THE DIRECT AND INDIRECT EFFECTS OF ROAD IMPROVEMENT: A STUDY OF FERTILIZER USE AND POTATO YIELD IN KINANGOP DIVISION, NYANDARUA DISTRICT, KENYA

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DECLARATION

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

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ABSTRACT

A survey of a number of studies, both empirical and theoretical, indicates a close link between road improvement and agricultural change. Improved roads provide rural people with access to markets, goods and services that are crucial to the development process. Despite this awareness, there is little information on the nature, scope and measurement of this relationship. This study analyzes the direct and indirect effects of the improvement of roads on fertilizer use and potato yield in Kinangop Division, Nyandarua District, Kenya.

Kinangop is an agriculturally rich area. The area is characterized by very poor roads. This research was conceived to study what effects road improvement might have on farm productivity in the area. Road improvement was hypothesized to have direct effect on fertilizer use and indirect effect on potato yield. A sample of 168 households, or 1% of the total number of households estimated to be living in Kinangop in 1994 was randomly selected for study. Household and farm related data sets were collected using a structured questionnaire schedule.

The data was then subjected to partial and multivariate analyses. Results obtained indicate that the improvement on road quality and increase in market accessibility have significant effect on fertilizer use. Similarly, the use of fertilizer has a strong and significant effect on potato yield. Change in the quality of roads has no significant effect on potato yield. These findings

demonstrate that road quality influences potato yield through fertilizer use. Farmers in areas served by high quality roads applied more fertilizer per acre than those in areas served by medium and low quality roads. Changes in average potato yield are linked to fertilizer use.

The importance of this study is that it has for the first time attempted to integrate the qualitative and quantitative aspects of roads by combining physical distance with road quality or 'class' into a market accessibility index. Such an approach may have wider application in studying the developmental impact of improving other infrastructure components. Thus, the significance of this study derives from the perception that improving the quality of roads enhances market accessibility. The study demonstrates that the quality of the rural road network has a direct effect on fertilizer use and an indirect effect on potato yield. The results of the study suggest that improving the quality of a road can induce farmers to invest more on fertilizer. As a consequence of this, there will be growth in agricultural productivity, rural incomes and national food security will be safeguarded.

DEDICATION

This thesis is dedicated to my dear late grandmother, **Damaris Nditi Masili**, and my beloved late sister-in-law, **Sarah Omolo Ochieng'-Odero**, both who died under separate circumstances during 1995 while I was writing this report.

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CHAPTER ONE

INTRODUCTION

Roads are widely perceived as critical for the achievement of economic and social development (World Bank, 1994; 1995; Ahmed and Donovan, 1992; Odero, 1992; and Cook, 1991). Road improvement is a basic strategy for promoting rural development in Kenya. While progress has been made in providing a basic network of primary and secondary roads, maintenance has been slow leading to the deterioration of infrastructure and increasing difficulty in transportation. 'Poor' roads[1] make the cost of transport prohibitive limiting access to input and produce markets (Gaile and Ngau, 1995, 1996). Without an adequate supply of fertilizer, for example, there is little prospect of increasing farm yield beyond current threshold levels in developing countries.

While average fertilizer use in developing countries is rapidly increasing as a result of green revolution technologies, particularly in Asia (Bumb, 1989),[2] per acre fertilizer use in sub-Saharan Africa is still very low at 4.5 kg/acre (Schatz, 1996). Promoting fertilizer use in sub-Saharan African (SSA) countries is therefore necessary to increase agricultural output and raise the standards of living. This is particularly true in Kenya where agriculture provides the means of livelihood for over 85 percent of the total population. The agricultural sector accounted for about 30 percent of the total gross domestic product and over 50 percent of total export earnings in 1993 (Republic of Kenya, 1994). Another pivotal and probably the most significant role played by agriculture is the provision of food to a rapidly growing population expected to reach 35 million by the turn of the millennium, an additional 10 million people onto the current estimated figure of about 25 million (Republic of Kenya, 1986 and 1994).

Considering that only 7 percent of Kenya's total land area is agriculturally high potential — having adequate and reliable rainfall accompanied by good soils — the long-term growth in food and cash crop production can only be expected to depend greatly upon increased yield from land that is already cultivated. Currently, the production levels achieved by Kenyan farmers are very low compared to other countries. In potato production, for example, average yield in Kenya is 8 tons/ha while in Netherlands it is 46 tons/ha (Waweru and Kamau, 1996). One reason that explains such differences is the wide gap in use of agro-chemicals especially fertilizer.

1.1 The Research Problem

Following the pioneering work of Johannes H. von Thünen (1826) on agricultural land use modelling, farm-to-market distance has been used to explain the impact of market access on agricultural productivity (Antle, 1983; Subbarao, 1985; von Oppen, 1985; Barnes and Binswanger, 1986; Binswanger, Yang, Boweres and Mundlak, 1987; Ahmed and Hossain, 1990; and Njehia, 1994). The use of physical distance, however, is inadequate because it underplays the importance of the quality of a road. For example, Antle specified a Cobb-Douglas production function model where the productivity level depends on physical inputs, education, research and infrastructure variables. The infrastructure variable used by Antle, however, fails to capture information concerning the quality of roads. Although attempts have been made to capture the quality variable of roads by, for example, von Oppen *et al.*, 1985; Binswanger *et al.*, 1987; and Njehia, 1994, these have been limited to the use of 'percentages of paved roads', a measurable but, nonetheless, negligible part of the rural road network in most developing countries. This is particularly true in SAA region where the densities of paved roads are still very low (World Bank, 1994).

To address this inadequacy in the way road quality has been measured in the past, a road quality index was developed in this study based on the relative densities of five classes of roads.[3] This index was then used to analyze the effects of improving road quality on fertilizer use and potato yield in Kinangop. Thus, instead of simply using road densities, these are weighted by the quality factor and adjusted for farm-to-market distance to represent market 'accessibility'.[4] The relationships between improving road quality, on the one hand and fertilizer use and potato yield, on the other, are then examined and discussed.

1.2 Research Questions

Considering the supply side, an adequate and efficient fertilizer distribution is necessary to ensure an increase in fertilizer use. On the demand side, improving road quality will lead to increased use of fertilizers only if farmers can afford to purchase fertilizers. When transport is viewed as a cost of production, the problem translates into a cost minimization problem where farmers want to minimize the cost of transporting fertilizer to their farms. Therefore, the response (demand) for fertilizer is likely to vary when the conditions of supply change, for instance when the quality of the road network is 'improved'.[5]

Taking the demand for fertilizer as given and using a supply side approach, the following two questions were posed for investigation:

1. What is the effect of improving road quality on fertilizer use in rural Kenya? Precisely, what is the relationship between the quality of roads and the use of fertilizer among potato growers in Kinangop?
2. What is the effect of road quality on yield? Specifically, what is the relationship between road quality and potato yield in a cross-section of farmers in Kinangop?

1.3 The Objectives of the Study

The study had the following objectives-:

1. **To demonstrate the effects that improving road quality has on fertilizer use and potato yield by estimating the significance of such empirical relationships.**
2. **To recommend policies that address the role of road quality improvement in agricultural development.**

1.4 Research Hypothesis

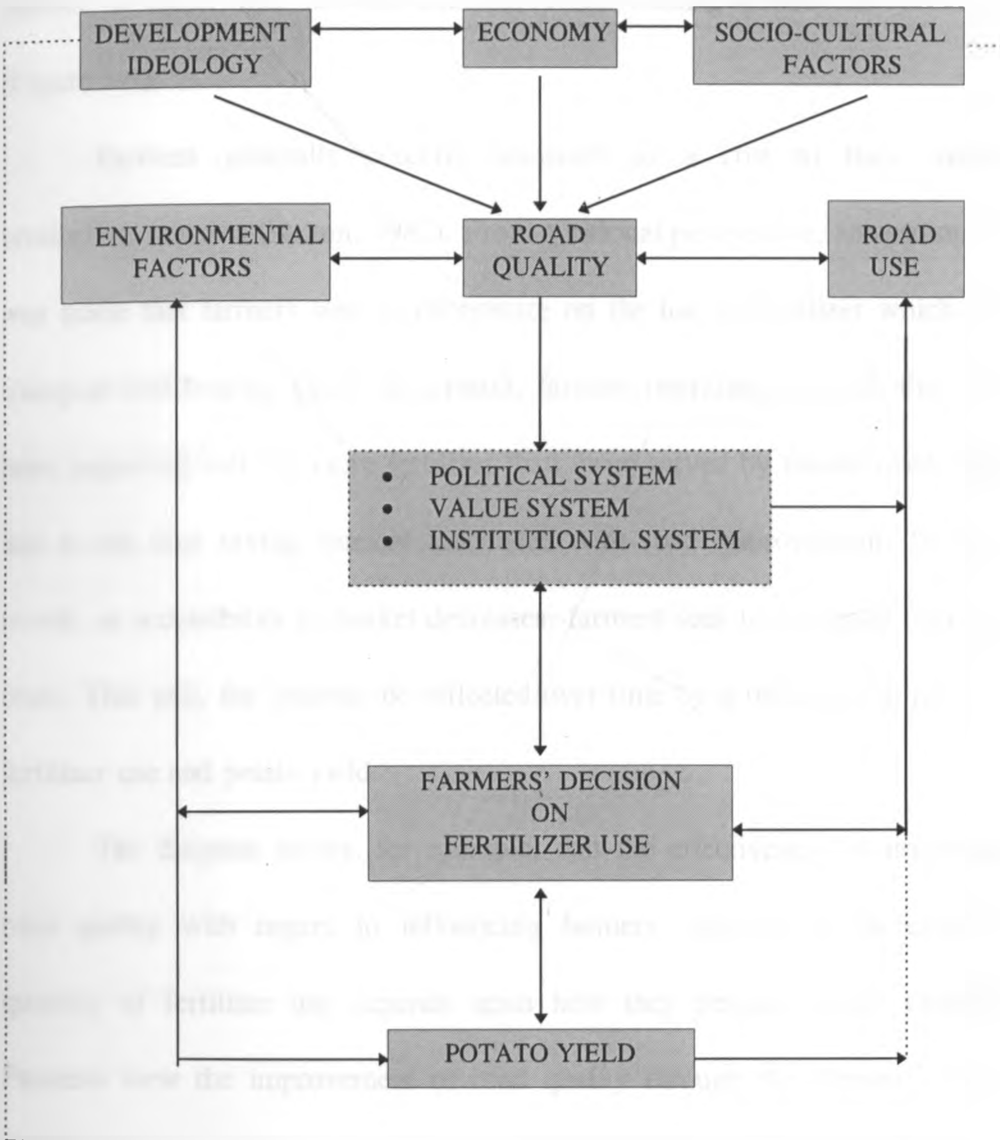
The hypothesis tested in this study is: per acre fertilizer use and potato yield vary significantly with improvements in road quality.

1.5 Theoretical Framework

In a broad sense, improving the quality of roads is influenced by social, economic and political circumstances. Per acre fertilizer use may also vary due to specific production conditions, agro-ecological and climatic circumstances, farmers' knowledge and their preference with regard to methods of farming and risk handling, differences in available information and habit formation, which might be influenced by research, education, extension service and industry (Desai, 1991; Agbola, 1990; Evans and Ngau, 1991; Asenso-Okyere, 1994; Mulagoli, 1995). These relationships are represented in Figure 1-1.

The economic and political environment is highly dynamic and open to external influence such as the effects of globalization. The dotted outer lines in Figure 1-1 is representative of an open system. The type and level of road services provided in an area, for example, the sitting of a road project, the size of the investment, as well as the determination of who benefits from such services are all the result of decisions made within a particular social, economic and political context. The perception of the actors, either as individuals or groups, regarding the effects of improving roads is equally important. These perceptions are constructed and re-constructed through interaction with the social, economic and political institutions. Kinship and peer groups, cooperative societies, markets, churches and political parties, are

Figure 1-1 A Model Showing the Link Between Road Quality Improvements, Fertilizer Use, Potato Yield and Other Factors



Source: Author

examples of institutional systems used by individuals and groups to construct ideology and consciousness.

Environmental factors such as soils, drainage and geomorphology also influence the surface conditions of a road at a particular time. With continuous use, the quality of roads deteriorate. Improvements are, therefore, intended to restore the quality of roads and enhance accessibility. Improvement or nonimprovement thus has an effect on the time-distance separating farm from market, a factor that farmers consider while making production decisions (Figure 1-1).

Farmers generally perceive transport as a cost to their overall production function (Button, 1982). From a rational perspective, an assumption was made that farmers seek to economize on the use of fertilizer which is a transport cost bearing input. As a result, farmers operating on roads that have been improved will use more fertilizer than those served by unimproved roads due to the cost saving element associated with road improvement. In other words, as accessibility to market decreases, farmers seek to minimize transport costs. This will, for instance be reflected over time by a reduction in per acre fertilizer use and potato yield.

The diagram shows, for example, that the effectiveness of improving road quality with regard to influencing farmers' decision to increase the quantity of fertilizer use depends upon how they perceive those changes. Farmers view the improvement of road quality through the "lenses" of the social, economic and political institutions which make up their "environment".

1.6 The Analytical Model

The theoretical framework discussed above neither replicates the real world nor does it totally neglect the crucial elements of reality. The assumptions on improving the quality of roads, fertilizer use and changes in potato yield are made on the premise that the actual amount of fertilizer used by farmers is an outcome of effective demand which in turn is met by efficient fertilizer supply and distribution systems (Desai, 1991). Accordingly, the dependent variable (potato yield) and independent variable (road quality) take the form shown in Figure 1-2. Road quality effects on potato yield are transmitted through the intervening test variable, fertilizer.

Figure 1-2 The Analytical Model

Road Quality ⟶ **Fertilizer Use** ⟶ **Potato Yield**
(Independent variable) (Intervening variable) (Dependent variable)

Source: Author

1.7 Research Methodology

1.7.1: The Study Area

Kinangop Division was selected as the study area because it epitomized the neglect of roads and the subsequent deterioration in their quality that has now become a common feature in most rural areas in Kenya. This meant that the lessons learnt in Kinangop by studying the effects of improving road quality could be applied in most other parts of the country where agriculture is still the dominant economic activity. Moreover, since road transport is often the only link between rural and urban areas, the pace of regional development in Kenya is partly due to the poor quality of roads.

Kinangop Division is endowed with fertile loamy volcanic soils and moderate-to-high precipitation averaging between 800 mm and 2200 mm per year. Due to the influence of the Aberdare Ranges, much of Kinangop is generally wet throughout the year. There are two main soil types in Kinangop, mountain and plateau. The 1989 population census reported 95,931 people living in Kinangop. The ratio of children between 0 to 14 years was estimated to be about 50 percent of the population. Adults form about 50 percent of the population. Majority of them are migrants from the neighbouring districts of Kiambu and Muranga.

Growing of potatoes, vegetables and livestock rearing are the main agricultural activities. The average farm-size is about 18 acres per household. As Table 1-1 shows, Kinangop has neither international nor national trunk road. Close to half (46.4 percent) of the total road network is made of special

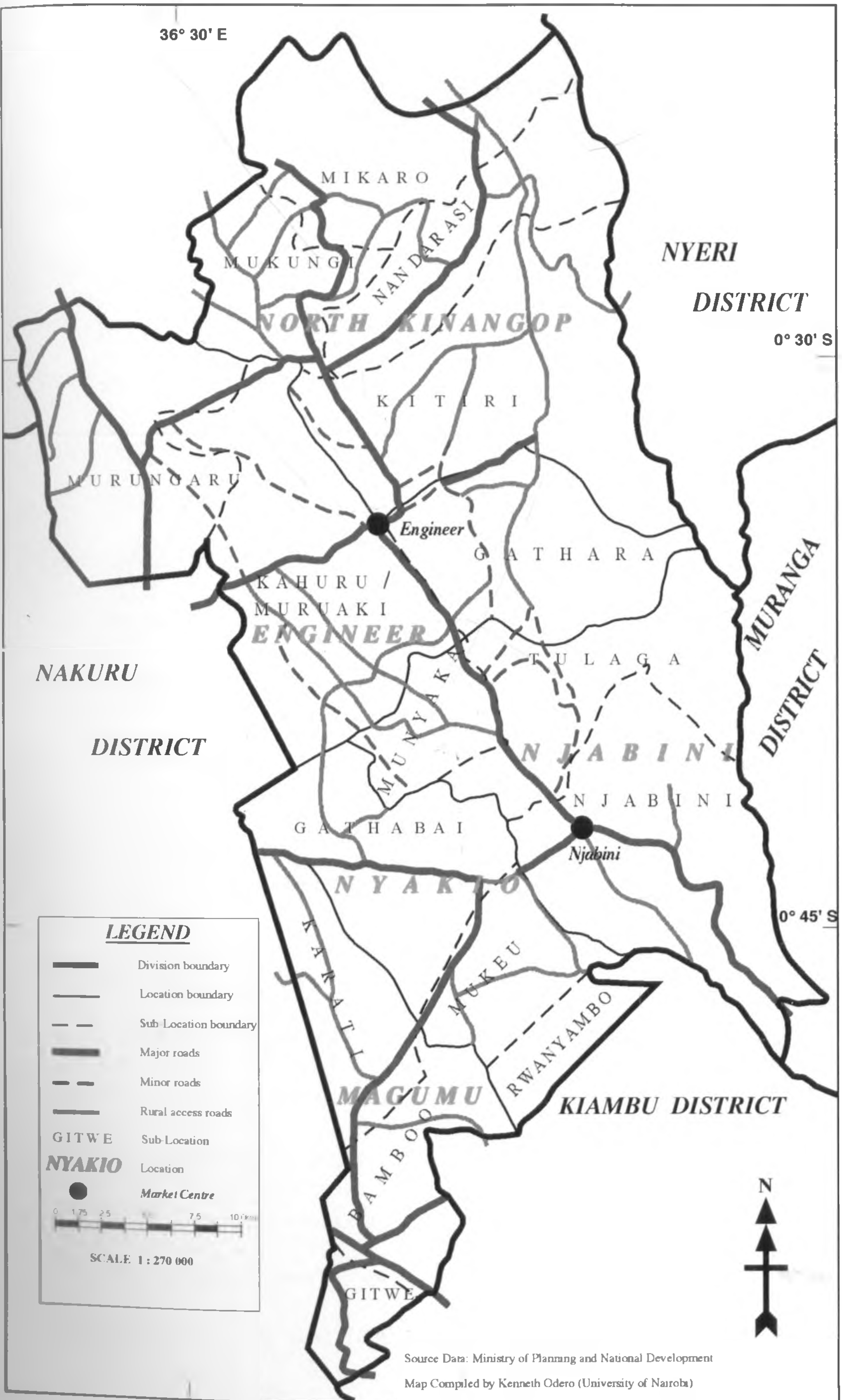
Table 1-1 Length of Road Network and Density by Road Class in Kinangop

Road Class	Length of Road (km)	Percentage of Total Road Length	Road Density (kms/sq. km)
A	0.0	N/A	N/A
B	0.0	N/A	N/A
C	43.0	24.1	0.05
D	28.5	15.9	0.03
E	24.1	13.5	0.03
F	45.3	25.4	0.05
RAR	37.5	21.0	0.04
Total	**178.4**	**100.0**	

Source: Field Survey.
Note: N/A - not applicable; * Rounded figure

purpose and rural access roads. Map 1-1 shows the road network in Kinangop Division.[6] Most of the roads in Kinangop are muddy and impassable during the months of March to May and August to November when rains are at their peak. Access to markets is consequently impaired.

MAP 1-1 KINANGOP DIVISION: ADMINISTRATIVE BOUNDARIES and ROAD NETWORK



1.7.2: Types and Sources of Data

Household and farm related data sets were collected using a structured questionnaire (Appendix A). The relevant information consisted of: age, sex, level of education and occupation; size of land owned and farmed by a household; farm inputs, output, output disposal; source of inputs; mode used to transport inputs to the farm; types and reasons for crops grown by farmers; access to agricultural extension and credit; land tenure; and land use.

Interviews were carried out between February and April 1995. Four enumerators were recruited locally within the study area and trained on how to apply the questionnaire and record the responses. The Ministries of Planning and National Development, Transport and Communication, Agriculture, Livestock and Marketing, and the Central Bureau of Statistics, were the main sources of secondary data. Published and unpublished records complement findings of the field survey.

1.7.3: Sampling

Kinangop Division has five administrative locations, namely, Njabini, North Kinangop, Magumu, Nyakio and Engineer. Each location has three sub-locations except North Kinangop that has four making a total of sixteen sub-locations (Map 1-1). For sampling purposes, the division was stratified into six zones on the basis of average annual rainfall and the road densities. Sub-locations receiving less than 1000 mm of rainfall per year were grouped together. Those which receive 1000 mm or more were grouped separately (Table 1-2).

Table 1-2 Stratification Criteria and Sampling Areas Selected

Road Density	Average Annual Rainfall (mm)	
	< 1000 mm	1000 mm +
Low	***Mikaro*** Gathabai	Rwanyambo ***Nandarasi***
Medium	***Karai*** Kitiri Murungaru	***Tulaga*** Bamboo Gathara
High	Mukeu Gitwe ***Kahuru/Muruaki***	Mkungi Munyaka ***Njabini***

Source: Field Survey.
Note: ***Mikaro*** - sampled sub-location.

Sub-locations falling in either group were assigned to one of the three road density categories — low, medium and high. Random sampling was done in each cell in Table 1-2. Six sub-locations, namely Mikaro, Nandarasi, Tulaga, Karati, Njabini and Kahuru/Muruaki were selected randomly. These are representative of the physiographic (rainfall) and road density conditions in Kinangop. While Njabini and Kahuru/Muruaki are the largest sub-locations, Karati sub-location is the smallest and most densely populated (Table 1-3).

Table 1-3 Area, Population Size and Density of Sampled Sub-Locations

Sub-location	Area (sq.km)	Total Population	Population Density	Number of Households	Sample Size
Njabini	96	13,588	142	2,300	53
Kahuru/Muruaki	96	12,703	133	1,731	40
Nandarasi	50	6,344	127	964	23
Karati	38	6,058	160	932	22
Tulaga	59	5,065	86	742	17
Mikaro	64	3,913	62	572	13
Total		**47,671**		**7,241**	**168**

Source: District Statistics Office, Nyandarua

1.7.3.1: ***Sample size.*** A sample of 168 households was randomly selected out of a total of 7,241 households in the sampled Sub-locations. The number of households per sub-location is shown in Table 1-3. The following formula adapted from Casley and Lury (1982) was used to determine the sample size.

$$n = \frac{K^2 \; R(100 - R)}{D^2} \qquad \text{..................................(1.1)}$$

where

n = sample size
K = constant associated with 95 percent confidence interval
R = estimated percentage of potato growers (results of the pre-test carried out in July and August 1994 showed that 87.5 percent of households in Kinangop grew potatoes)
D = error margin

When substituted the equation becomes

$$\frac{1.96^2 \times 87.5 \times 12.5}{5^2} = 168.1 \qquad \text{..................................(1.2)}$$

1.7.3.2: ***The sampling procedure.*** Prior to actual sampling, a sampling frame was identified. All the farms in each of the 6 sampling areas belong to at least one settlement scheme. The settlement schemes and sub-locations share similar names — Kahuru/Muruaki, Njabini, Tulaga, Mikaro, Karati and Nandarasi. A list was obtained from the Department of Settlement Office in Engineer numbering all plots in all the 6 settlement schemes (sub-locations). This list constituted the sampling frame.

Since the total sample size had been calculated, the proportion of households in each sub-location was used to determine the number of cases in each sampling area. The formula used is

$$\sum n_i = \frac{\sum h_j}{\sum H} \times 168 \qquad \text{...(1.3)}$$

where

$\sum n_i$ = the total number of cases in a sub-location
$\sum h_j$ = the total number of households in a sub-location
$\sum H$ = the total number of households in the 6 sampling areas

Equation 1-3 was used to derive the sub-sample in each sub-location. To identify the selected plots on the ground, maps showing plots in each sample area were obtained from the Provincial Survey Office in Nyeri. The maps were used to trace every plot selected from where interviews were conducted.

1.7.4: Data Analysis

An index based on the weighted densities of roads in various classes by sub-location was used in this study to measure road quality. The centrality of road quality in this study led to the choice of road classification and coverage as the basis for deriving the index. By integrating qualitative (road class) and quantitative (distance) aspects, the *road quality index* has the advantage of being a comprehensive indicator of the status of the road network.

Rural road improvements have profound socio-economic impacts. Some effects may be positive or negative, direct or indirect, temporary or sustainable (Cook, 1991). This makes the analysis of the relationships between variables very complex. It has been established, for example by Hussain (1993), that there are no suitable methods for studying the various aspects of the problem of measuring benefits accruing as a result of improving road quality. Due of this, a number of methodological approaches were used in exploring the nature of the data and in analyzing the effects of improving road quality and market accessibility on fertilizer use and potato yield.

To measure the effects of road quality variation on fertilizer use and yield, households grouped on the basis of the *road quality* and *market accessibility indices* were compared. A partial analysis approach was used to describe the changes in fertilizer use and potato yield under varying road quality conditions. To describe and interpret the data, various techniques that included frequency distribution, derived measures of central tendencies and variability were used. The results are presented in tables, graphs and charts to allow for easy interpretation.

As suggested by von Oppen *et al.*, (1985), when yield is expressed as a function of fertilizer use and road quality, a simultaneous equation arises. Improving the quality of roads has a direct effect on yield through cropping pattern allocation. It also has an indirect effect through input use. Likewise, the effect of using input on farm yield is a direct one. The three-stage least squares method has been used before to solve such simultaneous equations (for example Njehia, 1994).

In expressing fertilizer use and potato yield as a function of road quality improvements, this study likewise identified a simultaneous equation problem. In order to solve the equations specified in the model, this study, however, used the two-stage least squares (2SLS) estimator that was proposed by Zellner and Theil (1962). Use of this method allows for the simultaneous estimation of simultaneous equations. The 2SLS estimator also has advantage over the ordinary least squares (OLS) estimator because it enables separation of the direct from the indirect effects of road quality on yield. It also provides unbiased and consistent parameter estimates (Pindyck and Rubinfeld, 1991).

1.8 The Scope and Relevance of the Study

The study examined the relationship between road improvements, fertilizer use and potato yield in Kinangop Division, Nyandarua District, Kenya. Evidence was sought for observable changes in the average per acre fertilizer application in potato production and yield. Data was collected covering the crop year 1994. The results obtained are based on a cross-sectional analysis of variation in fertilizer use and potato yield among growers in Kinangop. By developing a road quality index and empirically measuring its effects on the dependent variables, this study contributes to the methodology of measuring road improvement benefits.

By focusing on potato production it was possible to come up with crop-specific policy recommendations relevant to the potato sector. Such recommendations are suitable for a country like Kenya. Small-scale agriculture in Kenya is dominated by producers growing several crop varieties from a single unit. Similarly, the range of fertilizers used in Kenya is equally broad. The model developed in this study which is premised on the response of a cross-section of potato growers in Kinangop toward improving road quality and, therefore, market accessibility, can be applied elsewhere in rural Kenya where the problems of poor transportation and sub-optimal use of resources are ubiquitous.

The policy choice in this study revolves around farmer's response when a constraint in fertilizer supply is lifted. This is relevant for agriculture and rural development policy given that the level of fertilizer use in Kenya and other sub-Saharan African countries is still very low (Schatz, 1996). Thus, by identifying policies which address constraints to growth in fertilizer use, the study contributes toward improvement in farm productivity and agricultural development.

It is possible to argue that causation goes the other way, i.e. increased yield generates demand for good roads. The cross-sectional research design adopted solves the problem of sequencing of development. Logically, potato yield is assumed to follow road improvements and, therefore, possible feedback effects are treated as occurring outside the scope of the research.

1.9 Structure of the Study Report

This report consists of six chapters. Chapter one covers the objectives of study, research questions, hypothesis, theoretical framework, methodology and scope of study. Various approaches and models linking transport and agricultural development are discussed in the second chapter dealing with the review of literature. Theoretical issues and policy concerns are examined and pertinent questions of cause and effect are explored. Chapter three provides a background of the study area. Presentation of the physical and demographic characteristics is followed by that of the agrarian background of Kinangop.

Results of partial analysis of the effects of road quality improvements on fertilizer use and potato yield are presented in chapter four. Chapter five in turn presents results of the multivariate analysis on the effects of road quality on fertilizer use and potato yield. Both the direct and indirect effects are discussed. In the final chapter, an attempt is made to formulate policy recommendations for Kenya's rural development process. Results from the analyses are used to answer the questions raised in the introductory chapter using the theoretical frame developed as the point of reference. Areas for possible further research are also suggested.

Notes on Chapter One

[1] *The quality of a road* can either be 'good', 'fair' or 'poor'. A nonpaved earth or gravel road is good when it needs only routine grading and spot repairs; fair when it needs reshaping or resurfacing (re-gravelling) and spot repair of drainage; poor when it needs reconstruction and major drainage works (World Bank, 1988).

[2] The total fertilizer use increased by 87 percent, from 37.8 million tons in 1979/80 to 70.8 million tons in 1992/93 with Asia contributing about 94 percent to this growth. In sub-Saharan Africa (SSA), fertilizer use increased from 0.7 million tons in 1979/80 to 1.2 million tons in 1988/89 and 1.5 million tons in 1992/93.

[3] *Primary Roads* ("Class C"), are supposed to link provincial important centres to each other or to higher class roads. Ideally, these are also supposed to be all weather roads and capable to take any type of traffic. *Secondary Roads* ("Class D"), link important centres to each other and higher class roads. Rural centres are supposed to be linked to the Primary Road network by Secondary roads or roads of higher classification. These are considered as 'access roads' in the rural areas connecting local markets. *Minor Roads* ("Class E"), link minor centres and are supposed to reach small resource areas. Ideally, each are in the rural setting is supposed to be at least a distance of 3.2 kms from a Class E road. This is considered as a convenient distance for accessibility. *Special Purpose Roads* ("Class F"), include tourist, township, agriculture, fish and strategic roads. Tourist, agriculture and fish roads are the ones usually referred to as "feeder roads" since they are connected with those particular project. *Rural Access Road* ("RAR"), is generally any road usually Class D and E, and in some cases Class C which is for general movement of people and goods, and connect nearly all important centres in the rural areas. "Access Roads" in this study are roads, other than the Class C, D, E and F that are under the Minor Roads Programme implemented by the Ministry of Transport and Communication.

[4] Access is defined by the *Oxford English Dictionary* as the ability to reach, visit or use. If there is no access to markets, farmers cannot buy inputs or sell their surplus crops. If they do not have access to information, they cannot learn of ways of improving either their skills or their productivity (Edmonds, *forthcoming*).

[5] As defined in the United Nations Road Maintenance Handbook, road quality 'improvement' has occurred when rehabilitation work involving selective repair, strengthening and shape correction of a roadway (including minor drainage improvements) to restore structural strength and ride quality is done. Road improvement also includes the betterment of width, alignment, curvature, or gradient of a road (including associated resurfacing and rehabilitation work) to improve traffic speed, safety and capacity (World Bank, 1990).

[6] When the Rural Access Roads Programme (RARP) was initiated in 1974, its objective was to improve priority rural roads that would provide all-weather access between high potential farming areas and market centres

CHAPTER TWO

LITERATURE REVIEW

2.1 Transport and Agricultural Land Use Models

There are three main theoretical approaches have dominated the study of transport and land use modelling during the last 40 years, namely the neoclassical, behavioural and structural perspective. These are discussed in the next three sections.

2.1.1: The Neoclassical Approach and Related Models

The *neoclassical approach* may be described as a positivist science which seeks to establish generalization and theories of spatial relations. Due to its emphasis on finding universally applicable theories, use of the neoclassical approach has resulted in land use models derived from deductive reasoning rather than empirical observation. Using a number of explicit assumptions, models developed under the neoclassical approach predict patterns of agriculture that should occur 'other things being equal'.

For example, von Thünen's agricultural land use model used an idealized agricultural region at the centre of which there is a single market-place where a large number of producers want to sell their products. Land is in the hands of a large number of landowners who are willing to rent their properties to the highest bidder, that is, to the producer who is willing to pay the highest rent. The other assumptions included in von Thünen's model are -:

1) The system under consideration is closed (isolated state) in the sense that there is no interaction with other regions, and that once equilibrium has been reached, no actors leave or enter the system.

2) Land is homogeneous in terms of fertility, productivity and transport costs, i.e. the cost of transport per unit of distance is constant in all directions.

3) There is only one market centre where all agricultural commodities are sold.

4) There is a large number of producers trying to maximize benefits, and a large number of landlords trying to maximize rent, hence, neither can individually control prices.

5) There is no cost involved when a producer or landlord decides to enter or leave the market.

Based on these assumptions, von Thünen analyzed the conditions of the land market for each individual producer. He argued that the form of land use which provides the greatest rent will make the highest bid for the land and thus displace all others.[1] Within this general theory, von Thünen developed two models. One, a crop model where there would be a zonal organization of crops around a market and, two an intensity model where land use intensity would decline with distance from the market. The concentric circle pattern was latter modified by the inclusion into the models of a navigable river and a minor market centre.

In studying the variation of potato yield in relation to fertilizer use that in turn is affected by road quality, this study comes closer to the intensification model. The framework represented in von Thünen's models is, however, better suited for analyzing an optimal location problem rather than a transportation problem such as is dealt with in this study. By looking at the relationship of a very limited number of factors and often using quantitative methods, the partial equilibrium models developed under the neoclassical perspective produce an optimal location and/or land use pattern where profits are maximized and/or costs minimized. Distance is assumed to be a predominant influence on human behaviour and spatial patterns can be accounted therefore by examining the relationship between distance and transport cost.

The use of the distance parameter alone in such analyses is not adequate. Transport costs, for example, are rarely exactly proportional to distance because of differences in road quality (Hide, Abaynayaka, Sayer and Wyatta, 1975). Moreover, the relationship between land rent and the other variables is, in reality, by no means linear. This shortcoming can apparently be remedied by introducing elasticity to replace the exogenously given demand function in von Thünen's model. Similarly, the assumption that the amount of land required to produce one unit of each commodity is fixed and exogenously determined can be remedied by introducing land demand functions (de la Barra, 1989).

The neoclassical approach exemplified in von Thünen's agricultural land use model suggests that the explanation of spatial patterns can be found from within the patterns themselves. Such an approach has been criticized for lacking real explanatory power (Healey and Ilbery, 1990). To overcome this problem, the effects of policy and socio-economic factors that define the institutional environment of potato producers have been analyzed in this study. This was done because of the shear impossibility to derive explanations from just within the descriptions themselves. The processes creating spatial variations in farm productivity are both internal *and* external to the actual patterns.

The assumptions of 'economic man', that *all* individuals are *perfectly* rational and *will always choose* the options that maximize their utilities, and that *all* individuals possess the *same* and *complete* knowledge, seem to be inconsistent with individual motives and behaviour in the real world. Individuals tend to have *part* and not complete information. They also tend to take many decisions based on economic *and* non-economic motives. Despite this weakness, the micro-economic models of land use take full advantage of consumer analysis and thus enjoy a sound theoretical basis. Because of this, the powerful abstraction of the micro-economic models which centre their analysis around individuals, classified as either consumers or suppliers, offer useful theoretical insight for understanding behaviour, but tend to have very little empirical content.[2]

Other specific criticisms of the neoclassical approach and the micro-economic models relate to their tendency to ignore the importance of history and the position of the firm within the total economic system, their apparent independence of cultural and behavioural reality and their mathematical tradition of continuous formulation, particularly in the way in which they treat space. Being essentially static, micro-economic models do not provide an easy access to empirical testing. This, however, does not mean that micro-economic models cannot be tested because they are formulated with continuous functions. Approximations can be constructed and tested, but they are bound to provide poor results (de la Barra, 1989). Their usefulness in empirical studies such as this one is, however, limited.

2.1.2: The Behavioural Approach and Related Models

The second perspective to inform this research is the *behavioural approach and related models*. Failure of the neoclassical approach, together with changes in the real world that seemed to defy the perfect competition thesis led to the adoption of behavioural approaches in the 1970s (Healey and Ilbery, 1990). Backed by inductive reasoning, behaviouralists considered the individual to be the main motive force in economic affairs and behaviour was inductively investigated in an attempt to discover generalizations. But unlike its neoclassical counterpart which was based on an idealized view of behaviour, behavioural approaches were centered on a wider range of variables including motives, values, preferences, perceptions and opinions.

Behaviouralism stresses the non-optimal behaviour of entrepreneurs and attempts to produce alternative theories to those based on 'economic man'. Entrepreneurs are assumed to have profit maximization *and* other goals. Consequently, attention is focused more on the process creating spatial variations in economic activity than on the actual pattern. For example, the main question facing potato farmers is how much to produce. The decision-making process is a major area of concern and a range of decision-making models and techniques have been formulated in agricultural and transportation studies. These models draw attention to two points concerning the location of economic activity and the distribution of land-use: 1) that decision-makers do not have perfect information when making their location choices, or perfect ability to use it; and 2) that conscious decisions are often made knowing that they are not optimal and that profits will not be maximized.

The behavioural approach argues that entrepreneurs may attempt to satisfy multiple goals other than profit-security, growth, risk minimization, self-preservation, and satisfaction. Alan Pred (1967 and 1969), for example, conceptualized the relationship between the amount of information available to decision-makers and the ability to use it in the form of a behavioural matrix. In the vertical axis of the matrix are the amount of information available while on the horizontal axis the ability to use that information. A farmer or entrepreneur's position in the horizontal axis will be influenced by such factors as size of holding, age, level of education, whereas on the vertical axis his or her position will, in part, be influenced by location, reflecting the importance of information flows.

Using the notion of 'satisficing'[3] behaviour, Pred recognized that it was possible to have entrepreneurs in different positions in the matrix having varying decisions and yet have two at the same position on the matrix reacting in contrasting ways to a given stimuli and thus making different decisions. In agriculture, for example, land-use patterns are likely to overlap in a disorderly way, distorting the distinct concentric pattern as envisaged by von Thünen (Healey and Ilbery, 1990).

The apparent conceptual power of the behavioural matrix has, unfortunately, not been matched by equally convincing empirical tests mainly due to the difficulty of accurately locating the cell in the matrix to which an entrepreneur belongs. Moreover, apart from knowing how information influences the behaviour of entrepreneurs, risk and uncertainty are other useful concepts that can enlighten the question of land use decisions as they help emphasize that entrepreneurs are unlikely to be optimizers and are more likely to be satisfisers.

Other than Pred's behavioural matrix, several models and techniques have been developed that stress the satisficing nature of economic behaviour (Mather, 1986; Gillmor, 1986; Ilbery, 1983; and Gasson, 1973). Most tend to include a number of distinct stages, including the stimulus, search, evaluation, and choice, and recognize that farming decisions are influenced by internal and external pressures and constraints. Mather (1986), for example, identifies eight factors which consciously or unconsciously affect land use decision-making. These are personality, ability, age, education, environmental perception, information and the nature of land unit and its wider cultural setting. Processes and objectives form the remaining components of Mather's model. Processes are depicted in a continuum ranging from conscious, rational ones to habitual, non-rational ones.

Other researches show that values vary with the type of farming practiced and the socio-economic characteristics of the farmers (Ilbery 1983 and 1985; Gillmor 1986; Healy and Ilbery, 1990). Although the above authors recommend that more research be done in different type of agricultural areas given the peculiarity in local conditions, nonetheless they warn of problems that are common to studies of decision-making processes in agriculture. It is argued, for example, that many of the factors affecting farmers' decisions are interrelated thus increasing the difficulty of isolating or measuring the importance of individual factors, especially at the aggregate level. A degree of circumspection is also required in the interpretation of questionnaire surveys which subjectively measure attitudes and motives. Lastly, it is difficult to examine the role of past decisions although it is recognized that the relationship between the past and the present influences agricultural decisions, especially as farmers tend to perpetuate family and area tradition. By focusing on a small area, therefore, the historical and geographical specificity of Kinangop became a meaningful part of the study.

In as much as behaviouralism provides an alternative perspective useful for the study of agricultural land use, it has not lived up to expectation with regard to explanation. Whereas it has highlighted the need to incorporate the motives of entrepreneurs into explanations of the changing patterns of economic activity, it has failed to solve the problem of poor explanation associated with neoclassical approaches. In focusing on *how* decisions are made as opposed to *why* they are made, behaviouralism has substituted descriptions for explanation thus becoming more or less a variant of neoclassical approaches.

Bunting and Guelke (1979) also note that behaviouralism places too much emphasis on the attitudes of individual entrepreneurs and too little on behaviour. Attitudes and behaviour are often erroneously assumed to be synonymous. According to Healy and Ilbery (1990), behavioural approaches are considerably varied in content that there is no generally accepted methodology. This has hindered the search for generalizations and the identification of strong empirical regularities in behaviour. Consequently, the development of theory has been slow.

Another criticism is that behaviouralism places a lot of emphasis on choice, taking much of the material world as given and examines how an individual operates within it. It is possible to explain how an individual acts only within the constraints they face. Decision environments are important as studies of agricultural land use and farmers in different areas have shown to emphasize different decision-making factors (Ilbery, 1985).

Lastly, in separating the farm from the broader environment, too much autonomy is afforded to factors at the farm level. This study avoids the pitfall of ignoring the wider processes operating in the economic system and society by recognizing the importance and uniqueness of the history of the study area. These "wider processes" relate to ideological factors, macro-economic factors and socio-cultural factors.

2.1.3: The Structuralist Approach

Structuralist approaches emphasize that relations external to the farm are crucial in understanding decision-making at the farm level. According to this theoretical perspective, space is what an economy makes of it and the economic landscape is the product of the overall structure of the economic system in which individual decision-makers operate. Structuralism thus adopts a more holistic approach than behaviouralism and argues that behaviour is constrained by wider social, political, and economic processes. This suggests that parts cannot be considered independently of whole. For example, culture rather than individual values and ideas, are the main determinants of behaviour (Healey and Ilbery, 1990).

Structuralists believe that a crucial factor in the development of any spatial structure is the way in which surplus capital is circulated, concentrated, and utilized in space (Johnston, 1987). In parallel with neoclassical theories, the search for profits is central to the structural approach. However, the similarities do not proceed any further as the non-assuming structuralists concentrate on explaining real world behaviour rather than with prediction. They argue that neoclassical and behavioural theories *cannot* explain spatial behaviour or account for changes in such behaviour. This is because the major decision-making processes are not contained within the patterns themselves, but in the processes.[4]

The theoretical orientation of the structuralist approach is empirically translated into a realist approach. The latter recognizes that individuals make choices within the constraints set by economic processes. Realism aims to explain the causes of events instead of seeking regularities or generalizations. It is argued for instance, that the study of causation is not dependent on the number of times an event occurs. Rather, it requires intensive research programmes which examine how causal processes work out in a particular case or cases (Johnston, 1987; and Sayer and Morgan, 1985). Intensive research, therefore, works on the basis that a national policy in agriculture, for example, can produce very different effects in different areas because of the way the factor in question is articulated in those locations in relation to other factors (Massey, 1985).

In spite of its strengths, structuralism is criticized of over-emphasizing macro-economic aspects therefore squeezing out of the picture the world of lived-experience (Johnston, 1987). Little attention has been devoted to real events in specific places and in specific times. Secondly, structuralists have been criticized by Duncan and Ley (1982) of being opposed to the idea of sovereign decision-makers, and individuals within a particular social class are assumed to behave in a standardized manner. Consequently, structuralism is thought of being deterministic (Healey and Ilbery, 1990).

Lastly, in assuming that all individual behaviour is determined by larger structures, the importance of local variations in economic behaviour at the level of the individual farm is ignored. Structuralism has been criticized (Healey and Ilbery, 1990), therefore, of being a one-sided analysis where attention is focused on constraints and choices are left to take care of themselves. By recognizing that people make choices within a set of constraints, this study has integrated the aspect of realism in its methodology.

It is implied by the above review of theoretical literature that there is no single ideal approach. Each one of the approaches reviewed has strengths and weaknesses. In this study therefore, it was decided to use the strengths from each of the neoclassical, behavioural and structuralist approaches. This resulted in the theoretical framework diagramatically represented in Figure 1-1. Rather than, for example, analyze the spatial pattern *per se*, as proposed by the neoclassical approaches, this study instead pays attention to decision-making processes related to potato production that are likely to be triggered when road quality is improved. Such an approach offers scope for a more complete conceptualization of space and tends to strengthen the arguments linking roads and agricultural productivity. Following the structuralist tradition, the socio-economic and political context of potato production in Kinangop is recognized. Factors such as the characteristics of farm households, the institutional and policy environment within which production, exchange and consumption are made and patterns of resource endowment are all analyzed in the study.

2.2 The Link Between Road Improvement and Development

Cook (1991) lists more than ten separate socio-economic effects that road improvements can produce in rural areas. Some impacts may be positive or negative, others beneficial or disruptive, temporary or sustainable. Due to the indirect nature of such effects, however, most models of development have come up with explanations of growth and development that imply a strategic but often 'hidden' role of roads.

One of the most incisive treatment of the concept of development is Dudley Seers (1972) seminal paper 'The meaning of development'. Seers considered declining poverty, unemployment and inequality, adequate education levels, freedom of speech, and citizenship of a nation that is truly independent, both economically and politically to be indispensable requirements of development. This study focuses on a specific effect without loosing sight of the broader impacts of road improvements.

Most studies done in the 1960's on the effects of road improvements (Bonney, 1964; Jones, 1964; and Jones and Orr, 1966) were informed by the modernization paradigm. These studies concentrated on production as the main economic benefit to road improvements. Increased business activity, agricultural and forest production were the major effects considered. Hardly any mention of social, political and environmental consequences was made. In spite of being narrowly focused these studies stimulated discussion about conditions that either favour or discourage road-induced growth. Out of this debate came the notion that prior dynamism together with economic potential are preconditions for a successful transport investment (Wilson, 1973).

Local conditions are important considerations in determining the impact of roads on communities. The construction of a road in one region of Papua New Guinea stimulated village gardening, new estate production of rubber, copra, cattle and timber milling, teak production, large-scale poultry farming and the growing of European vegetables (Ward, 1970). In another region, an ex-post study of the impact of roads found little evidence of much change having occurred in the marketable agricultural production (Bouchard, 1972). Because of the location specificity of road improvement effects, it is not easy to generalize from the results of isolated studies.

Where physical, economic and institutional conditions are favourable, it can be expected that improving roads will have greater effect on agricultural productivity than would otherwise be the case. Some of the "conditions" cited in literature that favour positive road improvement effects include availability of complementary services such as technical advice; the presence of a co-operative marketing organization; access to information, inputs, credit and non-farm income; existence of profitable markets and institutions that favour efficient land management (Lunning and Sterkenburg, 1973; World Bank, 1974; Blair, 1978; Hamilton, 1980; Idachaba, 1987; Evans and Ngau, 1991; and Gaile and Ngau 1995).

Uphoff and Ilchman (1972) argue that certain conditions are necessary for positive road quality effects to be realized. Equity in the distribution of factors of production such as land, investment in complementary infrastructure services such as technical, financial and marketing support targeted primarily at the small-to-medium-scale farmers, regional integration of market centres and access to profitable markets are examples of such conditions. The latter are particularly essential if fertilizer is to be made available to farmers in the correct quantity, at the right time, place and price.

Other conditions include efficiently organized flow of resources, an increment of factor endowment and the exercise of entrepreneurship. Availability of complementary and coordinated public policies and programmes in agricultural extension, education, health services and other sectors is another imperative. These are hardly the only requirements. Enhancing the intellectual, economic, political and social enfranchisement of farm households through increased possession and utilization of resources can also enhance the effects of road improvements (Friedmann, 1992).

Empowering poor farmers is a pre-condition for equalization of exchange of resources between partners. Equality in the exchange of resources significantly depends on the relative bargaining power of the parties involved in such transaction. The distribution of social, economic and political power is also thought to be critical in realizing productivity growth (Friedmann, 1992). Social distribution of resources and individual access to those resources is interdependent and necessary for raising productivity.

Aggregate productivity depends on individual productivity and the latter cannot be increased without raising people's economic, social, political and intellectual resources.

Several empirical studies support the assertion linking road improvements with socio-economic, political and environmental change (Chang, 1989; Al-Alwan, 1991; Njehia, 1994). The building of a road creates conditions that favour extended link between local and regional markets. Such an extension can contribute to increased productivity in two ways. It can allow resources to be put to more productive uses. There can also be a greater provision of productive factors because of the increased opportunity for beneficial exchange. This is possible if such integration does not result in enclave development (Uphoff and Ilchman, 1972).

Unchecked linkage can result in 'urban bias' where according to Lipton (1988), resources from the rural economy are expropriated and invested in non-profit making urban ventures thus generating a downward spiral of the rural economy. Lipton further argues that, while there is evidence that the diffusion of high yielding varieties of wheat and maize transformed agricultural productivity in India and Philippines, the balance of forces that emerged during growth did not help to strengthen the impoverished rural labourers and farmers. And according to Korten and Klauss (1984), the assumption that increased production would automatically translate into increased benefits for people was at best, ill founded.

2.3 Relevance of the Social and Political Context

In Kenya, the post-independence development ideology favoured equitable growth. However, by increasingly acquiring a class character, the state became an instrument mainly serving the interests of the affluent and, often, urban-based propertied class. Through the siphoning of resources from the rural to the urban economy, a lopsided, urban biased unequal development of infrastructure resulted (Lipton,1988). The problem of poor road services in rural areas must, therefore, find some explanation in the ideological or class character of the Kenyan state (Oyugi, 1995).

At the level of the social structure, ethnicity is a major mediating factor in the allocation of state resources and this influences the provision of services. Under the regime of President Kenyatta, the Kikuyu were a favoured group (Leonard, 1984). Under Moi's regime, budget allocation for new roads have increasingly favoured the ethno-regional bases of the President (Barkan and Chege, 1989). Political patronage on the basis of socio-political preferences leads to inter-regional *and* intra-regional disparities in the provision of services (Kanyinga, 1995 and Oyugi, 1995). Thus the socio-political and economic context in which road improvements are promoted has a direct bearing on the quality of the road and who uses it. Growing inequity is associated with benefits derived from better market access due to improved roads. An area with a more equitable distribution of land is likely to have a better spread of the gains accruing from road improvements. Moreover, the conversion of potential fertilizer use to effective fertilizer demand depends on the behavioural and institutional processes behind these services. Farmers who have good access to agro-service centres are more efficient producers than those with poor access (Njehia, 1994 and Oyeleye, 1994).

Improvement of roads potentially reduces the time and cost of obtaining information about the availability and productivity of resources, and transferring those resources from the marketplace to the farm. Improved roads pattern resource flows by linking farms to markets thus providing incentives for entrepreneurs to increase their activity and to employ and generate more resources. Sustained increase in farm productivity requires a growth in endowment of factors of production.

Thus, the role that road improvements play in facilitating efficient use of fertilizer and increase in potato yield in an area is largely specific to the location. It depends on the initial conditions with respect to agro-economic variables, farmers' response to incentives, as well as the behavioural and institutional variables behind the processes that establish and geographically expand fertilizer distribution and marketing systems.

2.4 Kenya's Macro-Economic Environment

During the first decade after independence Kenya's economic growth rate was remarkable. Between 1964 and 1973 the GDP grew at average annual growth rate of 6.6 percent (Republic of Kenya, 1997). However, the oil shocks of 1973/74 and the world recession beginning in the mid-1970s robbed the economy of its vitality. Economic growth slowed, increased borrowing created a heavy external debt burden, agricultural output declined while population continued to grow by around 3.8 percent annually (Republic of Kenya, 1974; 1979; 1984; 1986; 1989; 1994; and 1997a). The pressure exerted by these factors forced attention back to the purely neo-liberal economic policy.

By mid-1980s, Kenya needed serious structural reform to stabilize the economy and improve balance of payment. A series of reforms including the introduction of realistic exchange rates, improved incentives for agricultural production and adjustments in the trade regime accompanied by promotion of exports have since been made (Republic of Kenya, 1997a). If farmers are to take advantage of reforms in agriculture and other productive sectors and respond positively, they must have a dependable infrastructural support such as a robust road system. It is against this sort of policy background that the present study was conceptualized.

2.5 Rural Transport Policy and Agricultural Development

Kenya's rural development policy aims to increase food production, generate employment and improve the standard of living. The transport sector — particularly roads — is a key to unleashing the potential for increased production and income. Rural roads play a particularly important role in Kenya where agriculture accounted for 30 percent of Kenya's total gross domestic product and over 50 percent of its total export earnings in 1993 (Republic of Kenya, 1994). For an essentially agrarian economy, rural roads are obviously important. The road transport policies pursued by Kenya, however, have largely been ineffective and unsustainable. Specifically, the major constraints affecting the road sector are: uncoordinated planning; inadequate funding; difficulties in the execution of road works; nonavailability of equipment; inappropriate staff utilization, training and motivation; pavement overloading by heavy goods vehicles; an inadequate planning framework; and lack of coordination amongst donors (Republic of Kenya, 1997b). Prior to the 1990s, for example, efforts to improve the operation and maintenance of roads concentrated on strengthening management of roads, improving user-charging policies, and increasing allocation for road maintenance. Apart from lacking a comprehensive vision, these initiatives focused on technical rather that institutional solutions, and were generally implemented in a piecemeal fashion (World Bank, 1995).

Notes on Chapter Two

[1] William Alonso (1964) calls this bid price — the gap between revenue and costs is economic rent in the technical sense and becomes rent paid to the landlord in the ordinary sense. The rent of any location depends on the amount produced and on the price obtained in the market. The rent or surplus to the producer of a single commodity *m* at point *j*, S_j^m, will depend on the amount produced and on the price obtained in the market-place, and can be calculated by the formula

$$S_j = q^m (p^m - c^m - k^m d_{ij}) \quad \text{...(2.1)}$$

where q^m is the amount of commodity *m* produced per unit of land; p^m is the price per unit of commodity *m* at the market-place; c^m is the cost of production of one unit of commodity *m*; k^m is the cost of transport of one unit of commodity *m*; and d_{ij} is the distance from *j* to the market-place *i*. The basic von Thünen model remains the most general preposition because it equilibrates not only a land market, but a market of commodities as well (de la Barra, 1989).

[2] There are three possible reasons for this according to de la Barra (1989): 1) the restrictions imposed by use of linear or loglinear econometric techniques; 2) the treatment of space as a continuous variable which makes it impossible to represent the variety and richness of the urban and regional geography; 3) the practical difficulty of modelling individual behaviour of household or firms and landowners due to their large numbers.

[3] The term satisficing is, perhaps, best taken to mean the level of profit that an entrepreneur can reasonably expect given his or her knowledge and ability (Healey and Illbery, 1990). As used in the literature, the satisficer concept suggests that entrepreneurs will do the best they can on the basis of the information they acquire.

[4] A distinguishing feature of structuralism is its preoccupation with macro socio-economic and political processes which underlie spatial patterns of economic activity. Accordingly, it argues that explanations must not be sought neither can they be obtained solely through an empirical study of the economic sectors. Instead there is need to examine the general *structures* or *processes* which underpin the economic pattern.

CHAPTER THREE

BACKGROUND TO THE STUDY AREA

3.1 Physical Location

Kinangop Division of Nyandarua District lies between latitudes 0^0 17' 20"S 0^0 55"S and longitudes 36^0 22'E and 36^0 41'E (Map 1-1). Its western boundary runs along Nyairoko river, a tributary of Malewa river to the north and the Nyandarua-Nakuru District boundary to the south. The scarps of the Aberdare Range approximately mark the eastern limit and Nyeri-Nyandarua District boundary is the limit to the north-east. Kijabe Hill marks the southern tip while the northern limit is along the Naivasha-Nyeri road.

Administratively, Kinangop Division is divided into five locations namely, Njabini, North Kinangop, Magumu, Nyakio and Engineer. Each location has three sub-locations except North Kinangop that has four. This makes a total of 16 sub-locations in the Division. North Kinangop Location is the largest location with a total of 257 sq. kms. It is followed by Engineer Location (231 km^2), Njabini Location (179 km^2), Nyakio Location (109 km^2) and Magumu Location (92 km^2).

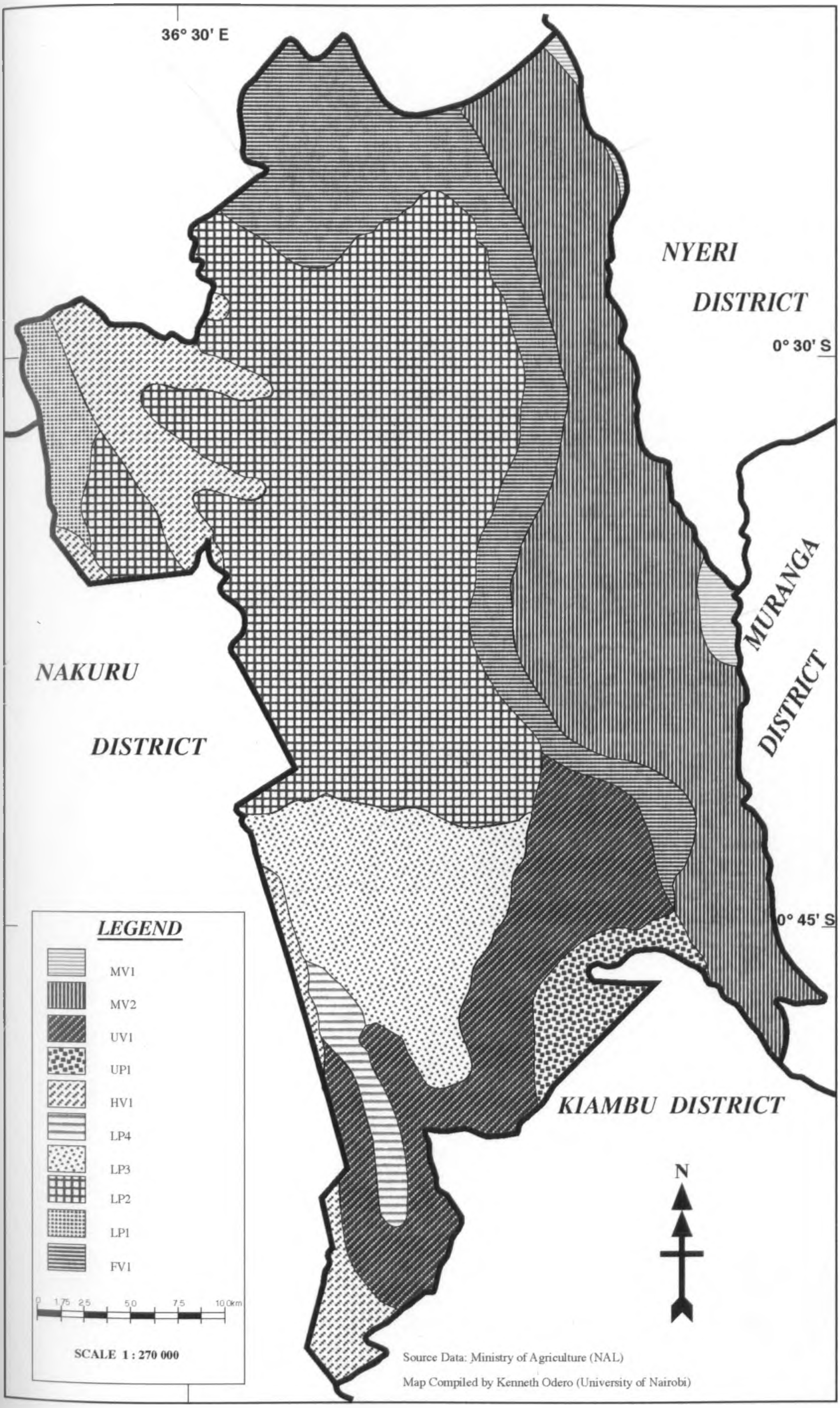
3.2 Topography and Soils

The topographic and soil conditions in Kinangop are varied ranging from the mountainous and well drained to the low-lying, poorly drained swampy areas. The physiographic features that beget the topography and soils in the area include mountain/major scarps, hills/minor scarps, plateaus/high-level structural plains, upper/middle/lower level uplands, and minor valleys. The distribution of soils and their characteristics are summarized in Map 2-1 and Table 3-1.

Agricultural potential in the Division differs by soil and climatic conditions. There are three main agro-ecological zones in Kinangop. They are the Tropical Alpine, Upper Highland and Lower Highland agro-ecological zones (Map 3-1). These zones present opportunities for various types of agricultural land use. High altitude, abundant rainfall and fertile soils in the Upper Highland Zone, for example, provide a suitable environment for sheep rearing, dairy farming, potato growing and horticultural production. In the Lower Highland Zone crops grown include potatoes, wheat, maize, barley, peas, rapeseed and horticultural products. Livestock is important in this zone and merino sheep are reared as well.

According to the District Development Plan for 1994-96 (Republic of Kenya, 1994), about 1.3 percent of the land area in Kinangop is categorized as cattle-sheep-barley (LH4) agro-ecological zone. Wheat/maize-barley (LH3) zone makes up 0.6 percent of the total land area and 48 percent is wheat-barley (UH3) agro-ecological zone. Pyrethrum-wheat (UH2) zone is the second largest (37 percent) while sheep and dairy (UH1) zone cover 12 percent of the total land area of Kinangop. While soil is, on one hand, an asset in the process of agricultural production, it is a liability on the other. Combined with topography, the soils in Kinangop present a major obstacle to road transport.

MAP 2-1 SOIL TYPES



MAP 3-1 : AGRICULTURAL LAND USES

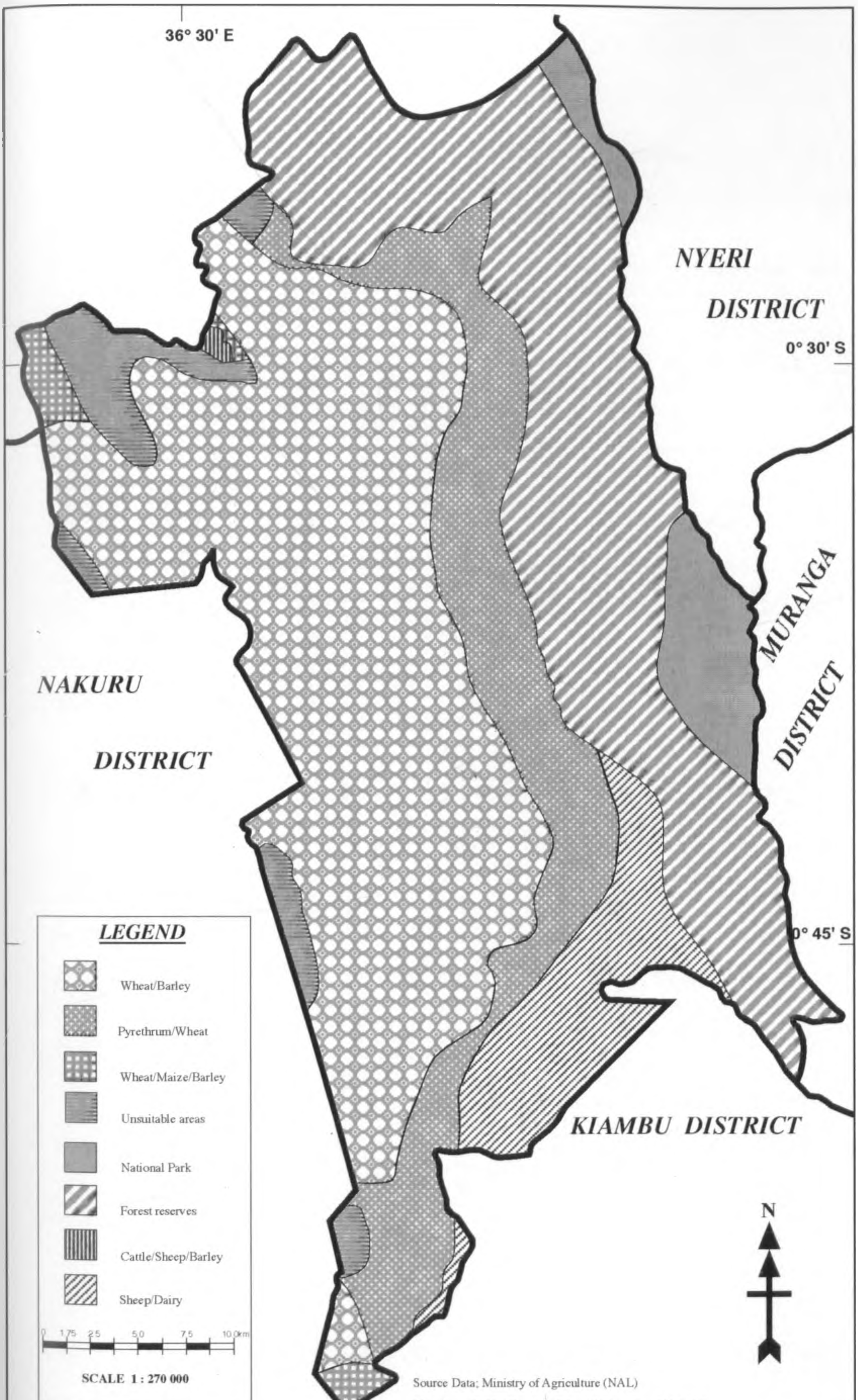


Table 3-1 Legend to the Soil Map of Kinangop

SOIL TYPE	SOIL PHYSIOLOGY	SOIL LITHOLOGY	SOIL DESCRIPTION
MV1	Mountains and Major Scarps	Undifferentiated or various Igneous Rocks	Perfectly drained, shallow to moderate deep, dark greyish, brown very friable, acid humic to peaty, loam to clay loam, with rock outcrop and ice in the highest parts. Distric HISTOSOLS, lithic phase; with LITHOSOLS and rock outcrops.
MV2	Mountains and Major Scarps	Undifferentiated or various Igneous Rocks	Well drained, very deep, dark reddish brown to dark brown, very friable and very smeary, clay loam to clay, with a thick acid humic topsoil; in places shallow to moderately deep and rocky. Humic ANDOSOLS, partly lithic phase.
HV1	Hills and Minor Scarps	Undifferentiated or various Igneous Rocks	Well drained, shallow, dark reddish brown, minor strongly calcareous, bouldery or stony, loam to clay loam; in many saline places. LITHOSOLS; with calcic XEROSOLS, lithic, bouldery and saline phase and rock outcrops.
LP1	Plateau & High Level Structural Plains	Pyroclastic Rocks	Well drained, moderately deep to very deep, dark brown, high level friable and slightly smeary, clay loam to clay; with a humic topsoil. Ando-luvic PHAEOZEMS.
LP2	Plateau & High Level Structural Plains	Pyroclastic Rocks	Perfectly drained, deep, very dark greyish brown, mottled, firm clay, abruptly underlying a thick topsoil of friable silty clay loam. Distric and eutric PLANOSOLS.
LP3	Plateau & High Level Structural Plains	Pyroclastic Rocks	Poorly drained, deep, very dark greyish brown, mottled, very firm clay underlying 30-45 cm of silty clay loam to clay loam. Distric PLANOSOLS.
LP4	Plateau & High Level Structural Plains	Pyroclastic Rocks	Poorly drained, deep, very dark greyish brown to very dark grey, mottled, slightly sodic, very firm clay, abruptly underlying 25-45 cm of silt loam to clay loam. Solodic PLANOSOLS.
UP1	Uplands, Upper, Middle & Lower Levels	Pyroclastic Rocks	Well drained, very deep, dark reddish brown to dark brown, very friable and smeary, silty clay loam, with a humic topsoil. Mollic ANDOSOLS.
UV1	Uplands, Upper, Middle & Lower Levels	Undifferentiated Rocks	Well drained, deep-to-very deep, dark reddish brown to very dark greyish brown, friable and slightly smeary clay, with a humic topsoil. Ando-luvic PHAEOZEMS.
FV1	Footslopes	Undifferentiated or various Igneous Rocks	Well drained, deep-to-very deep, reddish brown, friable clay, with an acidic humic top soil. Ando-humic ACRISOLS.

Source: Fertilizer Use Recommendation Project (Phase I), Final Report Annex III Vol. 19, Nyandarua District (Ministry of Agriculture, 1989).

Plateau soils (LP3 and LP4) are poorly drained sticky clays that are very difficult to travel. Trucks stuck in mud are a common site on most roads in

Kinangop. Similarly, hilly terrain is the main source of transport difficulties in areas otherwise traversed by the well drained mountainous soils.

In other places the dominant soils are deep and imperfectly-to-poorly drained. The poor drainage is explained by the soil and topographical conditions. Such soils are made of firm-to-very firm clay that can be extremely sticky when wet. Even where the soils are well drained and deep-to-very deep, the smeary nature of the friable-to-very friable soils in such areas coupled with the mountainous character of the topography still makes road transport a nightmare for several months in a year.

3.3 Rainfall

Average annual rainfall in Kinangop ranges from 800 mm to 2200 mm diminishing from east to west. The rainfall regime is shown in Map 4-1. Rainfall amounts are as varied as the topography. The central and western parts of Kinangop lie in the rain shadow of the Aberdare Range. Most of the rain falls in two seasons. The long rainy season occurs between April and May while the short rains fall between October and November (Table 3-2).

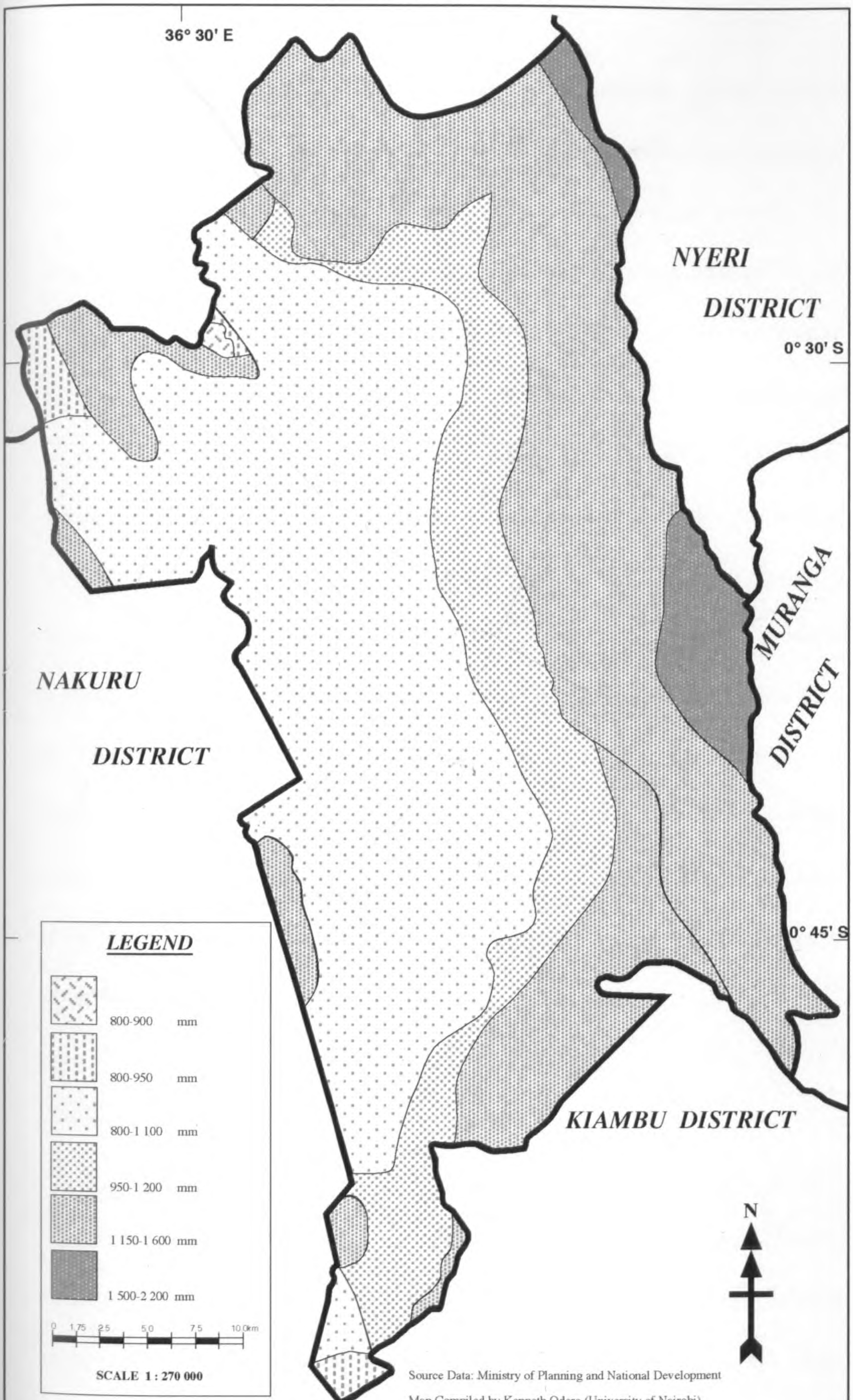
Table 3-2 Average Monthly Rainfall (mm) in Kinangop

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
Average Monthly Rainfall (mm)	43	53	85	163	155	108	75	89	103	95	89	69	1114

Source: E.A. Meteorological Department, Station No.9 036 025

Rainfall reliability limits agro-humid periods because of variability. It is

MAP 4-1 AVERAGE ANNUAL RAINFALL



more reliable on the Kinangop plateau decreasing eastwards. Rising easterly winds disrupt the two rainfall maxima and inhibit cultivation of permanent crops. There is sufficient rain or mist during most of the other months. The humid period normally lasts from March to about December or January.

The main agro-climatic problem in Kinangop is the low night temperatures. Cold air generated during clear nights on the moorlands of the Aberdare Range flows down to the Kinangop Plateau causing night frosts almost every month of the year. In the western parts of the plateau, further away from the Aberdare Range, where valleys give an outlet to this cold stream of air, some months are free from frost however. The minimum temperatures can be so low that even the vegetative growth of the potato crop is affected. Ground temperatures can go down to 3.5^{0}C, lower than the recorded air temperatures at a height of 1.5 meters in a weather nut. While such low temperatures may not necessarily affect potato production, it most certainly does negatively affect other crops like maize. In general, it tends to be suitable for wheat growing.

3.4 Road Network

As the expected rainfall in four (4) out of five (5) years ranges between 1000 mm on the eastern side to 800 mm on the western parts of the Division, there is considerable damage to the road network each year. Whenever it rains most roads are impassable due to their unpaved condition and little maintenance. This has a negative effect on agriculture which is the main source of livelihood for people living in the area.

To cope with transport difficulties, farmers have to be selective over the mode of transport to use. Bicycle is the most commonly used mode of transport in Kinangop (Table 3-3). It is used to transport fertilizer by over three-fifth of the households interviewed. This can be explained by the fact that bicycles are less costly to buy and to maintain than most other conventional modes of transport especially motorized ones. Bicycles are also robust and adaptable to poor road conditions than motor vehicles.

Table 3-3 Modes Used to Transport Fertilizer

Mode	Frequencies	Percentages
Bicycle	97	65
Matatu	31	21
Foot	17	11
Lorry	3	2
Wheel Barrow	2	1
Total	**150**	**100**

Sources: Field Survey.
Note : Nonresponses are excluded from calculations; Total % rounded to nearest digit.
'Matatu' is Swahili for mini bus transport

About 21 percent of households use *matatu* as a mode for transporting fertilizer while 11 percent transport fertilizer on foot using head and back loading. Very few (3 percent) use lorry or wheel barrow to transport fertilizer. Lorries tend to be expensive given the low quantities, in absolute terms, of input use by smallholders. This means that they have a higher transport cost per unit. A wheel barrow is cumbersome to push over a long distance and is perhaps only suitable for short distances, say from the main-road to the farm.

3.5 Population

Table 3-4 Actual and Projected Population, Kinangop Division

Administrative Areas	Square Kilometers	Actual Population (1989)		Projected Population (1994)	
		Total	Density	Total	Density
Tulaga Sub-location	59	4,201	71	5,065	86
Munyaka	24	3,515	146	4,238	177
Njabini	96	11,274	117	13,588	142
Njabini Location	**179**	**18,990**	**106**	**22,891**	**128**
Kitiri Sub-location	105	8,218	78	9,906	95
Mukungi	38	3,813	100	4,539	121
Nandarasi	50	5,263	105	6,344	127
Mikaro	64	3,245	51	3,913	62
N.Kinangop Location	**257**	**20,539**	**80**	**24,761**	**97**
Bamboo Sub-location	40	5,706	143	6,878	172
Karati	38	5,026	132	6,058	160
Gitwe	14	2,796	200	3,372	241
Magumu Location	**92**	**13,528**	**147**	**16,308**	**178**
Gathabai Sub-location	62	5,503	89	6,634	107
Rwanyambo	17	5,529	325	6,667	393
Mukeu	30	7,222	241	8,704	271
Nyakio Location	**109**	**18,254**	**167**	**22,005**	**202**
Gathara Sub-location	61	6,094	100	7,346	121
Kahuru/Muruaki	96	10,540	110	12,703	133
Murungaru	74	7,986	108	9,627	131
Engineer Location	**231**	**24,620**	**107**	**29,676**	**129**
Kinangop Division	**868**	**95,931**	**111**	**115,598**	**134**

Sources: Central Bureau of Statistics; Own Computations.
Note: A growth rate of 3.8% was used for the projections.

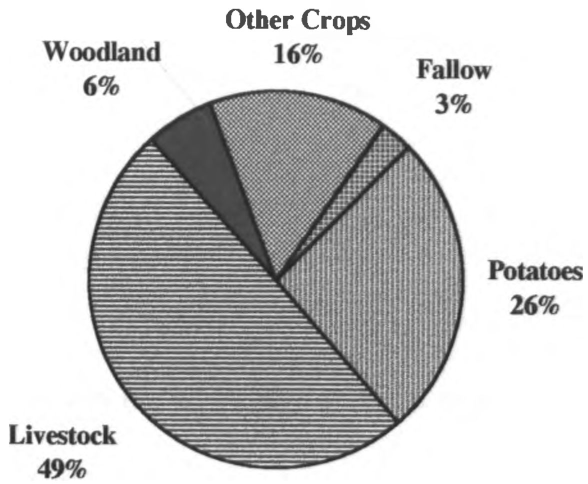
In 1989, Kinangop Division had a population of 95,931 people. Out of this Engineer Location had 25.7 percent of the total population in the Division, followed by North Kinangop Location (21.4 percent), Njabini Location (19.8 percent), Nyakio Location (19 percent) and Magumu Location (14.1 percent). In the projection for 1994, the Division was estimated to have 115,598 people. The corresponding total populations as well as population densities, both for individual sub-locations and for locations are shown in Table 3-4.

Using population statistics obtained at the Nyandarua District Statistics Office derived from the 1989 Population Census, the projection was made with an annual growth rate of 3.8 percent. In terms of population density, Kinangop was estimated to have 134 persons per square kilometer. Nyakio Location was estimated to be the most densely populated having about 202 persons per square kilometer. The least densely populated was North Kinangop (97 per sq. km).

3.6 Agriculture

Mixed farming is widely practiced in Kinangop. Farming is done for commercial and subsistence reasons. The main enterprises are livestock, potatoes, maize and vegetables. Less frequently grown are pyrethrum, wheat or barley and fodder crops. Potato is the most common enterprise on farms in Kinangop after livestock. Out of 168 farmers interviewed 165 (98%) grew potatoes in 1994. The findings of this study suggest that potatoes occupy a large share of land area compared to other crops. Specifically, the study found out that 26% of the total land operated by households in 1994 was under potato crop (Figure 3-1).

Figure 3-1 Land Use Distribution in Kinangop



Source: Field Survey.

The distribution of land among various enterprises shows a household's preference in land allocation. The use to which a particular piece of land is put is, of course, dependent on agro-ecological factors. Under each of the four agro-ecological zones in Kinangop, it is possible to have at least two enterprises. The proportion of land allocated to a particular type of enterprise is, therefore, partly due to individual preference.

The average farm-size in Kinangop is 18.24 acres per household. As shown in Table 3-5, close to 67 percent of the households own less than 20 acres of land each. Out of these, some 29 percent have less than 5 acres and 19 percent have 30 or more acres. Such a distribution can have important implications on farm productivity. Examples from other developing countries suggest that in small-sized farms, production is mostly geared toward intensive

Table 3-5 Farm-Size Distribution in Kinangop

Farm Size (Acres)	Frequency	Percentage
0.01 - 5.0	59	29.2
5.01 - 10.0	26	15.5
10.01 - 15.0	18	10.7
15.01 - 20.0	19	11.3
20.01 - 25.0	11	6.5
25.01 - 30.0	14	8.3
30.01 +	31	18.5

Source: Field Survey.

use of land through the application of yield enhancing technologies (Hayami and Ruttan, 1971).

3.6.1: The Potato Production Process

In a majority of farms in Kinangop, the potato production process starts with land preparation involving hoeing followed by ridging. Harrowing of the land before ridging can be avoided by first planting maize or beans on the plot. About 35 percent of potato growers in Kinangop practice mix-cropping while the rest planted potato in pure stand. Earthing of potatoes is done after the plants have started tuberation, usually during the second month after planting and is a subsidiary operation to weeding. Weeding is to protect the crop against competition for available nutrients and moisture largely depends on the weather conditions and availability of labour (Mbogoh, 1976).

Potatoes grow best at altitudes of between 1800 meters and 2200 meters which makes Kinangop naturally suited for it cultivation. At such high altitude, potatoes take about 3.5 months to mature. This makes it possible to produce two crops[1] of potatoes in a year and obtain more carbohydrates per unit of land from potato production (Acland, 1971). According to the International Potato Centre (IPC), potato tubers contain high quality protein and substantial amount of essential vitamins, minerals and trace elements. The potato provides more nutritious food from less land, less time, and often from adverse conditions than most other crops.

Another important consideration in potato production is labour. Potato is labour intensive during production and therefore the availability of household (and hired labour) is a key variable in the potato production process. Use of labour for potato production in Kinangop in farms in various size categories is shown in Table 3-6. The use of labour per acre of potato declines, albeit not uniformly with increasing farm size.[2] Farms measuring 5 acres or less on average used 2.73 adult labourers (both farm and hired labour) per acre of potato grown. Farms in the 20.01 to 25 acres category on average used the least, 1 adult per acre of potato.

Table 3-6 Use of Labour by Farm-Size

Farm-Size (Acres)	Number of Households	Percentage of Sample Households in Category	Actual Potato Acreage	Use of Adult Labour[1] (Person Per Acre of Potato)
5.0 or less	46	27	110	2.7
5.01 - 10.0	27	16	111	1.7
10.01 - 15.0	20	12	82	2.2
15.01 - 20.0	18	11	121	1.4
20.01 - 25.0	10	6	108	1.0
25.01 - 30.0	15	9	97	1.3
30.01 +	30	19	216	1.5
Total	**168**	**100**	**845**	

Source: Field Survey.
Notes: 1 = Adult family members working on farm plus adult hired labour.

Fertilizer and/or manure application follows land preparation. Trials done by the National Agricultural Research Laboratories (NARL) show that the soils in Kinangop are deficient in phosphorous. As a consequence, phosphates (P_2O_5) are the recommended fertilizers for potato growing in Kinangop. As Table 3-7 shows, double ammonium phosphate (DAP) is used by 73 percent of the households and manure by 41 percent of the households.

Table 3-7 Use of Purchased Inputs by Potato Growers

Type of Purchased Input	Percentage of Sampled Households Using Input Type	Average Quantity Used Per Acre of Potatoes
Potato Seed	84	260 kgs
DAP Fertilizer	73	40 kgs
Farmyard Manure	41	251 kgs
Insecticides	5	5 kgs
Fungicides	15	-
Herbicides	1	2 lts
Others	1	1

Source: Field Survey.

Potato seed and farmyard manure which are used by 84 percent and 41 percent of farm households in Kinangop are the bulkiest purchased inputs used in potato production. On average 260 kg of purchased potato seed and 251 kg of farmyard manure is used per acre of potatoes (Table 3-7). But, unlike fertilizer these are normally purchased from neighbouring farms which means that even though they are bulky, they are relatively more readily available and therefore their use is less influenced by the quality of roads. On the other hand, fertilizer which is used by 73 percent of the sampled households is purchased at designated market centres away from the farms. Thus, from a transport point of view, the use of fertilizer is more likely to be influenced by road quality than for instance potato seed and/or manure.

Harvesting and grading is the last operation. The current yield of 32 bags per acre is only 50 percent of the optimum yield level of 66 bags per acre.[3] During harvest potato is graded into three grades. Grade 1 are the large sized potatoes, grade 2 the medium sized and grade 3 the smallest ones. Traders who transport potatoes mainly to Nairobi employ young men (locally known as 'brokers') as agents. The brokers are given empty gunny bags to distribute to farmers according to individual needs and are informed of the current producer prices (*Kenya Times,* May 8 1987). The brokers are the intermediary between producers and buyers. They also wield enormous power as they control the potato business at the grassroots.

3.7 Agrarian Change in Kinangop: A Historical Perspective

The dynamics of agrarian change in Kinangop is closely linked with the broader social transformations that occurred in Kenya during the colonial and post-colonial period. The colonial land policy that instituted European settlements in the Kenyan highlands, for example, was responsible for creating artificial inequalities in land distribution. Land was alienated from the African population and allocated to settlers (Sorrenson, 1968; Leys, 1975; van Zwanenberg, 1975; Kitching, 1980; and Leo, 1985).

The settlers' appropriation of land redefined the channels of accessing land. Markets rather than social relations increasingly became the means of gaining access to productive resources under the colonial jurisprudence. This transformation led to serious social, economic and political conflicts culminating in the armed liberation struggle (Mau Mau). According to eyewitness account (Kikoyo, 1979), some of the battles were fought in the Kinangop area. As a result, a number of half-hearted policy reforms were started by the colonial administration to try and appease the Africans. The 'reforms' set out in the *Swynnerton Plan* of 1954 and the land settlement schemes initiated in the 1960s are examples of such efforts. According to Kanyinga (1996), these efforts were only meant to serve the vested interest of the ruling minority.

Before 1954, the primary concern of the colonial government was the development of European agriculture. Settler farmers were supported through various services such as extension and credit. African agriculture was developed to the extent that it was not competing with the interests of the European sector (Heyer, 1974). The spread of commercial agriculture created markets for the factors of production — land, labour, capital and technology. Once these 'markets' for farming inputs and produce were established, various political interests representing small- and large-scale farmers, traders, and merchants inevitably came into conflict as they competed for state-mediated allocation of resources. In the process, the colonial state was instrumental, and by no means neutral in managing this conflict (Ng'ethe and Odero, 1994).

The establishment of settlement schemes to resettle landless Africans was not a panacea for the issues of land distribution (Berry, 1993). Problems relating to land continued to dominate politics in Kinangop long after independence (*Weekly Review*, March 17 1975). Over the years, issues about the provision of public services such as roads have also gained importance (*Weekly Review*, October 9 1992). This is taken to mean that the benefits of state initiated programmes such as the provision of services, have not spread wide enough even within Central Province that received the lion's share of public investment in the immediate post-independence period.[4] According to Oyugi (1995), the dominant position of Central Province can be explained partly by the "unintended consequences of self-help participation" and also by the relative "political good will" and therefore material advantage (p.136).

3.8 Provision of Agricultural Services

The role of the government as the provider of agricultural services has been diminishing with increasing visibility of the private sector particularly in the late 1980s and 1990s (Semboja and Ole Therkildsen, 1995). Throughout the 1980s and 1990s, expenditure on agriculture as a percentage of total government expenditure has declined. Between 1980 and 1987, for example, the expenditure share was 8 percent falling to 5.2 percent between 1993 and 1995 (Republic of Kenya, 1997). Notwithstanding the shrinking budget, the government (both during colonial and independence period) remains the single most important provider of agricultural services to farmers.

Under the colonial government service provision was biased in favour of the dominant non-African settler farmers. Because they were relatively fewer in number (Odingo, 1971)[5] and perhaps better organized (Ng'ethe and Odero, 1994), the large-scale commercial settler farmers had easier access to services. They had, for example, access to good roads which, due to low utilization and low maintenance cost were often passable. This ensured easy accessibility to input and produce markets. Contact between settler farmers and extension workers was also regular, not only because of good roads, but due to the low extension worker-farmer ratio.

Land resettlement in Kinangop during the periods preceding and after independence led to a rapid increase in population in the area. From the early 1960 onwards, one farm after another was converted into settlement schemes until large-scale farms virtually disappeared. By 1967, the total area of 210,000 acres in Kinangop area had been divided into 17 individual schemes comprising high medium and low density plots (Republic of Kenya, 1967). Initially, subdivision of former large-scale farms into medium- and small-sized farms and the resettlement exercise led to the increase in population density.[6] Natural population growth and further migration led to more subdivision. This was made possible by the policy of registering freehold title on land whereby land became commoditized and was freely exchanged on the basis of willing buyer-willing seller.

These changes had two important implications. One, smallholder farming became a significant feature and, with time, the dominant mode of agricultural production in the area. This meant, therefore, that the government had to re-orient its service delivery approach to meet the demands of the new environment. While the unit cost of delivering some services such as extension and roads, among others, might have been reduced by the new settlement pattern, it also meant that the available resources had to be shared among a bigger group of farmers. This partly explains why the quality of services has declined over the years. Reduced government budget during Structural Adjustment, coupled with bad policies and misdirected priorities have to some extent led to the current inefficiencies in delivering agricultural services.

Farmers' response to these changes has been varied. There has been, for instance a noticeable inclination toward the production of horticultural crops that, to a large extent, have been spared from price and other controls imposed by the state. These include potatoes and all kinds of vegetable.[7] Although agro-ecological condition is a major factor influencing which kinds of crops can or cannot be grown in a particular area, in Kinangop farmers seem to have seized the opportunities made possible through free participation in production to diversify agricultural output in the area. Many farmers have turned away from 'traditional' crops such as pyrethrum in order to go into horticulture which has become a popular alternative because it bring fair prices and immediate returns (Dijkstra, 1997). This means, therefore, that the various kinds of inputs and services demanded by farmers have also been changing over time.

3.8.1: Agricultural Inputs with Emphasis on Fertilizer

The major inputs marketed in Kinangop include fertilizers, improved seeds, livestock feeds, drugs and chemicals, farm machinery and tools. This is done by private enterprises, government parastatals, and co-operative societies. During the colonial period, the availability and use of fertilizers was confined to large-scale farms that were advantaged in accessing inputs (Ng'ethe and Odero, 1994). At independence in 1963, the government established a working party to determine the problems of fertilizer availability and use by smallholder African farmers. The main constraints were identified as poor distribution and unaffordable prices (Amukoa, 1996).

A fertilizer subsidy was consequently introduced. The Kenya Farmers Association (KFA) and a number of other private stocking agencies were licensed to handle the importation and distribution of fertilizers (ibid). Between 1963 and 1973, fertilizer materials were imported and distributed in time. As Amukoa (1996) has suggested, this was perhaps due to the stable foreign exchange regime that prevailed at the time. However, there was some disquiet in the policy making circles of unfair trade practices in the fertilizer sector. Consequently, the government moved to restrict KFA's control over the fertilizer trade (KFA, 1971). Although there was a significant increase in fertilizer use at the time, there was little evidence that consumption among smallholders had increased.

In 1972, a government-appointed Working Party charged that KFA was using monopoly power to inflate fertilizer prices. This was further complicated by the oil crisis of 1973. This caused an increase in fertilizer prices. Local supply dwindled causing serious shortages in the market due to the high cost of importation. Consequently, the government took the following measures to stem the crisis. 1) It set price controls affecting all kinds of fertilizer. 2) The government solicited for donor support to import fertilizers. 3) Import quotas were introduced. 4) The Kenya National Trading Corporation was mandated to import fertilizer (Amukoa, 1996).

The crisis in fertilizer marketing grew worse when in 1975 the government sold fertilizer it had received as aid at 30 percent below the then prevailing market price. Private importers lost due to this with some being driven out of business. Between 1973 and 1983 all aid fertilizer was channelled through KFA and latter the Kenya Grain Growers Cooperative Unions (KGGCU). Over 80 percent of the fertilizer market was distributed through a sole distribution agent agreement signed with the government (ibid).

The price controls and import quotas introduced by the government in response to the oil crisis remained until 1989. In early 1990, the government decontrolled fertilizer prices. Later in the same year, import quotas were abolished. In 1992, the licensing of fertilizer imports was also abolished. The final step toward full liberalization of the fertilizer market was taken in 1993 when the foreign exchange market was decontrolled (ibid).

The precise impact of such changes in the macro-economic policy on fertilizer use in Kinangop is difficult to estimate, due not only to a paucity of comprehensive and reliable data, but due also to the complex nature of the relationship involved. This is particularly the case when the problem of farmers' access to fertilizer is examined from the lower end of the distribution network as has been attempted in the present study. This is in to way to suggest that changes in the macro-economic policy, or the other aspects of the distribution system are less important. On the contrary, actual fertilizer use is a function of the efficient working of the entire distribution system. Given that changes in the macro-economic policy environment are likely to have a similar effect in Kinangop area, not least because of its relatively small size, the analysis of local differences is more likely to explain variation in fertilizer use than the broader policy issues. Yet, the two are not mutually exclusive and must, albeit in varying degrees, both be taken into consideration if such analysis is to be meaningful.

3.8.2: Agricultural Extension

As argued in section 3.8, the provision of extension services during the colonial period favoured settler farmers who, despite being few in number, won legal guarantees, not only to top-quality land and subsidized agricultural services, but to the formation and financing of national agricultural unions (Ng'ethe and Odero, 1994). Through various organizational and networking strategies, the settler farmers were able to demand and get adequate, if not, exclusive extension services.

With the development of smallholder agriculture after independence, however, the demand for extension services increase tremendously. As a result, the priority of the government during the *1966-70 Development Plan* period was to add to the number of extension field staff (Republic of Kenya, 1966). This necessitated the expansion of training facilities of all kinds, such as Farmer Training Centres (FTCs). One such centre was started in Njabini. The objective of the centres was to provide thorough training for farmers in an environment which permits more sustained attendance and concentration than was possible in a village meeting (Adams, 1982). Facilities at FTCs such as the one in Njabini were often used for in-service training of field staff.

By the end of the first plan period, it was clear that the diverse nature of the agricultural sector in both clientele character and production system necessitated a variety of approaches. As a result in the *1970-74 Development Plan*, a more unified extension service with generalized extension workers rather than services organized under various specialized departments was adapted (Republic of Kenya, 1970). To reinforce these changes, the government made a commitment in the *1979-83 Development Plan* to improve the flow of information from research centres to farmers by strengthening the extension services through expansion of programmes for staff training (Nyangito and Kimenye, 1995). Given the diverse character of the agricultural sector, there was need to rationalize the extension delivery system to address the need of small, large, subsistence and/or commercial farmers. In areas like Kinangop where there is a concentration of smallholder farmers, group work was considered more practical than individual farm visits. In other areas contact farmers could be used for demonstration purposes (Republic of Kenya, 1984). Under the National Extension Project, use was to made of earlier experience with the contact farmer approach.[8] The group extension approach was also recommended based on the conviction that farmers, when given advice in groups will pass the knowledge to other farmers. This would stretch the coverage of extension workers.

An objective common to all extension approaches is to communicate information to farmers to enable them make good decisions suitable to their goals and farming conditions. Adams (1982) has suggested that the purpose of extension work is to awaken the desire for technical, economic and social change and to teach practical and managerial skills. Literature on the impact of extension service suggest that the number of contacts between farmers and extension workers and the quality of extension lead to significant increases in yield and adoption of inputs (Feder and Slade, 1986; Herdt and Capule, 1983). Despite its known benefits, provision of extension services in Kinangop is riddled with several problems. Poor roads, long distances to service point and low ratio of extension workers to farmers are the major reasons cited by farmers as constraining delivery of extension services in the area. As shown in Table 3-8, on average extension workers make one visit per year to each farm household.

Given such a low farmer-extension worker contact, it is very doubtful that the intended objective of facilitating farmers' access to useful production technology can be achieved. The government seems to have been aware of this problem for some time. In the *1989-93 Development Plan* for instance, the

Table 3-8 Extension Worker Visits to Farms by Sub-Location

Sub-locations	Mean Number of Visits Per Year	Percentage of Farmers Receiving Extension
Kahuru/Muruaki	1.3	75
Njabini	1.5	74
Karati	0.6	55
Tulaga	1.0	82
Nandarasi	2.0	74
Mikaro	1.2	77
KINANGOP	**1.2**	**73**

Source: Field Survey.

government affirmed the policy of encouraging the participation of the private sector in extension service delivery. The role of the private sector was seen as that of linking the farming community and agro-industry (Republic of Kenya, 1994).

Such public-private sector dichotomy can, however, be misleading. In Kenya, there are a number of institutions that provide extension services which do not necessarily qualify to be called either 'private' or 'public'. Farmers' organizations such as cooperative societies do provide extension services to their members. Universities and other research institutions also conduct out-reach extension programmes to farmers within their operation areas. The University of Nairobi Kibwezi Irrigation Project, the Coffee Research Foundation, and the International Centre for Research in Agroforestry are examples of knowledge-based institutions involved in providing extension services. Various Voluntary and Non-Governmental Organizations (NGOs) are also involved in providing agricultural extension.

In Kinangop, the government remains the main source of extension services to farmers. In 1994, the government provided about 86 percent of agricultural extension services (Table 3-9). Close to 10 percent was delivered by NGO workers. Of lesser importance are neighbours (2.3 percent) and potato buyers (1.4 percent). Evidently, there is need to create space for actors other than the government to effectively participate in the provision of extension services. More fundamentally, however, is the need to ensure that the quality of service reaching the farmer is the kind that produces results in terms of better and increasing yield.

Table 3-9 Sources of Extension Services provide to Farmers

Extension Service Provider	Percentage of Total Service Provided
Government	86.0
Non-Governmental Organizations	10.0
Neighbours	2.3
Potato Buyers	1.4
Input Suppliers	0.2
Others	0.1
Total	**100.0**

Source: Field Survey

3.8.3: Agricultural Credit

As Table 3-10 shows, access to credit in Kinangop is very limited. On average, only 7 percent of the farmers obtained credit in 1994. Of the sampled sub-locations Mikaro had the highest proportion of farmers receiving credit (15.4 percent) and Nandarasi the lowest (4.3 percent). The small credit market is a function of the poorly developed communications in the area. For instance, the effect of poorly maintained roads raises the cost of using formal bank

Table 3-10 Access to Credit by Potato Farmers

Sub-Location	Percentage of Sampled Households Receiving Credit
Kahuru/Muruaki	5.0
Njabini	5.7
Karati	9.1
Tulaga	11.8
Nandarasi	4.3
Mikaro	15.4
KINANGOP	**7.1**

Source: Field Survey

arrangements. Other aspects of rural credit markets in developing countries that might be relevant for Kinangop are: scarce collateral, underdeveloped complementary institutions, and covariant risk and segment markets (Besley, 1994).

The small credit market is a function of the poorly developed communications in the area. For instance, the effect of poorly maintained roads raises the cost of using formal bank arrangements. Other aspects of rural credit markets in developing countries that might be relevant for Kinangop are: scarce collateral, underdeveloped complementary institutions, and covariant risk and segmented markets (ibid.).

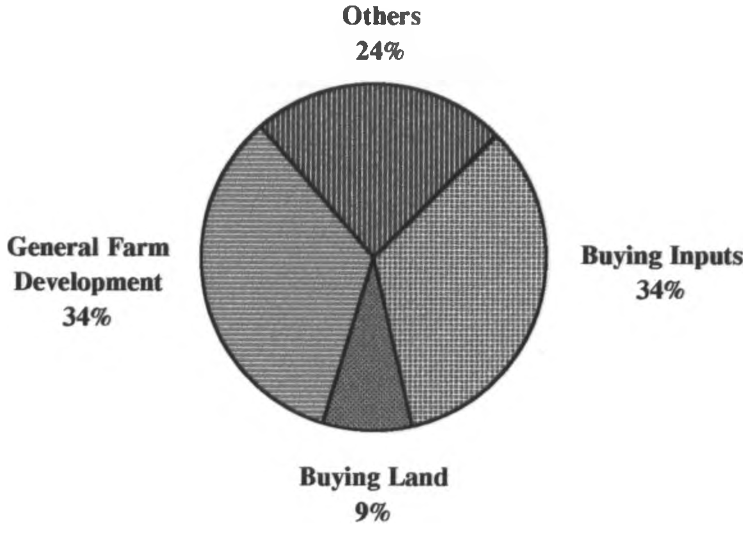
The use to which credit obtained was put to in each sub-location is shown in Table 3-11). In the entire division, 33% of the total credit was used to buy inputs. Another 34% was used for general farm development; 9% for buying land while the rest, 24% was used for other purposes (Figure 3-1). While no information was volunteered under 'other' uses, purchase of inputs and general farm development stand out as the two main uses of credit, both taking 68% of total credit.

Table 3-11 Relative Percentage of Credit Use by Sub-location

Sub-Location	Buying Input	Buying Land	General Farm Development	Others[1]	Total
Kahuru/Muruaki	50.0	0.0	0.0	50.0	100
Njabini	66.7	0.0	33.3	0.0	100
Karati	48.4	N.D	48.4	3.2	100
Tulaga	N.D	N.D	N.D	N.D	-
Nandarasi	0.0	50.0	50.0	0.0	100
Mikaro	0.0	50.0	50.0	0.0	100

Source: Field Survey.
Note: 1 Other uses not specified; N.D. = Not Disclosed.

Figure 3-2 Use for Credit in Kinangop



Source: Field Survey

In Kahuru/Muruaki, 50% of the total credit available was used to buy farm inputs with the remaining 50% allocated to 'other' uses. In Njabini farmers used about 68% of the credit to buy inputs with the rest being used on general farm development. In Karati, buying inputs and general farm development were each allocated 48.4% of the total credit with the remaining 3.2% for other uses. All the credit available in Nandarasi was used for general farm development. In Mikaro, credit was used for buying land (50%) and general farm development (50%).

In terms of sources of credit, relatives and/or friends accounted for 44.4% of credit sources, twice as much as formal banks (22.2%). Cooperative societies provide the remaining one-third (33.3%). These statistics support the observation that segmented credit markets in developing countries often depend on informal credit. The cost of segmentation is that funds fail to flow across regions or group of individuals even though there are potential gains from doing so (Besley, 1994).

Note on Chapter Three

[1] By 'crop' is meant one crop season, from planting to harvesting. Because of the favourable agro-climatic conditions and husbandry practices in Kinangop, in one year a farmer can have up to three crops--planting thrice and harvesting thrice (in a successful year). In 1994, 55.4 percent of potato farmers in Kinangop grew three crops, 40 percent two crops and 2.4 percent one crop. The most widely grown potato variety in the division is Kerr's Pink which takes about 3.5 months to mature.

[2] This could be as a result of local differences in labour demand and supply conditions. Areas that are served with better quality roads, that also have better accessibility might, in a comparative sense, suffer from high rates of labour emigration to urban centres outside the region than the least accessible areas.

[3] Results from fertilizer experiments carried out by the Kenya Agricultural Research Institute (KARI) show that potato yield can increase by over 70 percent when recommended amounts of appropriate fertilizers are applied (Muriuki, 1995). In Tulaga, potatoes showed increase with application of phosphorus (P_2O_5) and farmyard manure. In Njabini, potatoes showed positive response to nitrogen (N) and phosphorus.

[4] With regard to access to public services, Bigsten's (1981) analysis shows Central province got the most money (after Nairobi and Mombasa) followed by Rift Valley, while Western, North Eastern and Nyanza Provinces got the least per capita.

[5] The settler farms measured 988 to 1976 acres each.

[6] Later, additional settlement schemes were established in the forest reserves higher up the slopes of the Aberdare Range but the population density remained relatively low compared to other parts of the Kenyan highlands (Dijkstra, 1997).

[7] Dijkstra's analysis shows that horticulture has been of major importance to small-scale produces from the moment they settled Nyandarua District. "By 1970 about half of the total area under cultivation in the settlement schemes was being used to grow English potatoes, cabbages, green peas and other horticultural commodities...The district has developed into one of the chief suppliers of *potatoes* and cabbages to the Nairobi market" (p. 51).

[8] In the late 1960s and 1970s, the extension services in the then Ministry of Agriculture conducted thousands of maize demonstrations, initially focusing on hybrid seeds and later on fertilizer use with hybrid varieties. Between 1963 and 1973 the use of hybrid maize varieties in Kenya increased by over 20,000 percent (Adams, 1982).

CHAPTER FOUR

ANALYSIS OF THE DIRECT EFFECTS OF ROAD QUALITY IMPROVEMENT ON FERTILIZER USE AND POTATO YIELD

4.1 Deriving Road Quality and Market Accessibility Indices

The *road quality index* (RQI) was developed in three stages. In the first stage road densities were calculated. Distances of various classes of roads (Table 4-1) in every sampled sub-location were divided by the total area of the particular sub-location.

Table 4-1 Length of Road Network (Kms) by Sub-Location

Sub-location	Length of Road Class in Kms				
	Class C	Class D	Class E	Class F	RAR
Kahuru/Muruaki	7.0	15.0	0.0	30.0	17.0
Njabini	20.0	0.0	10.0	5.3	5.0
Karati	6.0	0.0	0.0	10.0	1.0
Tulaga	10.0	0.0	4.0	0.0	1.0
Nandarasi	0.0	12.5	2.6	0.0	3.0
Mikaro	0.0	1.0	7.5	0.0	12.5
Total	**43.0**	**28.5**	**24.1**	**45.3**	**37.5**

Source: Nyandarua District Road Map (Ministry of Transport and Communication, Nyahururu).
Note: RAR = Rural Access Road.

This resulted in a relative measure of road densities. The calculated road densities shown in Table 4-2 were then used to assign scores. The scores assume that a road in Class C is of higher quality than one in Class E, *ceteris peribus*. The scores were awarded as follows for the different road classes: C = 5, D = 4, E = 3, F = 2, and Rural Access Roads (RAR) = 1.

Table 4-2 Road Densities (km/km^2) in Sampled Sub-Locations

Sub-location	Area (sq.km)	Road Class and Density				
		Class C	Class D	Class E	Class F	RAR
Kahuru/Muruaki	96	0.07	0.16	0.00	0.31	0.18
Njabini	96	0.21	0.00	0.01	0.05	0.05
Karati	38	0.16	0.00	0.00	0.26	0.03
Tulaga	59	0.17	0.00	0.07	0.00	0.24
Nandarasi	50	0.00	0.25	0.05	0.00	0.06
Mikaro	64	0.00	0.02	0.12	0.00	0.19
KINANGOP	**403**	**0.11**	**0.07**	**0.06**	**0.11**	**0.09**

Source: Field Survey.
Note: RAR = Rural Access Road.

These scores were then multiplied by the road densities calculated in stage one. This resulted in a weighted density for every class of road in each sub-location. The individual densities were then added to obtain an aggregate of the weighted road densities called the *total weighted road density* (*TWRD*). The TWRD measures the distribution and condition of the road network by sub-location. Its values range from 1.79 in Kahuru/Muruaki to 0.63 in Mikaro (Table 4-3).

Table 4-3 Total Weighted Road Density (TWRD) and Road Quality Index (RQI)

Sub-Location	Weighted Density of Road Class						
	Class C	Class D	Class E	Class F	RAR	TWRD	RQI
Kahuru/Muruaki	0.35	0.64	0.00	0.62	0.18	1.79	0.35
Njabini	1.05	0.00	0.30	0.10	0.05	1.50	0.42
Karati	0.80	0.00	0.00	0.52	0.03	1.35	0.47
Tulaga	0.85	0.00	0.21	0.00	0.24	1.30	0.48
Nandarasi	0.00	1.00	0.15	0.00	0.06	1.21	0.52
Mikaro	0.00	0.08	0.36	0.00	0.19	0.63	1.00
KINANGOP	**0.55**	**0.28**	**0.18**	**0.22**	**0.09**	**1.32**	**0.48**

Source: Field Survey.

Since the sub-location with the highest weighting also has the best roads, this raises a problem of interpretation. A kilometre along good quality roads is theoretically shorter than a kilometre along poor ones. The TWRD therefore needed to be transposed to make it easy to interpret. This was achieved by taking the TWRD for Mikaro (0.63) and making it a base index. As the least well served sub-location, Mikaro represents the bench-mark for assessing road conditions in Kinangop. Its "isolation" epitomizes the problems of an underserved area.

To arrive at an index of road quality, Mikaro was assigned a unit value obtained by dividing the base figure (0.63) by itself. Indices for the remaining five sub-locations were arrived at by dividing the base index by the TWRD of a particular sub-location. For example, the RQI for Kahuru/Muruaki was obtained by dividing 0.63 by 1.79 giving an RQI of 0.35. The TWRD and the base figures were inverted in order to assign weights such that a sub-location with the 'best' road quality would have the lowest RQI.

The resulting ratios shown in the last column of Table 4-3 are logically consistent and easier to interpret. A low RQI signifies better quality roads and a high index poor quality. The quality decreases with increasing road quality index. Accordingly, Mikaro which has the poorest roads has an RQI value of 1, Kahuru/Muruaki with the best roads has an RQI of 0.35. The average road quality index for Kinangop is 0.48. The transposition was achieved while maintaining the proportional difference of road density based on the original weights. This, as it were, was the main reason for using the scores based on the TWRD. The advantage of using the actual TWRD scores as opposed to the alternative 'ranking' method is obvious. Ranking the TWRD scores would have for instance, resulted in Kahuru/Muruaki being ranked first and Mikaro sixth on a scale of 1 to 6. In so doing, the proportional difference between sub-locations would have disappeared nullifying any need for further analysis.

4.2 The Market Accessibility Index (MAI)

Improving the quality of roads enhances market accessibility. The *market accessibility index* (MAI) is therefore an extension of the road quality index. Deriving the MAI shown in Table 4-4 proceeded as follows.

Table 4-4 Average Farm-to-Market Distance and Mean Market Accessibility Index by Sub-Location

Sub-location	Mean Distance (kms)	Road Quality Index	Mean Market Accessibility Index
Kahuru/Muruaki	1.77	0.35	0.62
Njabini	4.50	0.42	1.89
Karati	8.31	0.47	3.91
Tulaga	5.13	0.48	2.46
Nandarasi	9.74	0.52	5.07
Mikaro	5.20	1.00	5.20
KINANGOP	**5.15**	**0.48**	**2.47**

Source: Field Survey.

The distance between the farm and the market centre where households bought fertilizer was multiplied by the RQI for the sub-location. This resulted in a relative measure of market accessibility per household. Multiplying the averages of the farm-to-market distance and the RQI gives the same results.

4.2.1: Market Accessibility by Sub-Location

The MAI gives an adjusted measure of farm-to-market distance along roads of various conditions. The sampled sub-locations were divided and assigned to three road quality categories based on the market accessibility index as follows -: Kahuru/Muruaki and Njabini — high road quality; Karati and Tulaga — medium road quality; and Nandarasi and Mikaro — low road quality. In terms of market accessibility, Kahuru/Muruaki has the best market accessibility (MAI = 0.62) and Mikaro is the least well served having a market accessibility index of 5.20. It is these indices that are used to analyze the effects of roads improvement on fertilizer use and potato yield.

4.2.2: Market Accessibility by Farm-Size

Market accessibility indices for various farm-sizes are shown in Table 4-5. MAI is the average distance from farm to market weighted for the quality

Table 4-5 Average Market Accessibility by Farm-Size

Farm Size (Acres)	Mean Market Accessibility Index (MAI)	Standard Deviation (n=117)	Percentage of Sample in Category
5.0 or less	2.34	32	69.6
5.01 - 10.0	2.16	24	88.9
10.01 - 15.0	2.97	12	60.0
15.01 - 20.0	3.97	14	77.8
20.01 - 25.0	2.22	7	70.0
25.01 - 30.0	3.32	6	40.0
30.01 +	1.88	22	68.8
KINANGOP	**2.52**	**117**	**69.6**

Source: Field Survey.
Note: A low MAI signifies better market accessibility; Nonresponses were excluded.

of the road network. The large farm-size category (> 30 acres) has the best market accessibility (MAI =1.88). Farms in the 15.01-20 acres category have the poorest market accessibility index (3.97)

The literature devoted to the location of agricultural production has shown that the intensity of land use increases continuously with increasing market accessibility. The closer the market tends to be the higher the local price per unit of commodity. Hence, the intensity of cultivation will be higher. This spatial correlation can be explained theoretically (Dunn, 1967). But, the correlation between accessibility and farm-size has no comparable theoretical explanation. It would require highly restricted assumptions about the character of agricultural production functions to establish such a relationship.

4.2.3: Market Accessibility by Agro-Ecological Zones

An area with differentiated soils such as Kinangop (Map 2-1) can be expected to exhibit a variable market access structure. Soils in Kinangop were categorized into three agro-ecological zones on the basis of the dominant soil types, namely, mountain, plateau and mixed soils. The depth and drainage conditions of different soils (as described in Table 3-1) was hypothesized to have some effect on road quality and therefore market accessibility. As shown in Table 4-6, the best market accessibility (0.62) is observed in areas with plateau soils and the poorest accessibility (4.43) in areas with mixed soils. The fact that areas with different types of soil also have differences in terms of market accessibility would strongly suggest that soil type influences road quality. The direct effect of agro-ecological zone/ soil type on fertilizer use and yield is discussed below.

Table 4-6 Market Accessibility by Agro-Ecological Zones

Agro-Ecological Zone/Soil Type	Mean Market Accessibility Index (MAI)	Standard Deviation (n = 117)	Percentage of Sample in Category
I Mountain Soils	2.37	64	77.1
II Plateau Soils	0.62	24	60.9
III Mixed Soils	4.43	29	64.4
All Zones	**2.52**	**117**	**69.6**

Source: Field Survey.

4.3 Fertilizer Use and Market Accessibility

Road networks are important channels for fertilizer distribution. Since all fertilizer consumed in Kenya is imported (Amukoa, 1996), sea and rail are important transportation routes. Nonetheless, roads remain an important link through which fertilizer reaches the farmer. Since improvements enhance road quality and increase market accessibility, it can be assumed that improving the network of roads acts as an incentive for farmers to invest in fertilizer. Consequently, farmers in sub-locations served by high quality roads (with easier market access), are on average likely to use more fertilizer per acre (Binswanger *et al.*, 1989).

Table 4-7 shows fertilizer application by sub-location. Njabini Sub-location has the highest average fertilizer application rate (79.4 kg/acre) followed by Mikaro Sub-location (56.9 kg per acre) Kahuru/Muruaki Sub-location (56.8 kg/acre each), Karati Sub-location (56.7), Tulaga Sub-location

Table 4-7 Average Fertilizer Use (Kg/Acre) by Road Quality

Road Quality Group[1] and Sub-Location	Fertilizer Use (Kg/Acre)	Standard Deviation (n = 116)	% of Sampled Households
High Road Quality			
Kahuru/Muruaki	56.8	42.0	60.0
Njabini	79.4	109.7	77.4
Sub-total	71.1	91.0	69.9
Medium Road Quality			
Karati	56.7	64.8	77.3
Tulaga	54.2	34.3	76.5
Sub-total	56.7	53.0	76.9
Low Road Quality			
Nandarasi	47.7	47.5	60.9
Mikaro	56.9	83.6	53.8
Sub-total	50.8	59.9	58.3
KINANGOP	**63.7**	**77.5**	**69.0**

Source: Field Survey.
Note: 1 Areas with high quality roads have better market access; Nonusers excluded in the calculations.

(54.2 kg/acre) and Nandarasi Sub-location (47.7 kg/acre). Average fertilizer usage drops with road quality. From 71.1 kg/acre in sub-locations served by high road quality, the per acre fertilizer use drops to 56.7 kg in sub-locations with medium quality roads, a drop of almost 20 percent, and 50.8 kg/acre in sub-locations with low quality roads, a fall of 29 percent from the highest to lowest per acre fertilizer use. These changes are consistent with the hypothesized relationship between the two variables

4.3.1: Fertilizer Use by Farm-Size

Farm-size is an important variable in studying fertilizer use because, the relative availability of land (and labour) determines the physical or technical combination of resources — the production function. In order to ease limitation set by land, for example, farmers try to economize in the use of the limiting factor or to substitute fertilizer for land. As Table 4-8 shows, fertilizer use in Kinangop varies by farm-size.

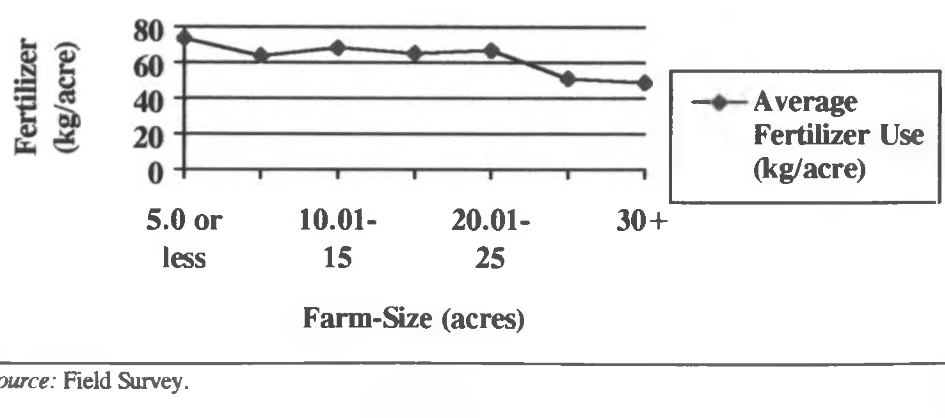
Average per acre fertilizer use by all farm-sizes is 63.7 kg. Intensity of fertilizer use is associated with smallholder agriculture and extensive use with large-scale farming. Per acre fertilizer use therefore tends to fall with

Table 4-8 Average Fertilizer Use by Farm-Size

Farm Size (Acres)	Average Fertilizer Use (Kg/Acre)	Standard Deviation (n=116)	Percentage of Sample in Category
5.0 or less	73.4	58.9	65.0
5.01 - 10.0	63.7	44.5	88.9
10.01 - 15.0	68.1	61.3	65.0
15.01 - 20.0	65.1	44.0	66.7
20.01 - 25.0	66.7	66.0	60.0
25.01 - 30.0	51.0	33.1	40.0
30.01 +	48.7	41.1	62.5
KINANGOP	**63.7**	**50.6**	**64.9**

Source: Field Survey.
Notes: Nonusers excluded in the calculations.

Figure 4-1 Fertilizer Use by Farm-Size



Source: Field Survey.

increasing farm-size as shown diagramatically in Figure 4-1. The empirical observation associating fertilizer use and farm-size is valid even though, as can be observed in both Table 4-8 and the corresponding diagram (Figure 4-1), the relationship is nonlinear. Underlying changes in the level of soil fertility, expected yield increases, fertilizer and crop prices, overall production costs, farm management and variation in weather explain the observed variation in fertilizer use between the small, medium and large farms.

4.3.2: Fertilizer Use by Agro-Ecological Zones

Soil fertility varies among different soil types with some being more fertile than others. With the continuous use of land for crop production, soil nutrients are used and there is a risk of depletion leading to exhaustion if not controlled though judicious application of fertilizer. Table 4-9 compares fertilizer use by potato farmers in three agro-ecological zones representing mountain, plateau and mixed soils.

Table 4-9 Average Fertilizer Use by Agro-Ecological Zones

Agro-Ecological Zone/Soil Type	Average Fertilizer Use (Kg/Acre)	Standard Deviation (n = 116)	Percentage of Sample in Category
I (Mountain Soils)	71.5	95.3	73.5
II (Plateau Soils)	56.8	42.0	60.0
III (Mixed Soils)	53.7	57.0	68.9
All Zones	**63.7**	**77.5**	**69.0**

Source: Field Survey.
Note: No responses are excluded in the calculations.

Fertilizer use is highest in agro-ecological I where mountain soils dominate. On average farmers used about 72 kg of fertilizer per acre of potatoes. In zone II characterized by plateau soils, fertilizer use was about 57 kg/acre, a difference of about 21 percent from zone I. In zone III comprising mixed soils, farmers used the lowest rate of 54 kg per acre. The average fertilizer use in Kinangop was 64 kg per acre of potatoes.

Mountain soils are mostly found in Njabini, Tulaga and Mikaro Sub-locations. Plateau soils, on the other hand, are ubiquitous in Karati and Kahuru/Muruaki Sub-locations. The third category, mixed soils, is mostly found in Nandarasi Sub-location. This latter soil type was excluded from the *t*-test of difference of means which was performed on the data to find out whether soil type has any effect on fertilizer use. Table 4-10a and 4-10b contain basic descriptive statistics and the *t*-values including their associated probabilities for fertilizer use during potato production for farms in Mountain and Plateau soil types (agro-ecological zones I and II).

If the population means are equal, the probabilities of observing differences in fertilizer use in agro-ecological zone I (Mountain Soil) and agro-ecological zone II (Plateau Soils) at least as large as the one in the sample are estimated to be 0.2 and 0.6. Since these two probability are greater than 0.05, the hypothesis that per acre potato yields in the population of farm households in Kinangop are equal for the two groups (Mountain and Plateau Soils) is not rejected. It can therefore be concluded that the type of soil or agro-ecological zone has no significant effect on per acre fertilizer use during potato production in Kinangop.

Table 4-10a Fertilizer Scores and *T*-Test Values for Mountain Soils

Soil Type	Number of Cases	Average Fertilizer Use (Kg/Acre)	Standard Deviation	Standard Error	Mean Difference
Mountain					
Group 1	83	44.1	50.1	5.49	
Group 2	85	34.6	48.2	5.23	9.5
Levene's Test for Equality of Variance: F = 0.002, P = 0.966					
		T-test For Equality of Means			
Variance	**T-value**	**Degrees of Freedom**	**2-tail Significance**	**SE of Difference**	**95% CI for Difference**
Equal	1.25	166	0.212	7.58	(-5.5, 24.5)
Unequal	1.25	165.4	0.212	7.58	(-5.5, 24.5)

Source: Field Survey.

Table 4-10b Fertilizer Scores and *T*-Test Values for Plateau Soils

Soil Type	Number of Cases	Average Fertilizer Use (Kg/Acre)	Standard Deviation	Standard Error	Mean Difference
Plateau					
Group 1	62	36.6	50.0	6.35	
Group 2	106	40.8	48.9	4.75	0.6
Levene's Test for Equality of Variance: F = 0.288, P = 0.592					
		T-test For Equality of Means			
Variance	**T-value**	**Degrees of Freedom**	**2-tail Significance**	**SE of Difference**	**95% CI for Difference**
Equal	-0.53	166	0.596	7.88	(-19.8, 11.4)
Unequal	-0.53	125.5	0.598	7.93	(-19.9, 11.5)

Source: Field Survey.

4.4 Potato Yield and Road Quality

As the results on Table 4-11 indicate, per acre potato yield rises by 8 bags from 27.8 to 35.9 bags/acre, an increase of 22.6 percent following improvement from low to medium quality roads. Although yield drops by 10.4 percent to about 32.2 bags/acre while the quality of roads have improved from medium to high quality, the general picture is indicative of a positive

Table 4-11 Average Potato Yield (Bags/Acre) by Road Quality

Road Quality	Potato Yield (Bags/Acre)	Standard Deviation (n = 156)	Percentage of Sample in Category
High	32.2	23.3	94.6
Medium	35.9	28.4	94.9
Low	27.8	20.5	86.1
All Roads	**32.3**	**24.1**	**92.9**

Source: Field Survey.
Note: Nonresponses are excluded in the calculations.

relationship between road improvement and increasing market accessibility, on the one hand and potato yield, on the other. The significance of the relationship between soil type and yield is shown in Table 4.14a and Table 4-14b.

4.4.1: Potato Yield by Sub-Location

Potato yield in Kinangop varies by sub-location (Table 4-12). This is not surprising given that the quality of roads in different sub-locations is also

Table 4-12 Average Potato Yield by Sub-Location

Sub-Location	Average Potato Yield (Bags/Acre)	Standard Deviation (n=156)	Percentage of Cases in Sub-Sample
Kahuru/Muruaki	14.9	8.4	84.6
Njabini	29.9	25.0	100.0
Karati	30.8	19.9	100.0
Tulaga	33.3	25.0	90.6
Nandarasi	34.9	21.8	87.0
Mikaro	44.9	31.4	88.2
KINANGOP	**32.3**	**24.1**	**92.9**

Source: Field Survey.
Note: Cases in which yield was not reported are excluded.

varied (Table 4-3). Yield in the different sub-locations ranges from 14.9 bags/acre in Mikaro to 44.9 bags/acre in Tulaga. The average yield is about 32 bags per acre. Apart from roads, agronomic factors such as use of fertilizers and land use can affect yield. Differences in agro-ecological conditions of soil fertility and socio-economic factors such as land distribution can also be important. These are explored in the following sections.

4.4.2: Potato Yield by Agro-Ecological Zones

In terms of the distribution of potato yield by agro-ecological zones, the results show that zone I (Mountain Soils) has the highest yield (32.9 bags/acre) followed by zone III (Mixed soils) with 32.3 bags/acre and zone II (Plateau Soils) 30.8 bags/acre (Table 4.13). A difference of less than 3 bags per acre between the three regions suggests that the soils in Kinangop play a limited role in potato yield. The *t*-test of difference of means (Table 4-14a and 4-14b) show the *t*-values and their associated probabilities for potato yield in areas with predominantly Mountain and Plateau Soils.

Table 4-13 Average Potato Yield by Agro-Ecological Zones

Agro-Ecological Zone/Soil Type	Potato Yield (Bags/Acre)	Standard Deviation (n = 156)	Percentage of Sample in Category
I (Mountain Soils)	32.9	26.7	89.2
II (Plateau Soils)	30.8	19.9	100.0
III (Mixed Soils)	32.3	23.4	93.3
All Zones	**32.3**	**24.1**	**92.9**

Source: Field Survey.
Note: Nonresponse cases are excluded in the calculations.

If the population means of potato growers in agro-ecological zone I and agro-ecological zone 2 are equal, the probabilities of observing differences in yield in agro-ecological zone I (Mountain Soil) and agro-ecological zone II (Plateau

Table 4-14a Yield Scores and *T*-Test Values for Mountain Soils

Soil Type	Number of Cases	Average Yield (Bags/Acre)	Standard Deviation	Standard Error	Mean Difference
Mountain					
Group 1	83	33.8	45.8	5.03	
Group 2	85	30.5	22.0	2.39	3.3
	Levene's Test for Equality of Variance: F = 2.493, P = 0.116				
		T-test For Equality of Means			
Variance	**T-value**	**Degrees of Freedom**	**2-tail Significance**	**SE of Difference**	**95% CI for Difference**
Equal	0.60	166	0.551	5.52	(-7.6, 14.2)
Unequal	0.59	177.5	0.554	5.57	(-7.7, 14.3)

Source: Field Survey.

Table 4-14b Yield Scores and *T*-Test Values for Plateau Soils

Soil Type	Number of Cases	Average Yield (Bags/Acre)	Standard Deviation	Standard Error	Mean Difference
Plateau					
Group 1	62	30.5	21.6	2.75	
Group 2	106	33.0	41.9	4.07	-2.5
	Levene's Test for Equality of Variance: F = 2.385, P = 0.124				
		T-test For Equality of Means			
Variance	**T-value**	**Degrees of freedom**	**2-tail Significance**	**SE of Difference**	**95% CI for Difference**
Equal	-0.44	166	0.658	5.73	(-13.9, 8.8)
Unequal	-0.52	163.9	0.606	4.91	(-12.2, 7.2)

Source: Field Survey.

Soils) at least as large as the one in the sample are estimated to be 0.6 and 0.6. Since these two probabilities are greater than 0.05, the hypothesis that potato yield in the population of farm households in Kinangop are equal for the two groups (Mountain and Plateau Soils) is also not rejected. From this it can therefore be concluded that the type of soil or agro-ecological zone has no significant effect on potato yield in Kinangop.

4.4.3: Potato Yield by Farm-Size

Farm-size is an important variable in yield studies because of its effect on intensity of land use. Small farm-size is associated with intensive cultivation and better agronomic practices (such as mixed cropping), leading to higher yields. Landholding was classified into seven categories of 5 acres interval each. Average potato yield in each farm-size category is shown in Table 4-15.

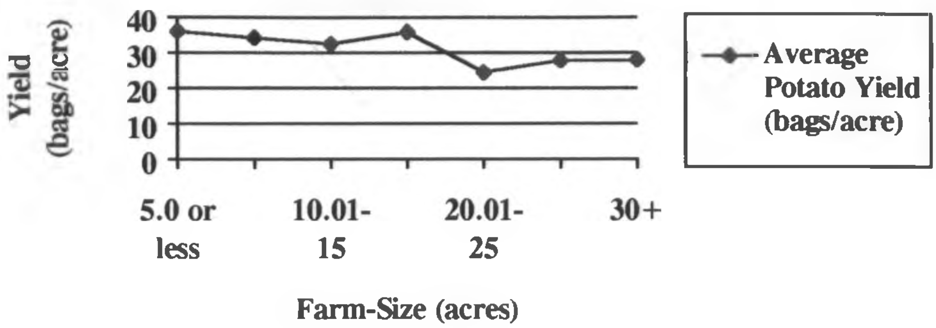
Differences in yield occur between farm-sizes. Figure 4-2 shows the relationship between yield and farm-size. Farms measuring 5 acres and below have the highest yield (36 bags/acre) while the lowest yield (24.4 bags/acre) occurs in the 20.01 to 25 acres category. This could mean that with decreasing farm-size, there is intensification leading to higher yield realized, perhaps,

Table 4-15 Average Potato Yield by Farm-Size

Farm Size (Acres)	Average Potato Yield (Bags/Acre)	Standard Deviation (n=156)	Percentage of Sample Household in Category
5.0 or less	36.0	32.4	89.1
5.01 - 10.0	34.2	21.5	100.0
10.01 - 15.0	32.5	19.4	95.0
15.01 - 20.0	35.9	26.7	83.3
20.01 - 25.0	24.4	13.4	100.0
25.01 - 30.0	27.8	18.7	93.3
30.01 +	28.0	19.2	93.8
KINANGOP	**32.3**	**24.1**	**92.9**

Source Field Survey.
Note: Nonresponses are excluded in the calculations.

Figure 4-2 Potato Yield by Farm-Size



Source: Field Survey

through application of greater quantities of fertilizer per acre. It could also mean that observed yield is as a result of the unique combinations of factors of production possible under the resource endowment conditions pertaining to a particular farm-size group. Thus, the yield in the 5.01-20 acres farm-size range is higher than in both the 15.01-10 and 10.01-15 acres farm-size groups. The first scenario is examined below by comparing the averages of per acre fertilizer use and potato yield. The relationship between the two variables is also tested for significance.

4.5 Fertilizer Use and Potato Yield

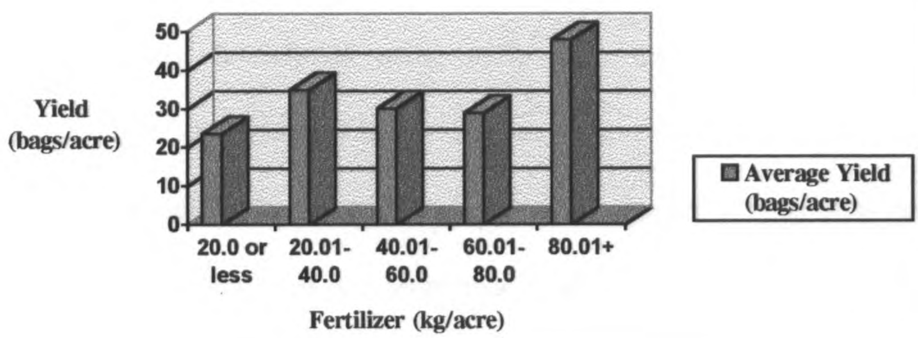
Average potato yield varies with fertilizer use (Table 4-16). Potato yield increases with increasing fertilizer use (Figure 4-3). Farmers who applied 80 kg of fertilizer per acre, or more, had the highest average yield of about 48 bags per acre while those who applied between 0.01-20 kg per acre had the lowest yield of about 24 bags per acre. The average yield is about 32 bags per acre.

Table 4-16 Average Potato Yield by Fertilizer Use

Fertilizer Use (Kg/Acre)	Average Potato Yield (Bags/Acre)	Standard Deviation (n=116)	Percentage of Sample Household
20.0 or less	23.5	14.7	23.2
20.01 - 40.0	34.9	24.0	21.6
40.01 - 60.0	30.1	24.3	20.7
60.01 - 80.0	28.8	30.5	6.9
80.01 +	47.9	32.4	27.6
All Users	**32.3**	**25.6**	**100.03**

Source: Field Survey.
Note: Nonresponses are excluded in the calculations.

Figure 4-3 Fertilizer Use and Potato Yield



Source: Field Survey.

However, since it is not possible to determine the significance of this association by either studying the table or the graph, a chi-square test of significance was performed on the two variables. The expected and actual yield and fertilizer values appear in Table 4-17.

4.5.1: Chi-Square Test of Significance for Fertilizer and Yield

Yield and fertilizer use were assumed to be related. The two were cross-tabulated to test the significance of the hypothesized relationship. As

Table 4-17 shows, if there was no relationship between fertilizer and yield, then 54.5 percent of households using below the average quantity of fertilizer of 64 kg/acre should have obtained yields lower than the average (32 bags/acre) and 45.5 percent should have obtained above average yields.

Among households using more than the average amount of fertilizer, 55 percent should have obtained below the average yield and 45 percent should have obtained above average yields. Observed frequencies, however, show that among households using below the average fertilizer, 65 percent obtained below the average yield and 35 percent obtained above average yield. Moreover, among households using more than the average quantity of fertilizer, only 36 percent had below than average yield and 64 percent had above average yield. The calculated *chi-square* value (8.475) is statistically significant at the 0.005 level of significance (Table 4-17). The null hypothesis that there is no relationship between fertilizer use and potato yield is rejected.

Table 4-17 Expected and Actual Yield and Fertilizer Use

Expected Cell Frequencies	**Below Average Yield**	**Above Average yield**	**Total**
Used below average fertilizer	38.7 (54.5%)	32.3 (45.5%)	71
Used above average fertilizer	21.3 (54.6%)	17.7 (45.4%)	39
Total	60.0	50.0	110
Observe Cell Frequencies	**Below Average Yield**	**Above Average Yield**	**Total**
Used below average fertilizer	46.0 (64.8%)	25.0 (35.2%)	71
Used above average fertilizer	14.0 (35.9%)	25.0 (64.1%)	39
Total	60.0	50.0	110
Chi-square = 8.475***			

Source: Field Survey.
Note: *** Significant at 0.005 level of significance.

4.6 Partial Analysis of the Effects of Road Quality Improvements and Increased Market Accessibility

The preliminary results presented above needed further exploration. In order to do this, a partial analysis approach was used to test for the significance of hypothesized relationships between the independent variable and the dependent variables. The effects of road quality improvement and increased market accessibility on fertilizer use is examined first. This is because the analytical model used in this study (Figure 1-2) assumes that fertilizer intervenes between road quality and potato yield. Then the relationship observed between yield and fertilizer use is also examined and discussed within the overall analytical framework of the study.

4.6.1: Road Quality and Fertilizer Use

In further examination of the relationship between road quality and fertilizer use, household data was categorized into three categories based on farm-size. The categories are 0.01 to 15 acres, 15.01 to 30 acres, and more than 30 acres. The average fertilizer use by farm-size controlling for road quality is shown in Table 4-18. The average quantity of fertilizer used per acre was observed to drop with declining road conditions. Comparing all farm-sizes, fertilizer use in Kahuru/Muruaki and Njabini, the sub-locations served by high quality roads is 71.1 kg/acre. This figure drops to 50.8 kg/acre in Mikaro and Nandarasi, sub-locations that are served by low quality roads. This difference in the average fertilizer use in areas served by low, medium and high quality roads is significant from zero at the 0.01 level of significance. This strongly suggests that fertilizer use

Table 4-18 Fertilizer Use by Farm-Size Controlling for Road Quality

Farm-Size (Acres)	Road Quality				
	Low	Medium	High	All Roads	*F*-ratio (Road Quality Comparisons)
0.01 -15.00	60.95 (71.10) n=13	64.23 (61.36) n=18	85.41 (111.96) n=38	**75.28** **(93.72)** **n=69**	17.197*** Significant
15.01 - 30.00	49.17 (33.12) n=5	43.34 (38.35) n=5	50.11 (41.98) n=15	**48.57** **(38.25)** **n=25**	19.076*** Significant
Over 30	9.33 (7.69) n=3	47.00 (38.87) n=7	51.81 (45.04) n=12	**44.48** **(41.43)** **n=22**	17.247*** Significant
All Farms	**50.77** **(59.87)** **n=21**	**56.73** **(53.02)** **n=30**	**71.06** **(90.97)** **n=65**	**63.68** **(77.57)** **n-116**	**33.688***** **Significant**
***F*-ratio (Farm-Size Comparisons)**	0.639 Not significant	0.851 Not significant	0.716 Not significant	**18.331***** **Significant**	

Source: Field Survey
Notes: n = number of cases. Nonusers are exclude from the calculations.
Figures in parentheses are standard deviations.
*** statistically significant from zero at the 0.01 level of confidence.

is related with market accessibility. In the smallest farm-size category (0.01-15 acres), fertilizer use drops from 85.4 kg/per acre in Kahuru/Muruaki to 61 kg/acre in Mikaro and Nandarasi. This drop in fertilizer use between areas with high, medium and low road quality is also statistically significant from zero at the 0.01 probability level.

The 0.01 to 15 acres category has the highest per acre fertilizer use (75.3 kg) among the farm-sizes. Fertilizer use in the other two farm-size categories (> 15 to ≤ 30 acres and > 30 acres), also vary significantly between sub-locations having high, medium and low road quality. In the 15.01 to 30 acres farm-size category, the largest drop in fertilizer use is between Kahuru/Muruaki and Njabini sub-locations (50.1 kg/acre), and Tulaga and Karati sub-locations (43.3 kg/acre). In the 30 acres plus category, farmers in Kahuru/Muruaki and Njabini use 51.8 kg/acre, in Karati and Tulaga 47 kg/acre and in Mikaro and Nandarasi 9.3 kg/acre. These differences in fertilizer use are also statistically significant.

While holding road quality constant, average fertilizer use was further observed to drop with increasing farm-size. The smallest farm-size category (0.01 to 15 acres) used the highest average amount of fertilizer (75.3 kg/acre) and the largest farm-size (> 30 acres) used 44.5 kg/acre. This shows that farming intensity decreases with increasing farm-size. Average fertilizer use by all category of farms is 63.7 kg/acre. Differences in fertilizer use between farm-sizes is statistically significant from zero at the 0.01 level of significance. Variation in fertilizer use between farm-size groups within each road quality grouping is not statistically significant.

The results of the partial analysis presented above are interpreted to mean that the effect of road quality improvement on fertilizer use is important. Fertilizer use is shown to vary by road quality in all farm-size groups. This difference is observed to be statistically significant. Improving the quality of roads reduces real distance between locations and enhances market accessibility. Road quality, therefore, has a strong and significant effect on fertilizer use in potato production. This suggest that the presence of fertilizer use in the model explains the relationship between road quality and potato yield. To see if this is indeed the case, the relationship between road quality and potato yield is analyzed below.

4.6.2: Road Quality and Potato Yield

Table 4-19 Potato Yield by Farm-Size Controlling for Road Quality

Farm-Size (Acres)	Road Quality				
	Low	Medium	High	All Roads	*F*-ratio (Road Quality Comparisons)
0.01 -15.00	24.67 (17.88) n=19	40.23 (32.43) n=23	36.00 (25.82) n=45	**34.64** **(26.62)** **n=87**	1.787 Not significant
15.01 - 30.00	43.07 (23.21) n=8	30.63 (14.49) n=6	25.73 (20.79) n=25	**30.04** **(21.16)** **n=39**	2.243 Not significant
Over 30	12.27 (5.48) n=4	27.58 (22.73) n=8	31.64 (18.47) n=18	**27.97** **(19.24)** **n=30**	2.263 Not significant
All Farms	**27.82** **(20.52)** **n=31**	**35.94** **(28.36)** **n=37**	**32.19** **(23.30)** **n=88**	**32.21** **(24.09)** **n-156**	**1.996** **Not significant**
***F*-ratio (Farm-Size Comparisons)**	1.181 Not significant	1.254 Not significant	1.048 Not significant	**1.309** **Not significant**	

Source: Field Survey.
Notes: n = number of cases. Nonusers are exclude from the calculations.
Figures in parentheses are standard deviations.

Average yield for farms in three size categories is presented in Table 4-19. Mean yield in the 0.01 to 15 acres farm-size is 34.6 bags/acre. The highest yield per acre (40.2 bags) in this category occurs in Karati and Tulaga, sub-locations served by medium quality roads. In Mikaro and Nandarasi, the average yield is 24.7 bags/acre. This difference in average yield was compared between areas of low, medium and high road quality. The *F*-ratio is 1.787 which is not statistically significant.

A similar comparison was made for average yield in the 15.01 to 30 acres and > 30 acres farm-sizes. The resulting *F*-values and significance levels for differences in average yield by farm-size controlling for road quality are shown in Table 4-19. Average yield between farm-sizes is not significant. It however increases with decreasing farm-size. Differences in average yield between sub-locations served by low, medium and high quality roads is also not significant.

Results shown in Table 18 and Table 19 support our contention that road quality affects yield only through the use of fertilizer. The partial relationship between road quality and fertilizer has been shown to be significant. On the other hand, the partial relationship between road quality and yield is shown to be insignificant. These results strongly and evidently suggest that the effects of road quality on potato yield are at best, indirect, and fertilizer use serves to clarify the mechanism through which this relationship occurs.

To confirm that road quality has an effect on potato yield, it was necessary to test the relationship between fertilizer use and per acre yield for statistical significance. As has been suggested by the partial relationships, road quality has a direct effect on fertilizer use and an indirect effect on potato yield. To separate the direct from the indirect effects, multivariate techniques were used.

CHAPTER FIVE

DIRECT AND INDIRECT EFFECTS OF ROAD QUALITY IMPROVEMENT ON FERTILIZER USE AND POTATO YIELD

5.1 The Seemingly Unrelated Regression (SUR) Model

The three main variables analyzed in this study, road quality, fertilizer use and potato yield have a close conceptual relationship. But as suggested by von Oppen *et al.* (1985), when yield is expressed as a function of fertilizer use and road quality, a simultaneity of equations arise. Improving the quality of roads and/market accessibility has a direct effect on yield through cropping pattern allocation. Also, improving the quality of roads and/or increasing market accessibility has an indirect effect through input use. Likewise, the effect of using inputs on farm yield is a direct one.

The three-stage least squares method has been used before to solve such simultaneous equations (Njehia, 1994). In expressing fertilizer use and potato yield as a function of road quality improvements this study likewise identified a simultaneous equations problem (equations 5.1 and equation 5.2). As a consequence, a *seemingly unrelated regression* (SUR) or *recursive* model[1] was used to specify the relationships between road quality, fertilizer use, potato yield and other variables.

$$\mathbf{Y_1 = a_0 + b_1 \hat{Y}_2 a_{11} X_1 + D_1 + e_1} \quad \text{.................................(5.1)}$$

$$\mathbf{Y_2 = a_0 + a_{12} X_1 + a_2 X_2 + e_2} \quad \text{.................................(5.2)}$$

$$\mathbf{Y_3 = a_0 + a_{13} X_1 + a_3 X_3 + D_1 + e_3} \quad \text{.................................(5.3)}$$

where

Y_1 = Potato yield in 120 kg bags per acre
Y_2 = Fertilizer use in kg per acre
Y_3 = Potato acreage per household member
X_1 = Market accessibility per household
X_2 = Total household monthly income (KShs)
X_3 = Area under livestock in acres
D_1 = Zero-one dummy for hired labour.

5.2 Rationale for Variables Included in the Model

The first equation in the model is based on the relationship between potato yield — dependent variable — and the independent variables, represented by fertilizer (farm input), a dummy variable for hired labour (farm resource) and market accessibility. By stating the relationship between yield and the independent variables in the form $Y = f(X_1, X_2, \ldots\ldots, X_n)$, a simultaneous equations problem arises. For example, use of fertilizer has a direct effect on yield. Also, use of fertilizer is dependent on market accessibility.

Market accessibility and household income were selected for inclusion in the fertilizer equation. *Access* is the ability to enter or exit from a location. According to Beenhakker *et al.* (1987), it connotes the ability to travel and to transport goods. Market accessibility was, therefore, considered to be an important factor in the transportation of fertilizer from the market to the farm. Market accessibility is represented by the weighted distance travelled by farmers to a market centre to procure fertilizer. The distance variable for each household was multiplied by the market accessibility index for the sub-location. This variable therefore measures the relative ease or ability to receive fertilizer into the study area. This presupposes a farmer's ability to buy fertilizer hence the rationale for including the variable of total monthly income as an indicator of households' purchasing power.

The area of land under potato is a function of market access, availability of labour as other competing land uses. As the value of land rises, i.e., as its accessibility to a market improves, producers are likely to invest more in other inputs in order to produce more per unit of land. Land required to produce one unit of potatoes will theoretically be maximum when land rent is zero, and will decay as land values increase. The distribution of land among various enterprises reflects a farmer's preference in land allocation.

Assuming that land is in the short run fixed, the area allocated to livestock has an effect on what can be committed to potato production. Since potato production is a labour intensive activity, the use or nonuse of hired labour is important in determining the area under potato acreage. Area under potato is likely to be greater if labour is hired than if it is not. The total area cultivated at any given time therefore depends on the amount of hired labour available. Labour was also included on the grounds that its availability affects timeliness in carrying out certain operations, for instance planting and weeding. Such production processes are indispensable in the prediction of yield levels.

5.3 Identification of the SUR Model

Two formal conditions must be met, the *order* and *rank conditions* for model identification, to check whether consistent estimators of response parameters exist. The order condition says that if an equation is to be identified, the number of predetermined or exogenous variables excluded from the equation must be greater than or equal to the number of included endogenous variables minus one. The order condition of identification can be stated as follows -:

$$\mathbf{K_{00} \geq G - 1} \qquad \text{...(5.4)}$$

where $\mathbf{K_{00}}$ = The number of excluded predetermined variables
$\mathbf{G}$ = The number of included endogenous variables.

In both the equations (5.1 and 5.2) appearing in the recursive model, the number of excluded predetermined variables is greater than the number of included endogenous variables. The equations would be 'over-identified' had the rank order condition been satisfied. The rank condition can be stated as follows -:

$$\mathbf{rank\ [\Pi_{00}] = G - 1} \qquad \text{...(5.5)}$$

If the rank condition holds, and if the number of $\mathbf{K_{00}}$ > $\mathbf{G}$, the equation is over-identified (Amemiya, 1985). This means that the order condition is a necessary but not a sufficient condition for identification. A necessary and sufficient condition for identification will be one that guarantees that **G − 1** of the equations are independent. However, because of the complexity involved in matrix ranking, the order condition was taken to be a satisfactory rule of thumb criteria for identification. Thus, besides the number of excluded exogenous variables being greater than the number of included endogenous variables, it was possible to obtain values of the parameters from the equations in a reduced form. Also, prior information about road quality conditions made identification possible. Given the knowledge that poor road conditions constrain fertilizer supply, it was not only possible to obtain information on fertilizer application rates, but on yield as well.

5.4 Methods of Estimation

Ordinary least squares (OLS) method was used to estimate equations 5.3. With the equation containing only exogenous variables on the right-hand side, OLS was found to estimate the equations consistently and without bias. For equations 5.1 and 5.2, the two-stage least squares (2SLS) method was used to estimate yield and fertilizer.[2] According to Pindyck and Rubinfeld (1991), 2SLS provides a very useful estimation procedure for obtaining the values of structural parameters in overidentified equations. It allows for the simultaneous estimation of simultaneous equations. The 2SLS estimator also has advantage over the OLS estimator because it enables separation of the direct from the indirect effects of road quality on yield. It also provides unbiased and consistent parameter estimates. Multiple regression analysis was done using the SPSS/PC+ software to estimate the parameters in equations 5.1 to 5.3.

5.5 Results of Model Estimation

5.5.1: Least Squares Estimates

The ordinary least squares procedure was performed to estimate the area of land under potato (POTACRE) measured in acres per person in the household. The results in Table 5-1 show that hiring labour (HLABOUR) is significantly correlated with potato acreage (POTACRE). Market accessibility (MKTACCESS) and area under livestock (LIVESTOCK) are, however, not significant predictors of POTACRE.

Table 5-1 Regression Coefficients of OLS Estimation of Equation 5.3

Dependent Variable	Independent Variable	B	SE B	Beta	T	Sig. T
POTACRE	HLABOUR	0.39115	0.18479	0.163	2.117	0.0358**
	LIVESTOCK	0.00545	0.00671	0.063	0.812	0.4182
	MKTACCESS	-0.01669	0.05628	-0.023	-0.297	0.7672
(Constant)		0.90644	0.21926		4.134	0.0001

Multiple R = 0.179   Adjusted R^2 = 0.0015
R^2 = 0.032   Standard Error = 1.184

Key:
POTACRE = Potato acreage per member of household
HLABOUR = Zero-one dummy for hired labour
LIVESTOCK = Area under livestock in acres
MKTACCESS = Market accessibility per household

Source: Field Survey.
Note: **Statistically significant from zero at the 0.05 level (two-tailed "t" test).

Potato growing is a labour-intensive activity. Its production involves land preparation, planting, weeding, harvesting and grading. As a consequence, hiring labour is an important factor explaining potato acreage. However, increasing the number of farm labourers while the amount of land is constant means that the total amount of land available per person declines. After some time, if labour continues to increase relative to land, then diminishing returns will set in. If the farmer can increase his or her land, say by hiring from a neighbour, the point of diminishing return can be extended. Given the land squeeze in Kinangop, however, such land transactions are not common.

5.5.2: The Two-Stage Least Squares Estimates

A two-stage least squares estimation was performed on equations 5.1 and 5.2 of the seemingly unrelated regression model so as to consider all restrictions imposed on the endogenous variables in the system. Table 5.2 and Table 5.3 show the statistical results of the separate effects of independent variables on fertilizer use and yield respectively.

Table 5.2 Estimated Parameter for Fertilizer Use

Dependent Variable	Independent Variable	B	SE B	Beta	T	Sig. T
FERTILIZER	MKTACCESS	-4.91683	2.35471	-0.202	-2.088	0.0393**
	TEARNINGS	8.22973	0.00020	0.039	0.409	0.6837
(Constant)		62.22720	7.27449		8.554	0.0000

Multiple R = 0.206 Adjusted R^2 = 0.239
R^2 = 0.043 Standard Error = 36.491

Key:
FERTILIZER = Fertilizer use in kg per acre
MKTACCESS = Market accessibility per household
TEARNINGS = Households' total monthly income in KShs

Source: Field Survey.
Note: ** Statistically significant from zero at the 0.05 level (two-tailed "t" test).

Table 5-3 Estimated Parameter for Yield

Dependent Variable	Independent Variable	B	SE B	Beta	T	Sig. T
YIELD	FERTILIZER	0.18958	0.0715	0.271	2.653	0.0093*
	MKTACCESS	-1.73231	1.6503	-0.102	-1.050	0.2964
	HLABOUR	6.15368	5.2371	0.118	1.175	0.2427
(Constant)		24.64098	7.6498		3.221	0.0017

Multiple R = 0.296 Adjusted R^2 = 0.061
R^2 = 0.088 Standard Error = 25.042

Key:
YIELD = Potato yield in 120 kg per acre
FERTILIZER = Fertilizer use in kg per acre
MKTACCESS = Market accessibility per household
HLABOUR = Zero-one dummy for hired labour

Source: Field Survey.
Note: * Statistically significant from zero at the 0.01 level (two-tailed "t" test).

These results show the magnitude and sign of correlation between each dependent variable and its relevant regressor.

5.6 Effect of Market Accessibility on Fertilizer Use

Market accessibility (MKTACCESS) was found to contribute strongly and significantly to the per acre quantity of fertilizer use (FERTILIZER). Statistical analysis shows that as road quality declines, and markets get less accessible, the rate of fertilizer use also decreases. Given that

$$\beta = b \pm t_{.025}\,\text{SE} \qquad \text{.........(5.6)}$$

then a unit change in MKTACCESS results in a

$$4.927 \pm 4.30(2.355) = 4.927 \pm 10.127 \qquad \text{.........(5.7)}$$

change in fertilizer use (at 95% confidence interval). That is, there is 95% probability that 1% change in market accessibility results in approximately 5 ± 10% change in fertilizer use. While this empirical relationship is by no means linear, partial analyses results show that underlying changes in accessibility to a large extent explain the observed variation in fertilizer use between the small, medium or large farms. Household income is a statistically insignificant regressor of fertilizer use.

5.7 Fertilizer Use and Potato Yield

The results on Table 5-3 are consistent with those of previous analyses. FERTILIZER is strongly and positively correlated with YIELD. This relationship was found to be statistically significant at the 0.01 level of probability. A 1% change in per acre fertilizer use leads to a 0.2% change in potato yield. Survey data for 1994 shows that 68% of farmers in Kinangop used DAP to grow potatoes, applying on average 63.7 kgs/acre.

While this rate is only about 2 kgs less than the recommended amount of 66 kgs/acre (Muriuki, 1995), supply of fertilizer remains an important aspect of agricultural policy in Kenya. Improving the quality of rural roads increases market accessibility and ensures a more efficient fertilizer distribution system. As better access entails shorter time-distance separating farms from markets, farmers' production decisions are likely to take into account savings in transport cost resulting from the use of improved and better roads. Where such decisions lead to more efficient use of farm inputs such as fertilizer, farm yields are likely to grow.

5.8 Market Accessibility and Potato Yield

MKTACCESS is not strongly correlation with YIELD. Decisions on the rate of fertilizer application are, however, meaningful in terms of farm productivity. The assumption on improving the quality of rural roads and/or market accessibility is that the actual amount of fertilizer used by farmers is an outcome of the conversion of economic potential into farmers' demand for fertilizer and this demand being met by fertilizer supply and distribution systems (Desai, 1991). The findings of this study suggest that the effects of improving market accessibility on potato yield are transmitted through an intervening variable — fertilizer.

5.9 The Effects of Improving Road Quality

Improving road quality enhances market accessibility. As a result, the effects of changes in market accessibility on potato yield are both direct and indirect. It has been demonstrated that market accessibility and fertilizer use are significantly correlated (Tables 5.2). Locations with better access to the market have a higher MAI and vise versa. Consequently, as the farm-to-market distances increase, market accessibility decreases faster in areas served by poor roads than in those served by better quality roads. Thus a 1% change in market accessibility results in a 5 $\pm$ 10% change in per acre fertilizer use.

Notes on Chapter Five

[1] The seemingly unrelated regression (SUR) model proposed by Zellner (1962) is, according to Pindyck and Rubinfeld (1991), a recursive model. It consists of N regression equations each of which satisfies the assumption of the standard regression model:

$$Y_i = X_i b_i + u_i, \qquad i = 1, 2, \ldots, N \qquad \ldots\ldots(5.8)$$

[2] Since fertilizer use, potato yields and road quality are endogenous variables in the structural equation model (5.1 and 5.2), applying OLS to the estimation of yield and fertilizer equations would generate biased and inconsistent estimators. According to Pindyck and Rubinfeld (1991), in such (simultaneous) equations models where endogenous variables in one equation feed back into variables in another equation, the error terms are correlated with the endogenous variables and OLS is both biased and inconsistent (p. 291).

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Kinangop is a potentially rich potato producing region. Currently, potato output in the area is about 32 bags per acre. There are differences in yield between sub-locations. The highest potato yield is about 45 bags per acre. This occurs in Tulaga Sub-location. The lowest yield (14.9 bags per acre) occurs in Mikaro Sub-location.

Analysis of the network of roads in Kinangop revealed variation between sub-locations in the total density of roads. The densities weighted by the class of the road, that is the *road quality index* (RQI), were multiplied with the average farm-to-market distances travelled by each household (n = 168) in 6 sub-locations. This resulted in a relative measure of market accessibility per sub-location. The *mean market accessibility index* (MAI) ranges from 0.62 in Kahuru/Muruaki Sub-location with the best market accessibility, to 5.20 in Mikaro Sub-location which has the worst market accessibility.

Fertilizer use was analyzed by farm-size controlling for road quality. Results show that use of fertilizer is strongly and significantly related with road quality. Per acre fertilizer use varies significantly with improving road quality (Table 4-18). The average per acre fertilizer (DAP) use in Kinangop is about 64 kilograms. Njabini Sub-location has the highest average fertilizer use (79.4 kg/acre), followed by Mikaro Sub-location (56.9 kg/acre), Kahuru/Muruaki

Sub-location (56.8 kg/acre), Karati Sub-location (56.7 kg/acre), Tulaga Sub-location (54.2 kg/acre) and Nandarasi Sub-location (47.7 kg/acre).

Since Kahuru/Muruaki and Njabini sub-locations were categorised as having high road quality, Tulaga and Karati sub-locations as having medium road quality and Mikaro and Nandarasi sub-locations as having low road quality, per acre fertilizer use is observed to vary significantly between areas of different road quality and/or market accessibility (Table 4-18). Similar analysis was done to test the relationship between road quality and potato yield. Yield was analyzed by farm-size controlling for road quality (Table 4-19). Average yield between farm-sizes is not significant. It however increases with decreasing farm-size. Differences in average yield between areas served by low, medium and high quality roads is also not significant. The *chi-square test* for independence between fertilizer use and potato yield showed that the two variables are not independent (Table 4-17). Further analysis revealed that potato yield is strongly correlated with fertilizer use. This relationship is statistically significant at the 99% level of significance. This means, for example that a 10% change in per acre fertilizer use would lead to potato yield increasing or decreasing by almost 2% (Table 5-3).

Regression analysis on the effect of improving road quality and increasing market accessibility confirmed the results of the partial analysis concerning the empirical relationships between road quality, fertilizer use and potato yield. Road quality is shown to be strongly and significantly correlated with fertilizer use. Improving the quality of roads and market accessibility has a strong and significant correlation with fertilizer use. A unit change in market accessibility results in 5 $\pm$ 10% change in fertilizer use (Table 5-2).

6.2 Conclusions

Improving road quality does not, *per se,* explain potato yield. Evidence from Kinangop clearly demonstrates that as the quality of roads improve thereby increasing market accessibility, average per acre fertilizer use also increases significantly. When market accessibility is compared with yield, the two variables are found to be positively but, not strongly correlated. This is interpreted to mean that the road quality improvement effects on potato yield are explained through changes in fertilizer use. Households in areas served with better quality roads have easier accessibility to markets defined as the distance between farms and markets adjusted for the quality of the road network serving an area. The average per acre fertilizer use in areas of high quality roads is higher than in the medium and low road quality areas. Potato yield follows a similar pattern. Average yield is higher in areas served by better quality roads. Yield decreases with worsening road conditions and declining market accessibility.

The relatively high potato yield in such areas is linked to higher rate of per acre fertilizer use. Because of the observed statistical significance in the relationships between market accessibility and fertilizer use on the one hand, and between fertilizer application and potato yield, on the other, it is reasonable to conclude that improving the quality of roads increases yield in a cross-section of farm households in Kinangop. Since the evidence provided by this study does not falsify the hypothesis that fertilizer application rates and potato yield vary significantly with improving road quality, the preposition is accepted.

While it is evident that improving the quality of the roads and/or increasing market accessibility remains necessary for the use of fertilizer and potato yield to increase, whether farmers will, in fact, use more fertilizer if and when roads are improved is untested. The results of micro-level studies in two districts, Nagpur and Mahbubnagar in South India, indicated that fertilizer consumption increased significantly among small and medium farmers following an increase in market access (von Oppen *et al.*, 1985). Similarly, in a study of the effects of the impact of market access on productivity in Nakuru District, improvement in market access was found to have a positive effect on the total productivity of small, medium and large farms (Njehia, 1994).

These three studies seem to point toward the same conclusion. That is, improving road quality and/or market accessibility results is better crop yield. However, this should not be interpreted to mean that improving road quality and market accessibility is a panacea for low input use. While the fertilizer distribution system (of which the road network is but a part) is important, the demand side of the fertilizer equation is equally important. It is crucial, therefore, that the role of other factors such as land use practices be included in a wider discussion of the effects of improving road quality on agrarian development.

6.3 Recommendations

1. Growth in per acre fertilizers use and related increases in farm yield presupposes that the farmer is getting the right fertilizer at the right time. In order to realize this, improving the existing network of rural roads must be made a priority. Input marketing and distribution policy should target at increasing market accessibility if farm inputs such as fertilizers, which are necessary for agricultural productivity growth, are to be made readily available to farmers in an increasingly 'liberalized' economy.

2. The approach developed here for measuring the effects of road quality and market accessibility contributes toward the search for methodologies that are applicable in the study of the impact of roads on development. Toward that end, there is an urgent need for the approach suggested in this study to be tested with other types of infrastructure, such as water, power or telephone networks. Hopefully, this will help to build on the still undeveloped body of methodological approaches appropriate for studying different infrastructural impacts.

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APPENDIX A

QUESTIONNAIRE SCHEDULE

Enumerator's Name..........................
Respondent's Name..........................
Time...................(hrs/min)
Date...................

1. Schedule Number

2. Sub-location

1-Mikaro 2-Nandarasi 3-Mkungi 4-Kitiri 5-Murungaru 6-Kahuru/Muruaki 7-Gathara 8-Njabini 9-Muruaki 10-Tulaga 11-Gitwe 12-Karati 13-Bamboo 14-Mukeu 15-Rwanyambo 16-Gathabai

3. Name of this village.......................

4. Respondent's relation to head of household (see codes in table A below)

A DEMOGRAPHIC AND SOCIO-ECONOMIC PROFILE

	Names of h/h members	Relation to head of h/h	Sex	Age	Marital Status	Level of Education Completed	Sources of Income	KShs earned per month	Work on the farm?
1									
2									
3									
4									
5									

Relation to Head of Household: 1-Head; 2-Wife; 3-Husband; 4-Son; 5-Daughter; 6-Father; 7-Mother; 8-Brother; 9-Sister; 10-Other relative (sp.); 11-No relation.
Sex: 1-Male; 2-Female. Work on the farm?: (Yes=1; No=2)
Marital status: 1-Single; 2-Married (monogamy); 3-Married (polygamy); 4-Divorced\separated; 5-Widowed; 6-Not stated.
Level of education complete: 1-Std 1-4; 2-Std 5-8; 3-Form 1-4 4-Form 5-6; 5-Tertiary (sp.); 6-None; 7-Not applicable.
Income sources: 1-Farm; 2-Non-farm; 3-Both; 4-Other (sp.) 5-None.

B LAND HOLDING/COMPOSITION

5. What is the total acreage of land holding (owned and leased) during various years

1994	1993	1992	1991	1990	1989	1988	1987

6. What was the total area of land owned in acres?

1994	1993	1992	1991	1990	1989	1988	1987

7. What was the total acreage of land rented from others?

1994	1993	1992	1991	1990	1989	1988	1987

8. How many acres did the household operate?

1994	1993	1992	1991	1990	1989	1988	1987

9. How many acres were owned and operated?

1994	1993	1992	1991	1990	1989	1988	1987

10. How many acres were rented or leased to others?

1994	1993	1992	1991	1990	1989	1988	1987

C LAND-USE

11. How many potato crops did the respondent grow in each of the following years?

1994	1993	1992	1991	1990	1989	1988	1987

12. What was the total acreage under potato production?

1994	1993	1992	1991	1990	1989	1988	1987

(b) Was the potato crop(s) pure stand or mixed with other crops? Enter M for mixed and P for pure stand.

1994	1993	1992	1991	1990	1989	1988	1987

13. How many acres did the household use for the production of other crops?

1994	1993	1992	1991	1990	1989	1988	1987

14. How many acres did the household use for livestock/pasture?

1994	1993	1992	1991	1990	1989	1988	1987

15. How many acres were woodland or forest?

1994	1993	1992	1991	1990	1989	1988	1987

16. How many acres were fallow?

1994	1993	1992	1991	1990	1989	1988	1987

17. State the reasons for growing potatoes

....

....

....

....

18. State the reasons for growing other crops (record reasons against specific crops)
....
....
....
....

D FARM INPUTS AND TRANSPORT COSTS

19. Which recurrent inputs does the respondent use on potato production?

Year	List each input used	Unit of inputs used	Qnty.	Cost of input (KShs)	Area in acres input was applied	Road distance from farm to centre in Km	Mode of transport used	Total transport cost
1994								
1993								
1992								
1991								
1990								
1989								

<u>Fertilisers</u>: 0-No Input; 1-Manure; 12-Urea; 3-DAP; 4-NPK; 5-Nitrates; 6-Sulphates;
<u>Herbicides/Pesticides</u>: 7-Insecticides; 8-Pesticides; 9-Fungicides; 10-Herbicides; 11-Others (sp.)
<u>Seeds</u>: 11-Improved; 2-Traditional/AD; 3-Both
<u>Unit of measurement</u>: 1-Kilogram; 2-Litres; 3-Numbers

20. Have you obtained and used credit in your potato enterprise? ....(Yes=1; No=2)

E CREDIT

20. Have you obtained and used credit in your potato enterprise?.........(1=Yes, 2=No)

Year	Credit Source(s)	Credit Type	Credit Use	Amount (KShs)
1994				
1993				
1992				
1991				
1990				
1989				
1988				

Credit Sources: 1-Bank; 2-Co-operative; 3-Relative/friend; Other (sp.); 6-None
Credit Types: 1-Development Loan; 2-Seasonal Credit; 3-Others (sp.); 4-Not applicable
Credit Use: 1-Buying Inputs; 2-Buying Land; 3-Leasing Land; 4-General Farm Development; 5-Other (sp.); 6-Not Applicable

21(a) Has there been changes in the use of credit over the years? ....
1-Yes, 2-No

(b) What were the causes for the changes experienced?
....
....
....
....

22(a) Do you receive extension services? .... (Yes=1, No=2).

(b) If no, why not?
....
....

(c) If yes, list the types of services received, the year first benefited and the sources.

Type of Service	Year it Started	Source (agency)
a).............	....	....
b).............	....	....
c).............	....	....

Type of Service(s):0-None: 1-Planting; 2-Kitchen Garden;
3-Dealing with insects; 4-Manure Preparation; 5-A.I.;
6-Fertiliser Application; 7-Soil Erosion; 8-Potato Storage; 9-Draining Water; 10-Others (sp.)
Source(s):1-Government; 2-Non-Governmental organisation (NGO); 3-Potato Buyers; 4-Input suppliers; 5-Neighbours; 6-Others (sp.)

(d) What constraint do you face in obtaining the services mentioned?
....
....
....

23. How many times did an extension agent visit your farm? (enter the number in appropriate cell).

Years	1994	1993	1992	1991	1990	1989	1988	1987
Number of Visits								

24(a) How has extension service affected potato productivity? ....
Increase=1, Decline=2, No Difference=3, Not Applicable=4

(b) Explain the reasons for the answer given in (a) above
....
....
....

25(a) Which co-operative societies are there in this area?
1...
2...
3...
4...

(b) What activities are the societies involved in?
1. ....
2. ....
3. ....

(c) Are you a member of a co-operative society?.........(Yes=1, No=2)

(d) If yes, name the co-operative society and the activities it is involved in
....
....
....
....

(e) How long have you been a member ....(years)

(f) What benefits have you received as a member of this society?
....
....
....

(g) If no, give reasons why you have not joined a co-operative society?
....
....
....

(h) Would you join a co-operative society if you had an opportunity to do so?.........
(Yes=1, No=2)

(i) What are the reasons for your answer in (h) above?
....
....
....
....

F FARM LABOUR

26. How many people were employed on the household's farm?

Year	Acre worked on	How many* family members		How many hired* labour		Total amount (Kshs) paid to hired labour		Wage rate (KShs/day)	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
1994									
1993									
1992									
1991									
1990									
1989									
1988									
1987									
1986									

* **Adult** = 18 years and above; **Child** = 1-17 years

27. What difficulties do you face in obtaining labour?

....

....

....

G OUTPUT DISPOSAL

28. What is the proportion of transport cost in the final cost of potato?

Year	Area grown in acres			Amount produced in bags			Total amount sold in all the seasons		Approx. distance (km) to where produce was sold?	How did* the farmer transport the produce to the market	What was the cost of transporting the produce (Kshs)?
	1st	2nd	3rd	1st	2nd	3rd	Bags	Kshs /Bag			
1994											
1993											
1992											
1991											
1990											

* Means of transporting produce: 0-Not applicable; 1-Matatu; 2-Lorry; 3-Bus; 4-Pickup; 5-On foot; 6-Pushcart; 7-Bicycle; 8-Animal; 9-Wheelbarrow; 10-Other (sp.)

29. What constraints do you face in marketing potatoes?

....

....

....

....

I INVENTORY/USE OF FARM EQUIPMENT

Category of Farm Equipment	Use Yes/No (Yes=1 -No=2)	No. of Units	Owned/Hired/Borrowed (1-Own, 2-Hired, 3-Borrowed)	Cost (Kshs) (Hired)	Freq. of use
Pangas					
Axes					
Jembes					
Ploughs					
W/barrows					
Carts					
Spraying pumps					
Debes					
Bicycles					
Others (sp)					