ANALYSIS OF RESOURCE USE IN SMALLHOLDER FOOD CROP PRODUCTION AT RIVER NJORO WATERSHED, KENYA

BY

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A Thesis submitted to the Graduate School in Partial Fulfilment for the Requirements of Master Degree in Agricultural Economics of Egerton University.

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DECLARATION AND RECOMMENDATION

DECLARATION

I declare that this thesis is my original work and has not been submitted in this or any other university for the award of a degree

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Recommendation

This work has been submitted with our approval as supervisors.

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Signature Date

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DEDICATION

I wish to dedicate this work to my dear wife Grace Wangui, my children Cecilia Muthoni, Benedict Muriithi and Benson Ngari.

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ABSTRACT

This research explores how small-scale farmers in River Njoro Watershed in Kenya allocate resources to production of the main food crops in order to understand the underlying causes of enterprise productivity differentials. The River Njoro watershed stretches from the Mau forest to Lake Nakuru; it is part of the on-going research under the Sustainable Management of Watersheds (SUMAWA), Collaborative Research Support Programme (CRSP). The study was done in the five locations that fall within the watershed, namely: Nessuit, Njoro, Ngata, Baruti and Kaptembwa. A representative sample of 120 small scale farmers was studied. It was only possible to collect cross-sectional data during the study. The study basically used primary data, collected using a Schedule, which was administered to the sampled farmers using face-to-face interviews. A translog specification of production function and linear programming procedures were used to analyse the data. SAS and GAMS software's were used for the analysis. Results indicate that farmers in the study area allocated the biggest portion of their farms to Maize-bean intercrop and that Potatoes were not included in the optimal programme. The Allen and Morishima elasticities of substitution among pairs of inputs and price elasticities of factor demands were computed. The results indicate that all the three enterprises are substitutes except in the Maize-bean intercrop, which are in the inelastic range. In the three enterprises seeds are very sensitive to their own price changes while land in maize-bean intercrop and labour in potato and wheat enterprises are sensitive to the changes in the prices of other inputs but least sensitive to their own prices. The results further indicate that the increase in prices of seeds, labour and fertilizers used in the Maize-bean intercrop is not favourable since it will trigger more land use. Policies should thus dwell on the increment of output without the expansion of land under cultivation

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LIST OF ACRONYMS AND ABBREVIATIONS

A.S.L	above Sea Level
AEZ	Agro-Ecological Zone
CRSP	Collaborative Research Support Programme
CES	Constant Elasticity of Substitution
GAMS	General Algebraic Modelling System
GNP	Gross National Product
GDP	Gross Domestic Product
KARI	Kenya Agricultural Research Institute
Kg	Kilogram
Ksh	Kenya Shillings
LM	Lower Midland
LIMDEP	Limited Dependent Variable Programme
NGO	Non-Governmental Organization
OLS	Ordinary Least Square
R.O.K	Republic of Kenya
2 SLS	Two Stage Least squares
SPSS	Statistical Package for the Social Sciences
SUMAWA	Sustainable Management of Watersheds
TA	Tropical Alpine
UM	Upper Midland

CHAPTER ONE

INTRODUCTION

1.1. Background Information

Agriculture is the backbone of Kenya's economy. It provides nearly all the food required by the population and directly or indirectly accounts for over half of the country's economic activities and generates nearly two thirds of the country's foreign exchange. It supports 80 percent of the population and contributes 21 per cent of the gross domestic product (GDP) (RoK, 2004b). Agricultural sector GDP growth rate decelerated from 2.7% in 2003 to 1.4% in 2004, (RoK, 2005a) this problem was made worse by the fact that farmers could not access credit facilities to purchase fertilizers and therefore crop yields were low. This has resulted in recurring food deficits in most parts of the country.

As in many other developing countries, the small-scale farmers in Kenya encounter multiple constraints in their production process. These include inadequate capital, seasonal labour shortages, poor marketing infrastructure and uneconomically small farms; most of the farmers are poor and are not able to invest in further development, among other things.

Nakuru district within which River Njoro watershed lies is a major producer of food and cash crops. For instance, in 2003 only 28 bags of maize, 30 bags of wheat, 7 bags of beans and 2.5 tons of potatoes were realized per hectare (RoK, 2004a). This compared poorly with the neighbouring Rongai division, which despite having almost similar climatical endowment recorded 35 bags of maize, 30bags of wheat and 12 bags of beans during the same year. However, the yields per hectare were far below the expected optimum levels, which were 40 bags for maize, 35 bags for wheat, 18 bags for beans and 3 tons for potatoes (RoK, 2004a). This could be attributed to poor resource use, and input combination by farmers. It was further pointed out that there was not enough food to last from one harvest to the next in the district. Also the cost of resources like land, labour, seeds and fertilizers was noted to be rather high. In all of the above cases poor use of resources was noted to be a major contributing factor to low yields (RoK, 2004a)

In the River Njoro watershed, the highest land cover changes occurred after 1989, with rapid loss in plantation forests and the conversion of forested areas into small-scale (mixed) agriculture. Additionally, several larger agricultural areas were transformed into smallholdings. By 2003 the majority of plantation forests (these are exotic trees that are planted in a portion of the forest reserve for a specified duration of time after which they are harvested for commercial purposes, usually timber) were converted to small-scale agriculture (Kenya Forest Working Group, 2001). Large increases in smallholder agriculture are significant throughout the watershed, but are especially pronounced in the lower regions. In these areas both plantation forest and large-scale agriculture were converted into small farms as population pressure increased (Tracy *et al*., 2004). See Appendix 2 for land maps showing the land cover changes covering the period 1986-2003.

Land constraints have increased in River Njoro Watershed which was formerly thought to be land abundant; population pressure density has risen, and fallow periods have decreased. Farm capital formation is expected to affect the productivity of land and labour, (i.e. technical efficiency of the farm), Increasing farm capital should also make farm labour and land allocation more flexible and responsive to changes in incentives and diverse land conditions (Savadogo *et al.,* 1995). Hence one should expect farm capital formation to increase allocative efficiency as well. Although technical opportunities to increase food productivity in a sustainable manner are available, yield performance remains poor and current production systems exhaust natural resources at a rapid pace.

Decisions on land use are basically made by agricultural households, taking into account their own objectives, availability of resources, institutional arrangements and access to markets. Household members supply the bulk of labour requirements, therefore the amount and quality of labour available to households depends on the numbers, age distribution of the family members among others. As the economy grows and income rises, the domestic demand for non-food goods and services rises faster than the demand for food, and the demand for fruits, vegetables, and animal products rises faster than the demand for grains and tubers. Of course, food consumption patterns are also affected by changes in relative prices, cultural factors, religious restrictions and demographic shifts, such as urbanization and diversification is driven by factors other than income growth, factors such as falling barriers to international trade, improvement in transportation infrastructure, and new agricultural technology. Nonetheless, income growth is probably the main factor affecting trends in food consumption and domestic demand is one of the most important drivers of income and crop diversification.

It is worth noting that institutional arrangements within Kenya after independence spurred large-scale land cover changes, principally indigenous and exotic forest conversion to small-scale agriculture, in the once white occupied highlands region around the Nakuru district. Census records indicate that population in the Nakuru District nearly doubled (from 270,912 in 1979 to 413,698 in 1999). The greatest population increase occurred after the 1989 census. Between 1979 and 1989 the recorded population only increased by approximately 15,000 with additional population increases occurring between 1989 and 1999.

1.2. Problem Statement

This study investigated the problem of resource allocation among small-scale farmers in River Njoro watershed as this could be the reason for the decline in yields. Low yields per unit area of land in the study region have been hypothesized to be due to insufficient input usage and poor management of resources by farmers. For instance in Njoro Division in the year 2004 the target yield/ha for maize was 40 bags of which only 28 bags were achieved, wheat target yield/ha was 35 bags out of which 30 bags were achieved, beans target yield/ha was 18 bags of which only 7 bags were achieved and Irish potatoes target yield/ha was 3 tons of which only 2.5 tons were achieved. The declining trend in yields had also been noted in the previous years. The prevalence of small-scale farming systems in the River Njoro watershed makes them a major driving force of agricultural development in the watershed.

1.3. Overall Objective

To evaluate the allocation and demand for factors of production by small-scale farmers in the River Njoro watershed.

Specific objective

i. To determine the demand for factors of production used by small-scale farmers in the River Njoro watershed under natural rain fed conditions.
ii. To determine the levels of resource use in the production of main food crops by small-scale farmers in the River Njoro watershed.

1.4. Research Questions

i. What determines the demand for factors of production used by small-scale farmers in the River Njoro watershed and why?
ii. At what levels of resource use do small-scale farmers in River Njoro watershed operate in the production of main food crops, and why?

1.5. Justification of the Study

Since smallholder farmers in Kenya contribute nearly 72 per cent to total sales, improved resource allocation could lead to higher output and thus improved welfare of the small-scale farmers. In the River Njoro watershed the major economic activity is agriculture, this study intends to show the importance of understanding how small-scale farmers allocate the meagre resources at their disposal to different enterprises in the production process. It is intended that the results of this study would enable small-scale farmers allocate their limited resources more efficiently.

River Njoro watershed has been selected due to the fact that it has been experiencing the problem of low yields and poor resource usage and this has had subsequent effects on the standards of living of the farmers. This has drawn a lot of concern from various Non-governmental organisations (NGOs) and institutions nearby. It is hoped that the results of this study will lead to increased production and productivity; idle resources will be put into more efficient use and also identification of slack and high demand periods for efficient farm planning. Agricultural extension staff charged with the role of advising farmers will use the information as decision support to formulate guidelines that improve production under varying conditions. The results of this study will also be generalised to other areas with similar characteristics. A clear understanding of how small-scale farmers in the river Njoro watershed allocate resources to the main enterprises and also the factor demands by small-scale farmers is required for technological and developmental interventions to be targeted appropriately. This is the information gap that this study intends to fill.

The information generated would assist planners, researchers and policy makers in formulating appropriate strategies for promoting small scale food crop production in River Njoro watershed and Kenya in general. The study findings will therefore add to the existing body of knowledge in agricultural economics

1.6. Scope of the Study

The study was done within the River Njoro watershed that stretches from the Mau forest to Lake Nakuru; it is part of the on-going research under the Sustainable Management of Watersheds (SUMAWA), Collaborative Research Support Programme (CRSP). It focused on optimal levels of resource use in smallholder crop production, the crops that were addressed were: maize, wheat, potatoes and beans. The study was done in the five locations that fall within the watershed, namely: Nessuit, Njoro, Ngata, Baruti and Kaptembwa. Due to time and money constraints, a representative sample of 120 small scale farmers was studied. It was only possible to collect cross-sectional data during the study. It is envisaged that this formed a representative sample from which results could be generalized to cover the whole of the study area.

1.7. Limitations of the Study

During the field data collection exercise some of the respondents were absent during the scheduled time with the enumerators, this necessitated call backs which led to time wastage. Some respondents especially in the upper watershed were not willing to divulge the full information about the farm as they considered this a male domain.

1.8. Definition of terms

Catchment: Refers to an area with common drainage, Area is usually forested or covered with natural vegetation.

Economic optimum: Level of input occurs when the marginal value of product of that input is equal to the price of the input.

Fixed Input: Are those inputs that do not vary as output change, they are incurred even when production is not undertaken

Household: Comprises of a person or group of persons who are generally bound together by ties or kinship or joint financial decision, who live together under a single roof or compound and are answerable to one person as the head and share the same eating arrangements.

Large scale farm household: Refers to the household who own land of more than five acres. The land ownership can either be leasehold, private or communal.

Linear programming: Is an operational method for studying the allocation of resources between enterprises when inputs are limited in their total amounts or are otherwise constrained.

Marginal physical product: The increase in output that occurs when one more input is applied

Marginal revenue product: The change in the farm's total revenue brought about by the employment of one extra unit of a resource.

Marginal revenue: is the change in the farm's total revenue per unit of output.

Off farm income: Income generated outside farming activities accruing to an individual.

Partial budget: A partial budget is a technique for assessing the benefits and costs of a practice relative to not using the practice.

Risk: Is restricted to situations where probabilities can be attached to the occurrence of events which influence the outcome of a decision making process.

Smallholder farm household: Refers to the household who own land and farm of up to a maximum of five acres. The land ownership can either be leasehold, private or communal.

Sustainability: Concept captures the idea that the living standards of future generations should not be compromised through environmental depletion by the current generation.

Technical efficiency: Is the maximum attainable level of output for a given level of production inputs.

Variable Input: Inputs whose quantity used varies as the amount of output from the production process changes.

Watershed: Refers to an area through which water flows to a common point.

CHAPTER TWO

LITERATURE REVIEW AND THEORITICAL FRAMEWORK

2.1. Literature Review

Optimum allocation of land and other resources is defined as what farming activities to undertake, how much land to allocate to each crop activity and what combination of inputs to use on each crop so that net farm returns are maximized. Empirical studies in optimum land use patterns, resource allocation and resource requirements have largely been attempted in many countries for different, usually theoretical average categories of farms. In such studies for each farm situation, some resources are taken to be given while others are hired or borrowed to the level where the marginal productivity of the resources gets equated to the marginal factor cost (price) of the respective resource. It is assumed that the resources that are hired are able to satisfy the estimated level of demand and that there is a limited stock of all such resources for the economy as a whole and each farm situation can draw upon it no more than its relative economic power in the economic system.

2.2. Review of Resource Utilization and Optimization Related Studies

2.2.1. Resource Utilization Studies

Singh and Jain, (1981) observed that labour supply during the peak periods may actually turn out to be less than the normative estimated requirement by an open model for each farm situation rendering the improved plans unfeasible in the overall real economic system. However, in macro level inter-regional programming models, these aggregative constraints are explicitly considered. Obare *et al.* (2002) in their study on smallholder production structure and rural roads in Nakuru district focused on land, machinery and labour as the main resource constraints in crop production. The study revealed that the two maize production strategies (pure or mixed stand) were mutually exclusive, i.e. farmers grew maize in either pure or mixed stands. Labour was found to be the resource over which farming households had the most control. The study also found that inadequate road infrastructure imposes significant burdens on cost-minimizing smallholder farmers in the study region and by extension, other areas with similar conditions.

Farmers faced with high farm-to-market access costs commit less land, fertilizer and machinery resources to production, but more labour; high access costs are also associated with more land devoted to maize, the region's, Kenya's and Africa's most staple food crop.

Omamo *et al.* (2002) found a significant relationship between inorganic and organic fertilizer use in Nakuru district, Kenya. They concluded that this could be due to access costs and other household specific variables. 2SLS regression results indicated that inorganic fertilizer use was significantly higher: the lower the manure use, the lower the share of food crops in production patterns the lower were the farm-to-market transport, the larger the quantity of family labour: and the greater the quantity of labour hired. The level of education appeared not to influence fertilizer use.). Though there was a positive and significant direct relationship between levels of chemical and organic manure use, the relationship was negative when corrected for farm-to-market transport costs. However, inorganic fertilizer use was more applied on cash crops than on food crops (Obare *et al.,* 2003)

Obare *et al.* (2002) in their analysis of Kenyan smallholder agriculture with respect to maize productivity and production strategies found out that land size, maize seed price, choice of pure stand maize strategy, total household size and fertilizer price were important determinants of farm decisions on whether farmers use hybrid seed or not. Adoption of a pure stand maize strategy was however found to be dependent on size of land owned and choice of hybrid seed. Considering that fertilizer is an important factor of production and that fertilizer use intensity is, in most instances below the optimal level, advocating the intensified use of hybrid seed would be an important strategy to mitigate the low level use of fertilizer with the corresponding effect of increasing yields and productivity.

By using a linear programming transportation model, Allan (1995), studied how transportation costs could be minimized in the smallholder tea sub-sector of Kiambu district of Kenya. In a study to evaluate the impacts of carrier transportation capacity, constraints and changes in prices of transportation services on grain marketing and transportation systems, Koo *et al.,* (1985), developed and applied a linear programming model to the U.S. grain transportation system. Their model included transportation and storage capacity constraints in addition to demand and supply.

Goswami (1997) in his study on the economic appraisal of indigenous farming systems of West Garo Hills District in India found that systematic farm planning was a paying proposition under the existing technology and with the existing resource base on the hill farms. Wambugu (1998) used the linear programming technique to analyze the importance of credit as a constraint among small-scale farmers in Nyandarua district. He found that small-scale farmers failed to meet the requirements for credit given by commercial banks and the agricultural finance corporation, and relied on informal borrowing, However, the funds obtained from such minor sources were usually little and inadequate. He concluded that credit was a major constraint to small-scale farmers in Nyandarua District.

Muhammad *et al. (*2000) found the existence of a significant extent of resource use inefficiency on the cotton farms in the cotton-wheat production system of Pakistani's Punjab. In many instances, the quantities of inputs used were unjustifiably higher than what would be required to achieve their present levels of crop output. Other existing studies on technical and economic efficiencies have used the traditional parametric methods to estimate "average" efficiencies only (Ali *et al.,* 1993; Parikh et *al.,* 1994.1995). The estimation of such "average" efficiencies appears to ignore the argument that the study of the individual farm is more important to measure the resource use efficiency, and that the parametric methodology provides insufficient information for policy analysis (Kalirajan *et al.*, 1986).

Barro *et al.* (1999) used a Cobb-Douglas type function to examine small-scale effects and showed the expansion of aggregate labour force per capital growth rate for a decentralized economy. The results thus showed the positive effect of labour on the marginal product of capital. In Central Malawi, Ng'ong'ola *et al.,* (1994) used a Cobb-Douglass production function to explain variation in barley and tobacco yield among tenants. Their results demonstrated that area under barley tobacco and quantity of fertilizer applied were the main factors determining tobacco yield. Donovan *et al.* (1991) reported estimates on research and development (R&D) using a Cobb-Douglas production function. In the estimation, rainfall per hectare, expenditure on technology, production costs per hectare and land under sugarcane had a significant impact on industrial yield of sucrose. An experimental model to study the relationship between output to land size, environmental and management indices (Odulaja *et al.,* 1996) showed that land size and environmental effects were significant in explaining variation among outputs of crops. Byiringiro *et al.* (1996) demonstrated that the marginal value product of land on small farmers were above rental price of land, implying factor use efficiency and constraints to land access

Bravo-Ureta *et al.* (1994) also employed a Cobb-Douglas function form to fit separate production frontiers for cotton and cassava using a maximum likelihood procedure. The dependent variable was annual total farm output of cotton or cassava and the explanatory variables were area devoted to cotton or cassava production, family and hired labour days used on cotton or cassava production, and value of materials such as seeds. The results showed an average economic efficiency of 40.1% for cotton and 52.3 % for cassava, indicating that the sample household had plenty of room to increase productivity and output on their farms. In Argentinean agriculture, a Cobb-Douglas type model was used to measure technical and cost efficiency (Gallechar *et al*., 1994). In the model, output was specified as a function of eight inputs and three dummy variables for location and climatic conditions. Results demonstrated that management; ownership and monitoring had a greater effect on marketing efficiency than on either technical or cost efficiency.

Fulginti *et al.* (1998) in their examination of changes in agricultural productivity using a combination of the Cobb-Douglas function and non-parametric output-based malonguist index; they reported that half of the countries studied had experienced a decrease in agricultural productivity. A two stage Cobb-Douglas production function and a Translog function were used to measure the productivity of pesticides, and the host- plant resistance and the substitutability between them (Widawsky *et a1.*, 1998). The results showed that under intensive rice production systems in eastern china, pesticide productivity was lower than the productivity of host- plant resistance and that host plant resistance was an effective substitute for pesticides. Returns to pesticide use were negative at the margin due to pesticide overuse.

Thirtle *et al.* (1998) used a two-stage constant elasticity of substitution (CES) production function to test the induced innovation hypothesis, based on data from South African commercial agriculture and reported that farm size, research and extension expenditures and policy variables were important factors. Shatiq *et al*. (1993) used regression methods to estimate a production function relating sunflower yield to number of plants per hectare, date of planting, quantity of nitrogen, soil type, usage of ridges and sunflower variety. The result showed that very little of the total variation in the yield was explained by agronomic variables. The only significant variables were those representing plant densities, implying that priority in sunflower research should be placed on stand establishment. Economic analysis demonstrated that sunflower could be a good alternative to wheat.

Cramer *et al.* (1996) analyzed production efficiency of Chinese rural households in farming operations using a shadow price profit linear Model. The shadow prices were estimated by a generalized profit function, which incorporates market distortions resulting from imperfect market conditions. The results showed that households living in mountain areas or whose family members were government employed were relatively inefficient.

Wawire *et al.* (1997) examined productivity and profitability of rain-fed rice production in western Kenya using a Cobb-Douglas model. Their study indicated that rain-fed rice production in western Kenya had not benefited from the use of improved technological components (e.g. improved varieties and inorganic fertilizers) and that there was some misallocation of traditional inputs (e.g. under utilization of labour for weeding).

Wiyo *et al.* (1999) while doing a study on the assessment of the effects of tie-ridging on smallholder maize yields in Malawi observed that there was a substantial yield gap (59-69%) between mean observed yields under small holder conditions and maximum yields possible under good management and inputs. This was as a result of low fertilizer inputs, declining soil fertility, management practices and variable climate. They further observed that the provision of nitrogen inputs still remained the best way to increase smallholder maize yields under current management practices and that the impact of on-field rainwater harvesting systems on maize yield was likely to be felt at high nitrogen input levels and management practices. Some studies used the Armington model to analyse the trade flows of wheat between importing and exporting countries by differentiating wheat by country of origin and other studies used the almost ideal demand system (AIDS) and the Rotterdam model to analyse import demand for wheat classes (Wilson, 1977; Allison, 1984). Fulginiti *et al.* (1994) argued that a production approach is conceptually more plausible than a utility based demand model in estimating demand for agricultural commodities used as inputs in the processing industry, but it is not an empirical panacea. They concluded that the bridge between theory and empirics is stronger for the production approach than the utility maximization approach (Koo *et al.*, 2001).

Own price variables have a negative sign as expected on the basis of economic theory and are significant at the 5% level in all the cost share equations except for the labour equation, indicating that the Japanese milling industry is sensitive to wheat classes (Koo et. al., 1985) The elasticities estimated in this study (Koo *et al.*, 2001) are much more elastic than those estimated by (Lee *et al.*, 1994). This is mainly because;

1). This study used a production theory approach by treating wheat as an input in the Japanese milling industry, while (ibid) used a Translog demand system and the AIDS respectively, by treating wheat as a consumer good and.

2). Own-price elasticities are elastic for all the wheat classes, but the demand for imported soft wheat classes, is less elastic than all the hard wheat and Japanese soft wheat.

3). These relationships also reflect the substitutability relationships between wheat classes; US and Canadian hard wheat can be substituted for each other, but other wheat classes are less substitutable. The positive signs of the AES indicate substitute relationships between any pairs of wheat classes. The negative signs of the off-diagonal AES imply complimentary relationships between any pairs of wheat classes. This could be mainly because Japanese millers blend different classes of wheat for many different types of wheat for many different types of wheat production. The own and cross price elasticities of factor demand were all inelastic indicating that farmer's response to changes in the price of inputs were small in magnitude.

A good number of studies (Binswanger *et al.*, 1984; Lopez, 1980) have been done by various researchers related to the present study, but most of these are related to foreign environment. Therefore, there is a reason to undertake such a study for reasons such as; updating estimates of technical change and elasticity estimates in a changed condition (Kamuzzaman *et al.*, 1996)

So the fundamental principle in analysis for factors of production is not only these factors (among others) that influence a farmers' (individuals) propensity to consume a particular farm input, but that they influence the propensity to consume at a particular price. In other words, demand factors influence the price-responsiveness of consumers, and a major role of analysis of demand for farm inputs is to investigate and explain how and to what extent this price responsiveness is influenced by which demand factors.

Thus the role of an analysis of demand for farm inputs is to explain the relationship between certain demand factors and the price responsiveness of farmers and their demand for farm inputs, and then to quantify that relationship using econometric techniques. The estimates of the parameters of demand for farm inputs can be used to predict the direction and degree of impact on demand.

2.2.2. Resource Optimization Studies

A multiple criteria and nearly optimal solutions in greenhouse management in Massachusetts U.S.A (Willis *et al.*, 1993) constructed a model for greenhouse decisions using the linear programming method. The optimal solutions required the use of about 4000 hours of unpaid family labour, along with hiring additional labour during peak periods. On the reasonable assumption that leisure or off-farm employment was preferred to unpaid on-farm family labour, they calculated non-inferior solutions considering expected profit and labour saving as twin objectives. It was revealed that the majority if not most operators would consider non-inferior solutions other than that corresponding to maximum expected profit to be superior. While on a related study (Moffit *et al*., 1989) used a linear program model to help green house operators make economic decisions about their business. They used information on twenty possible crops and the availability of bench space and labour along with marketing considerations and calculated the optimal cropping pattern and hiring from the minimum expected point viewpoint. Linear programming was used to choose optimal energy levels in broiler diets subject to meeting standard nutritional requirements for other diet elements (Allison *et al.*, 1978). Mariano *et al*. (1994) showed the separable linear programming model to be as accurate as the non-linear programming model while doing a study on maximization of profit in broiler production as prices change.

In their study on optimum land use patterns and resource allocation in a growing economy, (Alam *et al.,* 1996) examined land use patterns for the small farmers at the farming systems research site Jessore, Bangladesh. Results of the study revealed a considerable divergence between the existing and optimum plans under both limited and borrowed capital situations. They suggested that strengthening of the extension services and market network, besides strong financial support, would go a long way in improving the prospects of the small farmers in the study area.

Uddin *et al*. (1994) in their study of an optimum cropping plan for a sample of farms in a farming system research area of Bangladesh, sought to examine the existing resource allocation patterns and to establish an optimum crop plan to determine how far the profitability of the farms could be improved if the resources were reallocated optimally. They used the linear programming model, which showed that resource allocation patterns in the optimum plan both with restricted and unrestricted capital were remarkably different from those in the existing plan. In general, the optimum plan suggested a lesser degree of diversification in crop production than was normally being practiced. They recommended that a good number of crops currently being produced need to be eliminated from the farm plan. The results also showed that net returns from crop production increased with an increase in the level of capital. However, given the resource endowments and other constraints, there remains enough scope to improve returns from the crop components by reorganizing the enterprises and reallocating resources to the desired enterprises. The optimum plan appeared to be capital intensive and at the same time highly profitable. Abdulkadri (1998) used the linear programming model to determine how efficient farmers were in the use of farm resources. The optimal farm plans suggested sole cropping to be the most profitable system in the three zones studied. Since farmers are not only concerned with maximizing profits in developing economies such as that of Nigeria. The optimal plans they generated gave the best achievable results when the only objective was to maximize profit. When other implicit objectives that were not quantified were introduced, the alternative farm plans (AFPs) offered more realistic solutions to the farmers in their individual settings.

Asamenew (1980) used linear programming optimization to investigate constraints to agricultural production on small-scale farms in the star-grass zone of Embu District. Land and working capital were found to limit production in small sized farms. Working capital and labour (not land) limited production in medium and large farms. Rop (1981) used linear programming to compare profitability and optimum resource use in the Ainabkoi east and west settlement schemes

Sanat *et al. (*2001) while on a study on the economic analysis of borrower and non-borrower rice farmers in Cuttack district of Orissa, India. Found that borrowers had used higher amount of critical inputs, which enabled them to obtain higher per hectare rice yield as compared to their counterparts. Both borrowed and owned funds were used in rice production. As regards optimization of resources, the credit recipients got maximum profit from rice production through optimum use of credit financed inputs. They further found that non- borrower farmers could also allocate their resources optimally by higher investment from owned funds through increase in their non-farm income.

Linear programming optimization of existing enterprises was used to investigate the reasons for declining pyrethrum production in Kiambu District (Mbai, 1984). His findings showed that pyrethrum was unprofitable to grow and was totally excluded from all optimal farm plans. Linear programming analysis was used to investigate the role of resource use optimization in improving farm incomes in small-scale irrigation schemes; smallholder farms were characterized on the major enterprises grown in Mitunguu irrigation project in Meru District of Kenya. Results showed that the existing farming systems were operating sub-optimally and there was substantial capacity to generate increases in farm incomes by optimizing resource use (Kamunge, 1989). While on a study on the economics of smallholder legume-cereal rotation technology in Nakuru district, Kenya. Ithinji (2001) found that even though the highest gross margins were associated with fresh tomato and Irish potato, these enterprises were also coupled with high capital and labour demand and therefore were allocated low acreage by farmers. The implication is that the profitability of an activity alone does not guarantee its inclusion into farm plans. Enterprise demand for scarce household resources must be consistent with the resource base of the farmers. He further noted that in most farms working capital was a major constraint. Smallholder farmers in Nakuru district were found to be more constrained by shortage of working capital than by land resource. In central Uganda, Gowa *et al.,* (2001) used the Cobb-Douglas function in determining optimal levels of resource use in clonal Robusta coffee production. Their results showed that land and capital were the most limiting factors in clonal coffee production for poor farmers whereas land and labour were identified as the most limiting factors for rich clonal coffee farmers. Overall, land and labour were found to be most limiting.

2.3. Critique

Some of the studies in the literature above, attempted production analysis revealing the marginality conditions of resource use in respect to the production of individual or selected enterprises. Such type of analysis, in addition to being very partial in nature, addresses only the existing aspect in the organization of the farm business, and fails to answer as to what would the optimum combination of enterprises under given restraining conditions.

Performance analysis using arithmetic and functional analysis may reveal a particular enterprise to be highly profitable. However, there may be serious limits to the expansion of the enterprise, imposed by physical, economic, social and environmental constraints. Thus the performance of the farm is governed by a number of constraints, which need to be accommodated in planning a farm.

In the study carried out by (Uddin *et al.,* 1994) the sample size was rather small as only 40 farmers were considered, the area devoted to some of the crops was also too small to generate any robust input-output coefficients thus sufficient caution should be exercised in making generalizations out of the results of the study. Though the study by (Goswami, 1997) developed optimum farm plans at existing levels of resource use it was made under the basis of shifting cultivation, such farming practices are hardly sustainable as much of the farming is on a temporal basis without much regard to soil fertility sustenance and sound cultural practices. In a similar study, Alam *et al.,* (1995) the crop activities which were termed as "recommended "includes those from the experimental results of the on-farm research division; the farmers however produced other crops which were considered as major land use alternatives. The analysis, however, was not carried out in terms of these crops. The study by (Willis *et al.,* 1993) was carried out under green house controlled conditions; results may therefore not be relevant to resource poor farmers who operate under uncontrolled environments. It is also worth noting that the majority of the studies targeting resource uses by farmers have been done in other countries. These may have better technology and managerial ability than Kenya. Many of the studies have assumed the objective of profit maximization which may not be necessarily true as is the case with a majority of the Kenyan small-scale farmers; also the demand factors of production at the household level by small-scale farmers has rarely been addressed.

2.4. Theoretical Framework

This study is based on the neoclassical theory of production and resource use. The Theory begins with the farmer as an individual decision maker concerned with questions such as how much labour to devote to the cultivation of each crop, whether or not to use purchased inputs, which crops to grow in each field, among other things. It thus centres on the idea that the farmers can be able to vary the level and kind of farm inputs and outputs.

Three kinds of relationships are typically recognized as encompassing the economic decision making capacity of the farmer: Varying levels of output corresponding to different levels of variable inputs; Varying combination of two or more inputs required to produce a specified output (method or technique of production); and Varying outputs which could be obtained from a given set of farm resources.

This three-fold capacity for varying the way in which farm production is organized only attains analytical relevance when placed in the context of the farm family and the resource constraints of the individual farm.

In practice, farm families may have different goals: namely income stability, Family food security, and achievement of certain preferences in consumption and fulfilment of community obligations. The farm may also face constraints of varying severity that limit the capacity to vary the organization of production. For example, land may be fixed over considerable periods of time. Labour may not be available for seasonal peaks in activity, Working capital may be unavailable or expensive. Purchased inputs may be variable in availability, quality and price.

It thus centres on the idea that farmers can vary the level and kind of farm inputs and outputs. Farmers' behaviour in terms of resource allocation can best be explained by the theory of cost minimization and output maximization. Farmers are assumed to either minimize the cost of production, maximize the total farm output or both. Therefore, any factor that affects cost or/and the level of production is likely to influence farmers' behaviour in relation to resource use. The farmer's resource allocative behaviour can thus be analysed using the linear programming or the demand system model. The linear programming model determines whether farmers allocate their resources optimally. Moreover, the demand model explains the farmer's allocative behaviour.

2.4.1. Theory of Production and Resource Use

Households are both producers and consumers of goods and services, production and consumption are made simultaneously and these two decisions are therefore inseparable. In economic theory the problems of production decisions, consumption decisions, and labour supply decisions are usually analysed simultaneously since consumption and production are inseparable through the behaviour of three classes of agents: producers, consumers and workers. However, the same household is faced with three classes of decision making. A household is engaged simultaneously in production, consumption and work decisions. The three problems must be integrated into one single household problem: that of utility (u) maximization. This can be formulated as:

$$\text{Max } u = f(q_i, \ldots\ldots, q_n), \text{ utility function, where } \quad q = 1 - 4 \tag{1}$$

$$\text{S.t. } q_i = f(x_i, \ldots\ldots, x_n) \text{ where } n = 1 - 3, \quad \text{production function} \tag{2}$$

$$x_i = f(p_i, p_j, z_{ij}) \text{ where } j = 1 \ldots n \tag{3}$$

where p_i is price of own input, p_j is price of alternative inputs, q is the output produced from a given set of resources, x_i is the input under consideration; and z_{ij} is a set of household characteristics like the family size, gender, level of education among others.

A farmer derives utility from a set of outputs, the quantities produced are subject to the input combinations, while the input use is subject to its own price, price of other inputs and a set of socio-economic variables as given above. In order for the farmer to maximize utility, he/she must make simultaneous decisions to allocate inputs to different crops under budget constraining situations.

The resource use for the small-scale farmers will be obtained using optimization techniques. These techniques involve the formulation of an objective function to minimize costs subject to a technology constraint. The mathematical optimization model is as follows.

$$\text{Maximize:} \quad Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n \tag{4}$$

$$\text{Subject to (s.t.):} \quad a_{11}x_1 + a_{12}x_2 + \ldots\ldots\ldots + a_{1n}x_n \leq b_1 \tag{5}$$

$$a_{21}x_1 + a_{22}x_2 + \ldots\ldots\ldots. + a_{2n}x_n \leq b_2 \tag{6}$$

$$a_{m1}x_1 + a_{m2}x_2 + \ldots\ldots. + a_{mn}X_n \leq bm \text{ and} \tag{7}$$

$$x_1 \geq 0, x_2 \geq 0, \ldots. x_n \geq 0 \tag{8}$$

where Z is the objective function. The restrictions constraints, the first m constraints (those with the function $a_{i1}x_1 + a_{i2}x_1 + \ldots\ldots\ldots + a_{in}x_n$ representing the total usage of resources on the left of the inequality are sometimes called functional constraints). Similarly, the xj ≥0 restrictions are called non-negativity constraints. the x_j variables are decision variables. The input constants $a_{ij,}$ cj may be referred to as parameters of the model. Linear programming is a mathematical tool for solving maximization and minimization problems (Nicholson, 1986). Linear programming is the suitable optimization technique to use when the relationship is linear; it is also more appropriate for this study since it can handle large data sets, is less complex, as compared to other approaches like the quadratic forms and has fewer computational mistakes.

2.4.2. Estimation of Demand for Factors of Production

A farmer's production structure can be studied empirically using either a production function or a cost function; however the choice should be made on statistical grounds. Direct estimation of the production function is more convincing in the case of endogenously determined output levels, while in the case of exogenous output levels; the cost function is more preferable due its flexible nature.

In most cases, particularly in a country like Kenya, the price of most agricultural commodities is determined through the market forces. However, the markets may be subject to perfect competition at times due to information asymmetry. The small scale farmer only makes entrepreneurial decisions regarding levels of inputs to use, and he/she competes with other activities for factors of production and this leads factor prices to be exogenous. Since the arguments of the cost function are the output and factor prices, its estimation is statistically more logical than that of the production function. The translog cost function does not constraint the production structure to be homothetic nor does it impose restrictions on the elasticities of substitution. However, these restrictions can be tested statistically. A cost function corresponds to a homothetic production function if, and only if, the cost function can be expressed as a separable function in the output and the input factor prices (Deaton *et al.,* 1980) A homothetic cost function is further restricted to be homogenous if, and only if, the elasticity of cost with respect to the output is constant. The elasticities of substitution can be restricted to unity by eliminating the second-order terms in the prices of the Translog cost function. Hence, the unitary elasticity of substitution are restricted to zero.

The Linear Approximate Almost Ideal Demand System (LA/AIDS) model was used in this study to estimate the demand for the factors of production (Deaton *et al*., 1980). The factor shares used in the estimation were derived from a cost function of the Translog form as follows.

$$\ln C(Q_{i,}P_i) = \ln \beta_0 + \Sigma\beta_i \ln P_i + \frac{1}{2}\Sigma\Sigma\theta_{ij} \ln P_i \ln P_j + \Sigma\gamma_i \ln P_i \ln y + b(\ln y)^2 \quad (9)$$

where C (Q_i, P_i) is the cost as a function of quantity Q and price vector P, y is the total cost of inputs, θ_{ij}, β_i, γ_i are parameters to be estimated, P_i, P_j are the prices of the inputs and substitutes respectively.

A Translog specification is used to represent the cost function of small scale food production in the River Njoro watershed. The Translog cost function is well known for its flexible functional form in terms of the local- order approximation to any arbitrary functional form. The Translog cost function is positive, symmetric, and linearly homogenous in input prices.

The theoretical properties of additive, homogeneity in prices and income, and symmetry of the cross effects of demand functions, imply the following parametric restrictions on the cost function above.

$$\sum_i \beta_i = 1, \sum \gamma_{ij} = 0 \text{ and } \sum \theta_{ij} = 0, \theta_{ij} = \theta_{ji} \text{ for } i = 1, \ldots\ldots, n \quad (10)$$

Taking the derivatives of the translog cost function (equation 9), share equations are obtained as:

$$\frac{\partial \ln C}{\partial \ln P_i} = \beta_i + \sum \theta i_{ij} \ln P_j + \gamma_{ij} \ln y \quad (11)$$

Where:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{1}{C}\frac{\partial C}{\partial P_i} \div \frac{1}{P_i} = \frac{P_i}{C}\frac{\partial C}{\partial P_i}$$

but $\frac{\partial C}{\partial P_i} = X_i$ by shepherd's lemma (Debertin, 2002). Hence

$$\frac{P_i}{C}\frac{\partial C}{\partial P_i} = \frac{P_i X_i}{C} = w_i \quad (12)$$

where w_i signifies the budget share of the i*th* input factor. The translog cost function Therefore yields a cost share equation as given below:

$$w_i = \frac{P_i X_i}{C} = \beta_i + \sum \theta_j \ln P_j + \gamma_{ij} \ln y \quad (13)$$

It is possible to estimate the parameters of the cost function using ordinary least squares (OLS), but that neglects the information contained in the cost share equation. An alternative estimation procedure is to estimate the cost shares as a multivariate regression system. The optimal procedure is to jointly estimate the cost share equations as a multivariate regression system. Inclusion of the cost share equations in the estimation results in more degrees of freedom without adding any unrestricted regression coefficients, results in more efficient parameter estimates. Additive disturbances are assumed for the cost function as well as for each of the share equations. Following Zellner (1962), it is also assumed that the error in each equation is homoscedastic and non auto correlated but that there is a non zero correlation between contemporaneous disturbance terms across equations. By eliminating one of the share equations from the system and using the iterative Zellner estimation procedure until convergence, maximum-like hood estimates are available. The iterative Zellner procedure is a computationally efficient method for obtaining maximum-likelihood estimates and has been used by many researchers for estimating Translog cost functions (Meil *et al.*, 1988; Obare, *et al.*, *(*2003)). This study also uses the iterative Zellner method.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study Area

River Njoro watershed occupies five locations namely: Nessuit, Njoro, Ngata, Baruti, and Kaptembwa. It is in Nakuru district of Rift Valley Province in Kenya (figure 1.) and lies between latitude 0^0 15^1 S and 0^0 25^1 S and between longitude 35^0 50^1 E and 36^0 0^1E. The watershed stretches from the Mau forest to the Southwest and to Lake Nakuru to the east. The length of the river is about 50 kilometres and the catchment is about 200km^2. The source of the river, which empties into Lake Nakuru, is the eastern Mau hills (Shivoga *et. al*. 2003).

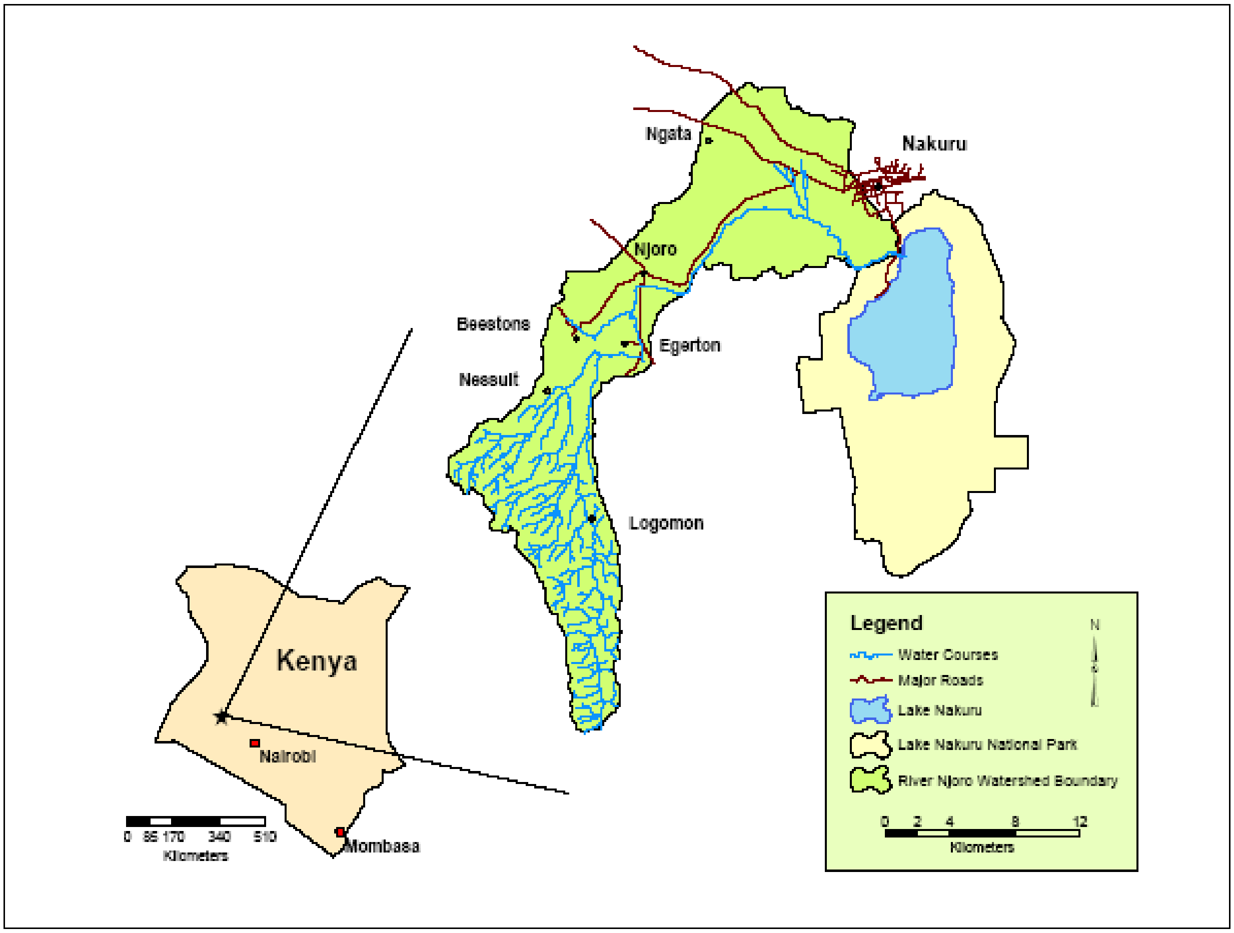

Figure 1. Map Showing the Location of the Njoro River Watershed Relative to Kenya and Nakuru District

Source: Baldyga (2005).

The watershed has more than 3000 individual farm holding units with a population of over 100,000 people. It is divided into three major agro-ecological zones. Zone 1 comprises of agro-ecological zones ranging from tropical alpine zone 1 (TA1), and upper highland zone 0 (UH0) , with an altitude range of 2400-3000m above sea level , mean rainfall of 1200-1300 mm per annum and a mean temperature range of 10^0-15^0C. Zone II comprises of agro-ecological zones (UH1), UH2, Lower Highland zone 2 (LH2) and LH3, with an altitude between 1890-2400M and mean rainfall of between 760-1270 mm per annum. Finally, Zone III comprises of mainly upper midland zone 4 (UM4). It covers an area with altitude of between 1520-1890M and receives rainfall of less than 760mm per annum. This is a semi-arid zone that covers a very small part of the watershed bordering Lake Nakuru. Baldyga (2005).

The lake is enclosed within the lake Nakuru National Park. A Ramsar site, the park is famous for its large population of flamingos. (Shivoga *et al*, 2003). Climate in the Njoro region is characterized by a trimodal precipitation pattern (Figure 2) with long rains occurring from April-May, short rains occurring from November –December, and a small peak occurring in August.

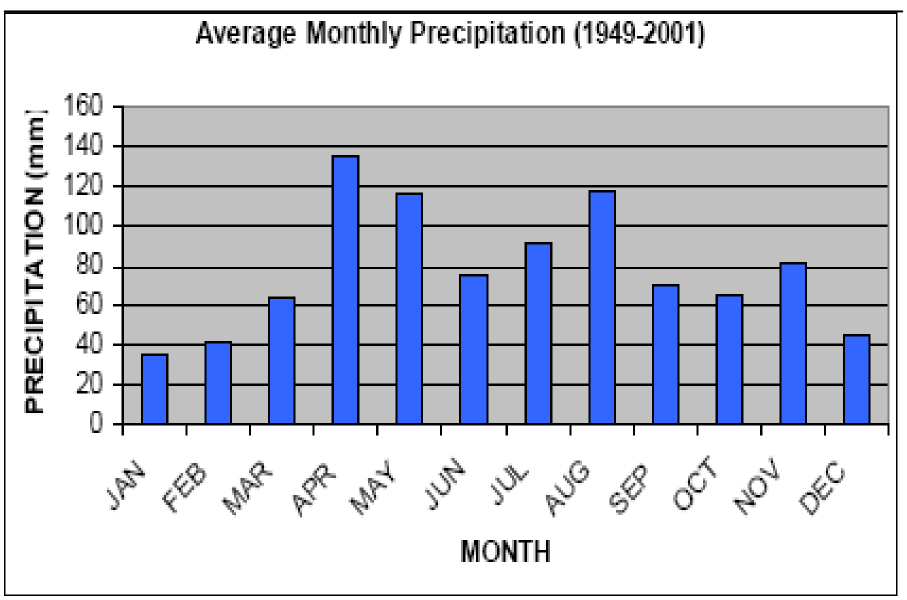

Figure 2. Average Monthly Precipitation Recorded at Njoro Town Centre from 1949 to 2001
Source: RoK 2003.

Mean annual rainfall measured at Njoro town centre from 1949-2001 is 939.3mm. Average annual minimum and maximum temperatures from the area range are 9^0 and 24^0C, respectively (Figure 3)

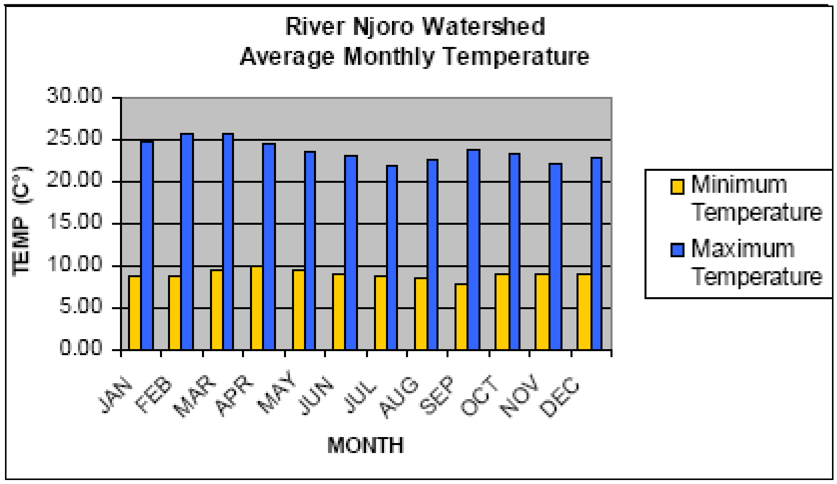

Figure 3. Average Monthly Minimum and Maximum Temperatures Recorded at Njoro Town Centre
Source: RoK, 2003

Vegetation cover in the watershed ranges from 0% in areas affected by anthropogenic practices such as agriculture and livestock husbandry. However, between Logoman and Egerton University, there are various sized tracts of agricultural and pasture lands.

The main economic activities within the watershed include forestry, sand harvesting, crop production and livestock production. Small-scale subsistence farming dominates the land scape (Photo 1) while maize intercropped with beans being the major enterprise (Photo 2).

Photograph 1. River Njoro Watershed Region where Small Scale Subsistence Farming Dominates the Landscape**.**

Source: Author's Survey, (2004).

The multitude of diverse vegetation found in the watershed serves a wide range of purposes including timber harvesting, medicine, human food, livestock fodder, building materials and fuel wood (Baldyga 2005)

Photograph 2. A Typical Small Scale Farm in the Watershed Showing Maize Intercropped with Beans.
Source: Author's Survey, (2004)

3.2. Methods of Data Collection

The study basically used primary data, collected using a Schedule which was administered to the sampled farmers using face-to-face interviews (Appendix 1), this enabled the person administering the questionnaire to have an opportunity to establish rapport, explain the purpose of the study, and the meaning of the items that may not have been clear to the respondent. Primary data entailed the data on the households and farm characteristics, crops grown, input and output data together with institutional and policy issues. Secondary data were sourced from documented information on food crop production, agricultural production economics and related research findings.

3.3. Sampling Procedure

The target population for this study comprised the smallholder farm households falling within River Njoro watershed. During March 2004 a mini-survey by "Sustainable Management of Watersheds" (SUMAWA) was carried out within the watershed, through which a sample size of 353 households was established. The sample size was spread across all zones within the watershed in order to capture as much variation as possible.

When the list was verified, only 180 smallholder farmers were adopted as the sample frame for this study. The rest of the households were found to comprise of households who were mainly farming on small plot sizes and others who may not have significant farming activities on their farms, which may not be relevant to this study. A sample size of 120 smallholder farmers was selected for this study according to the statistical measures (Kothari, 1990), the sample was selected from the sampling frame using linear systematic random sampling method based on the assumption that the population proportion (*P*) is 50 percent , confidence level of 95 percent associated with the Z- statistics for one degree of freedom(*z*) is 1.96 and the designated degree of accuracy as reflected by the amount of sampling error that can be tolerated (*e*) is 0.05.

$$n = \frac{Z^2.P.q.N}{e(N-1)+z^2P.q} \tag{14}$$

where N is size of population ,*n* is size of sample, *e* is acceptable error, *p* is population proportion of positive respondents and *q* is population proportion of negative respondents

3.4. Data Collection and Analysis.

The data was obtained through the use of a pre-tested structured interview schedule administered to the smallholder farm households within the watershed by the researcher and enumerators. The Statistical Package for Social Sciences (SPSS-Version 11.5), computer software was used for processing of the data. GAMS software was used for analysis of resource allocation while SAS software was used to analyse demand for factors of production.

3.5. Demand for Factors of Production: Empirical Model

In this study, an approximation of the Almost Ideal Demand System, proposed by Deaton and Muelbaeur (1992) was used to address the first objective which was to determine the demand for factors of production used by small-scale farmers in the River Njoro watershed under natural rain fed conditions. The model has been widely applied in demand analysis because it has some convenient features. First, if the system of equations is complete (the actual budget shares sum to 1.0), then the predicted budget shares will also sum to 1.0, a feature known as adding up. In addition, it is relatively easy to impose or test for symmetry in the cross-price terms (according to demand theory, demand systems based on rational behaviour should be symmetric, meaning that the effect of a one unit increase in the price of good *i* on the demand for good *j* should be equal to the effect of a one unit increase in the price of good *j* on the demand for good *i*). Third, the equation is consistent with economic theory in that the demand equation can be derived from a well-behaved utility function. The factor shares used in the estimation were derived from a cost function of the Translog form (equation 9). Therefore a factor share for each input with respect to a particular enterprise was estimated. This resulted into 12 factor share equations which were estimated simultaneously. Since the error terms across equations are correlated by the fact that the dependent variables need to satisfy the budget constraint, the seemingly unrelated regression (SUR) provided estimates that are more efficient (Zellner, 1962). Each of the factor share equation was then defined as follows:

$$w_{iz} = \beta_{i0} + \sum \theta_{ij} \ln P_j + \gamma_{ij} \ln y + v_i \qquad (15)$$

Where *i* are inputs (land, labour, fertilizer and seeds), z are enterprises (maize, beans, potatoes and wheat), w_{iz} is factor share of input *i* in enterprise *z, j* are input substitutes, P_j are prices of other input substitute *j*, θ_{ij} is price elasticity of input *i* with respect to input *j*'s price, γ_{ij} is output elasticity of input *i* with respect to input *j*'s price, *Y* is the output and v_i is the error term.

The Allen partial elasticities of substitution (ê) and pr ice elasticities of demand for the input factors (η_{ii}), respectively, can be calculated as;

$$\hat{e}_{ij} = \frac{\theta_{ij} + w_i w_{j,}}{w_i w_j} \qquad i, j = l, f, m, e \qquad i \neq j \qquad (16)$$

$$\hat{e}_{ii} = \frac{\theta_{ij} + w_i^{\,2} - w_i}{w^2{}_i} \qquad i, j = l, f, m, e \qquad (17)$$

and

$$\eta_{ii} = \hat{e}_{ii}\, w_i \qquad (18)$$

$$\eta_{ij} = \hat{e}_{ij} w_j \qquad (19)$$

According to Blackorby and Russell (1989), the Morishima elasticities of substitution (MES) can be calculated as:

$$M_{ij} = \eta_{ji} - \eta_{ii} \text{ and } M_{ji} = \eta_{ij} - \eta_{ji} \quad (20)$$

While the output elasticities will be calculated as:

$$\eta_{iY} = 1 + \frac{\beta_{iY}}{w_i} \quad (21)$$

A Translog specification is used to represent the cost function of small scale food production in the River Njoro watershed. The Translog cost function is well known for its flexible functional form in terms of the local order approximation to any arbitrary functional form.

Using the Translog function it was possible to investigate the substitutory and complementary relationships between pairs of factor inputs. This property of Translog function can be considered a great advantage over the discussed production function. The information on substitutability and complementarities between pairs of factor inputs will help understand the process of agricultural growth, so the Translog function appears to have great potential as the truly useful analytical model. The Translog cost function has some constraints (Binswanger, 1974) on its parameters.

1). It is assumed that the Translog cost function is twice differentiable, so that the Hessian (H) of this equation is twice symmetric, i.e. $\beta_{ij} = \beta_{ji}$, where *I, j,* = H.

2). Since it is a cost function, it has to satisfy the economic constraints of linear homogeneity, i.e. total cost doubles when all factor prices double. (see equation 10)

3). The cost function must be an increasing function of the input prices.

$$\frac{\partial \ln C}{\partial \ln P_i} = \beta_i + \sum \theta i_{ij} \ln P_j + \gamma_{ij} \ln y \quad (22)$$

Since labour, land, fertilizer and seeds are used as inputs to produce different crops; the demand function for the various crop outputs has been derived on the basis of production theory. The Allen partial elasticities of substitution and price elasticities for the different inputs used were calculated from the estimated structural parameters. Since the sum of the budget shares is equal to unity, the cost share equation for labour was dropped to ensure the non-singularity of the disturbance covariance matrix, and the price of labour was used as numeraire. The parameters associated with the dropped cost share equation were derived from the relationships with the estimated parameter.

The cost function shows the least required cost of producing output level (y), this function is assumed to exhibit the following prices: Strictly positive and non-decreasing in input prices and output; Positively and linearly homogenous and Concave in input prices.

Substitution elasticities can be calculated using the Allen Partial elasticities of substitution. Micro-economic theory requires that the cost function be monotonically increasing and concave in input prices under cost minimization. This requires fitted shares to be positive and the matrix of substitution to be negative semi definite at each observation point (Blackorby *et al.,* 1989). The Translog specification cannot satisfy monotonicity and concavity globally. Thus, we maintain these microeconomic properties since they hold at the mean point.

For more information on variables used see the table 1 below:

Table 1. Variable Description and Measurement

Variable	Explanation	Unit of measurement	Expected sign
W_l	Budget share of land	Kenya Shilling	+
W_f	Budget share of fertilizer	“	+
W_m	Budget share of seeds	“	+
W_e	Budget share of labour	“	+
P_l	Rental rate of land / acre	“	+
P_f	Price of fertilizer/ Kg	“	-
P_m	Price of seed	“	-
P_e	Price of labour	“	+
y	Total output	“	+

Note: the budget shares and the input prices are for each of the three enterprises considered in the study; maize/bean intercrop, potatoes and wheat respectively.

3.6. Estimation of Optimal Resource Allocation.

A linear programming model was used to address the second objective, which was to determine the levels of resource use in the production of main food crops by small-scale farmers in the River Njoro watershed. In this study, four crops were considered: namely maize, beans, potatoes and wheat. The model considered three main constraints, namely, labour, land and working capital (fertilizers and seeds). The general form of the model was thus presented in the basic scenario as follows

$$\text{Maximize } Z = \sum g_i X_j \quad (23)$$

Subject to (s.t).

$$\sum X_j \leq \text{Land} \quad (24)$$

$$\sum L_i X_j \leq \text{Labour} \quad (25)$$

$$\sum C_i X_j = \text{Capital} \quad (26)$$

where Z refers to total farm output, X_j is average number of hectares under enterprise j, L_i is average amount of labour in man-days required per hectare under enterprise j in a year, C_i is average amount of working capital (Ksh) required per ha under enterprise j in a year and gi is total output per ha of enterprise j.

Another scenario of this linear programming model took into account the fact that despite the desire for farmers to maximize their production, a minimum amount of food must be provided for family consumption. This implies that a certain minimum area of the land available must be devoted to the production of certain foodstuffs. Among the four crops considered: maize, beans and potatoes form the basic foodstuffs in the study region. A certain minimum acreage of these enterprises must be produced for the purpose of food security to the household. The area under maize, potato and beans therefore became important restrictions of the model as follows;

$$X_1 \geq a_1,\ X_2 \geq a_2,\ X_3 \geq a_3 \quad (27)$$

where X_1, X_2, X_3 are the hectares of land under maize, beans and potatoes respectively; a_1 a_2, a_3 are the minimum hectares of these crops respectively which must be produced.

The relative economic advantages of different cropping systems can be evaluated by linear programme modelling, an evaluative technique where the optimum cropping system can be selected from many alternatives (Hazel *et al.*, 1986).

Once a linear programming model is used to identify an optimum cropping system under a defined set of resources and product prices, parametric changes in either or both the resource constraints or product prices can be used to determine the effects of varying them on management decisions. Linear programming copes well with small-scale farming systems that are characterized by a high degree of interdependence between production and consumption, consumption and investment, investment and resource availability and socio-cultural constraints. Though, it may not be worthwhile carrying out linear programming of individual farms, the analysis does provide important guides to the following issues if done for a region: Optimal product mixes and optimal production techniques; The effect of innovations; Problems that require research and solutions and Shadow prices of critical resources.

In this study the target sample comprised of small-scale farmers in the river Njoro watershed, where a small scale farm was taken to be a multiproduct firm, which provides two or more products by means of a variety of variable and fixed inputs, which are allocated among competing products.

Although the shortcomings of linear programming, lie in its rather unrealistic assumptions of linearity, divisibility and perfect knowledge. By the very nature of model construction, no meaningful model is devoid of unrealistic assumptions. What is important is the ease of applicability of a given model, the realistic ness and practical policy utility of its results, and how well the results compare with those of alternative approaches. On this score, it can be said that linear programming has been found to be more popular than both marginal analysis and non-linear programming models for the analysis of farm firms since it's popularization in the early 1950's.

3.7. Linear Programming

Since the early 1950's, agricultural economists have utilised several mathematical modelling techniques for farm level studies including linear, non-linear, integer, dynamic and stochastic programming as well as network planning and simulation.

Among these, only linear programming and systems simulation have been widely and relatively successful models for micro planning and decision making. In agriculture, linear programming has been widely used, accepted and applied.

Agricultural economists in more developed countries have frequently applied linear programming analysis in individual farms. On the other hand, in less developed countries, where small scale farming predominates and construction of linear programming models for numerous individuals farms would be prohibitively expensive, linear programming models have been constructed and used for analysing problems of 'representative' farms with a view that results can be applied to groups of similar farms on the aggregate. A number of studies (Asamenew 1980; Muthui 1980; Mukhebi 1981; Nguta 1992; Wambugu 1998 and Ithinji 2000) have used this approach.

Agricultural production in most farms is constrained by shortage of farm labour, and this is directly influenced by the family size, which determines the amount of hired labour needed per farm. The amount of family labour available for farm work in this study was determined by finding out the number of people available for farm work, the number of hours in a day devoted to farm work by each person and the number of days available per month. The total from such computations gives the maximum demand, which can be placed by various farm operations on family labour without the plan becoming infeasible under the existing conditions. This places a theoretical upper limit on family labour supply.

While different researchers have computed family labour differently. In this study the average person was assigned a weight of 1 regardless of gender as it was found that both women and men contribute equally to family labour during the pilot survey. Children were assumed to perform less work than the 'average man' or 'average woman' and therefore were assigned a weight of 0.5. This is in line with Taibajuka (1994) who did not assign different weight to adult males and females in the Kagera region of Tanzania. This is indicated in Table 2 below.

Table 2. Weighting System for Family Labour

Category	Man-equivalents
Children between 0-6 years	0.0
Children between 7-14 years	0.5
Adults between 15-64 years	1.0
Adults between 65-75 years	0.5
Adults over 75 years	0.0

Source: Adapted from Taibajuka, 1994.

The determination of working capital is often problematic and thus different researchers have used different proxies for it. Wambugu (1998) in a linear programming analysis of smallholder agricultural credit used credit as a proxy for working capital. From pilot survey results, acquisition of agricultural credit was rare amongst farmers (10 %) in the area and this disqualified the use of credit as a proxy for working capital in the present study. With the absence of strong agricultural cooperatives generally associated with cash crops like coffee and tea, and the non performance of the Agricultural Finance Corporation, smallholders in the River Njoro watershed lack reliable sources of agricultural credit. Due to insufficient records available with the farmers due to the problems of sorting out family and farm expenditure, the total cash expenditure, on the farm during the year in question is the best estimator for total cash available for farming. Thus, in this study the working capital requirements were estimated from variable costs for enterprises grown on the farm during the 2003 cropping year. Estimation of working capital was done on an annual basis. Another constraint in this study's linear programming model is the subsistence food requirement. In smallholder agriculture, the subsistence food requirement has to be met first and then the surplus marketed.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Demographic and Socio-Economic Characteristics of Respondents

Table 3 is a summary of farm household characteristics. It shows that the respondent's age ranges between 20 and 94 years with a mean age of 49.6 years. This is an indication of participation of both the young and old in farming hence a great variation in households' age data. Farmer's experience in farming was measured with respect to how long the respondent has been staying in a given parcel of land. The result shows an average of 17 years with a range between zero and fifty years, showing that the majority of respondents have been staying for more than 17 years on their land. On the other hand, gender concentration shows that male headed households are 46%. This implies that the remaining percentage is comprised of female headed households. This was mainly due to the fact that within the watershed, women mostly remain at home and engage in farming activities while men tend to be employed in off-farm activities and thus stay away from home most of the time. This implies that women have influence on the daily farm management activities on the farm. The success of smallholder crop production is thus likely to be determined by the empowerment of women in the decision making process in farming activities and resource endowments.

The average household size of 6.8 is higher than the national level of 5.8. This an indication of increased population pressure on land within the watershed. Consequently, there are high chances of most households to intensify their farming activities in order to meet their daily food demand and also have surplus for sale. The common livestock types comprise of cattle, shoats (sheep and goats), and donkeys. Each household owns an average of 3.6 livestock units (a mature cow equivalent). Total monthly household income had a mean of Ksh 5920.10, which comprise of Ksh 2,891 being off-farm income. This is a clear indication that most of the households within the watershed depend on farming activities for their daily livelihoods. However, the annual expenditure on education per household is quite high at Ksh. 18,648.30. This translates to about a third of the households' monthly income. The results show that the average cost of travelling to the nearest market centre is Ksh 21.00, with a range between 0 and Ksh 160.00. In addition, the average distance to the nearest motorable road is 2.0 kilometres, with a range between 0 and 9 km. There is therefore high accessibility to the markets from the farms, as farm produce and inputs can easily be transported within a distance of 2 Km even by using bicycles or donkey carts.

Table 3. Demographic and Socio-Economic Characteristics of Respondents

Variable	Mean	Minimum	Maximum	S.D.
Age of Respondent	49.59	20.00	94.00	16.72
Percent of male headed households (%)	46.00	0.00	1.00	0.50
Household size	6.83	1.00	20.00	3.16
Livestock holding units	3.60	0.00	96.60	6.84
Total monthly household income	5920.10	0.00	185,800.00	4638.23
Cost of traveling to nearest Market center	21.00	0.00	160.00	30.64
Distance to the nearest Motorable road (Km)	1.97	0.00	9.00	1.70
Duration of land occupancy	17.16	0.00	50.00	9.93
Percent of households with Perceived security of land tenure (%)	79.00	0.00	1.00	0.40
Land under cultivation (Ha)	2.45	0.00	4.00	1.56
Land under pasture	1.09	0.00	1.50	0.67
Percent of households that had Access to credit	10.00	0.00	1.00	0.30
Household annual education Expenditure	18648.30	0.00	277500.00	42635.60
Household off-farm income	2891.68	0.00	180000.00	13599.90
Percentage of households with Formal education (%)	77.70	0.00	1.00	0.42
Percentage of households with Primary education	43.00	1.00	8.00	3.00
Percentage of households that have Received extension services within The last two years (%)	27.40	0.00	1.00	0.45

Author’s Survey, (2004)

On average, respondents who were interviewed have attained primary school level of education of 4- 8 years (43%). This was low as compared to 78% of farmers who had attained primary level of education in a study by Waiganjo *et al.,* in 2000 in an area of similar agricultural potential. This shows that household members with secondary and tertiary education do not actively work on the farms, as they tend to be employed off-farm. This can be attributed to the fact that education increases household's off-farm employment opportunities. Furthermore, the existing policies are not in favour of agricultural production and highly educated members of the household tend to look for greener pastures in off-farm activities. This is because of the traditional nature of farming activities within the watershed which most people view as not competitively rewarding as compared to non-farming activities. The traditional nature of farming activities within the watershed has made most people to view farming as not competitively rewarding as non- farming enterprises, hence education discourages participation in farming. Besides, the knowledge and skills gained through education do not help in improving farming but rather diverted towards the improvement of off-farm activities. Despite the low number of highly educated households depending on agriculture as their main source of income, the results show that most of households within the watershed depend on farming activities for their daily livelihoods. This may be probably due to the fact that most people have just the basic education and therefore have limited off-farm employment opportunities.

Access to credit facilities by households is quite limited with only 10% of households who had received credit in the previous 2 years before the survey. However, even among these, very few households reported to have received credit purposely for agricultural activities. The credit obtained was mainly for payment of school fees or other home development such as purchase of land and house construction this means that the fungibility aspect is quite evident in the Watershed. Moreover, those who had access to credit were mainly those with a stable source of income from off-farm employment. Farmers, therefore, lack sources of credit in order to improve their production, this is consistent with results by Wambugu (1998) who found out that most of the financial institutions were not willing to fund agricultural projects, due to the high risk involved in farming. Farmers are also reluctant to look for credit from the commercial banks which charge high interest rates due to the fear of loosing their collateral in case of loan default occasioned by unstable income from farming.

The average land under cultivation (1.750 Ha) is higher than that under pasture (0.70 Ha) indicating reduced land area under fallow. This shows that most of the small scale farmers in the River Njoro watershed are engaged in food crop production.

Most households' feel secure in their land ownership (79%), which suggests that insecurity of land tenure, cannot mainly be blamed for poor agricultural practices (RoK, 2004b) within the watershed. However, the fact that just a few farmers feel insecure in their land tenure status may not override its importance in the adoption of improved farming practices within the watershed. Only 27% of households had received extension services in the previous two years preceding the survey. This an indication of poor institutional support in the study area

4.2. Linear Programming Results

To achieve the second objective of this study, a linear programming model was developed and used. This model utilised production data for the year 2003. Since the results of gross margin analysis do not give optimal enterprise combination, linear programming analysis has been found to be an appropriate model that can handle the farmer's production environment suitably.

The linear programming model used in this study considered three main enterprises, namely maize/beans intercrop, potatoes and wheat. These enterprises were taken to represent a typical farm in the study area, though there were other crops in the farming system, they were considered to be of minor importance due to the low acreage allocated to them and the importance the farmers gave them. Table 4 below gives some of the variables calculated for the model. Maize bean intercrop was grown on 1.512 ha, while potato and wheat were planted on 0.18 and 0.8 ha respectively.

From these results it is evident that maize/bean intercrop was given the biggest acreage by the farmers. This can be attributed to the enterprises importance both as a cash crop and also source of food in the study area. Though wheat used the most working capital per ha, it also recorded the largest gross margin among the three enterprises. Maize/bean intercrop had the highest labour requirement of 173.5 mandays per year followed by wheat with 167.5 mandays, while potatoes had the least labour requirement of 147 mandays. This is because maize mixed stand takes the longest period in the farm, and also requires several farm operations right from planting to harvesting.

Table 4. Some Important Variables Calculated for the Model

Model	Maize/beans	Potato	Wheat
Area(Ha)	1.512	0.18	0.80
Yield/year(bags)	25.00	15.00	12.00
Average price/bag	1034.00	500.00	1800.00
Working capital/ha	13760.00	14600.00	13302.00
Total labour requirement (man-days)	173.50	147.00	167.50
Gross margin/hectare	12090.00	-7500.00	8300.00

Source: Author's Survey, (2004)

The units for yields are as follows: maize/beans- 90 kg bags, potatoes –100 kg bag, wheat- 90 kg bag, prices, gross margins and working capital are calculated in Kenya shillings. The average land size is 4.6 acres. The average total labour availability to the household for the year was approximated at 732 man days in a year with the following monthly distribution (Table 5).

Table 5. Monthly Labour Availability to the Household

Month	Labour available in man days
January	50.00
February	56.00
March	57.28
April	59.25
May	64.42
June	69.35
July	69.35
August	69.35
September	65.00
October	64.00
November	56.00
December	52.00

Source: Author's Survey, (2004)

As indicated earlier, in the calculation of man-days, adult male and female labour was treated equally. Despite both males and females working for the same duration on the farm, both received a daily wage of Ksh. 100. It was further assumed that for a person working full time on the farm, he/she can work approximately 300 out of 365 days in a year. This excludes Sundays and public holidays.

The model was run on the GAMS (General Algebraic Modelling System), computer package for linear programming problems. The model was first run without the minimum food requirement restriction.

Table 6. Resource Use Levels in the Optimal Programme

Resource	Lower	Level	Upper	Marginal
Land	-INF	1.750	1.750	15307.958
Labour	”	299.247	732.000	0.000
Capital	”	45327.000	45327.000	0.406

Note: -INF refers to negative infinity

Source: Author's Survey, (2004)

The column headed lower and upper limit simply restate the greater than (LOWER) or less than (UPPER) constraints of the problem (Table 6). All the constraints in River Njoro watershed were the less or equal to constraints. The last column, marginal activity, gives the shadow prices (or dual values) for the fixed resources and constraints that are fully used. These marginal prices are calculated for each resource as the cost to the objective function value if one unit of the resource were withdrawn from use by increasing the corresponding slack activity by one unit.

The optimal programme gives a total gross margin of Ksh. 45203.15. This means that if the farmer were to follow the cropping pattern given in the optimal programme, his total gross margin would be Ksh. 45203.15. The optimal programme includes maize/beans and wheat only. Out of the 1.750 hectares available, the programme devotes 1.020 hectares to maize/beans and 0.730 hectares to wheat production. Potatoes did not feature in the optimal programme. The optimal solution utilises a total of 1.750 hectares, which is 95 % of the 1.840 hectares available.

The marginal values often called reduced costs indicate the amount by which the objective function value would decrease if one unit of an activity not in the optimal programme was forced into the programme. The reduced cost is also referred to as the opportunity cost. Consequently, any activity in the optimal programme has a reduced cost of zero. The results indicate that by devoting one hectare of land to potatoes, the small-scale farmer in River Njoro watershed would forego Ksh. 4370.54. This is the opportunity cost of devoting a hectare of land to potatoes, which the optimal programme rejects. The logic here is that if land was to be allocated to potatoes, this would entail reducing the amounts of land allocated to maize/beans intercrop and wheat production, which are in the optimal solution and have much higher gross margins than potatoes. It is worth noting that the dual values are meaningful only for non-basic rows or columns in the optimal solution, if they contain information about the rate at which the objective value would change if the associated bound or right hand side is changed.

Dual prices refer to the shadow prices of the various resources used in the production process. Any resource whose slack is not equal to zero has a shadow price of zero. Shadow prices are assigned to those resources that are binding, that is resources that are completely exhausted. If a resource is in excess, there is no need to add more into the production process. No shadow price can therefore be assigned to such a resource. In the optimal programme, all constraints except land and capital have a shadow price of zero. Land has a shadow price of Ksh 15308 and working capital a shadow price of Ksh 0.41. This means that the shadow prices of land and working capital are Ksh 15308 and Ksh 0.41, respectively. If the farmer would need an extra hectare of land, he would have to part with Ksh 15308 for it. The farmer would not be willing to pay a rental price greater than the shadow price of land. This indicates the worth or the rental value of a hectare of land in the River Njoro watershed. Similarly, the shadow price of working capital is given as 0.41.

This means that if an extra unit of working capital were added in the production process, it would be worth Ksh 0.41. This implies that if working capital was to be borrowed in the form of credit, the farmer will have to pay an interest equivalent to 0.41/1.00 that is 0.41 shillings for every 1 shilling borrowed. Borrowing at an interest rate higher than this, means that the farmer is paying more for a resource, not worth that much.

The constraints of a linear programme can be classified either as binding or non-binding. If a constraint is binding, it may be regarded as a scarce resource, since it has been used completely. On the other hand, a non-binding constraint represents an abundant resource. In the above table; land and capital are obviously constraining resources since they have marginal costs. According to the results labour is an abundant resource. Land has a lower value of negative infinity and a current value of 1.750 hectares and an upper value of 1.750. This indicates that land as resource is completely used up by small scale farmers in the River Njoro watershed. To change the objective value in the optimal solution the farmer therefore requires an extra Ksh. 15307.958 to hire an extra hectare of land. Labour is an abundant resource since the farmer can be able to use only 299.247 mandays out of the total 732.00 mandays available and still be able to meet the goal of produce optimization. Within this range of 299.247 to 732.00 man-days the shadow price for labour remains unchanged. This can be supported by the fact that the area has a high population density of 6.8, which is higher than the national average of 5.8. For working capital, the results indicate that it is completely exhausted since it has a level value of Ksh. 45327.00 respectively which is all the capital that is available to the small scale farmer in the River Njoro watershed. Exceeding the allowable increase or decrease changes the shadow price of a resource.

In the second scenario, the model was run again this time taking into consideration the fact that certain amounts of maize, potatoes and beans must be produced for the household food requirements. In setting the minimum hectarages of these enterprises to be produced, it was approximated that half of the enterprise is marketed while the other half is consumed at the household level. The average land available for each of the enterprises is therefore divided into two: one half must cater for food security at the household level while the other half is marketed. Using this estimate, a minimum of 0.756 hectares of maize/beans, 0.0885 hectares of potato and 0.730 hectares of wheat must be produced (Table 7). Running this model gives an objective function value of Ksh. 45203.1467.

Table 7. Cropping Pattern with the Food Crops Restricted Model.

Enterprise/activity	Area (ha)
Maize/beans	0.7560
Potatoes	0.0885
Wheat	0.7300

Source: Author's Survey, (2004)

The results indicate that the optimal programme this time includes maize/beans. Out of the 1.750 hectares of land available, 1.501 hectares is devoted to subsistence requirements, i.e. maize/beans intercrop and potato production (Table 8).

Table 8. Resource Use Levels in the Food Crops Restricted Model

Resource	Lower	Level	Upper	Marginal
Maize/beans	-INF	1.750	1.750	15307.958
Labour	”	299.247	732.000	0.000
Capital	”	45327.000	45327.000	0.406
Subsistence	”	1.501	1.750	0.000

Note: -INF refers to negative infinity

Source: Author's Survey, (2004)

The results indicate that all the land is used up in the optimal programme. Of all the 732.00 mandays of labour available to the farmer in a year, He/she can use up to 299.247 mandays and still be able to attain the optimal solution (Table 8). Hence, labour supply is in excess of his requirements. This therefore means that the labour is not a binding constraint in his production process.

The marginal values indicate that if a farmer decided to devote one hectare of his land to Potatoes production, he would forego Ksh 4370.539. Since the other two enterprises are in the optimal solution, their marginal values (reduced costs) are equal to zero. For subsistence, the farmer can use as low as 1.501 hectares and up to 1.750 hectares and still be able to achieve the objective of optimising production. Where a resource is completely exhausted and is constraining production, more of the resource can be added through hiring, borrowing or buying. Working capital can be borrowed at the going interest rate and more land can be bought or hired where it is constraining. In the optimal programme, more land can be hired while more working capital can be attained through credit.

The marginal value for land is Ksh 15308. This means that if the farmer were to loose 1 hectare of land for example by subdivision then his maximum attainable total gross margin would decline by Ksh 15308. The negative of a marginal price indicates the maximum amount by which the model's objective function could be increased if an additional unit of the resource were to become available. Thus, in the case of land, Ksh 15307.958 is the maximum rent that the farmer should be willing to pay for an extra hectare of land beyond his 1.750 hectares in a year.

Table 9. Farm Activities Levels for Different Enterprises

Enterprise/activity	Lower	Level	Upper	Marginal
Maize/beans	-INF	1.020	+INF	0.00
Potatoes	0.00	0.000	+INF	-4370.539
Wheat	0.00	0.730	+INF	0.000

Note: -INF refers to negative infinity

Source: Author's Survey, (2004)

Thus the optimal plan for the small scale farmers in river Njoro watershed consists of 1.020 hectares of maize/beans intercrop, 0.730 hectares of wheat and zero hectares of potatoes. The lower levels indicate any constraints that were imposed on the individual activity levels. The last column headed the marginal is similar to a shadow price for the resource constraints. It is the amount by which the objective function value would decline if a unit of the corresponding activity were forced into the solution. Equivalently, the negative of the marginal value is the amount by which the activity per hectare gross margin would have to be increased before that activity is profitable enough to be included in the optimal farm plan. The gross margins would have to increase by Ksh 4370.539 per hectare for potatoes before this activity could be included in the optimal solution (Table 9). The marginal value coefficients are of course zero for those activities already in the optimal plan. The marginal costs often called reduced costs or dual values indicate the rate at which the objective value will change if the associated bound or right hand side is changed. The marginal costs are also referred to as the opportunity cost. Consequently, any activity in the optimal programme has a marginal value of zero. The results indicate that by devoting one hectare of land to potatoes the farmer in River Njoro Watershed would forego Ksh.4370.539. This is the opportunity cost of devoting a hectare of land to potato production, which the optimal programme rejects. The logic here is that if land was to be allocated to potatoes, this would entail reducing the amounts of land allocated to maize/beans intercrop and wheat production, which are in the optimal solution, and have much more higher gross-margins than potatoes. The results indicate that the objective equation has a value of Ksh. 45203.1467. This is the amount of money that the farmer would get from his farming activities if he/she were to produce at the optimum level.

The results for the various constraints indicate that only land and capital are binding constraints. All the land available to the small scale farmer is completely exhausted. The opportunity or marginal cost of hiring one more hectare of land is Ksh. 15307.958. In order to be able to satisfy the optimum condition, the results of the study indicate that labour is not a binding constraint encountered by small scale farmers in the River Njoro watershed as they continue with the production process, farmers can utilise 299.247 man-days and still be able to produce at the optimum level. This means that labour has a slack of 732.00-299.247= 432.753. The slack or excess value indicates the amount of a resource that is not utilised in the optimal programme. This is the number of excess or extra units of the resource. The results indicate that 432.753 man-days are not used in the optimal programme. This means that the farmer has an excess of 432.75 man-days, which can be hired by other farmers or used in other non-farm income generating activities to earn more income, which can be used to better the standards of living of his/her family. Capital is a binding constraint in the optimal farm plan, since it has a marginal value of 0.406. This means that the objective function will be reduced by this much.

4.3. Demand of Inputs Analysis

The input shares for the different enterprises and the respective prices of resource were calculated and are as indicated in table 10. The translog model was analyzed using imposing homogeneity, symmetry and adding up restrictions as implied by demand theory. SAS software was used; two restricted models were estimated and compared with the unrestricted model. The log-likelihood ratio, the calculated chi square, and the critical chi square for 5% significance level are given in Table 11.

Table 10. Descriptive Statistics for Explanatory Variables used in the Demand Model

	Maize/beans		Potatoes		Wheat	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.
w_l	0.24	0.11	0.16	0.07	0.20	0.09
w_f	0.10	0.09	0.13	0.07	0.13	0.07
w_m	0.09	0.06	0.11	0.06	0.16	0.07
w_e	0.30	0.14	0.30	0.12	0.40	0.12
p_l	2626.17	348.30	2837.17	330.27	2961.26	554.38
p_f	25.05	3.39	25.28	2.26	20.10	2.96
p_m	109.76	28.36	137.49	191.58	70.00	5.69
p_e	18.15	1.09	16.25	2.20	18.46	1.63
Y	32550.12	2432.56	36421.16	5698.7	4367.86	3112.51
C	21279.81	13945.33	12145.7	755.31	18456.87	11614.04

Note: S.D. Standard deviation; *l*, Land; *f*, Fertilizer; *m*, Seeds; *e*, Labour; *p*, factor prices; *w*, factor share; *y*, physical output; C, total production cost.

Source: Author's Survey (2004)

Table 11. Model, No of Restrictions, Log-Likelihood Ratio, Calculated and Critical Chi-Square At 5% Level Of Significance

Model	No. of restrictions	Log-likelihood Ratio	Calculated χ^2	Critical χ^2 5% sig. Level
		Maize-bean		
Unrestricted		351.25		
Homothetic	3	342.41	2.78	7.81
Homogeneous	4	341.22	3.40	9.49
		Potato		
Unrestricted		445.17		
Homothetic	3	442.32	3.10	7.81
Homogeneous	4	442.11	3.15	9.49
		Wheat		
Unrestricted		349.14		
Homothetic	3	345.71	2.88	7.81
Homogeneous	4	345.40	3.50	9.49

Author's Survey, (2004)

The homogeneity and symmetry restrictions could not be rejected at 5% level of significance. This means that farmers are pursuing a maximization of utility from their production or they are maximizing profits. The estimated parameters for the homogeneous translog cost function for the four inputs in each of the three enterprises (maize and beans intercrop, potatoes and wheat) are given in Table 12. The cost function is homogeneous in input prices because of the homogeneity restrictions. A well behaved cost function is concave in the prices and its demand functions are strictly positive. The concavity restriction is satisfied if the Hessian or Slutsky matrix (matrix of second order partial derivatives) is symmetric and negative semi definite. The negative semi definite requirement dictates that the quadratic expansion of the Slutsky matrix be less than or equal to zero. It was found that the Hessian matrix was negative semi definite following its quadratic expansion.

Table 12. Estimated Parameters of the Homogenous Translog Cost Function of the Smallholder Farmers in River Njoro Watershed

Parameters	Maize-bean intercrop	Potato	Wheat
B_0	0.4568(2.127)**	0.8264(0.085)	-1.1099(-2.530)**
β_l	0.3341(2.045)**	0.530(2.590)**	1.3147(0.685)
β_f	0.1234(1.348)	0.3522(0.301)	0.5934(0.2322)
β_m	0.5141(0.0710)	0.1640(0.472)	1.0240(0.3640)
β_e	0.0284(1.034)	0.2930(0.360)	-0.8842(0.3933)
β_{ll}	0.0621(3.800)***	0.0051(2.039)**	-
β_{ff}	0.0141(0.289)	0.0072(2.686)***	-0.0038(0.7)
β_{mm}	0.0077(2.562)**	-0.0010(-1.687)	-0.0008(0.299)
β_{ee}	0.0469(0.0274)	0.0163(1.0450)	-0.00714(-0.309)
β_{lf}	0.0108(-0.0420)	-0.0031(-1.60)	0.00230(1.433)
β_{lm}	-0.550(-0.215)	0.0034(1.62)	-0.00035(-0.414)
β_{le}	0.0037(1.617)	-0.0054(-2.029)**	-0.00195(-0.260)
β_{fm}	-0.0014(-1.687)	0.0022(1.719)	-0.00164(-1.933)*
β_{fe}	-0.0019(-1.717)*	-0.0063(-2.685)**	-0.00374(-1.590)
β_{me}	-0.4866(-0.607)	0.00460(-2.036)*	0.0111(0.330)
β_{ly}	0.01330(0.818)	0.06560(0.300)	0.10960(0.399)
β_{fy}	0.0288(0.168)	0.00006(0.367)	-0.00087(-0.800)
β_{my}	0.00103(0.094)	0.00002(0.145)	-000506(-0.297)
Bey	0.0110(0.399)	-0.0556(-0.289)	-0.00874(-1.283)

Note: t-statistics are in parenthesis.
* Significance level at 10 %,
**Significance level at 5%,
***Significance level at 1%.

The estimated parameters are given in table 12. The results show that 5 coefficients of the maize bean intercrop are significant; six coefficients for potato are significant while two for wheat crop are significant. This fairly reliable result considering that homogeneity restriction was imposed.

Both Allen Elasticities of substitution (AES) and Morishima Elasticities of substitution (MES) were estimated using the estimated translog parameters for the three enterprises as indicated below.

$$\hat{e}_{ij} = \frac{\theta_{ij} + w_i w_{j,}}{w_i w_j} \qquad i, j = l, f, m, e \qquad i \neq j \tag{28}$$

$$\hat{e}_{ii} = \frac{\theta_{ij} + w_i^{\,2} - w_i}{w^2_{\;i}} \qquad i, j = l, f, m, e \tag{29}$$

$$M_{ij} = \eta_{ji} - \eta_{ii} \text{ and } M_{ji} = \eta_{ij} - \eta j_j. \tag{30}$$

Table 13. Allen and Morishima Elasticities of Substitution in Maize-Bean Intercrop.

Enterprise/factor Input	Land	Fertilizer	Seeds	Labour
Land	-2.0886	0.550	-1.546	1.0514
	(0)	(0.633)	(0.130)	(0.753)
Fertilizer	0.550	-7.590	0.844	0.937
	(0.814)	(0)	(0.843)	(0.853)
Seeds	-1.546	0.844	-9.156	-8.022
	(0.685)	(0.900)	(0)	(0.896)
Labour	1.0514	0.937	-8.022	-1.813
	(0.859)	(0.825)	(0.303)	(0)

Note: Morishima elasticity of substitution is in parenthesis

The AES and MES elasticities for maize-beans intercrop are reported in table 13. above. The Allen's elasticities of substitution of land by fertilizer, land by labour, fertilizer by seeds, and fertilizer by labour are all positive and hence the inputs are substitutes while the elasticities of land by seeds and seeds by labour were found to be negative and thus the inputs are complements in the maize-bean intercrop. By convention when coefficient of demand elasticities are greater than one then they are said to be elastic and if they are less than one then they are said to be inelastic. Such situation applies in the area under study in which land by labour is found to be elastic while the substitution between the other inputs is inelastic.

The best measure of substitution in the case of more than two inputs is the MES (Kant and Nautiyal, 1997). The basic difference between the AES and MES is that the AES are always symmetric while the MES need not be. Further the MES are symmetric if and only if, they are equal to the same constant. The most striking feature of the MES in this enterprise is that one they are all positive and that the substitution among all the inputs is inelastic. Morishima elasticities show the two-way ease with which the inputs can be substituted. For instance, it was found that farmers within river Njoro watershed would with much ease substitute fertilizer by land (0.814) than land by fertilizer (0.633). This could be interpreted to mean that farmers preferred to increase the land under the intercrop so as to increase their farm output than going for the expensive fertilizers. The MES for seeds by land (0.685) and land by seeds (0.130) also indicates that farmers prefer to increase their land under the intercrop than go for the expensive high quality seeds. This could be attributed to that many farmers used their recycled seeds instead of buying new quality seeds, with this resulting to further reduced yields and consequently prompting them to increase their farms. A similar situation is observed in land and labour. The three inputs can be easily substituted by land confirming land intensive maize-bean intercrop. Similar results showing that land is a substitute for a majority of inputs were obtained by Obare *et al*., (2003). Although the AES for land by labour show an elastic relationship (1.0514), that it is easier to substitute land by labour, the MES for the same inputs are, for land by labour (0.753) and labour by land (0.859) show the opposite that it is easier to substitute labour by land. The latter holds on the basis that MES are the best measures of substitution for the case of more than two inputs. Besides, if land is available, farmers are assumed to increase the area under cultivation instead of increasing their labour either through hire or employment.

The AES and MES elasticities of substitution in the potato enterprise are reported in table 14. The AES and MES in this enterprise indicate that all the four inputs are substitutes.

Table 14. Allen and Morishima Elasticities of Substitution in Potatoes

Enterprise/factor Input	Land	Fertilizer	Seeds	Labour
Land	-5.172	0.851	1.193	0.888
	(0)	(0964)	(1.019)	(1.094)
Fertilizer	0.851	-6.266	1.154	0.838
	(0.925)	(0)	(0.964)	(0.923)
Seeds	1.193	1.154	-8.174	0.861
	(1.030)	(1.026)	(0)	(0.994)
Labour	0.888	0.838	0.861	-2.152
	(0.912)	(0.897)	(0.904)	(0)

Note: Morishima elasticity of substitution is in parenthesis.

Although the ease with which an input is substituted is shown by the MES, the range is relatively small compared to the maize-bean intercrop enterprise (0.130) to (0.900). The MES in this enterprise ranges from (0.897) to (1.094). In this case the farmers' field of input preference is spread within a short range. The MES in this enterprise show both inelastic and elasticity relationships. The MES for land by seed, land by labour, seed by land and seed by fertilizer are elastic while the other MES are inelastic. The potato enterprise was found to be labour intensive since $M_{el} > M_{le}, M_{ef} > M_{fe}, M_{em} > M_{me}$. This result can be supported by the fact that potato requires a lot of labour especially during the harvesting period. The same conclusion can be inferred from Obare *et al.*, (2003).

The AES and MES elasticities of substitution in the wheat enterprise are reported in table 15. Similar to the potato enterprise the AES and MES show that all the inputs are substitutes. The MES for land by fertilizer, seed by land seed by fertilizer labour by land and labour by seed are elastic while the others are and are inelastic. The MES for land by labour is unitary elastic but labour by land is slightly elastic. The former implies that a change in the share of land is accompanied by an equivalent change in the amount of labour with the latter implying a slight ease in the substitution of labour by land. The range of MES is between (0.967) to (1.087). The MES for land by seed (0.989) are equal and AES for land by seed (0.989). This enterprise exhibits a fertilizer intensive nature of production technology. This can be seen through that, $M_{fl} > M_{lf}, M_{fm} > M_{mf}, and M_{fe} > M_{ef}$. the a *priori* assumption that can be appended to this outcome is that most of the labour in wheat is in the form of mechanization which is more expensive compared to the fertilizers used. Hence farmers will tend to use more fertilizer to increase their output.

Table 15. Allen and Morishima Elasticities of Substitution in Wheat

Enterprise/factor Input	Land	Fertilizer	Seeds	Labour
Land	-4.00	1.089	0.989	0.998
	(0)	(1.018)	(0.998)	(1.00)
Fertilizer	1.089	-6.510	0.921	0.928
	(0.988)	(0)	(0.966)	(0.967)
Seeds	0.989	0.921	-5.604	1.173
	(1.055)	(1.044)	(0)	(1.085)
Labour	0.998	0.928	1.173	-1.545
	(1.02)	(0.989)	(1.087)	(0)

Note: Morishima elasticity of substitution is in parenthesis

The estimated price elasticities of the four input translog are given in table 16 below.

$$\eta_{ii} = \hat{e}_{ii} w_i \quad (31)$$

$$\eta_{ij} = \hat{e}_{ij} w_j \quad (32)$$

All the own-price elasticities in the three enterprises for the four inputs are negative as expected. They all lie in the inelastic range. All the cross-price elasticities are positive except for those of seed by land, land by seed and seed by labour in the intercrop enterprise. The negative elasticities between land and seed indicate a complementary relationship for the two inputs. However the MES for the same inputs show that they are substitutes with seeds being easily substituted by land. Since MES are a difference between cross-price elasticities and own-price elasticities, positive MES will always result because the own elasticity magnitude will always exceed the cross elasticity.

Table 16.The Estimated Price Elasticities for the Translog Homogeneous Four Input Cost Functions for the Small-Scale Farmers in River Njoro

Factor input Enterprise	Land	Fertilizer	Seeds	Labour
		Maize-bean		
Land	-0.501	0.055	-0.140	0.315
Fertilizer	0.132	-0.759	0.076	0.281
Seed	-0.371	0.084	-0.824	-0.241
Labour	0.252	0.094	0.072	-0.544
		Potato		
Land	-0.828	0.111	0.131	0.266
Fertilizer	0.136	-0.814	0.127	0.251
Seed	0.191	0.150	-0.899	0.255
Labour	0.142	0.109	0.095	-0.646
		Wheat		
Land	-0.800	0.142	0.158	0.399
Fertilizer	0.218	-0.846	0.147	0.371
Seed	0.198	0.120	-0.897	0.469
Labour	0.200	0.121	0.188	-0.618

The output elasticities are as given in table 17 below.

$$\eta_{iY} = 1 + \frac{\beta_{iY}}{w_i} \tag{33}$$

Table 17. Output Elasticities for the Different Crops

Input factor	Maize/beans	Potatoes	Wheat
Land	1.055	1.41	1.550
Fertilizer	1.029	1.00	0.993
Seed	1.011	1.00	0.968
Labour	1.037	0.815	0.978

Source: Author’s Survey, (2004)

The output elasticities are highest for the intercrop, while labour in potato, fertilizer, seed and labour in wheat are inelastic. An increase in output in all enterprises will lead to an increase in the share allocated to all the inputs. Therefore, land in all the three enterprises increases by the largest share.

CHAPTER FIVE

CONCLUSIONS AND IMPLICATIONS

5.1. Summary and Conclusion

Farmers in the study area allocated the biggest portion of their farms to Maize/beans intercrop; this can be attributed to the enterprises importance both as a cash crop and source of food in the study area. The optimal programme includes Maize/Beans and wheat only. Out of the 1.750 hectares available, the programme devotes 1.020 hectares to maize and beans and 0.730 hectares to wheat production. Potatoes did not feature in the optimal programme. The successful estimation of a translog cost function indicates that the production structure is homogenous and that the failure to reject symmetry restriction is an indication that the farmers pursue mainly a cost minimization objective. This study further strengthens the fact that MES compared to AES are the best measures of substitution. According to the MES obtained, all the three enterprises are substitutes except in the Maize-bean intercrop, which are in the inelastic range. In the three enterprises seeds are very sensitive to their own price changes while land in maize-bean intercrop and labour in potato and wheat enterprises are sensitive to the changes in the prices of other inputs but least sensitive to their own prices. The output elasticities lead to the conclusion that wheat is more economically viable since an increase in output leads to less increase in seeds, fertilizer and labour. This shows that there are economies of scale in wheat enterprise than in the others. The results of the elasticities obtained lead to the conclusion that the production structure is not separable between any input groups since there are no substitution elasticities between the factor of production that are identical

5.2. Policy Implications

Many policy implications can be made on the basis of the results or the conclusions reached in this study. Nevertheless, one needs to be cautious when making policy recommendations given the period and the coverage of the study. However, the data was used to simulate a farm operation unit i.e. representative of the area and a group of holdings. Several clear implications and recommendations that can be made out of the study can be; the price elasticity of demand for inputs (-.899 to 0.399) has very strong policy implications. Once the price elasticity is known, one can determine how much of the inputs to use in order to achieve a planned level of output The AES indicate a complementary relationship between seed and land (-1.546) and seed by labour (-8.022) and labour pairs in the Maize-bean enterprise (-1.813). This indicates that policy makers will find it advantageous to implement policies regarding use of seeds if there is idle land and labour. Results from the study further indicate that an increase in prices for seeds, labour and fertilizers used in the Maize-bean enterprise is not favourable since it will trigger more land use. Policies should thus dwell on the increment of output without the expansion of land under cultivation. All the inputs in all the three enterprises are responsive to their own prices and output, these factors will therefore warrant some attention in policy formulation Since the results of the linear programme model indicate a significant reduction in the maximum attainable gross margin due to loss of land by way of subdivision. It may require formulation of policies that discourage further subdivision of agricultural land this is in line with the current government policy, which states that the minimum acreage of land meant for agricultural purposes not be below 2.5 acres (Rok 2005b).

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APPENDICES

Appendix 1: A Schedule

EGERTON UNIVERSITY

SUMAWA/CRSP

Sustainable Management of Watersheds - River Njoro:
A Socioeconomics Study, 2004.

Farm Household No ……………………

Date ……………………

Respondent(s)………………………. Village…………………….

Enumerator………………

SECTION A: PERSONAL DATA

1. Study zone
   Nessuit 0 Njoro 1 Ngata 2 Kaptembwo 3 Baruti 4
2. Location of Household (GPS)
   UTM ………………….. Long…………………….
   Latitude…………………. Altitude………….........
3. Are you the head of the household? YES 0 No 1
4. Date of birth (year)? ....
5. Gender: Male 0 Female 1
6. What is your marital status? Married 0 Single 1 Widow2
   Widower 3 Others 4

7. What level of education have you attained?

Primary	0	Tertiary	2	None	4
Secondary	1	University	3		

8. Please state the number of the following members of your household.

Husbands /wives…… Sons…… Daughters…… Other Relatives… Workers………..

9. How many of the people you mentioned above have been living with you for more than a month?

Husbands /wives…… Sons…… Daughters…… Other Relatives… Workers………..

SECTION B SOCIO-ECONOMICS

ECONOMIC ACTIVITIES AND EARNINGS

10. What is your **main** economic activity?

Crops production	00	Vending livestock	07
Livestock production	01	Formal Employment	08
Selling firewood	02	Casual employment	09
Selling timber	03	Running a kiosk / shop	10
Water vending	04	Selling sand	11
Sale of seedlings	05	Selling charcoal	12
Vending food crops	06	others (specify)	13
N/A	14		

11. For each of the activities you engage in, please state your earnings for the year 2003.

Activity	**Monthly Income (K.Sh.)**
Crop production	
Livestock production	
Selling firewood	
Selling timber	
Water vending	
Sale of seedlings	
Vending food crops	
Vending livestock	
Formal Employment	
Casual Employment	
Running a kiosk / shop	
Selling sand	
Selling charcoal	
Others (specify)	

12. Why do you engage in other economic activities?

13. Apart from the economic activities mentioned above, do you have any other sources of income? Indicate the income using the codes provided below.

Pension	0	Insurance dividends	3
Remittance from relatives	1	Bonuses	4
Donations from organizations	2	Others (specify)	5

14. Have you had access to credit in the last 2 years? Yes 0 No 1

If no, go to Question 19.

I5. If yes, how much, from where and for what purpose?

Amount of credit	Source	Purpose

16. If you have not had access to credit, why is this so?

HOUSEHOLD EXPENDITURE

17. Type of housing (observation)

    Stone walled house 0 Timber 1

    Mud-walled with iron sheets 2 Mud-walled with thatch roof 3

    Other (Specify) 4

18. Is the house rented or owned?

    Rented 0 Owned 1 Care taking 2

19. If rented, how much is the rent per month? K.Sh...............

20. Which of the following modes of transport do you use in your household?

    Private motor vehicle 0 Bicycle 2 Donkey cart 4

    Public motor vehicle 1 Handcart 3 Wheel barrow 5

    Others (specify) 6

21. Which among the above do you own in your household? (Write the codes).

22. How much do you spend on average on transport per month? KSh………..

23. How much does it cost you to travel to the nearest market centre? K Sh……

24. What is the distance from your homestead to the nearest bus stage? ………Km

25. Please estimate your Average expenditure on the following items on a monthly basis.

    Food KSh… Electricity KSh………….

    Firewood KSh………. Gas/Biogas KSh………….

    Charcoal KSh……….. Clothing KSh…………

    Kerosene KSh……….. Telephone KSh…………

    Others (Specify) KSh……… Medical KSh………….

26. How much do you spend on the following education items last year (2003)?

School fees K.Sh…………… Uniforms K.Sh… Tuition K.Sh…

Books and other writing materials K.Sh……… Others (specify) K.Sh…………..

27. Do you perceive your household well-being as?

Going up 0 Steady 2 Dropping 1 Other, specify 3

28. Give reasons for your answer in Question 28 above.

LAND TENURE SECURITY

29. How many acres of land do you own?

30. How did you acquire the land?

Inherited 0 Bought 1 Settled by government 2 Others 3

31. When did you acquire the land? (Year)…………

32. How long have you lived on this land? (No of years)…………

33. Have you ever sub-divided your land? Yes 0 No 1

34. If yes, for what purpose?

35. Do you feel secure with the form of your land ownership?

Yes 0 No 1

36. If not, why? Explain briefly.

37. Do you hire land out/additional land for farming?

Yes 0 No 1

	In	**Out**
Acreage		
Price/acre		
Where hired		

38. How much of your land is under

Cultivation………acres Pasture………acres

SECTION C: CROP PRODUCTION

39. What were the main crops grown in your farm and how much were your farming costs in 2003? Please indicate the code of each crop in the crops column.

Maize	00	Onions	04	Kales	08	Green peas	12
Beans	01	Cabbage	05	Fruits	09	Leak	13
Pyrethrum	02	Wheat	06	Tomatoes	10		
Potatoes	03	Millet	07	Carrots	11		

Production				**Cost of production (K.Sh.)**									
Crops	Area (acres)	Yield-s	Price/unit (Ksh)	Land prep.	Weed-ing	Plant-ing	Harvesting	Fert-s	Seeds	Pesticides/ herbicides	Irrigation	storage	Total cost
						.							

Input requirements

40. Fertilizer type and use.

i) Did you apply any fertilizer to your crops in the last year?

□Yes □ No

ii) If "No" to (i) what prompted you not to apply fertilizer? _____________________

iii) If yes to 26 (i) what type of fertilizers did you use? _________________________

iv) For what crop was each fertilizer type used? _______________________________

v) What amounts of each fertilizer type was applied to each crop? ________________

vi) In which month was the fertilizer applied? __________________________

vii) What was the unit cost of each fertilizer (ksh)? _______________________

viii) What was the transportation cost per bag of fertilizer (if any)? _________________

Type of fertilizer used	Crop	Amount fertilizer (bag)	Month of application	Cash kg/bag	Transportation cost (kg/bag	Total cost (ksh)

41. Land preparation cost

i) What area was ploughed or hand cultivated in acres? ___________________

ii) What area was harrowed (if at all) in acres? ______________________

iii) What were the charges per acre? __________________________

iv) What was the total cost (ksh)? _________________________

v)

Type of cultivation	Area ploughed hand dug (acres)	Area harrowed	Ploughing cost ksh/acre	Harrowing cost ksh/acre	Total cost (ksh)

42. Purchased seed cost

i) Did you purchase seeds for planting □Yes □ No?

ii) What seeds did you buy? _________, ______________, _________

iii) What amount of seeds did you use for each crop? ______________________

i) What was the cost per unit (specify units)_____________________________

ii) What transportation cost did you incur (if at all) in Ksh per unit? __________________

iii) What was the total cost for each seed type? _____________________

Type of seed bought	Amount bought (kg)	Amount used (kg)	Cost ksh/bag	Transportation cost ksh/kg	Total cost (ksh)

43. Please indicate your total yields for each crop for the last season, the quantity consumed at home and the total revenue from the surplus.

Product		**Quantity** (specify) (Units)	**Home consumption** (units)	**Unit price(Ksh)**	**Total revenue(Ksh)**
Green	Maize				
Dry	Maize				
Beans					
Potatoes	Extended bag				
	Normal bag				
Pyrethrum					
Cabbage					
Onions					
Kales					
Wheat					
Oranges					
Avocadoes					
Passions					
Others – Specify					

44. Where do you get advice on better farming practices?

Government extension officers	0	Neighbours	3
NGO's	1	None	4
Private Companies	2	Others (specify)	5

45. What type of advice do you get?

46. Do you use the advice? Yes 0 No 1

47. Are you aware of soil erosion as a significant problem that influences agriculture production?

Aware 0 Uncertain 1 Unaware 2

48. Is your farm experiencing any form of soil erosion? Yes 0 No 1 Uncertain 2

49. How would you classify the level of soil erosion on your farm?

Severe 0 Moderate 1 No erosion 2

50. What is the level of soil erosion in the farmers' main farm unit? Please observe and state as in Question 46 above)

51. If the farm is experiencing soil erosion, what effect does it have on your farm?

Affects productivity 0 Lowers soil fertility 1 Destroys crops2

Destroys the farm 3 Causes water logging 4

52. What is the general slope of the main farm unit? (to be observed by the enumerator)

Flatland 0 Gentle 1 Steep 2 Very steep 3

53. Are you aware of any soil conservation measures?

Yes 0 No 1

54. If yes, from what source did you get the awareness?

Government extension officers	0	Neighbours	3
NGO's	1	None	4
Private Companies	2	Others (specify)	5

55. How many times have you received advice on soil conservation within the last 2 years?...............................

56. Which of the following soil conservation practices are you using or have desire to use? Please state as:

Already using 0 Have desire to use 1 Reluctant to use 2

i. Crop rotation ii. Terracing iii. Contour ploughing iv. Contour Strip cropping v. Grass strips vi. Contour ridging vii. Fallowing vii. Mulching ix. . Tree planting

57. Do you use the conservation measures as a group or individually?

As a group 0 individually 1

58. Do you think the following technologies have any significant effect on the listed attributes?

Yes 0 No 1

	Attributes			
Technology	Increased labour demand	Increased soil/water retention	Increased sustainability of production	Improved productivity
Crop rotation				
Terracing				
Contour ploughing				
Contour strip cropping				
Grass strips				
Contour ridging				
Fallowing				
Mulching				
Tree planting				

59. Which of the following factors do you think would hinder most people from responding effectively to soil conservation activities in your area?

Please rank them in order of importance thus.

Very important 0 Less important 1 Unimportant 2

i. Lack of awareness of soil erosion.
ii. Lack of knowledge on soil conservation measures.
iii. Lack of finance to enable them to construct structures
iv. Limited farm implements to facilitate conservation measures
v. Few soil conservation measures easily convertible within the farming system
vi. Lack of extension services
vii. Lack of importance of soil conservation measures.

60. In your opinion, what are the possible solutions to these problems?

61. Which water conservation measures do you undertake on your farm?

Waterholes 01 Roof catchments 02 check dams 03

62. What are the main crop production problems in your area?

63. What in your perception are possible solutions to the crop production problems mentioned above?

SECTION D: LIVESTOCK KEEPING

64. Do you own livestock? Yes 0 No 1

65. If yes, please state the type of livestock, the number kept, management practices and the cost of production in each enterprise in the table below.

Livestock	**Number**	**management**	**Unit cost**	**Total cost**
Cattle				
Sheep				
Goats				
Poultry				
Rabbits				
Donkeys				
Beehives				
Others (Specify)				

Types of management practices:

Tethering 0 Zero-grazing 1 Paddocking 2

Free range 3 Improved hive 4 Semi-Zero grazing 5

Housed 6 Traditional hive 7 others (specify) 8

66. Do you have feed problems?

Yes 0 No 1

67. If yes, please specify the problem(s) and the month when it is most critical.

68. Please specify your main livestock product(s), quantity produced per period of time, and the selling price per unit.

Product	**Quantity /time**	**Home use**	**Surplus**	**Price /unit**	**Total**
Milk					
Cattle					
Sheep					
Goats					
Donkey					
Eggs					
Chicken					
Honey					
Wool					
Others specify) (eg Hides and skins					

SECTION E: FARM FORESTRY

69. Who planted the trees in your farm?

    Husband 0 Wife 1 Children 2 others (specify) 3

70. Who makes decisions on the use of trees in the family?

    Husband 0 Wife 1 Others 2

71. What forestry practices do you follow? (Observation)

Hedge row intercropping	0	Woodlot	3
Boundary planting	1	Compound Planting	4
Trees scattered within the farm	2	others (specify)	5
Along soil conservation measures	6		

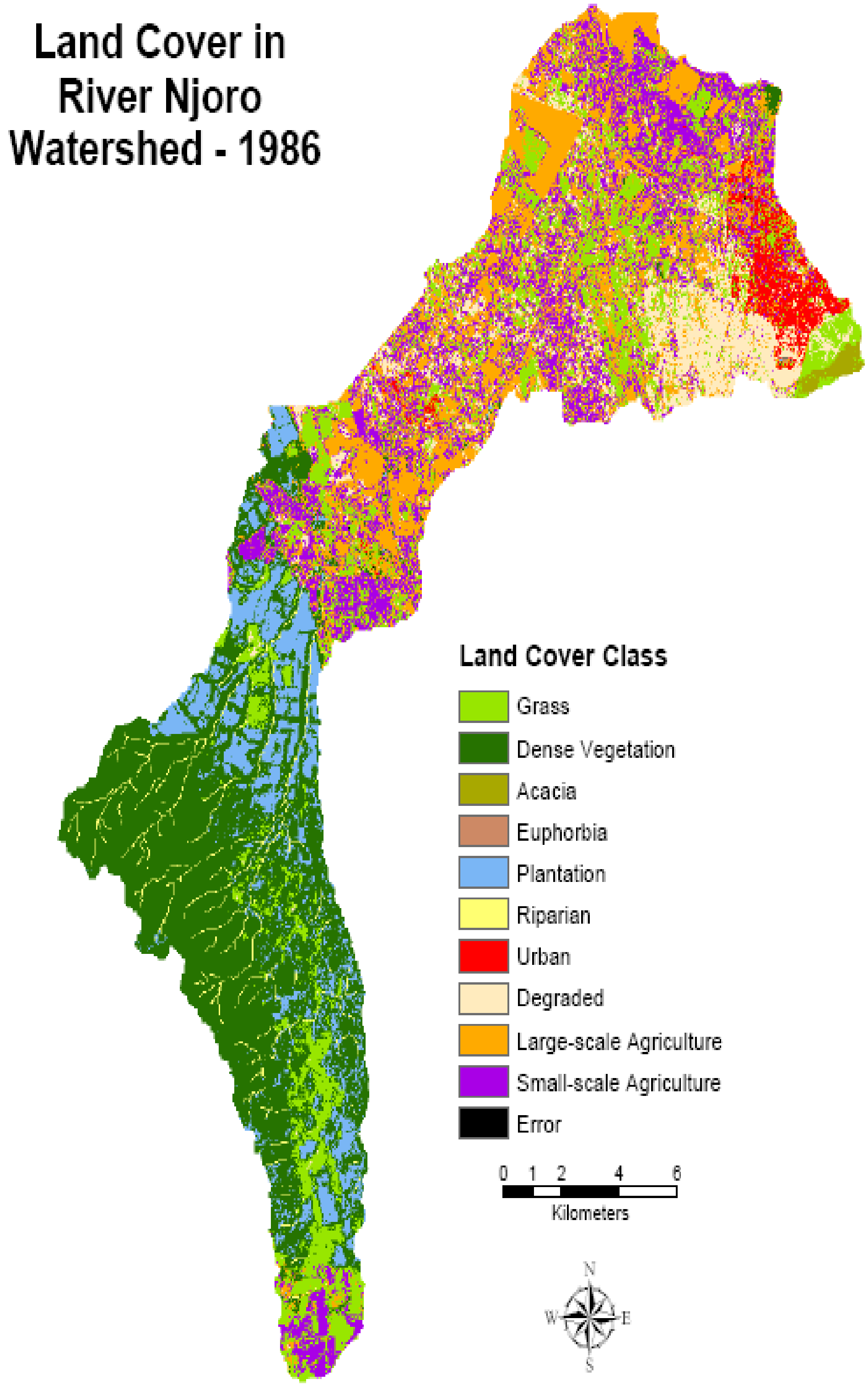
72. Is livestock grazing a threat to tree planting?

    Yes 0 No 1

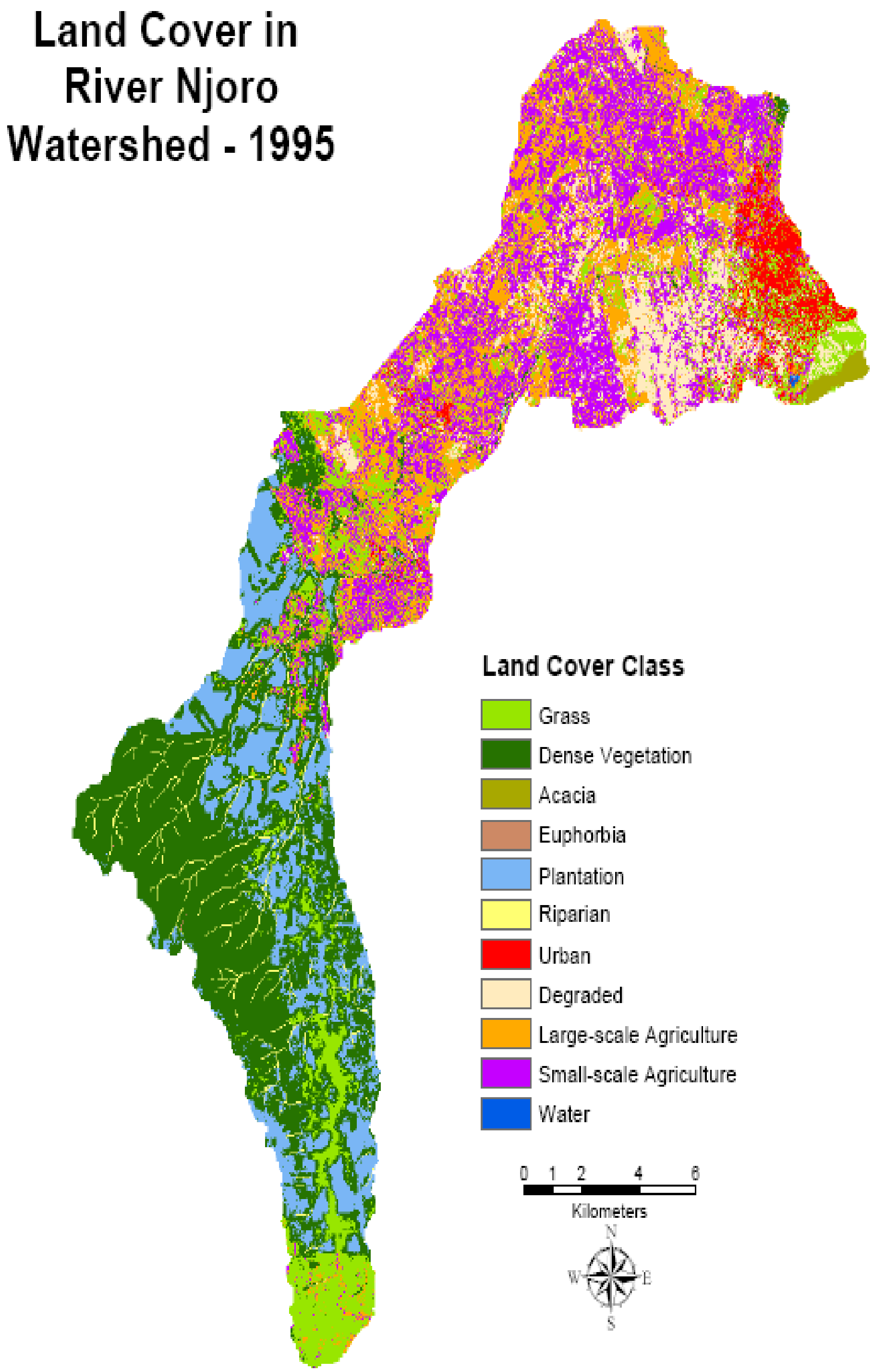
73. If yes, how in your opinion could this problem be alleviated?

Appendix 2:

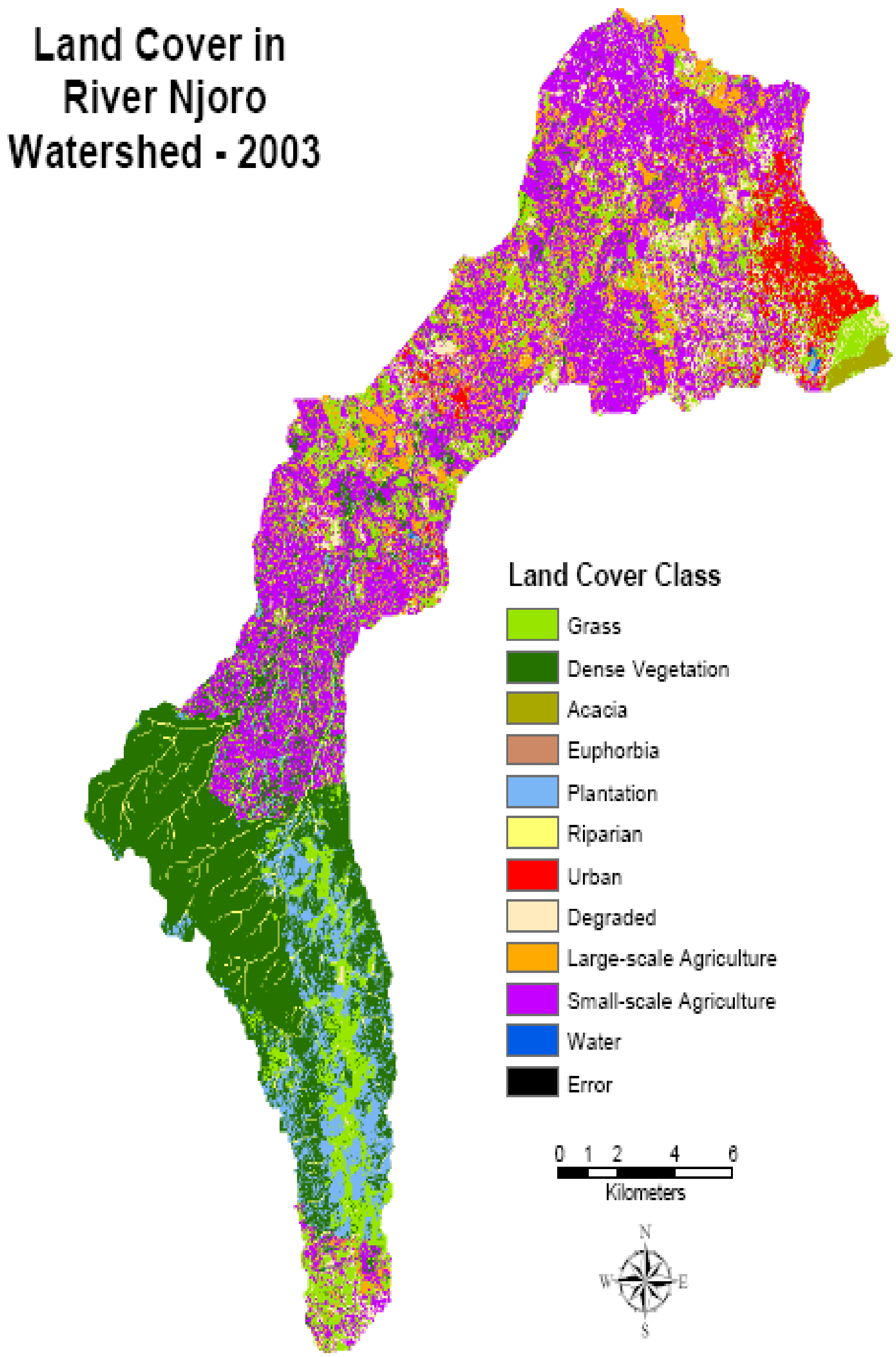
Land Cover Maps of River Njoro Watershed



Source: Baldyga (2005).



Source: Baldyga (2005).



Source: Baldyga (2005).