the Indian Agriculture by Bhalla as reported in Feder and O'Mara (1981) revealed that small and large farmers differed in the reasons offered for not using fertilizers in 1970 - 71 season. Lack of credit was the reason given by 48 percent of the small scale farmers but by only 6 per cent of the large farmers. Similarly, Gladwin in 1976 while working with the Puebla Project, found out that the decision to increase fertilizer use, was limited by lack of credit.

Studies in India by Desai and Singh (1973) have indicated that irrigation, area under commercial crops, and spread of fertilizer responsive high yielding varieties of cereals are the main determinants of fertilizer consumption levels. They attributed these results to differences in farmers' decision making.

Therefore, they argued that proper understanding of the observed patterns of fertilizer use can emerge only by understanding the behaviour of the individual farmers.

Timmer (1974) working on rice focused his study on impact of relative prices on derived demand for fertilizer while considering other factors such as farm incomes, capital assets, accessibility to markets, banks and transport. He grouped the determinants of fertilizer consumption into two categories; price and non-price factors. Results of his study revealed that price plays a major role in determining the demand for fertilizer than the non-price factors, such as land tenure systems and farm size.

Salaam (1975) studied the socio economic and institutional factors influencing fertilizer use in Punjab. Using a farm management survey, he revealed that the rate of fertilizer application was higher on small farms than on medium and large farms though application rates in all farm categories were below the recommended levels. Resource constraints, higher prices and lack of fertilizer supplies at the needed time were some of the major constraints. He concluded that the price of fertilizer should be fixed at levels that guarantee reasonable levels of profits to the farmers and institutional credit sources need to be encouraged to provide short term loans for the purchase of fertilizer while access of small farmers to institutional credit should be made easy. Further, when opening new fertilizer sales depots, their proximity to the consumption centres and their accessibility by link roads should be taken into consideration.

Roy and Seetharamn (1977) formulated a representative comprehensive demand function for fertilizer for rice as follows:

$$Q_{jt} = f(p_y, p_f, p_x, y_{t-1}, c_t, e)$$

where:

Q_{jt} is fertilizer demand in period t,

p_y is the price of output in period t,

p_f is the price of fertilizer in period t,

p_x is the price of other input in period t (e.g. seed).

Y_{t-1} is the farmer's income in the previous period, t-1.

C_t is the credit availability in period t

e is the farmers' expectation of the future prices of input and output as well as weather behaviour.

Y_{t-1} and e represent the impact of the past and the future.

Based on this model, it was emphasized that the two most important variables were the price of fertilizer and the price of the product, since fertilizer is not a final consumer good but its demand is derived. This analysis was however based on the assumption that the farmers' objective is profit maximization. Profit maximization is not necessarily the objective of small holder farmers (Roy, R.N. and Seetharaman, S. 1977). Food self sufficiency or risk aversion could be major objectives.

Sindhu and Banaante (1979) estimated farm level demand for fertilizer, labour, and irrigation water for Mexican wheat in India. They used a normalized profit function by differentiating the latter with respect to respective normalized factor prices, thus:

$$X_i = \delta\pi/\delta p_i \; ; \quad I = N, K, L.$$

where X = the quantity of factor I

π = profit

N = labour

K = chemical fertilizer

L = irrigation water

p_i = price of factor I

Using cross-section data from a stratified random sample, the results obtained indicated that output price is a more powerful policy variable than fertilizer price in influencing fertilizer use. Even when farmers use fertilizers, great variations occur in their rates of fertilizer application according to output prices received.

The foregoing conceptual and empirical studies have shown that there are many factors influencing fertilizer use in crops. The major factors revealed are: farmers' objective(s) of farming, resource endowment (land size, land tenure system and income), fertilizer supply, extent of commercialisation in the farm and institutional access (markets, credit and extension). The factors responsible for fertilizer use are, however, region specific depending on the farmer circumstances. Since the farmer circumstances vary from place to place, this study attempted to isolate factors that are responsible for fertilizer use in Western Kenya instead of adopting factors influencing fertilizer use as observed in other regions.

Empirical studies to explain inter-farm variability in fertilizer use on farms by Dayanatha and Rakesh (1981) in India considered variations in average rate of fertilizer application per farm. They postulated that inter-farm variations in fertilizer use arise from socio-psychological attributes of the farmers, perceptions regarding profitability of fertilizer use, resource endowments, institutional setting and agro-climatic differences. Dayanatha and Rakesh used regression analysis to determine factors that influence fertilizer use decisions. However, the analysis was done at two levels emphasizing inter-farm variability in fertilizer use and it also tried to understand influences of some plot level characteristics on fertilizer use. Farm level analysis considered only farmers who used fertilizers whereas plot level analysis considered only plots that were fertilised. The empirical results revealed that the extent of commercialization and credit showed some positive influence on fertilizer use. Rainfall was found to be an important determinant of decisions regarding rate as well as area fertilized.

This study will focus on farm level analysis. It is at the farm level that decisions on fertilizer use patterns are made. It is also at this level that responses to policy changes, investment and technological interventions take place. Hence, new policies and guidelines for designing more appropriate institutional and technological strategies aimed at increasing fertilizer use can be formulated with the knowledge of these farm responses and constraints.

During 1985/86 agricultural year, Jayanatha and Behjat collected data from 330 households in Eastern Zambia with a view to understanding the variations that characterised the amount of fertilizers farmers used. Based on cross-section household data at sub-national level, they used the adoption-diffusion framework for the analysis. Differences in fertilizer use between households were examined in relation to socio-economic, cultural and specific farm characteristics. Prices and other dynamic variables were not included in the model. The results of the study indicated that the variables age, liquidity, fertilizer supply credit and market access were significant in affecting fertilizer use. Farmers' liquidity, access to credit, and market infrastructure, as well as functioning distribution system, were also the major factors that affected the use or non use of fertilizer in any particular year. The predictive power of the equation explaining intensity of use was very low (adjusted R^2 = 0.11). Management practices and residual fertilizers also affected the quantity of fertilizers used by farmers. However, the effect of these factors could not be captured by the household analysis because the data were plot specific.

This study unlike the Zambian study, assumed that farmers are aware of fertilizer use but delved to identify what determines the amount of fertilizer farmers apply in their respective maize fields.

Marfo and Tripp (1991) in a study of "Maize Technology Diffusion in Ghana" observed a sharp decline in fertilizer use in maize in 1990 after a previous four years' upward trend. They conducted a survey in six areas and obtained information from 330 randomly selected farmers. Using descriptive analysis, the survey results showed that about 50 percent (165 farmers) had previous experience with fertilizer use. Of those who previously used fertilizer, 117 didn't apply fertilizer in 1990. When asked why they didn't use fertilizer, 53 percent cited lack of cash or high fertilizer price, 29.9 percent said soil was good and 7.7 percent cited non-availability. It was then concluded that although farmers may be familiar with fertilizer use, changing economic circumstances e.g. unfavourable price changes and supplies of fertilizer may hamper significant increase in fertilizer use. Marfo's study unlike this study dealt with farmers who grow maize as a major cash crop (about 70 percent of the maize produced is sold). In this study farmers grow maize mainly for subsistence except for Trans Nzoia District and in Lukuyani Division, Kakamega District.

Dlamini (1993) undertook a study which sought to identify and discuss factors associated with the adoption of basal fertilizer use by Swazi Nation Land (SNL) farmers as a way of encouraging farmers on increased input use and hence increase farm productivity. He conducted a field survey on 220 SNL randomly selected maize growing farmers. He considered output price, basal fertilizer price, farm size, education levels, production uncertainty, risk, draught power ownership, extension - worker contacts, farm sales and family labour supply as factors that influence basal fertilizer adoption. He used the stepwise regression technique for data analysis. Extension - worker contacts, farm sales and family labour supply were the factors that were found to statistically influence the adoption of basal fertilizer at 10 per cent level of significance. Together, the three variables explained 65 percent of the total variation observed in the adoption of basal fertilizers among the SNL farmers. He concluded that apart from prices, a number of nonprice factors seemed to be of considerable importance in influencing the adoption of modern technology by farmers. These nonprice factors included availability of extension services and advice, the presence of output market services and availability or intensity of family labour. He recommended that the government should be more effective in promoting basal fertilizer use by farmers by taking these non-price factors into account in formulating its policies and programs.

Dlamini's study like this study aimed at identifying the determinants of fertilizer use, an important input necessary in accelerating the growth in food production. However, Dlamini's study differs from the present study in that the SNL farmers faced different farmer circumstances from the farmers in Western Kenya.

2.3 Empirical studies in Kenya

Several studies in form of agronomic experiments have been carried out in Kenya on crop response to fertilizer use, levels of use and methods of application. However, studies considering both economic and non economic factors which influence fertilizer use at farm level have been in the form of isolated surveys which are descriptive and offer no statistical support for the direction and magnitude of the effects of these factors (Baguma, 1991; Shiluli, 1992). However, a few empirical studies as documented here have been carried out.

Mwangi (1978) analysing the farm level demand responses for fertilizer use in Kenya indicated that lack of cash, lack of fertilizer supplies at the required time, transport costs, lack of credit and low literacy level were major constraints in increasing fertilizer use in Central Kenya. Using a linear programming model, he assumed that farmers had perfect knowledge of input output prices and technology. This approach assumes ideal farm conditions which are rare in real life. This is because maize farmers do not work under contractual arrangements and hence are uncertain of input and output prices, more so with the liberalisation of both inputs and product prices. Unlike Mwangi's study, this study moves away from a normative situation and takes on a positive approach. The study investigated the fertilizer use "as is with farmers" unlike "what it should be".

Ongaro (1988) carried out his study in Nandi and Kisii districts on " adoption of new farming technology". The study among other things sought to find out the causes of maize yield variation in 1983/84 in the area. The factors influencing yield which also impede the use of farm inputs - especially fertilizers were identified. Out of the 257 sample farmers interviewed in Kisii (127 farms) and Nandi (130 farms), 25 percent (64 farms) did not apply chemical fertilizers to their maize. In order to establish the determinants of fertilizer use in the sample farms, he used total quantity of fertilizer applied on each farm as the dependent variable. The independent variables he used included size of land under maize crop, off-farm employment, access to credit and extension contacts. The results of the study indicated that the quantity of land was found to have a positive and significant effect on fertilizer use at 10 percent level of significance. Access to credit and extension contacts, and off farm employment were found to be significant at 1 percent and 10 percent respectively. However, the study did not consider all aspects of the determinants of fertilizer use such as fertilizer cost, and quality of land which were considered in the present study. Ongaro argued that since farmers are doing their best given the available resources, decision makers should increase efforts to improve extension contacts and access to credit.

Muturi (1989), carried out a study in Murang'a district to identify and quantify socio-economic factors that affect the use of fertilizers by smallholder maize and coffee farmers. He postulated that high price of fertilizer affected quantity purchased by farmers, and vice versa, that is, with a high previous year's product price and constant fertilizer price, there is an incentive to increase fertilizer use. He used the previous year's product price in his analysis and assumed that it was the one that had influence on the current year's fertilizer use. Other factors he considered were literacy level of the farmers, credit availability and extension service to farmers. Muturi used regression analysis to determine the effect of these factors. He specified the model as follows:

$$F_q = C + P_m - P_f + P_{man} + Ed + Ext + Cr + u.$$

Where F_q = Quantity of fertilizer nutrients on maize.

C = Constant

P_m = Price of maize (previous Season)

P_f = Price of fertilizer (current season)

P_{man} = Price of manure

Ed = Education level of the farmer

Ext = extension services

Cr = Credit

u = error term.

The results of the analysis indicated that output price, credit availability and fertilizer price were significant determinants of fertilizer use in maize. He further observed that farmers who get cash credit didn't use it to purchase fertilizer. He therefore recommended the use of credit in kind. It has however been observed in Kenya's sugarbelt that when such fertilizers are given, some farmers convert it to cash by selling it to meet other family cash obligations e.g. paying school fees for their children (MOALD, 1986). Muturi's findings may not be generalised for the whole country because his work was based on a small sample of 80 farmers from one division. The region is also a major coffee growing region, where maize production is not a major farming activity. Therefore, it is not representative of a major maize growing region. This therefore calls for similar studies in the country where farmer circumstances are different. This study is a positive response to this call.

The present study is specifically an analysis of determinants of fertilizer use at farm level in Western Kenya. Since previous studies on fertilizer use in maize have focused on response of maize to fertilizer or the economics of fertilizer use in Central Kenya, it is hoped that this study will contribute towards availing information on fertilizer use in a major maize growing region in the country dubbed "the granary of Kenya".

CHAPTER THREE

3.0 METHODOLOGY

The chapter gives a description of the data sources, data collected, an overview of the study area in terms of its climate, topography, soil types and population densities. It also gives an account of the data collection procedures, data analysis and organisation.

3.1 Data Sources

Both secondary and primary data were collected. Secondary information collected include those on climate, population and soils of the study area. Secondary data were collected from several sources among them publications from Kenya Agricultural Research Institute (KARI), Ministry of Agriculture, Livestock Development and Marketing (MOALDM) and public libraries.

Primary data were collected on :

a) Farmer and farm characteristics: farm size, enterprise patterns, farm cropping history, production figures.

b) Resource characteristics: fertilizer use (kg/ha), off-farm employment, income generated from sale of farm produce.

c) Institutional access: distances covered to nearest fertilizer and product markets, distance to the nearest credit institutions, access to extension contacts and prices of maize and fertilizer.

3.2 Area of study

The area covered by the study included Kisii, Kakamega and Trans-Nzoia Districts. The area falls in the Moist Transitional maize zone which encompasses Moist High Tropics, Moist Sub-Tropics and Dry High tropics. The area varies between 1400-2000 m above sea level and receives between 500-1000 mm of rain (March-August) with a mean temperature of 19.7° c (Hassan et al, 1994a).

Table 3: Some characteristics of the study area.

Characteristic	Kisii	Kakamega	Trans Nzoia
% maize coverage area (1991)	20 - 40	20 - 40	20 - 40
Agro-climatic zone (March rains)	Moist High Tropical	Moist Sub Tropical	Dry High Tropical
Population (People/km^2)	400-800	100-400	100-400
Natural fertility of the predominant soil	moderate to high	low	low
Land size (km^2)	2196	3520	2495

Source: Hassan et al.,1992; Jaetzold, R. and Schmidt, H. Vol IIa, 1982 ; and Vol IIb, 1983

The region experiences bimodal rainfall pattern and late maturity maize germplasm (600 series) are used by majority of the farmers. Table 3 shows some of the major features of the study area. These features include area of each district, average area occupied by maize, population density and agroclimatic zones. Together, the statistics show the importance of maize in the area.

3.3 Data collection procedures

Data collection procedures include sampling procedures and the methods of data collection.

Sampling procedures

This study used the three-stage sampling method to select the sample of farmers interviewed from a population of smallholder maize farmers in Western Kenya. Smallholder maize growers were defined as those farmers with total farm size of not more than 8 ha and growing maize.

First sampling stage: This involved selection of the districts.

Based on the Maize Data Base (MDB) survey report (Hassan et al, 1994a), Kisii, Kakamega and Trans Nzoia Districts were chosen for the study. The choice of these districts was guided by the following considerations:

(a) Density of population: Kisii is the most densely populated of all the districts in rural Western Kenya (Ongaro, 1988), while Trans Nzoia is sparsely populated. Kakamega's population density is in between the two. This criterion has implications for the distribution of agricultural land per household. There is higher pressure on land use in high population density districts due to higher subsistence requirements. This in turn leads to high rate of nutrient depletion due to intensive farming unless commensurate replenishment of nutrients takes place.

(b) The districts are among the major maize growing regions in the country. Hybrid maize use especially the H600 series is high. Because of the reported high rate of hybrid maize use (Gerhart, 1974) it was expected that these farmers were using fertilizer to enhance the hybrid maize productivity.

(c) Fertilizer use among maize farmers in Trans Nzoia District has been observed to be one of the highest in Kenya. It was therefore interesting to investigate whether there are any differences in the factors that influence fertilizer use in Trans Nzoia District as compared with areas where fertilizer use was reported to be low such as Kisii District.

(d) The districts are in the same agroecological zone (Moist Transitional). The agroecological zone accounted for 41 percent of the maize produced in Kenya in 1991. Despite being in the same agroecological zone, it was perceived that there could be variations in their farming practices and use of inputs such as fertilizer due to differences in subsistence pressure resulting from differences in population density or differences due to extent of agricultural commercialisation (Cash cropping and Dairying).

Second sampling stage: This stage involved selection of clusters. The procedure adopted for selection of survey clusters from the selected districts utilised the sampling frame of the National Sample Surveys and Evaluation Programme III (NASSEP III) of the Central Bureau of Statistics (CBS), - Ministry of Planning and National Development. This frame covers all districts and urban centres. It has 36, 24 and 24 clusters in Kisii, Kakamega and Trans Nzoia Districts, respectively. To ensure an even distribution of selected clusters across districts, systematic random sampling was used to select the clusters. Four clusters were selected for each district. The selected clusters by district were:

Kisii: Keumbu, Nyamache, Nyacheki and Ogembo.

Kakamega: Mumias, Shinyalu, Khwisero and Lukuyani.

Trans Nzoia: Moto I&II, Mateket, Sirende and Kapomboi.

The systematic random sampling was used to capture as much variability that may exist in each district rather than intra site variability, as little variation was expected within the clusters.

Third sampling stage: In this stage the farmers interviewed were selected. The sampling frame used was that of NASSEP III for the selected clusters. Each cluster comprises of over 100 households. The NASSEP III sampling frame lists the name of the household head, his occupation, and other data such as those pertaining to farm size and production systems. The main reason for sampling from NASSEP III clusters other than any other alternative procedure was the fact that NASSEP III provides a listing of locations and enumeration areas (EAs) and farmers within each enumeration area. Furthermore, at the time, it was considered that NASSEP III provided the most up-to-date farmer listing in the country.

For each selected cluster, 10 farmers were randomly selected. In total, 40 farmers were selected for interview from each district, making a total of 120 farmers interviewed in the study. This is in line with the International Maize and Wheat Improvement Centre's (CIMMYT) guide of 40 farmers per district. According to CIMMYT a sample size of 40 is thought to be sufficient for meaningful statistical analysis in a homogenous group of farmers.

The three-stage sampling procedure was adopted because interviewing cost and travel time are reduced because of the geographical clustering of the farmers. Besides, with this procedure, it only becomes necessary to construct lists of farmers for selected clusters unlike in simple random sampling where every farmer in the population is listed. In addition, this procedure enabled enumerators from within the clusters to work more effectively and efficiently since they were known by all cluster members.

After farmer selection was done on paper, an initial trip was made to physically locate the farmers. In the trip were the researcher, a local agricultural assistant or CBS representative and one researcher representing the Kenya Agricultural Research Institute (KARI). The local agricultural assistant assisted in physically identifying the farmers already chosen and also identifying the possible enumerators.

Data collection

Primary data were collected by enumerators through a formal survey. To ensure ability to fill the questionnaires, only those with a minimum of form four level of education were considered. Additionally, enumerators who speak the respective local languages were chosen for the respective areas to ensure an ability to communicate with the farmers. The formal survey was conducted using a pre-tested structured questionnaire over the main maize growing season in 1995. The questionnaire was administered in bits corresponding to periods of major activities in maize production. This was necessary to minimise loss of memory of facts about the practices carried out in the farm such as types and rates of fertilizers used. This is because most farmers do not keep farm records and most responses were based on memory. These periodic multivisits to the farms also assisted in increasing reliability of data collected. Thus, unlike in single visit surveys, doubtful cases of data collected were verified in subsequent visits. This approach also avoided problems of non - response by farmers due to absence during the day of interview common with single visit surveys. The researcher who acted as supervisor made frequent visits to the farms and verified any doubtful information as per the filled questionnaires.

The essential characteristic of the formal survey justifying its use is that it gives a uniform set of data from a relatively large number of farmers that as a whole are representative of the region. It also gives a reflection of the true nature of the phenomena in the field. It reflects a natural farm condition unlike experimental data which reflect highly controlled conditions which do not exist in real life. Thus, through the survey a more reliable picture of farmer circumstances in the area is obtained and its results can be quantitatively communicated to interested parties. However, it should be noted that in survey data there is greater variability (hence large error term) than occurs with experimental data.

In order to determine the inherent soil fertility of the study area, soil sampling was done at the land preparation stage. Laboratory soil tests were later carried out to determine the levels of macro-nutrients in the soil. The results were used to develop an inherent fertility index which was later used as an independent variable in the regression analysis on the rate of fertilizer use. The soil tests were carried out only in fields where maize was to be grown.

3.4 Data Organisation and Analysis

Before giving a description of the methods used in data analysis, the term "fertilizer use" needs clarification. The term is used in this study to mean the total amount of nutrients in kilograms the farmer used in maize field per hectare for the particular season. It is the sum total of phosphatic, nitrogenous and potassic fertilizers used.

For purposes of explaining fertilizer use patterns and rates of use, both Descriptive Statistics and Ordinary Least Squares (OLS) estimation were used.

3.4.1 Descriptive Analysis

Descriptive analyses for variables considered to influence fertilizer use patterns were considered. Differences in these variables were used to explain the observed inter farm variations in fertilizer use. Among the major variables considered were land size, access to fertilizer market (physical as well as financial access), fertilizer types and rates of application, farm yard manure application and farmers' perceived constraints to fertilizer use. Frequency tables and means were computed where appropriate.

3.4.2 Regression Analysis: The theoretical framework for estimating fertilizer use determinants.

Research on the determinants of use for an innovation such as fertilizer draws heavily from the adoption-diffusion framework on one hand, and from factor demand theory on the other. Such studies range from socio-cultural-economic determinants at the farm household level to more aggregative analyses which incorporate the role of prices, environment and policy factors.

This study used the factor demand theory framework to analyse the main determinants of fertilizer use rather than adoption-diffusion framework. The rate of application of fertilizers depends on the available levels of soil management and agronomic factors, price of fertilizer and the price of maize. Thus, to achieve the objective of establishing fertilizer use determinants, statistical estimates of the relationships were required. The estimation required the specification of the model in mathematical forms so that statistical methods could be used for their estimation. In this study, linear mathematical relationships were specified because they are computationally easier to handle. A single equation model was used on the basis that the fertilizer use relationship is a unilateral causal relationship with quantity of fertilizer use dependent on a number of predetermined factors rather than a simultaneous equation model whose variables are without prior information not considered as dependent and independent variables but as mutually determined variables. Thus, a single equation multiple regression model was adopted. Multiple regression was used to quantify, test and validate economic relationships in fertilizer use. The method reveals structural relationships between variables so that appropriate policy evaluation could be undertaken depending on the resulting regression coefficients. To investigate determinants of fertilizer use in maize, the Ordinary Least Squares (OLS) method was used to estimate the model. The OLS method gives the best straight line that fits the sample of independent variables, dependent variable (XY) observations in the sense that it minimises the sum of the squared deviations of each observed point on the graph from the straight line. The OLS estimators of β_i are widely used because they are BLUE (best linear unbiased estimators). That is, among all unbiased estimators, they have the lowest variance. However, nonlinear estimators may be superior to OLS estimators (i.e. they might be unbiased and have lower variance). Since it is often difficult or impossible to find the variance of unbiased nonlinear estimators, however, the OLS estimators remain by far the most widely used and was thus adopted in this study. Furthermore, the OLS estimators being linear, are also algebraically easier to use than nonlinear estimators.

The general model used for the analysis can be expressed as:

$$X_i = \beta_1 + \beta_2 Z_2 + \beta_3 Z_3 + \ldots + \beta_k Z_k + e_i$$

Where X_i = The dependent variable.

Z_i = The independent variable (I = 1,2,...n).

e_i = The error term.

The assumptions underlying this model include:

a) The model is specified as given above i.e. linear. The variables x_i and z_i (where I = 1,2,..n) represent numerical quantities observed without error.

b) The Z_i are nonstochastic. This means that each independent variable has values fixed in repeated samples. This is because the values of Z_i are either controllable or fully predictable. The statement that the values of Z_i are "fixed in repeated samples" indicates that the set of values of Z is taken to be the same from sample to sample. In addition, no exact linear relationship exists between two or more of the independent variables. If such a relationship exists there is the presence of multicollinearity. When multicollinearity is present, it becomes difficult to disentangle the effects of the individual Z values on the dependent variable. In order to ensure that multicollinearity was absent among the explanatory variables in the model, this study used the "rule of thumb" as specified by Pindyck and Rubinfeld (Pindyck, R.S. and Rubinfeld, D.L., 1981). This rule states that multicollinearity is likely to be a problem if the simple correlation between two explanatory variables is larger than the correlation of either or both variables with the independent variable. The problem of multicollinearity was not found when this test was performed.

c) i) The error term is an unobservable random variable, with a zero mean and such that, for any sample size n,

$$(\frac{1}{n})\sum(z_i-\bar{z})=0$$

and its limit, as n-->∞, is a finite number, and constant variance (homoscedasticity) for all observations. The assumption of zero mean implies that the error term is continuous and ranges from -∞ to +∞, that it is symmetrically distributed around the mean. The assumption of the error term having a zero mean is necessary for the parameters of β_i to be identifiable. In short, the expected value of the error term has to be zero if the model is to provide the basis for econometric analysis. The assumption of constant variance means that every disturbance has the same variance (δ^2) whose value is unknown. This assumption rules out, for example, the possibility that the dispersion of the disturbances could be greater for higher than for lower values of Z. In terms of the fertilizer use model, the assumption of homoscedasticity could imply that variations in quantity of nutrients used is the same whether, for instance, the price of fertilizer is high or low. To test for the presence of heteroscedasticity, the bartlett test was performed. The results of the bartlett test are presented in appendix 2.

ii) Errors corresponding to different observations are uncorrelated. If the error terms are correlated, there is the problem of autocorrelation. If autocorrelation exists, the regression estimators will be unbiased, but the standard error of the regression will be biased downwards. This will lead to the conclusion that the parameter estimates are more precise than they actually are. There will be a tendency to reject the null hypothesis when, in fact, it should not be rejected. To test for the presence of autocorrelation, the Durbin-Watson statistic was used.

iii) The error variable like any random variable is normally distributed and determined by two parameters, the mean and the variance. The meaning of the normality assumption is that small values of the error term have a higher probability to be observed than large values; extreme values of the error term are more and more unlikely the more extreme they get. The assumption of normality is necessary for conducting the statistical tests of significance of the parameter estimates and for constructing confidence intervals. If the assumption is violated, the estimates of b_0 and b_1 are still unbiased and best, but we cannot assess their statistical reliability by the classical tests of significance (t and F tests) because the latter are based on normal distributions.

A brief description of the variables in the specific regression model postulated as a single equation model on the basis of a priori grounds of economic, biological and physical logic and notation used is as follows:

The dependent variable : Quantity of fertilizer applied per hectare (X_1).

The sampled farmers were asked what types and amounts (kg) of basal and nitrogenous fertilizers they used in their maize fields. Since farmers use different fertilizer types, a common denominator, quantity of nutrients applied per hectare, measured as kilograms of plant nutrients of nitrogen (N), phosphate (P_2O_5) and potassium (K_2O) was used as the dependent variable in the regression analysis. The study sought to explain how various factors explain the rate of nutrients applied by farmers in maize production. For purposes of estimation, only farmers who used fertilizers were considered.

To convert quantity of fertilizer applied per hectare to quantity of nutrients per hectare, the FAO formula (FAO, 1985), was used as follows:

The formula adds up the fertilizer analysis numbers and divides their sum by 2 for 50 kg bag and by 4 for 25 kg bag. For instance: If a farmer used 50 kg D.A.P./ha for planting and 50 kg C.A.N. for topdressing, then total quantity of nutrients was calculated as follows.

a) Kg of nutrients = (18 + 46 + 0) / 2 = 32.
from D.A.P. (18:46:0)

b) Kg of nutrients from

C.A.N. (26:0:0) = (26 + 0 + 0) / 2 = 13.

Therefore total nutrients applied (X_1) = 32 + 13 = 45 kg.

The independent variables

Data were collected on several independent variables which included resource characteristics of farmers (area under maize production, method of cultivation, total farm sales, land size, off farm employment), institutional access (distance in kilometres to fertilizer market, receipt of extension advice, distance in kilometres to credit giving institutions), other institutional factors (prices of fertilizer and maize) and inherent soil fertility status.

However, management practices such as timeliness of operations, efficient weeding, and residual fertilizer that affect response of maize to fertilizer application, and in turn affect the quantity of fertilizers used by farmers, assuming they know the nature of the interactions were held constant. These variables could not be captured by the household analysis because they require data from specific plots. Dummy variables were used for independent variables like extension advice, farm yard manure use and off farm employment.

Stepwise multiple regression was used to specify which independent variables seemed to provide the best explanation of the behaviour of the dependent variable. This helped to overcome the problem of having a large number of independent variables as suggested by economic literature relative to the number of observations. However on a priori grounds, other independent variables almost certainly known to influence rate of fertilizer application were included although their estimated regression coefficients were not statistically significant. Consequently, the independent variables considered on the basis of reducing unexplained variation (stepwise regression procedure) and a priori information are described here:

a) Normalised price of fertilizer (NPF) in shillings.

The Price of fertilizer nutrients per kilogram normalised by the farmgate price per kilogram of maize was used. This is the relative fertilizer:output price ratio.

To calculate the nutrient price of fertilizer, computation of both price per kilogram of nutrient applied and also per kilogram of maize sold was done.

(I) PF - price of fertilizer .

The price of fertilizer per kg of nutrient, represented the total cost a farmer meets to get 1 kg of nutrient at the farmgate. The fertilizer price was thus calculated as:

PF = (price of planting fertilizer + price of topdressing fertilizer + cost of transport)/ total nutrients applied.

For instance:

A farmer used 50 kg D.A.P. for planting and 50 kg C.A.N. in his maize plot for topdressing. D.A.P. cost Ksh. 1000.00 per 50 kg bag and C.A.N. ksh. 800.00 per 50 kg bag. It cost him a total of Ksh. 120.00 to transport each bag to his farmgate (transport cost = fare + transport/bag of fertilizer).

Then:

Pf per 1 kg nutrient = (1000 + 800 + 2(120))/ (32 + 13) = Ksh. 45.33

(ii) Price of maize (pm)/ kg = (price / 90 kg bag) / 90.

Thus, NPF = (price of 1 kg nutrient/price of 1 Kg maize)

This was used as a proxy for the farmer's per unit cost of production and reflects the terms of trade in maize production at the farm level. If the terms of trade are favourable (represented by a low value), then the farmer is expected to use more nutrients / unit area and vice versa. This is because if the fertilizer price : maize price ratio is high, then more money is invested to produce a unit of maize implying reduced profits to a farmer.

b) Inherent soil fertility index (INPK)

This was a proxy for land quality and was postulated to have an effect on the rate of fertilizers farmers applied in the fields. In order to capture this variable, soil testing was done and analysed for macro nutrients that affect maize production. Since the analysis for various nutrients used different methods and employs different units to depict the various levels of the respective nutrients, a "soil fertility index" was developed for purposes of this study.

Available nutrients were classified as shown in Table 4:

Table 4: Classification of nutrient availability in soils.

	Low	Moderate	High
K (m.e.%)	<0.2	0.2 - 1.5	> 1.5
P (ppm)	< 20	20 - 80	> 80 (Merlich)

source:Ahn,P.M.

For purposes of developing an index, these classifications were assigned 1,2, and 3 for low, moderate and high respectively. Nitrogen was classified as either low (< 0.2 percent) or adequate (> 0.2 percent). Thus low was assigned 1 and adequate 3. The fertility index developed was a summation of the values assigned to the respective soil nutrient analysis figures. For instance, a farm that had 2.60 m.e. K / 100 g soil, 2 ppm P and 0.38 percent N had its index calculated as shown in Table 5.

Table 5: Soil Fertility Index

Nutrient	Observation	Class	Assigned value
K	2.6 m.e	high	3
P	2 ppm	low	1
N	0.38%	adequate	3

Thus the inherent soil fertility index assigned for this farm was (3 + 1 + 3) = 7.

A soil with the highest soil fertility was assigned an index of 9 and the one with the lowest soil fertility was assigned 3. A major limitation of this index was the assumption that the response of maize to each of the three nutrients considered was the same. However in a real farming situation, a greater response is expected from the application of the soil's most limiting nutrient. Notwithstanding, the index provided a common denominator for the soil fertility of the different soil types that made it possible for this variable to be included in the model that analysed the determinants of fertilizer use.

c) Total Farm Sales (sales) in shillings

Total farm sales is a summation of all crop, livestock and livestock product sales during the maize production period (October 1994 - June 1995). This represented the period when decisions on input purchases especially fertilizers were made for the 1995 maize production season. This variable was used as a proxy for liquidity, which was expected to have a positive effect on rate of fertilizer use.

d) Land Size (W) in hectares

The economic status of farmers (usually measured as wealth) exercises a positive influence on fertilizer use. In the context of African smallholder farming systems and in the absence of relative statistics of farmers' wealth, the variable, land size was expected to capture this effect. Additionally, land size could be viewed as a surrogate for other important factors such as access to credit, capacity to bear risk and access to scarce inputs such as fertilizers. It was therefore expected that land size could positively influence fertilizer use.

e) Farm Yard Manure (FYM)

Farm Yard Manure (FYM), like inorganic fertilizers supply plant nutrients to crops. However, unlike inorganic fertilizers, FYM, supply small quantities of the nutrients. The available plant nutrients in FYM vary depending on several factors. These factors include, age and species of the animal, type of production, type of feeds animal is fed on and method of FYM preparation. Besides, the weight of well decomposed FYM at the farm level is difficult to measure. This is because FYM is stored or prepared under diverse environmental conditions and hence it could be of different moisture contents. Given, the problems of standardising FYM in terms of moisture content and available nutrients, quantity of FYM was not chosen as an independent variable in the regression analysis. Instead, the FYM was treated as a dummy variable.

f) Dummy variables used and their interpretation

Dummy variables were used to explain the effects of qualitative explanatory variables in the regression analysis. A dummy variable is dichotomous, thus taking a value of one or zero. Dummy variables were used to capture changes (shifts) in the intercept of the estimated regression model. Use of this dummy variable technique assumes that other regression coefficients in the regression equation are not affected by the value of the dummy variable (Mansfield, 1990). For instance, it is assumed that the slope of the relationship between the rate of nutrient application and extension advice is the same for farmers who received it and those who did not.

In this study, three dummy variables were used, one each for extension contact (ext), farm yard manure use (fym) and off farm employment (off), thus:

D_{ext} , Dummy variable taking value of one if farmer received previous extension advice, and zero otherwise.

D_{fym}, taking the value of one if farmer used FYM , or zero otherwise.

D_{off} , Dummy variable taking value of one if farmer had off farm employment, and zero otherwise.

Thus, if the coefficient for any of the dummies is significant, it is interpreted as the effects on rate of nutrient application (X), of the group of the dummy taking the value of one relative to that group taking the value zero. If a coefficient is not statistically significant, then this suggests that there was no measurable statistical difference between the two groups.

The interpretation of the error term

The error or disturbance term reflects the variability unaccounted for in explaining X_1. Some of the reasons for unexplained variation in rate of nutrients applied could be due to:

(a) Omission of relevant variables which could not be measured such as unforeseen family problems, and unexpected weather patterns.

(b) Misreporting of information either by the farmer or enumerator or both.

Possibilities of errors during processing of data e.g. during transferring, copying or computing.

(d) Problem of aggregation occurring due to non-homogeneity of a variable. For instance, measuring land input simply in hectares ignores differences in land quality even within the same soil type.

3.5 Tests of significance of parameter estimate and Goodness of fit

Tests of significance are used to test for statistical significance of the parameter estimates (β_i) of the regression i.e. they test for the reliability of the estimated parameter coefficients. The tests used in this study include: t statistic, F statistic and Coefficient of Determination (R^2).

a) The t - Statistic

The t statistic is a ratio of the estimated coefficient to its standard error.

$$t=(\hat{\beta}-\beta)/(S_{\hat{\beta}}).$$

where,

S is the estimated standard error of β.

The t statistic tests the hypothesis that one of the estimated coefficients individually exerts statistically significant linear influence on the dependent variable. For example, consider a coefficient j, the null hypothesis to be tested will be

$$H_0 = \beta_j = 0 \; ; \quad j = 1, 2, \ldots, k.$$

For large degrees of freedom (n-k > 0), where n = sample size and k = number of regressors, the t distribution approximates the normal distribution and in this case, as a rule of thumb, if the t ratio exceeds 2, then the coefficient is statistically significant.

For purposes of this study, 1 per cent, 5 per cent, and 10 per cent levels of significance were chosen to test the statistical linear influence of the coefficients on the rate of nutrients applied. The levels of significance mean that if an infinite number of samples were drawn from the population with mean, u_0, only 1 percent, 5 percent and 10 percent respectively of the time could one get a value of Z that could lead to an incorrect rejection of the null hypothesis. The higher the level of significance chosen (in this case 10 percent), the narrower the acceptance region i.e. the probability of incorrectly rejecting a null hypothesis increases with higher levels of significance.

b) The F - Statistic

The F statistic is defined as the ratio of

(Explained variance of X) / (Unexplained variance of X),

where X is the dependent variable.

The statistic tests the null hypothesis of the regression that all coefficients of the regression other than the intercept are zero.

$H_0 = \beta_2 = \beta_3 = \ldots. = \beta_K = 0.$

It tests the significance of the regression as a whole for the existence of a linear relationship between the dependent variable and all the explanatory variables jointly. If the computed F ratio is greater than the tabulated F ratio (from mathematical tables), then the regression analysis shows that all regression slopes are not zero and therefore the explanatory variables in the model linearly influence the dependent variable.

c) The Coefficient of Determination (R^2)

This is a measure of the goodness of fit of the estimated regression line.

R^2 = (Explained variation in the dependent variable / Total variation).

R^2 is an overall index of how well the dependent variable can be explained by all the regressors. R^2 tends to increase with additional variables even though they have little explanatory power. Hence, some statisticians use coefficient of determination adjusted (Adj R^2) for degrees of freedom to determine the explanatory value of a regression.

$\text{Adj } R^2 = 1 - (1 - R^2)((n - 1)/(n - k))$

Where,

n = number of observations.

k = number of regressors.

The adj R^2 does not increase with an additional independent variable unless the latter leads to a reduction in unexplained variation i.e. decrease in $(1 - R^2)$ is more than offset by $(n - 1) / (n - k)$. In this study, both R^2 and Adj R^2 values are presented in the regression results.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter shows and discusses the results obtained from descriptive analysis of the survey data on the fertilizer use patterns. It also presents and discusses the results of regression analyses of the determinants of fertilizer use for each district besides testing and discussing the hypotheses of the study.

4.1 Descriptive Analysis Results and Discussions.

This section uses the mean and frequency tables to present results of fertilizer use patterns on the basis of resource endowment and access to fertilizer. It also presents results of trends in fertilizer use and farmers' perceptions to fertilizer use.

4.1.1 Land size and ownership.

Resource availability and use patterns are important in choice of any technology a farmer may wish to adopt. Land is a basic resource in any farming activity. The quantity of land can be seen as an indicator of the level of assets; that is, high level of assets could imply a greater ability and/ or willingness for a farm household to take risks. Table 6 gives the distribution of land ownership by size in the study area by district.

Table 6: Percent of farmers owning land in various farm categories (hectares).

District	n	<2.0	2.1-4.0	>4.0	Mean
Kisii	40	62.5	35.0	2.5	1.96
Kakamega	40	62.5	25.0	12.5	1.98
Trans Nzoia	40	75.0	17.5	7.5	1.60

Source: Survey data.

The figures indicate that around 67 percent of the farmers sampled have a land size of less than or equal to two hectares.

Table 7: Soil conservation practices by farmers by district.

Conservation method	Percent of farmers		
	Kisii (n=40)	Kakamega (n=40)	Trans Nzoia (n=40)
Terraces	30	40	42
Cut Off Drains	2.5	20	12.5
Trashlines	32.5	0	0
Napier grass bunds	20	0	0
Cover crops	7.5	0	0
None	32.5	47.5	55

Source: Survey data

Note: Due to multiple responses, percent totals exceed 100 percent.

Thus, with an average farm household population of 7-8 people, the need to achieve food self sufficiency and some surplus is translated into greater pressure on the available land holdings. This has led to crop intensification and subsequent depletion of soil plant nutrients, more so in Kisii district. Indirectly this has had a positive influence on the way the farmers manage their soils. This is shown by a high figure, 55 percent, of farmers who practise one method or another of soil erosion control measures such as terracing, trashlines and planting of napier grass in strips across fields as shown in Table 7.

4.1.2 Land utilisation patterns

Mixed farming was practised in all the districts under study. Among the major livestock kinds universally kept were cattle of various breeds and poultry. Keeping of goats was mainly prevalent in Nyacheki Division, Kisii District whereas sheep rearing was common in Lukuyani Division, Kakamega District. The major crops grown included maize, bananas, millet, cassava and sweet potatoes. There were various levels of cash cropping in the areas. Tea was a major cash crop among all clusters of Kisii District whereas sugarcane was the sole cash crop in Mumias, Khwisero and Shinyalu Divisions in Kakamega District. Unlike in Kakamega District, where sugarcane was the sole cash crop, bananas, pineapples and sugarcane (for chewing) and coffee were other major cash crops grown in Kisii District.

Unlike in the other two districts, Trans-Nzoia District and Lukuyani Division, Kakamega District, were areas where maize production is the major farming activity. There was no other crop of significance grown for commercial purposes in these areas, other than maize. These areas also differed from Kisii District and most parts of Kakamega District in that dairying was an important activity whereby the improved (Grade) cattle were predominantly kept.

Maize was grown in Kisii District primarily for subsistence. This was also the case for Kakamega District except lukuyani Division. In Trans Nzoia District and Lukuyani Division of Kakamega District, maize was mainly grown as a commercial crop.

4.1.3 Maize production

Maize occupied an average of 34.1 percent, 42.5 percent and 59.5 percent of total farm size in Kisii, Kakamega and Trans Nzoia Districts, respectively. This shows the different levels of importance of maize production in these districts.

In Trans Nzoia District, Lukuyani Division and Kisii District, maize production took the prime land. The crop also took a significant proportion of the land under food crops. However, in the sugarcane growing areas of Kakamega District (Shinyalu, Khwisero and Mumias Divisions), all prime land was devoted to sugarcane production. The less fertile land and valley bottoms which are inaccessible to tractors which ferry the cane to the sugar factories were devoted to maize production. Maize was also grown in valley bottoms partly because of less striga incidence.

Sugarcane appeared to occupy all the available good land in the lower parts of Kakamega District and its expansion looked uncontrollable. This observation supports an earlier study by Ochieng (1981) who reported that of the 2.16 ha mean farm owned by Mumias farmers, 1.2 ha was devoted to sugarcane production making it the most important crop in the area in terms of area coverage. This has implications on the future food status of the region since maize is the major food crop. Soon, the region may be turned into a maize deficit area if the trend continues although climatically it has good potential for food production.

Hybrid maize was grown by a majority of the farmers; 95 percent, 65 percent, and 100 percent in Kisii, Kakamega and Trans Nzoia Districts, respectively. However, in some parts of Kakamega District, local unimproved maize varieties which are less responsive to fertilizer application were grown. This was because it was perceived that the local varieties offered better resistance to striga, a weed which when present drastically reduces maize yields. Some farmers in parts of Kisii and Kakamega Districts also grew several different varieties even in the same field as a risk minimising strategy to ensure food security. The most popular variety in Kisii District by far was H625 while H614 was popular in Trans Nzoia District. The two varieties were grown in almost equal proportions in Kakamega District. The main season maize cropping calendar in the region is shown in Table 8.

Table 8: Main season maize cropping calendar in the region.

	Jan Feb Mar Apr May Jun July Aug Sep Oct Nov Dec
Kisii	&&&&&&&########## %%%%%%% ********
Kakamega	******&&&&&&&&&####### %%%%%%%%%%%% **
Trans Nzoia	**********&&&&&&&&&######## %%%%%%%%%%%

Key:

******* Land preparation &&&&&&&&& Planting

####### Weeding %%%%%%%%% Harvesting.

Maize cropping patterns

Knowledge of cropping patterns is essential in understanding fertilizer use patterns. The cropping pattern of a region is however governed by among other factors, climate, soil type, population density and farmer resources. There were several maize cropping systems which were observed (Table 9). The major one was intercropping, of which the maize/beans intercrop was the most common. Fertilizer use in maize was the same as fertilizer use in maize intercropping systems as the intercrops never got additinal fertilizers.

Table 9: Intercropping patterns in Kisii, Kakamega and Trans Nzoia Districts.

	Percent of farmers		
Intercropping pattern	Kisii (n=36)	Kakamega (n=24)	Trans Nzoia (n=32)
Maize/beans	84	87.5	100
Maize/bananas	14	0	0
Maize/sugarcane	14	0	0
Maize/Other*	25	12.5	0

Source: Survey data.

* millet, pyrethrum, irish potatoes, pineapples.

Purestand maize cropping was not a common practice. However, in Nyacheki Division, Kisii District a new cropping pattern, has evolved over the past three years. This involves planting pure stand maize and when maize has tasselled, the farmers relay it with beans during the long rains season. Relay cropping is said to have an advantage in increasing bean yields over conventional intercropping. However, there are no agronomic research findings available to ascertain the authenticity of the farmers' claim.

4.1.4 Fertilizer use in maize

Fertilizer use in maize was examined in terms of types used, quantities applied, trends of use and access of farmers to the fertilizers.

Fertilizer use by type

The purchase of different kinds of fertilizer by farmers was used as a proxy for availability of the right type of fertilizer. The farmers reported that the right package size of fertilizer required was not a problem as all available fertilizer package sizes (10 kg, 25 kg and 50 kg) were available in all regions.

After market liberalisation of fertilizers in 1990, procurement and distribution of fertilizers is now done by both public and private sectors.

Several fertilizer types commonly available in the market were used in maize production. Diammonium Phosphate (DAP, 18:46:0) was by far the most popular planting fertilizer used whereas Urea (46:0:0) and Calcium Ammonium Nitrate (26:0:0) were popular in topdressing. Table 10 shows the different fertilizer types as used by farmers.

Table 10: Use of different fertilizer type by farmers.

Type	Percent of farmers		
	Kisii (n=40)	Kakamega (n=25)	Trans Nzoia (n=37)
DAP	92.5	68	67.6
20:20:0	2.5	4	0
23:23:0	0	12	5.4
25:5:5+5S	25.0	0	0
Urea	0	52	30.0
CAN	5.0	20	42.2
MAP (11:50:0)	0	0	5.4

Source: Survey data.

Use of NPK (25:5:5+5S) in parts of Kisii District indicated cases of fertilizer diverted from the tea industry. This type of fertilizer is provided by Kenya Tea Development Authority (KTDA) for use in tea production. Eighty percent of the 10 farmers who used 25:5:5+5S in Kisii District used it for topdressing. Similarly, there was widespread use of Urea in topdressing maize especially in Mumias Division, Kakamega District. The Urea is provided by Mumias Sugar company for sugarcane production but diverted to maize production.

Rate of application of N and P_2O_5 by district/cluster, Versus the recommended rates

Fertilizer use levels were quite variable across the districts and even within each district (Table 11). The average levels of basal fertilizer use were 19.3, 22.3 and 45.5 kg of nutrients per ha for Kisii, Kakamega and Trans Nzoia Districts, respectively, and 12.5, 31.5 and 47.0 kg of nutrients per ha respectively, for top-dressing. Fertilizer use was higher in single season cropping areas of Trans Nzoia District and Lukuyani Division, Kakamega District. These areas fall within the former "White highlands" and have only been recently exposed to continuous cropping. In Kisii District, fertilizer use in maize at planting was common but little if any topdressing took place. In Kakamega district especially in Mumias area, there was minimal use of planting fertilizer. This could be attributed to the belief that valley bottoms are fertile and therefore don't warrant use of fertilizers. This belief was found to be untrue as the soil test results from the area indicated that all farms had low phosphorous levels.

Table 11: Quantities of fertilizer nutrients (N and P)in kg/ha used in maize production in Western Kenya.

Region	Actual rate						Recommended rate (FURP)	
	Basal application (P)			Top dress (N)			P	N
	Min	Mean	Max	Min	Mean	Max	Mean	Mean
Keumbu	2.3	29.4	57.5	1.8	11.5	22.5	50	0
Nyamache	11.5	19.5	32.8	4.8	7.0	12.8	50	0
Nyacheki	0.3	9.1	18.8	2.0	6.6	18.5	50	0
Ogembo	7.0	19.0	35.0	2.5	25.0	70.4	75	0
KSI	0.3	19.3	57.5	1.8	12.5	70.4		
Mumias	0.0	5.6	30.0	0.0	20.7	75.5	25	0
Shinyalu	0.0	20.6	76.8	0.0	8.0	30.0	25	0
Khwisero	0.0	4.5	57.5	0.0	2.3	11.3	0	0
Lukuyani	28.8	58.4	115.0	55.5	95.9	121.0	0	75
KAK	0.0	22.3	115.0	0.0	31.7	121.0		
Moto I & II	0.0	43.4	57.5	0.0	25.8	49.5	0	75
Mateket	14.5	59.8	115.0	0.0	50.5	135.0	0	75
Sirende	0.0	36.1	100.0	0.0	43.4	90.0	0	75
Kapomboi	0.0	42.7	76.8	0.0	68.3	80.5	0	75
T/NZ	0.0	45.5	115.0	0.0	47.0	135.0		

Source: Author's survey, 1995.

where KSI, KAK and T/NZ refer to Kisii, Kakamega and Trans

Nzoia districts respectively.

However, use of Urea for topdressing is common. Most farmers who applied fertilizer on maize did not use it on the other food crops grown in the farm. The major reason given was that due to insufficient cash, maize was given first priority because it is the main staple food crop. This shows that besides fertilizer price, other factors such as subsistence pressure determine the use of fertilizer in maize.

FURP which conducted On-farm researcher managed trials in 71 sites across the country for five years came up with site specific recommendations. Recommendations for this region are presented (Table 11). The recommendations were based on value - cost (i.e. price of one kg of maize : price of one kg of fertilizer nutrient) analysis of the estimated maize response to fertilizer use model. The recommendations are the economic optimum levels of fertilizer use based on the value - cost method. However, these recommendations are prone to change with changes in value - cost ratio due to changes in relative prices of maize and fertilizer.

The results of comparing FURP recommendations and the current levels of fertilizer application for Kisii District indicated that farmers applied less than 50 percent of the recommended phosphorus. However, they applied small amounts of nitrogen although FURP did not recommend use of nitrogen in Kisii District. In Kakamega District, farmers in Mumias and Lukuyani clusters applied about 25 percent and 80 percent respectively of FURP's recommendation of 25 kg N/ha and 75 kg N/ha respectively. Farmers in Khwisero cluster used little nitrogenous fertilizers. This was consistent with

FURP's recommendation of no use of nitrogenous fertilizers in the area.

In Trans Nzoia District, farmers applied about 63 percent of FURP's recommendation of nitrogen. However, they applied an average of 45.5 kg P/ha contrary to FURP's recommendation of no phosphorus use.

Reasons for farmers not following FURP's recommendations were however not clear. However, according to this survey, some of the reasons for sub-optimal use of fertilizers in this region include lack of knowledge on rates of use, belief that their farms were fertile, inadequate cash and high fertilizer price.

Fertilizer use by farm size

The relationship between farm size and amount of fertilizer used was analyzed in order to determine how uniformly fertilizers were used within the smallholder maize sector. The purpose was to indicate whether this technology has any size bias. For purposes of this study, farm size among smallholder maize farmers was grouped into three categories. The mean rates of fertilizer use by farm category are presented in Table 12.

Table 12: Fertilizer use (kg/ha) by farm size by district

	Kisii		Kakamega		Trans Nzoia		mean	
Farm size (ha)	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
< 2.0	13.6 (27)	21.3 (27)	32.6 (26)	20.5 (26)	39.9 (34)	42.2 (34)	31.1 (87)	29.2 (87)
2.1-5.0	9.0 (12)	14.4 (12)	20.9 (9)	24.5 (9)	63.3 (3)	85.0 (3)	20.3 (24)	27.1 (24)
> 5.0	22.0 (1)	19.3 (1)	43.6 (5)	18.4 (5)	20.5 (2)	65.8 (2)	35.1 (8)	30.4 (8)

Source: Survey data.

() **figures in brackets show the number of farmers in each farm size category.**

The results indicated that even small scale farmers who are primarily subsistence oriented found it worthwhile to use fertilizers. The mean rate of the smallest farm category used 31.1 kg N and 29.2 kg P_2O_5 /ha while that of the largest small scale farm category used 35.1 kg N and 30.4 kg P_2O_5/ha. In the middle category, a mean of 20.3 kg N/ha and 27.1 kg P_2O_5/ha were used. In the absence of a discernible trend, one could only suggest that fertilizer use in the study area did not have a scale bias.

Trends of fertilizer use

While more than 75 percent of the farmers who used fertilizers had done so before, the majority of them indicated that they had not changed the rate of use. Table 13 shows a summary of the trends in the rate of use over the years since time of first use.

Table 13: Temporal trends in fertilizer use.

Trend	Percent farmers		
	Kisii (n=40)	Kakamega (n=26)	Trans Nzoia (n=38)
Maintained rate of use	50	69.2	59
Increased rate of use	37.5	15.4	18
Reduced rate of use	12.5	15.4	23

Source: Survey data.

An inquiry into why about 60 percent of the farmers had maintained the rate of fertilizer use in reported areas revealed that the most important reasons were high fertilizer price and farmers' belief that the quantities of fertilizers they applied were adequate (Table 14).

The farmers who indicated an increase in fertilizer use in their fields had the desire to increase yields. However, about 19 percent of them believed that their soils were fertile.

Table 14: Farmers' reasons for continued maintenance of fertilization levels.

Reason	Number of farmers			% of total who maintain
	Kisii	Kakamega	Trans Nzoia	
Fertilizer rate adequate	14	8	6	39.5
High fertilizer price	8	8	19	49.3
Uses Farm Yard Manure	0	3	1	5.6
Other	3	0	0	4.2
Total	26	19	26	

Source: Survey data.

Frequency exceeds number of those interviewed due to multiple responses.

The reported reduction or non use of fertilizers was said to be due to lack of cash to purchase and transport fertilizers, and too much rain. The latter reduces the response of maize to fertilizer application as part of the applied fertilizer is leached into deeper soil horizons and / or washed away as part of the eroded soils. This then renders this fertilizer portion unavailable to the maize plant.

Farmers' access to fertilizer use

Farmers' use of fertilizer can be influenced by fertilizer supply and distribution network. The right fertilizer should be available at the right place and right time at the affordable price i.e. availability of fertilizer at the right time in accessible locations is important. No data were however collected on fertilizer procurement and distribution. However, proxies were used to draw inferences on them. Credit availability improves farmers' liquidity position and was used as a proxy for financial access to fertilizer use. Basically, there are several different sources from where smallholder farmers in Kenya may get credit to purchase farm inputs. First, money may be raised directly from sale of farm produce. Second, private money lenders may supply the capital required. Third, cash may be obtained from commercial banks, cooperatives or the Agricultural Finance Corporation (AFC). In case of formalised credit institutions, a number of restrictions exist. These restrictions include: size of farmer's land holding, a farmer's membership (in case of Cooperative credit) and credit worthiness. The survey, however, found out that in 1995 all sampled farmers financed fertilizer purchases outside formal credit. Most farmers in the three districts indicated that they financed their fertilizer purchases through crop sales, livestock sales and off farm employment.

Distance travelled to the nearest commercial bank or Agricultural Finance Corporation (AFC) was used as a proxy to physical access to credit. It was expected that the nearer farmers were to credit institutions, the greater exposure they could have to credit use. However, none of the sampled farmers used credit in 1995 because they could not meet the minimum AFC loan award elegibility criteria, hence the hypothesis could not be tested.

The study also revealed that despite the fact that in Kisii and Kakamega Districts, land adjudication took place two to three decades ago, still 36 per cent of the farmers had no title deeds hence had no collateral to offer to lending institutions in order to get formal credit.

The mean distance a farmer travelled to the market to purchase fertilizer was used as a proxy to physical access to fertilizer. This is also referred to as market access. It was postulated that as the distance to the market increases, the purchase of fertilizer was anticipated to decrease. Table 15 shows the mean distances covered to purchase fertilizers and the modes of transport used. The state of most roads was murram, some of which were rendered impassable during the rainy seasons. The results showed that Kisii farmers on average travelled shortest distances to fertilizer markets as opposed to Trans Nzoia farmers who travelled longest distances. This means that farmers in the Kisii sample were most accessible to fertilizers. However, the Trans Nzoia farmers who were least accessible used the highest rates of fertilizer. This then implies that other factors were responsible for the rates of fertilizer use in these regions rather than physical access per se.

Motorised transport was used in all cases as the mode of transporting fertilizers to the farms. Thus in order for the farmers to deliver the fertilizers to their farmgates, they incurred some transport costs. The transport costs had two components: a fixed component and a variable component. The fixed component was the fare that the farmer was charged while going to purchase the fertilizers and while delivering it to the farm. This cost was fixed regardless of the quantity delivered. However, it varied with the distance travelled. The variable component was the amount charged to a farmer per bag of fertilizer delivered. While any volume of fertilizer could be transported, the total per unit cost of transportation increased with decreasing quantities of fertilizers delivered. Besides, farmers who purchased low analysis fertilizers such as C.A.N. incurred higher transportation costs per unit unlike those who used high analysis fertilizers such as D.A.P.. This is because the variable component of transportation cost was based on quantity of fertilizer rather than quantity of nutrients delivered. For example: A farmer who transported 5 * 50 kg bag of DAP (18:46:0) from Kitale to Kapomboi incurred Ksh. 25.00 /bag and Ksh. 100.00 for a return fare. This costs the farmer Ksh. ((5 * 25.00)+ 100.00)) = Ksh. 225.00 to transport (0.64*5*50) = 160 kg of nutrients, (Since DAP contains 0.64 kg of nutrients /kg of DAP fertilizer). Thus the average cost incurred by the farmer to transport one kg of nutrients is Ksh. (225.00/160) = Ksh. 1.41. However, another neighbouring farmer who purchased one 50 kg bag of CAN (26:0:0) incurred the same return fare as the other one on top of Ksh. 25.00 for the bag of fertilizer transported. This farmer therefore incurred Ksh.(100.00 + 25.00) = 125.00 to transport (0.26*50) = 13 kg of nutrients (Since one kg of CAN contains 0.26 kg of nutrients). Thus the farmer incurred Ksh. (125.00 / 13) = Ksh. 9.60 to transport one kg of nutrients.

Table 15: Average distance and mode of transport used for fertilizer purchases, 1995.

Region		Average distance (km)	Mode of Transport	
			Motorised	Other*
Kisii	Keumbu	4.5	100	0
	Nyamache	2.8	100	0
	Nyacheki	4.8	100	0
	Ogembo	2.1	100	0
Kakamega	Mumias	10.9	100	0
	Shinyalu	1.4	100	0
	Khwisero	5.0	100	0
	Lukuyani	12.1	100	0
Trans Nzoia	Moto I & II	27.3	100	0
	Mateket	10.0	100	0
	Sirende	8.3	100	0
	Kapomboi	25.0	100	0

Source: Survey data.
*** bicycle, foot, draught animal.**

Farmers' perceptions of constraints to fertilizer use

Most farmers know that use of fertilizers will enhance maize yields, however, the quantities applied varied very much at the time of planting and topdressing. Farmers were asked the reasons for low fertilizer application as a means of identifying the constraints that militated against fertilizer use. The most important constraints were high fertilizer price, lack of credit, low price of maize, maize diseases and pests, and poor weather conditions (Table 16). High fertilizer price meant that fewer farmers bought fertilizers or those farmers who were aware of fertilizer use benefits, only bought "small" quantities. Lack of credit and low maize price implied low liquidity position of the farmers who in turn responded by reducing or not using fertilizers at all. The three factors collectively accounted for over 50 percent of the major reasons advanced by farmers as the constraints to fertilizer use in each district. Maize diseases and pests were given by 67 percent of the farmers in Trans Nzoia. Notable among them were; maize stalk borer, rodents and maize blight. Presence of these factors led to maize yield reduction, thus low farm revenue leading to low farmer liquidity position and presumably low fertilizer use. Fifteen percent of the farmers in Kakamega District reported weeds as a problem to fertilizer use. These farmers were mainly from Mumias and Khwisero divisions where striga infestation of maize fields reduces maize yields significantly. Poor weather conditions in form of unreliable rains, hailstorms and strong winds especially in Kakamega district were also reported as factors that reduce maize yields and subsequently led to low fertilizer use by farmers.

Table 16: Farmers' responses to constraints to fertilizer use.

Response	Percent of farmers		
	Kisii	Kakamega	Trans Nzoia
High fertilizer price	87.5	82.5	67.5
Lack of credit	67.5	65.0	37.5
Low price of maize	50.0	50.0	70.0
Fertilizer not available	10.0	22.5	12.5
Right fertilizer package unavailable	5.0	2.5	0
Adequate soil fertility	7.5	30.0	5.0
Poor weather (drought, wind)	0	47.5	22.5
Labour shortage	0	7.5	0
Lack of cash	27.5	17.5	10.0
Maize diseases and pests	25.0	5.0	67.5
Weeds (couch and striga)	5.0	15.0	0
Poor maize variety available	2.5	0	2.5

Source: Survey data.

4.1.5 Farm Yard manure use in maize

Farm Yard manure is used to increase soil fertility, as is the case for inorganic fertilizers. Thus since both are used for the same purpose, use of Farm Yard Manure may influence use and amounts of artificial fertilizers used. It was therefore important to establish whether a relationship exists between the two.

Farm Yard Manure use was quite varied. The amounts applied also varied greatly, from several kilograms to a few tonnes per hectare. The most common method of Farm Yard Manure preparation involved heaping it out of the boma for full decomposition before application. Out of the 40 sample farmers for each district, only 15 percent, 57.5 percent, and 25 percent of the farmers in Kisii, Kakamega, and Trans Nzoia respectively used Farm Yard Manure. In all cases the Farm Yard Manure was applied before planting and was spread in planting holes or furrows.

Despite the widespread keeping of livestock in all areas except in Kapomboi, Trans Nzoia District, it was apparent that use of organic manure has not been integrated as a fertility enhancing strategy in the study area. Manuring is more labour intensive compared to fertilizer use and this partly explains its minimal use. There was also lack of adequate amounts due to the keeping of a few animals under extensive grazing systems. Thus, inorganic fertilizers are preferred presumably because of their availability and also due to them being less labour intensive.

4.2 Results and discussions of the Multiple Regression Analyses on fertilizer use determinants.

The regression analyses on determinants of fertilizer use at farm level considered only farmers who used fertilizers. This is because if farmers who never used fertilizer were included in the analysis, the OLS estimates would be biased because the dependent variable could have zeros as observations (Parikh, A., 1990). The results which are given by district discuss the independent variables that were found to be statistically significant at 5 percent level or below. The other independent variables with peculiar or unexpected results although not statistically significant are also discussed. Table 17 shows the multiple regression results on determinants of fertilizer use in Kisii District.

Table 17: Multiple Regression Results on determinants of fertilizer use in Kisii District.

Variable	β	S.E.	t
Farm Yard Manure (Fym)	17.089	7.230	2.364***
Sales	1.4E-04	1.236E-04	1.132
Normalised Fert. Price (Npf)	-16.366	3.509	-4.664***
Off-farm employment (Off)	8.754	5.525	1.585
Land size (W)	-1.408	2.033	-0.692
Inherent Soil Fertility (Inpk)	0.908	3.043	0.298
Extension Contact (Ext)	10.249	5.947	1.724*
(Constant)	119.531	31.642	3.778***
R^2 = 0.648, Adj R^2 = 0.571	F = 8.404, n = 40		D.W = 1.63

Significance levels: *** = 1%; ** = 5%; * = 10%.

The estimated model is of the form:

X = 119.53 + 10.25 Ext - 1.41 W + 8.75 Off + 0.91 Inpk - 16.37 Npf + 1.4 E-04 Sales + 17.09 Fym. The various variables used are described in section 3.4.2.

Overall the model explained 64.8 percent of the variation in rate of nutrients applied. Only Farm Yard Manure use and normalised price of fertilizer were significant at the 1 percent level of significance. Extension contact was significant at 10 percent level of significance.

The relationship between use of Farm Yard Manure and the rate of nutrients applied was positive and significant. Both inorganic fertilizers and Farm Yard Manure enhance soil fertility thus increasing crop yields. Thus, farmers may use both sources of the nutrients in combination or one of them in isolation. In the former case, Farm Yard Manure is used to complement inorganic fertilizers and the latter case represents a situation where Farm Yard Manure is a substitute. The case of Farm Yard Manure acting as a complement to inorganic fertilizer was the one observed in Kisii District. This partly can be explained by the inadequate supplies of Farm Yard Manure as evidenced by a small number of animals kept per farm under extensive grazing systems. The inadequate supplies available is also shown by the small number of farmers (6) who used Farm Yard Manure in the sample.

The normalised price of fertilizer was significant (1 percent level) and had the expected negative sign. This implies that if the terms of trade are in favour of the farmer, more nutrients are applied and vice versa, that is, if price of fertilizer per kilogram increases more proportionately than to an increase in price of 1 kilogram of maize, less nutrients will be applied and vice versa. Specifically, an increase in the terms of trade in favour of fertilizer price by one unit will reduce nutrients applied by 16.37 kg/ha.

The positive and significant relationship between extension contacts and nutrients applied is consistent with expectations that extension contact increases fertilizer use. The coefficient shows that those with extension contact used 10.25 kg/ha of nutrients more than those without.

The sales coefficient, though positive was not statistically significant despite the high extent of cash cropping and increased commercialisation as shown by values of total farm sales. This suggests that money obtained from sale of farm produce was not necessarily used to purchase fertilizers. This can partly be explained by the place maize occupies in the economy of the district. Maize is normally produced to meet subsistence needs. Increases in maize production is done over time, that is, through production both during the long and short rains seasons rather than by increases in fertilizer use to meet any subsistence shortfall. Thus, even though the farmers' liquidity is high, they may not increase fertilizer use if they are able to produce adequate amounts of food to meet their subsistence needs.

Table 18 presents the results of the multiple regression analysis on the determinants of fertilizer use in Kakamega District.

Table 18: Multiple Regression Results on determinants of fertilizer use in Kakamega District

Variable	β	S.E.	t
Farm Yard Manure (Fym)	5.494	20.058	0.274
Sales	2.929E-04	2.451E-04	1.195
Normalised Fert. Price (Npf)	-46.506	15.016	3.097***
Off-Farm Employment (Off)	18.442	18.124	1.018
Inherent Soil Fertility (Inpk)	9.919	12.081	0.821
Land size (W)	-11.793	5.989	-1.969*
Extension Contact (Ext)	14.201	27.743	0.512
(Constant)	230.584	139.159	1.657
R^2 = 0.737 F = 6.814 Adj R^2 = 0.629 n = 25 D.W. = 1.29			

Significance levels: *** = 1%; ** = 5%; * = 10%.

The estimated model for the rate of nutrient application / ha is given as:

$$X = 230.58 + 14.2\ Ext - 11.79\ W + 18.44\ Off + 9.92\ Inpk - 46.51\ Npf + 2.93E\text{-}04\ Sales + 5.49\ Fym.$$

The model explained 73.7 percent of the total variation of the observed rate of fertilizer use. As in the case of Kisii

District, normalised price of fertilizer had the expected sign and was statistically significant indicating the role input : output price ratio plays in the use of fertilizers by farmers. For every unit increase in normalised fertilizer price, fertilizer consumption rate per hectare could drop by 46.5 Kg.

Land size influenced rate of fertilizer use negatively and was significant at 1 percent level. This portrays the case whereby to increase maize production, more land was put into production rather than by land use intensification through increased fertilizer use.

All other variables except inherent soil fertility had the expected signs but INPK was not statistically significant even at the 20% level.

Table 19 presents the multiple regression results on the determinants of fertilizer use in Trans Nzoia District.

Table 19: Multiple Regression Results on determinants of fertilizer use in Trans Nzoia District

Variable	β	S.E.	t
Farm Yard Manure (Fym)	-11.911	14.958	-0.796
Sales	9.874E-04	2.594E-04	3.807***
Normalised fert. price (Npf)	-2.994	1.909	-1.568
Off-farm employment (Off)	19.921	12.507	1.593
Inherent soil fertility (Inpk)	-9.882	5.836	-1.693*
Land size (W)	6.800	6.558	1.036
Extension contact (Ext)	31.438	13.395	2.347***
(Constant)	123.365	45.838	2.691***

$R^2 = 0.636$ F = 7.238 D.W = 2.07
Adj $R^2 = 0.548$ n = 37

Significance levels: *** = 1%; ** = 5%; * = 10%

The estimated model is of the form:

$$X = 123.37 + 31.48\ Ext + 6.80\ W + 19.92\ Off - 9.88\ Inpk - 2.99\ Npf + 9.88E\text{-}04\ Sales - 11.91\ Fym.$$

The model explained 63.6 percent of the total variation in fertilizer use observed in Trans Nzoia District. The most important determinants of fertilizer use in maize production were: value of total farm sales, inherent soil fertility and extension contacts.

The results shown indicated that total farm sales positively influenced the rate of fertilizer application and was significant at 1 percent level. The model estimated that for every Ksh. 10000.00 received in farm sales, nutrient application increased by 9.88 Kg/ ha. This provides further evidence that income has a positive effect on fertilizer use.

Extension contacts positively influenced the rate of fertilizer use. The extension regression coefficient showed that those who had extension contacts on average used 31.4 kg/ha more nutrients than those without.

Inherent soil fertility was found to influence rate of nutrients applied as expected. For every unit increase in the inherent fertility index, rate of fertilizer use was expected to decrease by 9.88 kg/ha. Furthermore, those farmers who received extension advice applied 31.44 kg/ha on average more nutrients than those who did not, showing a positive influence of extension contacts on rate of fertilizer use.

Comparison of the Multiple Regression Results

Not even a single independent variable was found to influence rate of fertilizer application significantly across the three districts at the 5 percent level of significance. Nonetheless, several variables need further discussions.

Land size was only found to be statistically significant in Kakamega District. In both Kakamega and Kisii Districts, land size negatively influenced rate of nutrients applied, a situation explained by land use intensification through relay cropping and substituting fertilizer use by increasing cultivated land in the districts respectively. In contrast, land size was found to be positively related to rate of nutrient use in Trans Nzoia District, though not significant. In Trans Nzoia District, land ownership by the present farmers has been recent since this area used to be part of the former European Settlers' farms commonly referred to as the " White Highlands". Thus, the new farmers, some of whom worked in the "White Highlands" had been trained on the importance of fertilizer use by the former settlers and hence continued using fertilizers on maize production in their new farms. Furthermore, the size of the parcels of land bought reflected the wealthy status of the farmers. Thus, those who had large pieces of land were wealthier and hence afforded to use more fertilizers than the poorer farmers.

Related to land size is inherent soil fertility. The variable was only statistically significant at 10 percent level in Trans Nzoia District and with the expected negative sign. In other districts, the relationship was positive. Conventionally, it is expected that the relationship be negative. The statistically insignificant positive relationship between inherent soil fertility and fertilizer use in both Kisii and Kakamega Districts means that inherent soil fertility does not linearly explain differences observed in fertilizer use in the two districts. This then implies that other factors were more important in explaining fertilizer use rates in Kisii and Kakamega Districts rather than soil fertility.

Total farm sales which was statistically significant at 1 percent level in influencing the rate of nutrients applied in Trans Nzoia District unlike in the other districts, was a reflection of the extent of maize commercialisation. In value terms, mean total farm sales were higher for both Kisii and Kakamega Districts where tea and sugarcane are major cash crops respectively than in Trans Nzoia District, where maize is the major cash crop. However, the results suggest that the income from these other crops have little influence on rates of fertilizer application in these areas contrary to the findings of some earlier study (Ongaro, 1988). Thus, the level of commercialisation in maize production is a major determinant of fertilizer use.

4.3 Results and Discussions of hypotheses testing

Four hypotheses were tested in the study. The tests were evaluated on the basis of the t statistic at the 5 percent level of significance.

a) The <u>first null hypothesis</u> stated that farm size did not have an influence on the rate of application of nutrients ($B_w = 0$). The null hypothesis was tested against the alternative hypothesis, that farm size had an influence on the rate of application of nutrients (B_w is not equal to zero) by regressing farm size on rate of application of nutrients, where b_w is the slope coefficient for the variable, land size.

In stating this null hypothesis, it was assumed that fertilizers were readily available in the 10, 25 and 50 kg packets. The rationale behind the null hypothesis was that since fertilizers were available in all sizes, then size of the farm could not influence the rate of use. The null hypothesis was tested on the basis of the value of the t ratio corresponding to land size from the regression analyses on rate of fertilizer use and a combination of several factors. The regression results showed that the effect of farm size on nutrient application was negative and insignificant at the 5 percent level of significance for Kisii and Kakamega Districts. The calculated t-ratio was less than 2.0, the critical t ratio at the 5 percent level of significance. The fact that the coefficient was insignificant means that statistically, there was no linear relationship between total farm size and the rate of application of nutrients, that is, the coefficient was not different from zero. Thus, at 5 percent level of significance, the null hypothesis can not be rejected. In Trans Nzoia District, farm size was insignificant at 5 per cent. The land size coefficient was however positive. Since the t ratio for land size was less than 2.0, the null hypothesis that land size does not influence rate of fertilizer application cannot be rejected.

b) The <u>second null hypothesis</u> that location does not influence the rate of nutrients used by farmers ($u_1 = u_2 = u_3$) was tested against the alternative hypothesis that location influences rate of nutrients used by farmers (Not all u_i are equal), where u_1, u_2, and u_3 are the mean nutrients in kilograms applied in Kisii, Kakamega and Trans Nzoia Districts respectively. The null hypothesis assumed that there was no difference in the rate of fertilizer use based on differences in location of the three districts.

The rationale behind the null hypothesis was that since the districts fall in the same agroecological zone and most farmers use late maturing maize varieties, the response of maize to fertilizer use was expected to be similar. The F statistic was used to test the null hypothesis at the 5 percent level of significance. Table 20 presents the results of the analysis of variance for effect of location on fertilizer use while the computations of the analysis of variance are presented in appendix 1.

Table 20: One way ANOVA for effect of location on rate of fertilizer use.

Variation	Sum of squares	df	Mean square	F - ratio
Explained by Location (Between Columns)	55057.2	c-1 = 2	27528.6	10.28
Error or Unexplained (Within columns)	313290.9	(r-1)c = 117	2677.7	
Total	368348.1	rc = 119		

From the Mathematical tables, value of $F_{(2,117)}$, at 5% level of significance is 3.07. Since the calculated F is greater than the tabular value, the null hypothesis is not accepted, that the population means are the same. Thus, the rate of fertilizer use varies with district.

c) The <u>third null hypothesis</u> that the value of total farm sales does not influence the rate of fertilizers use positively ($B_{sales} = 0$) was tested against the alternative hypothesis that the value of farm size influences the rate of fertilizer use positively (B_{sales} is not equal to zero), where B_{sales} is the slope coefficient for the variable, value of total farm sales. The rationale behind the null hypothesis was that since a high value of total farm sales indicates a high liquidity position of the farmers. It was thus assumed ceteris paribus that farmers with higher liquidity levels could purchase more fertilizers and vice versa and hence the relationship between fertilizer use and value of total farm sales could be positive. The value of the t ratio corresponding to the variable, total farm sales obtained from results of the regression analyses were used as a test for the hypothesis. The test was done at the 5 percent level of significance.

Regression results showed that the coefficient of value of total farm sales for Trans Nzoia District was positive and significant at the 5 percent level of significance. The computed t-ratio was greater than the 2.0. Therefore at this level of significance, the null hypothesis that farm sales does not influence the rate of fertilizer use was rejected. Essentially, farmers with high farm sales used more fertilizer than those with low or no farm sales. This result is consistent with theoretical expectations. This is because farmers with greater marketed surplus would most likely have more own savings compared to those without. Some of these savings could then be invested in farming.

However, for Kakamega and Kisii Districts farm sales were statistically insignificant at the 5 percent level of significance although still positive. This could partly be explained by the farmers' major objective of growing maize, that is, whether subsistence only or both subsistence and cash. Thus, for the two districts, the null hypothesis that value of farm sales does not influence rate of fertilizer applied positively was not rejected at the 5 percent level of significance.

d) The <u>fourth null hypothesis</u> that the presence of off-farm employment does not influence the rate of fertilizer use positively (B_{off} = 0) was tested against the alternative hypothesis that the presence of off farm employment influences the rate of fertilizer use positively (B_{off} is not equal to zero), where, B_{off} is the slope coefficient for the variable, off-farm employment.

Like the third hypothesis, presence of off farm employment implies improved liquidity position of the farmers. Hence, with improved liquidity position, it was assumed that more funds were available possibly to purchase fertilizers and subsequently use it in maize production. The value of the t ratios corresponding to the variable, off-farm employment, was used to test the hypothesis at the 5 percent level of significance. The t ratios were positive but insignificant in all districts. Thus, the null hypothesis that off farm employment does not influence fertilizer use positively was not rejected.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter gives a summary of the research objectives, methodology and results of the study. Conclusions and recommendations are then drawn on fertilizer use in the light of experiences from Kisii, Kakamega and Trans Nzoia Districts.

5.1 Summary and Conclusions

Maize is the main staple food for the people of Kenya. Increase in maize production is therefore central in attaining food security which is a major food policy objective of the government of Kenya. Research in maize production is recommended as a way of achieving this objective. Through research, it has been found that yield increase in maize can be achieved by timely land preparation, planting, weeding and pest control. It can also be achieved through increased use of hybrid maize seed and use of fertilizers. Of these methods, use of hybrid maize seed has most been adopted by farmers and fertilizer use least among the purchasable inputs (Gerhart, 1974, Hassan et al, 1994b). Although, the role of fertilizer in increasing maize production has been documented in Kenya (Allan, 1971; Gerhart, 1975 and FURP, 1994), its use varies widely with regions and even within farms. A study by Ruigu and Schulter (1990) also indicated that the amounts of fertilizers used were below levels recommended by Agricultural Research Centres. The reasons for the sub-optimal levels of fertilizer use are, however, not known. Thus, this study was formulated with three major objectives:

a) Describe the fertilizer use patterns among smallholder maize farmers in Western Kenya.

b) Identify the major determinants of fertilizer use among the same farmers.

c) Determine factors responsible for inter-farm differences in fertilizer use in maize.

In order to achieve these objectives, data were collected using a structured questionnaire over the 1995 main maize growing season. The study collected data on fertilizer use from a random sample of 40 farmers each from Kisii, Kakamega and Trans Nzoia Districts. Descriptive statistics and regression analyses were used to analyze the data. The following is a summary of the results and conclusions drawn.

Fertilizer use patterns and inter-farm differences in fertilizer use.

The descriptive analysis results indicated that fertilizer use in maize varied within the three districts studied according to resource base, liquidity position of the farmers, access to extension services and markets. The highest level of fertilizer nutrient use was 87.3 kg/ha in Trans Nzoia District while the lowest average was in Kisii District estimated at 35.5 kg/ha. The estimated mean amount of nutrient fertilizer use in Kakamega district was 54.3 kg/ha. The rates of use partly reflect the importance of maize as a commercial crop. In Trans Nzoia District and Lukuyani Division of Kakamega District, maize is grown as a commercial crop while it is grown for subsistence in the rest of Kakamega District but it is a semi commercial crop in Kisii District. Despite the differences in the rates of use, most farmers in these regions have tended to maintain the levels of fertilizer use over time partly because they believe that the amounts used are adequate and partly because of the perceived high fertilizer prices.

It was also shown that in the striga prone areas notably Khwisero and Mumias Divisions in Kakamega District, the weed impacts negatively on the rate of fertilizer use and growing of hybrid maize. This dual negative impact leads to low production of maize. If the striga infestation goes unchecked in the future, then these areas will become major maize deficit regions.

It is widely acknowledged that availability of credit enhances the liquidity position of farmers and hence increases the farmers' ability to purchase fertilizer and other complementary inputs. However, the study revealed that of the 120 farmers interviewed, none of them got institutional credit for maize production in 1995. Some of the reasons advanced by farmers for this failure included lack of knowledge of the credit facilities, lack of collateral and illegibility due to small farm sizes owned. The Agricultural Finance Corporation (AFC) requires a minimum of two hectares for a farmer to qualify for seasonal credit. Thus, it was not possible to determine the effect of credit on fertilizer use.

Determinants of fertilizer use.

The results of the regression analyses indicated that the fertilizer - maize price ratio was the only important determinant of fertilizer use which cut across all the three districts, though it was not highly significant in Trans Nzoia District. This finding reinforces the generally accepted notion in agricultural economics literature that the relative profitability of use of the input will enhance the adoption or use of inputs or new technology.

The study found a strong linear relationship between fertilizer use and total farm sales in Trans Nzoia district, a commercial maize dominant area. Thus, commercial maize farming is a major determinant of fertilizer use in Kenya.

The other important determinants of fertilizer use were use of FYM (α =0.01) in Kisii District, land size (α =0.1) in Kakamega District, initial soil fertility (α =0.1) in Trans-Nzoia District and extension contact (α = 0.1 and α = 0.01 respectively) in Kisii and Trans-Nzoia Districts. The use of Farm Yard Manure acts as a complementary input and therefore enhances fertilizer use particularly basal fertilizers. Land size influenced the use of fertilizer negatively in Kakamega District at 10 percent level of significance. The inverse relationship reflects a case where the use of land extensively acts as a substitute for fertilizers. The inherent soil fertility was insignificant at the 10 percent level in Kisii and Kakamega Districts. Statistically, this means that at the 10 percent level of significance there was no linear relationship between inherent soil fertility and rate of fertilizer use. However, inherent soil fertility significantly influenced the rate of fertilizer use inversely at 10 percent level of significance in Trans Nzoia District. The inverse relationship shows that inherent soil fertility reduces the rate of use of fertilizers. This is plausible because the higher the fertility level of the soil the less fertilizers are required to enhance fertility and vice versa. Extension contacts were found to influence the rate of fertilizer use positively indicating that availing information to farmers about the benefits realised from fertilizers can enhance its use.

In view of the expected findings that high fertilizer price and low maize price negatively affect fertilizer use among smallholder maize farmers, it could have been useful to estimate optimal fertilizer use levels for different maize price levels. However, such an analysis had been done by Mugunieri (1997).

5.2 Recommendations

The findings of this study indicated that a wide range of factors influenced the rate of fertilizer use and that the importance of these factors varied from place to place. This therefore means that efforts should be taken to understand the constraints farmers face in the use of the fertilizers and appropriate solutions specific to the region implemented if fertilizer use is to be enhanced. Specifically, the following recommendations are given;

a) Research should be intensified in an effort to improve agronomic practices, particularly striga control before any advances are made to farmers to use fertilizer in the affected areas.

b) Since the study revealed that at the 10 percent level of significance apart from prices, a number of nonprice factors such as extension contacts, farm size and FYM use, played a major role in fertilizer use by farmers, it is recommended that the government should strengthen the agricultural extension programme to ensure that the necessary information on fertilizer use in relation to these factors is timely made available to farmers in order to increase maize production.

c) It was also reported that the major reason by farmers for maintaining the usual rates of fertilizer use, was the high fertilizer cost. The fertilizer cost is a summation of the fertilizer purchase price and the transportation cost a farmer incurs. It was also revealed that the average distance covered by farmers to the fertilizer market in Western Kenya was 8.7 km. The state of most roads in the region is murram which are rendered near impassable during the rainy season. It is therefore recommended that the road network in the districts should be improved in order to minimise the fertilizer transportation cost and also ensure the timely supply of fertilizers to the remote areas of maize production.

d) Since farmers complained of strict AFC loan award criteria as a major reason for non use of formal credit, it is recommended that the AFC and other lending institutions should revise their credit elegibility criteria so as to make credit more available to farmers. It is anticipated that this will improve the liquidity position of the farmers and hopefully increase fertilizer use in maize production.

e) Research findings on why striga is not as prevalent in valley bottoms as opposed to the uplands can elucidate possible ways of striga control.

f) The study has shown that factors which determine the level of fertilizer use may be specific and therefore there is need to identify the factors which create constraints to fertilizer use for each particular region in order to formulate policies which can overcome them.

g) Finally, although this study has helped to explain the patterns and determinants of fertilizer use in maize, one has to recall, however, that not all aspects of the agricultural economic system have been considered (such as labour, topography, rainfall). It is therefore recommended that future studies should incorporate these additional factors in order to further improve our understanding of the system of fertilizer use by farmers.

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APPENDICES

Appendix 1: Computations for One-way Analysis of Variance for effect of location on fertilizer use (figures are in kg of nutrients).

Kisii	Kakamega	Trans Nzoia
32	27.5	61.3
36	60.3	79.9
53.5	19.3	80
80	41.8	40.0
36.5	19.3	112.5
80	0	96.3
32	13.8	0
32	61.0	66.3
3.3	0	80.0
24	4.5	80.0
19.3	0	29.0
16	25.8	76.3
23.3	32	160.3
31	0	250.0
33.5	0	133.0
45.5	106.8	0.0
17	12.8	139.3
19.5	29.3	112.5
26.5	0	112.5
42.8	80	135.0
20.3	0	21.5
20.3	0	190.0

37.5	0	132.0
10.5	0	87
8	0	112.5
16	0	18.5
16	0	57.5
16.1	40	112.5
28.4	0	32.3
2.5	40	16.3
44.5	112.8	32.5
32.5	178.5	112.5
114.8	195	0.0
61.8	122.5	80.0
9.5	175.5	112.5
95.5	217.5	157.3
38.8	145	142.0
11.3	106.8	95.3
32	156.8	107.3
41	148.8	26.3
Total 1341	2173.4	3490
Mean 35.5	54.3	87.3
$\sum x^2$ 68049.7	289417.2	423545.4
S 24.3	66.3	55.2
s^2 590.5	4395.7	3047

The following steps were followed:

a) Calculation of the mean rate of fertilizer use for each district.

Generally mean is given as

$$\frac{\sum X}{n} \ldots\ldots\ldots\ldots\ldots(1)$$

Thus for Kisii, mean = 1341/40 = 35.5; Kakamega, mean = 2173.4/40 = 54.3 and Trans Nzoia, mean = 3490/40 = 87.3

b) Calculate the Grand Mean is given by;

$$\bar{\bar{X}} = \frac{\sum\sum X_{ij}}{rc} = \frac{1341.0+2173.4+3490.0}{40(3)} = 58.4 \ldots\ldots\ldots(2)$$

where r= number of observations per sample, and c = number of samples.

c) Estimation of the variance from the variance between the means or columns.

$$\sigma^2 = \frac{\sigma_{\bar{X}}^2}{n} = r\frac{\sum(\bar{X}_j - \bar{\bar{X}})^2}{c-1} \ldots\ldots\ldots(3)$$

where;

$$\bar{X}_j,\ \bar{\bar{X}},\ r,\ c;$$

are the sample or column mean, the grand mean, the number of observations in each sample and the number of samples respectively.

From equation (3), σ^2 =[{(35.5-58.4)^2 + (54.3-48.4)^2 + (87.3-

58.4)^2} * 40]/ 2 = 27528.6

d) Estimation of population variance from within the samples or columns.

The individual district's population variance is estimated thus:

For Kisii,

$$S_1^2 = \sum \frac{(X_{i1}-\overline{X}_1)^2}{r-1} \text{........(4)}$$

which is equal to:

((32-35.5)^2 + (36.0 -35.5)^2 +...+ (32.0-35.5)^2 + (41.0 - 35.5)/(40-1) = 590.5

For Kakamega,

$$S_2^2 = \sum \frac{(X_{i2}-\overline{X}_2)^2}{r-1} \text{..........(5)}$$

which is equal to:

((27.5 -54.3)^2 + (60.3 - 54.3)^2 +...+ (156.8-54.3)^2 + (148.8 - 54.3)^2)/(40-1) = 4395.7

For Trans Nzoia

$$S_3^2 = \sum \frac{(X_{i3}-\overline{X}_3)^2}{r-1} \text{............(6)}$$

which is equal to:

((61.3 - 87.3)^2 + (79.9 - 87.3)^2 + ... + (107.3-87.3)^2 + (26.3- 87.3)^2 /(40-1) = 3047

The population variance $(\delta)^2$ is then given as the mean of the individual sample variances thus:

$$\delta^2 = (s_1^2 + s_2^2 + s_3^2)/c = (590.5 + 4395.7 + 3047.0)/3 = 2677.7$$

e) Calculation of the F ratio

F = (Variance between sample means/ Variance within sample means) = (27528.6 / 2677.7) = 10.28.

Appendix 2. BARTLETT TEST FOR HETEROSCEDASTICITY

<u>Procedure</u>

1. Estimate

$$S_g^2 = \left(\frac{1}{N_g}\right)\sum (Y_i - \overline{Y}_g)^2.$$

for each group of observations g = 1,2,...G. S^2_g is a consistent estimate of σ^2_g

2. Calculate the test statistic S:

$$S = -(N\log(\sum \frac{N_g}{N}S_g^2) - \sum N_g \log S_g^2)/1 + (1/3(G-1))(\sum \frac{1}{N_g} - \frac{1}{N}).$$

where: N = Observations available for regression model.

N_g = Number of observations associated with the g^{th} group

$\overline{Y_g}$ = *Mean of the sample values of Y within the $g^{(th)}$ group.*

(a) Bartlett test for Kisii District's Data (kg nutrients/ha).

	Keumbu	Nyamache	Nyacheki	Ogembo
1.	32.0	19.3	20.3	44.5
2.	36.0	16.0	20.3	32.5
3.	53.5	23.3	37.5	114.8
4.	80.0	31.0	10.5	61.8
5.	36.5	33.5	8.0	8.5
6.	80.0	45.5	16.0	95.5
7.	32.0	17.0	16.0	38.8
8.	32.0	19.5	16.1	11.3
9.	3.3	26.5	28.4	32.0
10.	24.0	42.8	2.5	41.0
S^2_g	519.7	99.9	90.5	1045.8

S = - 8.35

Under the null hypothesis that σ^2_i is constant, the test statistic S will follow the chi-square distribution with 3 degrees of freedom (Number of groups minus 1). At the 5 percent level of significance, the critical value of the chi-square is 7.81. Thus, we fail to reject the null hypothesis of homoscedasticity at the 5 percent level of significance.

(b) **Bartlett test for Kakamega District's Data (kg nutrients/ha).**

	Mumias	Shinyalu	Khwisero	Lukuyani
1.	27.5	0.0	0.0	112.8
2.	60.3	25.8	0.0	178.5
3.	19.3	32.0	0.0	195.0
4.	41.6	0.0	0.0	122.5
5.	19.3	0.0	0.0	175.5
6.	0.0	108.8	0.0	217.5
7.	13.6	12.8	0.0	145.0
8.	61.0	29.3	40.0	106.8
9.	0.0	0.0	0.0	156.8
10.	4.5	80.0	40.0	148.8
S^2_g	348.8	1261.5	256.0	1177.2

$S = -3.93$

Since the calculated S is less than the critical value (7.81), the null hypothesis of constant variance is not rejected at the 5 percent level of significance.

(c) **Bartlett test for Trans Nzoia District's Data (kg nutrients/ha).**

	Moto I & II	Mateket	Sirende	Kapomboi
1.	61.3	29.0	21.5	32.5
2.	79.8	76.3	190.0	112.5
3.	80.0	160.3	132.0	0.0
4	40.0	250.0	87.0	80.0
5.	112.5	133.0	112.5	112.5
6.	96.3	0.0	18.5	157.3
7.	0.0	139.3	57.5	142.0
8.	66.3	112.5	112.5	95.3
9.	80.0	112.5	32.3	107.3
10.	80.0	135.0	16.3	26.3
S^2_g	878.2	4372.2	3097.0	2401.9

$S = -2.62$

Like in (a) and (b) above, the calculated S was less than the critical value 7.81, hence the null hypothesis of homoscedasticity is not rejected at the 5 percent level of significance.

Appendix 3: Questionnaire

ECONOMICS OF FERTILIZER USE AMONG SMALLHOLDER MAIZE FARMERS IN KENYA

Enumerator's Name..................Date...........

1. **Farm Identification**

District ....   Division ....

Farm Number ....

2. **Farmer Identification**

2.1 Farmer's Name ....   Sex..........

Education level...................

2.2 Size of family ....

3. **Farm characteristics**

3.1 Size of farm ....(ha)

3.2 Crop Enterprises on the farm (1995).

	Enterprise	Purpose	Acres	Output/ acre	Total value (Ksh)
1					
2					
3					
4					

3.3 Livestock enterprises (1995)

	Livestock type	Number of animals	Output / animal	Total Value (Ksh.)
1				
2				
3				
4				
5				

3.4 (i) Do you have land title deed? Yes/No. If Yes, when did you receive it? ....(state year).

(ii) Of the following farm machinery which one(s) do you own? .... Tractor .....Plough .....Planter .....Sheller ......Knapsack sprayer (Tick as appropriate)

3.5. Specify off-farm activities the farmer is involved in (if any)

(i) ....

(ii) ....

(iii) ....

3.6 Maize Output Information:

(i) What was production last year ? ....bags

(ii) What was the area under maize last year ? .... ha

(iii) What was the price of maize last year ? .Ksh/bag

4. Field History

4.1 For maize grown in 1995 indicate size of each field

Field	ha
1	....
2	....
3	....
4	....

4.2 Are the fields owned or rented? If owned, go to 4.3. If rented, go to 4.9.

4.3 What activities have you been undertaking on these fields for the last 3 years?

Field	Season	1994	1993	1992
1	1st			
	2nd	-		
2	1st			
	2nd			
3	1st			
	2nd			
4	1st			
	2nd			

4.4. Did you use fertilizer in these maize fields last year ?
If yes, indicate.

Field	Season	Type	Quantity (Kg)
1	1st		
	2nd		
2	1st		
	2nd		
3	1st		
	2nd		
4	1st		
	2nd		

4.5. Did you apply organic manure on these fields last year ?
If yes, specify;

Field	Season	Type	Quantity
1	1st		
	2nd		
2	1st		
	2nd		
3	1st		
	2nd		
4	1st		
	2nd		

4.6 When did you first use fertilizer on maize? .... (year).

Have you since increased/reduced/maintained the fertilizer rate used? (Tick as appropriate)

If reduced/increased/maintained, state reasons

....

....

....

4.7. Have you undertaken any other cultural activity on these fields i.e. terracing, liming, etc? Y/N

If Yes, specify ;

Field	Activity	Reason
1		
2		
3		
4		

4.8. Specify any other problem you encounter on these fields,

....

....

....

....

4.9 Specify the years you have rented this field

....

....

....

4.10 What crops have you been growing on this field

Field	Years rented	season	Crops grown
1			
2			
3			
4			

4.11 Did you apply fertilizer on this field last year? Y/N (applicable only if rented last year), if yes, specify in table below

Field	Season	Fertilizer type	Quantity
1			
2			
3			
4			

4.12 Did you use organic manure on this field last year? Y/N (applicable only if rented last year), if yes specify in the table below;

Field	Season	Manure type	Quantity
1			
2			
3			
4			

4.13 What problems have you experienced on these rented fields;

....

....

....

....

5. **Information on maize production**

5.1 Which maize variety (ies) do you grow ?

Field	Variety (ies)
1	
2	
3	
4	

5.2 Do you grow pure stand or intercrop ? ....

If intercrop, specify

Field	Type of intercrop	hectareage(of inter-cropped area)
1		
2		
3		
4		

5.3 Did you use fertilizer for planting ? Y / N. If yes, specify in the table below:

Type of fertilizer used in planting.

Field		1	2	3	4
Fertilizer Type					
source	purchase d				
	stocked				
Cost of fertilizer					
Time applied					
Amount applied					
Method of application					

If N, give reasons for not using:

(I).......................................

(ii).....................................

(iii)....................................

(iv).....................................

5.4 Did you use Organic manure? Y/N

If yes, specify

Field	Type	Quantity
1		
2		
3		
4		

5.5 Top dressing:

(I) Do you topdress? Y/N

(ii) If yes specify :

Field	Fertilizer used	Cost of Fertilizer.	Amount of fertilizer used
1			
2			
3			
4			

(iii) Which method did you use in fertilizer Top-dressing?

....

(ie banding, along the rows, broadcasting, others-specify)

(iv) Why did you use the method you have mentioned in (iii) above?

tick

-It is the recommended method ....

-It is labour saving ....

-any other reason (specify)

....

....

....

....

6. **Fertilizer use information:**

6.1 Do you apply fertilizer to other crops on the farm?

Y/N

crop	fertilizer type	source	Reason for applying

6.2 If you don't apply fertilizer to all crops, what are your reasons for applying or not applying

....

....

....

....

....

6.3 Fertilizer source

	1991	1992	1993	1994	1995
Distance from farm (km)					
Cooperative					
Local Stockist					
KGGCU					
Middlemen at Farmgate (Neighbours)					
Open Market					
Other (specify)					

6.4 What is the state of the road tarmac/murram/other(specify)........................ (tick one applicable)

6.5 How much fare do you pay from here to where you purchase fertilizer?......................

6.6 What is the transport cost for fertilizer from your purchasing centre? specify in the table below;

Fertilizer bag size(Kg)	Cost of transport
10	
25	
50	
other	

6.7 Of the fertilizer packaging sizes, which one do you prefer to buy?

<u>Tick</u>

10Kg ....

25Kg ....

50Kg ....

any other(specify)...............................

6.8 Is the "right" package size normally available?

Yes/No

6.9 Give reasons for your answer in g above;

....

....

....

6.10 Have you ever got credit to purchase fertilizer?

Yes/No

If Yes, when? ....

source.................

rate of interest.................

If No, why? ....

....

....

If No, what are your sources of finance for maize production inputs such as fertilizer:

Crop sales..........

Livestock sales.....

Off-farm activities.........

Other.............

(specify)

6.11 How far is it from your home to the nearest market centre where there is a bank or AFC?

....................................Km.

6.12 What was the price of fertilizer this season ? Fill table as appropriate.

Type of fertilizer	Fertilizer bag size	Cost of the fertilizer

7. What constraints do you face in fertilizer use on maize?

Constraint	Rank eg 1,2,3,etc
(I) Fertilizer not available..........	
(ii) Right fertilizer package unavailable..........	
(iii) High price of fertilizer..............	
(iv) Lack of credit.................	
(v) Weather not good................	
(vi) Low price of maize..................	
(vii) Soil fertility adequate..........	
(viii) Labour availability	
(ix) Others	
(specify)...................................	
....	
....	
....	

8. Have you ever received extension advice on maize production? Yes/No..............

If yes, specify below;

Advice received		**Year and Season**
land preparation method.	....	....
type of seed to use.	....	....
type of fertilizer to use in planting	....	....
quantity of fertilizer to use.	....	....
fertilizer to use in top-dressing.	....	....
plant spacing	....	....

any other ....

9 **Manure Treatment**

How do you treat FYM before application in the field?

............applied fresh ....heaped out of boma to decompose before application ....continuous heaping until time of application..........direct dropping in field by livestock .... other.

10 If you had limited fertilizer, to which of the crops you grow could you apply the fertilizer to? .... (list them) and give reasons for your choice..............

....

11 If you had limited cash, where could you invest it in?

......Purchase of P fertilizer

......Purchase of N fertilizer

......Purchase of either of the above

......Purchase of hybrid Maize seed

......Purchase of other agrochemicals eg pesticides for stalk borer and rodent control

12 **Maize marketing information** (to be answered whether farmer has sold maize or not).

12.1 What was the price of one bag of maize? ....

12.2 Indicate where you have been selling your maize in the years indicated below;

	1991	1992	1993	1994	1995
Distance of market used from home for respective years					
N.C.P.B.					
Local market					
Middlemen at farmgate					
cooperative					
Other					

If Cooperative, Do they offer you credit to buy fertilizer ? Yes /No. If yes, do they give you fertilizer or cash ? ....

12.3 How do you transport your maize to the market?

.....Tractor/Truck; ......Cart/donkey; ......Bicycle

.......Head ;............Other.

12.4 State, if any, problems you face when marketing maize

(i)..................................

(ii)................................

(iii)................................