CODESRIA

Thesis

By

SAMUEL MAZERA MWAKUBO

MOI UNIVERSITY

TRANSACTION COSTS IN SMALL HOLDERAGRICULTURE: THE CASE OF SOIL CONSERVATION IN SEMI-ARID AREAS OF KENYA

APRIL 2003

TRANSACTION COSTS IN SMALL HOLDER AGRICULTURE: THE CASE OF SOIL CONSERVATION IN SEMI-ARID AREAS OF KENYA

BY

SAMUEL MAZERA MWAKUBO

A THESIS SUBMITTED TO THE SCHOOL OF ENVIRONMENTAL STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN EVIRONMENTAL ECONOMICS OF MOI UNIVERSITY

APRIL 2003

DECLARATION

DECLARATION BY CANDIDATE

I hereby declare this thesis is my original work and that it has not been submitted for a degree in any other university. No part of this thesis may be reproduced without the prior permission of the author or Moi University.

S.M. MWAKUBO............ Date 29/4/03
(SES/D.PHIL.14/98)

DECLARATION BY SUPERVISORS

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

Dr. W.K. Yabann .... Date 29th April, 03
Dean, School of Environmental Studies

Prof. H.K. Maritim .... Date 29/4/03
Dean, School of Business Management

TRANSACTION COSTS IN SMALLHOLDER AGRICULTURE: THE CASE OF SOIL CONSERVATION IN KENYA

By S.M. MWAKUBO
SES/D.PHIL.14/98

Abstract

Marginal areas in Kenya that comprise about 80% of the total land area are ecologically vulnerable with very serious problems of soil erosion. A decline in agricultural productivity is the result, accompanied by serious household food insecurity. As more people immigrate to these areas coupled with births, the problem is bound to get worse.

Nevertheless, these areas can be productive if farmers make investments on their land. Investments into soil and water conservation include terraces, trees, cattle, manure, fertiliser, equipment, wells, dams and other infrastructure. Investments into soil and water conservation may be undertaken when sufficient returns are expected. These returns, in particular monetary returns, can be related to many factors, but are always influenced by transaction costs of market exchange which subsequently determine the level of access to input and output markets.

Essentially the research seeks to determine the influence of transaction costs on soil conservation in smallholder agriculture and their role and impact on sustainable resource management and agricultural productivity.

A multi-stage random sampling was used to collect cross-sectional data from farming households using a structured questionnaire in Machakos and Kitui Districts. Besides descriptive statistics, econometric analysis using Three Stage Least Squares (3SLS) estimated with the help of Heckman Two Stage procedure was used to test whether transaction costs to the market was a binding constraint to soil and water conservation, resource use and agricultural productivity. A Cobb-Douglas type of regression function was also used to investigate how farmers respond to the net benefits of soil conservation measures. Further, a dynamic simultaneous agricultural household model was used to model households as both production and consumption centres.

The study findings show clearly that transaction costs reduce manure and fertiliser use of farming households as well as and more importantly soil conservation investments including net benefits of soil conservation investments. The results further show that transaction costs increase labour use. This apparent anomaly can be explained as household's response to increased transaction costs and the need to meet subsistence needs (i.e. food security). Simulation of the agricultural household model of a 10% reduction in transaction costs shows that soil conservation investments increase though with a lower magnitude depending on resource endowments of farming households.

Thus generic measures that can significantly reduce transaction costs such as improvement of road infrastructure; formation of co-operatives, marketing producer groups, and self-help groups serve as viable policy areas in order to induce investments in soil conservation measures on a large scale, with consequent sustainability of farming systems. Other likely policy measures include revamping extension service, improving property rights, and taking into account mobilization of social capital as part of the policy package towards sustainable agriculture.

DEDICATION

To my friend and co-worker in the Kingdom, David Weinman

ABSTRACT

Marginal areas in Kenya that comprise about 80% of the total land area are ecologically vulnerable with very serious problems of soil erosion. A decline in agricultural productivity is the result, accompanied by serious household food insecurity. As more people immigrate to these areas coupled with births, the problem is bound to get worse.

Nevertheless, these areas can be productive if farmers make investments on their land. Investments into soil and water conservation include terraces, trees, cattle, manure, fertiliser, equipment, wells, dams and other infrastructure. Investments into soil and water conservation may be undertaken when sufficient returns are expected. These returns, in particular monetary returns, can be related to many factors, but are always influenced by transaction costs of market exchange which subsequently determine the level of access to input and output markets.

Essentially the research seeks to determine the influence of transaction costs on soil conservation in smallholder agriculture and their role and impact on sustainable resource management and agricultural productivity.

A multi-stage random sampling was used to collect cross-sectional data from farming households using a structured questionnaire in Machakos and Kitui Districts. Besides descriptive statistics, econometric analysis using Three Stage Least Squares (3SLS) estimated with the help of Heckman Two Stage procedure was used to test whether transaction costs to the market was a binding constraint to soil and water conservation, resource use and agricultural productivity. A Cobb-Douglas type of regression function was also used to investigate how farmers respond to the net benefits of soil conservation measures. Further, a dynamic simultaneous agricultural household model was used to model households as both production and consumption centres.

The study findings show clearly that transaction costs reduce manure and fertiliser use of farming households as well as and more importantly soil conservation investments including net benefits of soil conservation investments. The results further show that transaction costs increase labour use. This apparent anomaly can be explained as household's response to increased transaction costs and the need to meet subsistence needs (i.e. food security). Simulation of the agricultural household model of a 10% reduction in transaction costs shows

that soil conservation investments increase though with a lower magnitude depending on resource endowments of farming households.

Thus generic measures that can significantly reduce transaction costs such as improvement of road infrastructure; formation of co-operatives, marketing producer groups, and self-help groups serve as viable policy areas in order to induce investments in soil conservation measures on a large scale, with consequent sustainability of farming systems. Other likely policy measures include revamping extension service, improving property rights, and taking into account mobilization of social capital as part of the policy package towards sustainable agriculture.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
AIDS	Almost Ideal Demand System
ALDEV	African Land Development Board
CBS	Central Bureau of Statistics
DANIDA	Danish Development Agency
GAMS	Generalized Algebraic Modelling System
GDP	Gross Domestic Product
GOK	Government of Kenya
GPS	Global Positioning System
IMR	Inverse Mills Ratio
KARI	Kenya Agricultural Research Institute
Kg	Kilogram
Km	Kilometre
Ksh	Kenya Shilling
LM4	Livestock and Millet Zone
LP	Linear Programming
M	Metres
NGO	Non-Governmental Organization
NPV	Net Present Value
OLS	Ordinary Least Squares
NWO	Nederlands Wetenschappelijk Onderzoek/Dutch Scientific Research
SAP	Structural Adjustment Programmes
SIDA	Swedish International Development Agency
3SLS	Three Stage Least Squares
Std.	Standard Error
TCA	Transaction Cost Analysis
TOT	Training of trainers

PREFACE

This thesis is divided into six chapters. In the first chapter the problem under study is introduced. Further, the objectives, hypotheses, significance of the study and background to the study area are presented. In chapter two, a detailed review of literature covering soil conservation, transaction costs and analytical approaches is carried out.

Chapter three deals with the methodology, which includes conceptual framework, how sample units were selected, and methods of analysis. Chapter four describes the data. This includes characteristics of the individual parcels of land, households, and villages; and types of investments in sustainable agriculture.

Chapter five discusses Three Stage Least Squares (3SLS) estimation of a system of five equations involving determinants of soil conservation investments with aggregate value of crop output in the first section. The application of an agricultural household model is in this section. The second section looks at how the net benefits of soil conservation (incentives) are influenced by transaction costs and other factors.

Chapter six presents the summary, conclusions and policy implications.

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those without whose understanding and encouragement, this would not have been accomplished. First and foremost, my special thanks go to those institutions that provided assistance and an enabling environment to accomplish this study. I send my gratitude to NWO under the project, "Environment and the Economy", Sub-program, "Agricultural transition towards sustainable land use in the Tropics", for paying my tuition fees and research support. I also acknowledge with gratitude an award from CODESRIA for thesis writing support that went to buying essential books, stationary and the numerous counterchecking trips to the field. My thanks go to my University supervisors, Dr. W.K. Yabann, Prof. H.K. Maritim and Dr Fred Zaal who took a lot of their precious time to guide me through this study and whose ideas, suggestions, criticisms, materials and logistical support facilitated this study and improved the quality. The Soil conservation staff in the Ministry of Agriculture, Machakos also deserve special appreciation for their ideas, comments and assistance in the course of my research. I also thank Dr. Steve Omamo for his patience and support during my struggle with agricultural household model. Others who provided support include Prof. Ton Dietz, Prof. David Starret, Dr. Fred Zaal, Dr. Kees Burger, Dr. Remco Oostendorp, Dr. Gideon Kruseman and Dr. Gideon Obare.

Special thanks go to Messrs Mutunga, Kimeu, Nyamai, Eshe, the late Wambua, Maluki, and Kilaka who participated in the research as enumerators. I also want to acknowledge my colleagues Michael Bowen and Millincet Mokua whom we suffered together the rigour of a D.Phil. program. Especially Bowen whom we used to discuss a lot about our research topics. Thank you Bowen for that.

Further, I am particularly indebted to my siblings for their patience, love, concern and learning not to create any disturbance or problem. There are many others whose names have not been mentioned that contributed a great deal to this study. Thanks all of you. All errors and shortcomings of this study remain my responsibility.

Finally to my Heavenly father who receives all the glory and honour. His grace has been sufficient all the time. I can say with confidence, " that far the Lord has brought me". I remember those times I used to pray, " Lord give a breakthrough with this agricultural household model". And He surely did.

CHAPTER ONE: INTRODUCTION AND THE RESEARCH PROBLEM

Agriculture has been and is still an important sector of the Kenyan economy. Currently the sector contributes about 25% of the GDP (GOK, 2002-2008). The sector accounts for 80% of national employment, 60% of total export earnings and 45% of Government revenue. In the rural areas, where much of the Kenyan population resides, about 80% of the people derive their livelihood from agriculture. The majority of the farmers are small holders. Their production accounts for about 70% of total output and 50% of gross marketed production (GOK, 1997-2001a).

In developing countries, smallholder farmers represent the majority of the population. They represent even a larger share of the population below the poverty line as rural poverty is more extensive than urban poverty (Holden and Biswanger, 1998). They also form a major link between the economy and the environment as their livelihoods depend directly on utilisation of the land (soil and vegetation) resources. In essence, poverty in developing countries, Kenya included, is predominantly rural and some of the most vulnerable groups are located in rural areas. Besides, the incidence of poverty continues to rise with some districts in the arid and semi-arid areas of Kenya registering poverty levels in excess of 80%. Growth in agriculture and improved rural incomes will therefore have a significant and direct impact in reducing overall poverty in Kenya.

However, a number of constraints are retarding the growth of the agricultural sector. Poor economic incentives for soil conservation, for example, and other inappropriate farming practices are increasingly leading to falling yields, lower farm incomes and soil exhaustion in smallholder agriculture in Kenya (Sanchez et al., 1997). Poor choices by farmers and other circumstances have also led to soil erosion[1] and soil mining thus threatening the sustainability of the agricultural environment (Lutz et al.1994; Woomer et al, 1998; Smalling et al, 1997). Other constraints include policy-related disincentives for technology adoption, actual and/or perceived low returns; and barriers to entry to key complementary markets such as credit.

Moreover, about 80% of the total land area in Kenya is marginal for agricultural production.

[1] However, changes in soil conservation and management practices, as land intensification occurs could slow

These areas are faced with frequent drought and food shortages, are ecologically vulnerable and receive irregular and low amounts of rainfall. They also face very serious problems of environmental degradation such as soil erosion and soil mining. Soil degradation[2] is thus increasingly being regarded as a major, perhaps the most threatening environmental problem in developing countries (Reardon and Vosti, 1992). The main negative consequence of soil degradation[3] is on-farm[4] decline of crop production[5]. Yields decline partly because essential nutrients and organic matter are lost. Eroded soil also suffers from moisture deficiency because subsoil structure is generally blocky, hard, and dense compared to topsoil (Walker, 1982).

While loss of topsoil threatens long-term productivity in most of semi-arid tropical areas, water is the natural resource that most determines yields in the short term. When there is too little water yields decline due to moisture stress. Moreover, water and soil management are highly interdependent because erosion is highly correlated to run-off, water moving along the soil surface loosens and transports soil particles (Cogle et al., 1996).

As the population increases in these areas due to immigration and high birth rates, the situation is bound to get worse. Consequently, food availability and accessibility of large population groups may be severely reduced in the near future (World Bank, 1992).

Nevertheless, marginal areas can be very productive if farmers make substantial investments on their land. Such investments include terracing[6], application of manure, planting of trees, among others. These investments conserve water and the soils[7] at the farm household level. Once these investments are undertaken, the food security situation will improve and other

down the process of land degradation, ensuring sustainable agricultural production (Boserup, 1965).

[2] Soil degradation is defined as a reduction in the land's actual or potential uses.

[3] Other forms of soil degradation include damage to physical and chemical properties of soil and reduction in moisture retention capacity. In many cases, different forms of degradation are correlated. Whatever its form, soil degradation is reflected in lower yield or, if compensating measures are taken, in higher costs for a given yield.

[4] This is not to belittle the importance of off-farm effects of soil degradation, such as siltation of reservoirs and waterways. But even where such off-farm effects are the primary concern, considering them at the farm level is appropriate because that is where the conservation measures would have to be implemented.

[5] In developing countries, where substantial numbers of people still depend directly on agricultural production, the effect on yields is often very critical.

[6] A terrace is an embankment or ridge of earth constructed on a parcel of land to control run-off and minimize soil erosion by modifying the slope length and degree (Gichuki, 1991).

[7] Ideally, a conservation practice reduces soil loss so that crop production could be sustained each year indefinitely without depleting the resource.

national objectives, notably poverty alleviation and employment generation, will also be met. Moreover, soil conservation also raises the long-term sustainability of farming systems.

Evidence of this sustainability has been observed in some areas in the country. In the 1950's, the semi-arid Machakos district in Kenya was a disaster area, evidenced by soil erosion, low crop productivity, and poverty. However, as Tiffen *et. al.*, 1994 points out, population has increased threefold and so has per capita output increased with a similar magnitude. Soil erosion has also been arrested significantly. Machakos district now, boasts of some of the best-terraced[8] land in Kenya. There are other districts in Kenya with conditions similar to those of Machakos in the earlier periods, yet they have not undergone the transition that Machakos has. Some of these districts include Taita-Taveta, Baringo, Kitui, Mbeere, lower parts of Keiyo district and Tharaka. This raises the question as to how Machakos made it while the other districts have not. Can the "Machakos miracle" be induced on a large scale in other similar areas?

As a first step, it is indeed crucial to understand the factors that induced farmers to invest in farming systems that are sustainable in Machakos district. Investments into soil conservation may be undertaken when sufficient returns are expected. The returns to the investments critically depend on what the household can do with the crops. These returns, in particular monetary returns, can be related to many factors, but are always influenced by transaction costs of market exchange which subsequently determine the level of access to input and output markets. As Shiferaw and Holden (1998) argue, negative returns to soil conservation may undermine households' incentives to invest in conservation technologies.

Eggertsson (1990) defines transaction costs to include information search, negotiation, the making of contracts, the monitoring of contractual partners, the enforcement of contracts, and protection of property rights against third party encroachment. These costs arise when individuals exchange ownership rights of economic assets and enforce their exclusive rights. Sadoulet and De Janvry (1995) on the other hand define transaction costs to include also

[8] In the hilly and erosion-prone environment of the Machakos district, terracing is a very visible element in the landscape. Adequate terraces help a lot to curb water erosion and gully formation, they stabilize soils, they are a form of water harvesting (prevent the outflow of water), and they prevent the disappearance of soil nutrients. Terraces often dominate the discussion about sustainable agriculture, more than nutrient or fertility management and more than agro-forestry (Dietz, 2000).

consequences of imperfect and asymmetrical information that lead to adverse selection and moral hazards as a consequence of the opportunistic behaviour it allows. Transaction costs are thus taken to include transportation costs (caused by distance from the market and poor road infrastructure), high marketing margins due to merchants with local monopoly power, high search cost and recruitment costs due to asymmetrical information flow, and supervision and incentive costs on hired labour.

A general phenomenon in Sub-Saharan Africa is the fragmentation of factor and commodity markets due to limited access and imperfect information. This is attributed to the existence of transaction costs and as a consequence farmers responsiveness to price changes are limited. Transaction costs contribute to the wide price margin between market prices and the farm gate price. As a result, farmers resource use differ from one another, to eventually refrain from market transactions if their subjective equilibria for the production of commodities they also consume or for the use of factors they also own falls within their own price band, or to use contracts in order to achieve transactions at a lower cost than through the market (Sadoulet and de Janvry, 1995).

Smallholder farmers are usually only partly integrated into markets. Typical market imperfections include missing markets, partly missing markets (rationing, seasonality), thin markets (imperfect competition), and interlinkage of markets (Holden and Biswanger, 1998). Such imperfections, incorrect or missing price signals may possibly result in inefficiencies. Possible outcomes are also too rapid extraction of and too low investments in natural resources.

Most product and input markets in developing countries are characterized by high transaction costs and differential access to markets for different households, creating constraints in the amount of produce sold and quantity of inputs purchased (i.e. returns received). Differential transaction costs by households stem from asymmetries in access to assets, information, services and remunerative markets (Delgado, 1998). Transaction costs in marketing and processing in Africa typically arise because market prices do not fully reflect the true costs and returns to participation for all market actors, who have unequal initial endowments and for whom market solutions (such as borrowing against receivables or knowing where purchasers can be found) may not be equally available (Holloway et al, 1999). The high level of transaction costs in Sub-Saharan Africa is related to long distances to markets and poor road infrastructure making transport costs very high and local traders with monopolistic power making marketing margins rather high. Transport costs vary with distance, number of transport carriers and condition of roads. Transaction costs may thus lead to low crop returns and this might serve as a disincentive to investment in increased productivity measures. This is because transaction costs blunt the incentives and abilities of farmers to use markets to their advantage.

Transaction costs have been calculated to be up to 70% of the product price in sub-Saharan Africa (Kruseman et al, 1997). Nyoro and Jayne (1999) argue that high transport costs and by extension transaction costs lead to low returns and hence lower incentive to invest in productivity-enhancing technologies by farmers in Kenya. A study by Dijkstra (1997) shows that transaction costs account for more than 80% of the product price in the market in Kenya. The most important categories according to this study are transport, information search and negotiation. As Delgado (1995) argues, it will be hard to increase rural growth without finding a way to address Africa's very high transfer costs. Africa's relative costs in this regard far exceed those of any other major region of the world, and they present a difficult barrier to commercialization. More broadly as suggested by De Janvry et al., (1993), one of the major challenges of the post-SAP era is to find ways through nongovernmental organizations of various types to reduce transaction costs generally in rural Africa. Thus the rise of co-operatives and self-help groups[9] in Kenya may have been a response to market imperfections and high transaction costs.

1.1 Soil Conservation Programs in Kenya

Kenya became a British colony in 1885 with the end of the East Africa Protectorate (Eriksson, 1992). In order to make the colony self-sustaining, many European farmers were allowed to settle in a number of areas in the country. This was after 1903 and they owned about three million hectares of land. As a result, African farmers were restricted to 'native lands' and were not allowed to grow cash crops.

[9] The underlying motivation for collective action is obvious: to achieve goals that each member could not meet in isolation, e.g., favorable prices for products, access to affordable credit, access to distant markets and access to specialized information (Omamo, 2003).

The Colonial Government introduced soil conservation programs in Kenya within the Department of Agriculture in the 1930's. The structures by then included wash-tops (cross-slope barriers) of trash lines, rows of stones and grass strips. The barriers were laid on the contour. Excavated terraces were not made by then, as the main tool, the hoe was inappropriate. The introduction of soil conservation programs was as a result of a mounting international concern about soil erosion, population pressure on African reserves, and increasing incidence of drought (Anderson, 1984). The Colonial Government committed funds to anti-erosion measures particularly in the semi-arid districts of Machakos and Kitui. Some of these measures were contour trenching, destocking, planting Napier grass, and rotational grazing for the case of grazing lands; cut-off drains and terraces for farming areas.

The traditional soil erosion control and soil fertility activities that were used included: shifting cultivation, trash lines, terracing which were practiced in Mbooni as far back as 1884; mixed farming, crop rotation, interplanting of legumes, and agroforestry. In 1938, the Colonial Government established a Soil Conservation Service. However, the extension program was mainly beneficial to European farmers and to those farmers in districts along the railway line. Most of the programs introduced by the Extension service focused on mechanical construction of soil conservation structures.

Funds were later advanced through the African Land Development Board (ALDEV) and then through the Swynnerton Plan[10] in 1950's. The extension service through the help of chiefs coerced the people into undertaking soil conservation measures. After independence in 1964, the government continued with the soil conservation measures within the Ministry of Agriculture. These efforts were complemented by the Permanent Presidential Commission of Soil Conservation and Afforestation established in 1982 that built demonstration sites for gully control, cut-off drains and terraces, fodder establishment, afforestation and pasture reclamation on badly eroded lands (Tiffen et al, 1994).

In 1974, the Swedish International Development Agency (SIDA) begun to support soil and water conservation in Kenya through the ministry of Agriculture. SIDA supported the construction of cut-off drains and terraces with food for work schemes. Danish Development

[10] This plan was to improve African agriculture by allowing them to grow cash crops and providing credit.

Agency (DANIDA) also supported soil conservation works. Currently the Agency is still running some programs in Kitui, Makueni and Taita-Taveta districts. Non-Governmental organisations have also contributed to soil and water conservation activities, particularly since the drought of 1984. These include Catholic Diocese of Machakos, Green Belt Movement, Action-Aid, and the Kenya Institute of Organic Farming. They support community mobilisation for self-help, and provide financial assistance for minor rehabilitation works and the promotion of better farming methods. They work mainly with self-help groups.

Many farmers have been practising on-farm (individual) approach to soil conservation on their farms for many years. With this approach, soil conservation is practised and supported on an individual basis (Eriksson, 1992). If possible, farmers are approached by extension workers and given support. Farmers also seek assistance from Technical Assistants (TAs), but with increasing transportation costs, this assistance is not more readily available. The on-farm approach, therefore, relies on farmer interest in and understanding soil conservation measures and benefits. The advocates of this approach cite, as an advantage, the laissez-faire tradition which is thought to recognise farmers' integrity and right to self-determination within their farms and in a broad sense, the local community (Eriksson, 1992).

Another approach to soil conservation was also developed. This was the catchment approach also with the support of SIDA. The rationale for this was the cost-effectiveness and the public good characteristic of soil erosion and soil conservation. Moreover, work groups provide a method of cost sharing by 'pooling' labour at no cash cost to the farmer. The soil conservation tools were provided by SIDA as farmers in a group moved from one farm to the other laying conservation structures according to guidance from the extension staff.

1.2 Problem Statement

Soil erosion is a serious problem in Kenya's marginal areas. The resultant effect has been a decline in agricultural productivity with consequent increase in food insecurity and poverty. Soil and water conservation in marginal and fragile areas are thus key ingredients for sustainable agricultural development. Transaction costs underpinning the success or failure of these measures have received insufficient attention in the empirical literature. The rather limited studies so far, (Kruseman et al, 1997, for Mali; Pender and Kerr, 1996, for India; and Shiferaw & Holden, 1997 for Ethiopia) have not incorporated important aspects concerning soil conservation measures. This is true especially with the role of road infrastructure, co-operative societies or producer groups and social networks or self-help groups in reducing transaction costs that may have a profound influence on soil conservation investments.

This is even more apparent in relation to its effect in land and resource management in ecologically fragile areas for agricultural land use. Yet, the effect of transaction costs in the initiation and success or otherwise of soil and water conservation investments, and as production constraints imposed by both the environment and economic institutions is rarely a major consideration in policy formulation and policy instrumentation. Transaction costs are the embodiment of barriers to access to market participation by poor smallholder farmers.

Apparently, different forms of transaction costs under different institutional arrangements would have differential effects on households' engagement in production and resource management. It follows, therefore, that identifying different forms of transaction costs and institutional arrangements and their functional relationship to resource management, agricultural development and sustainable land use should be core to explaining resource use management and agricultural productivity.

The functional relationship between transaction costs and sustainable land use in marginal agricultural setting should provide a basis for integrated policy intervention with households as the center of focus. Understanding the interrelationship between transaction costs and land use management and agricultural productivity will provide information that would be used to improve on policies that influence food security, poverty alleviation and sound management of natural resources. It will further motivate better policies for food, agriculture and the environment for the benefit of the poor.

The study therefore aimed at finding the influence of transaction costs on investments in soil conservation in Kenya.

1.3 Objectives of the Study

The overall objective of the study is to investigate, analyse, and document the influence of transaction costs in marginal areas and evaluate its effects on soil conservation investments, resource use patterns and agricultural productivity.

The specific objectives were:

1.3.1. To determine the effect of different forms of transaction costs on soil conservation investments.

1.3.2. To investigate the link between transaction costs, resource use and agricultural productivity; and

1.3.3. To understand the interaction between transaction costs and social networks in relation to soil conservation investments

1.4 Hypotheses of the Study

The hypotheses for the study were:

1.4.1. High transaction costs have a negative significant effect on soil conservation investments.

1.4.2. High transaction costs significantly reduce labour, manure and fertiliser use in agricultural production with a consequent reduction in soil conservation investments

1.4.3. High transaction costs lead to a reduction in agricultural productivity with a consequent reduction in soil conservation investments.

1.4.4. Social networks such as self-help groups are positively and significantly related to investment in soil conservation

1.5 Purpose and Justification of the Study

The purpose of the study was to determine the central role of transaction costs in soil conservation (i.e. soil fertility management) in smallholder agriculture. This would help in the drive to encourage farmers to invest in the quality of land. This is crucial especially when lands with degrading soils are a critical source of food security for subsistence or semi-subsistence producers with few alternative livelihood options.

The information generated from this study will be of help in soil fertility management. Apart from reducing soil loss and consequently the rate of decline in yield, conservation measures can influence yields by encouraging the retention of moisture and stimulating improvements in the soil's physical structure (English et al, 1994, Shaxson et al, 1989). In arid areas, therefore, soil conservation can often reduce the risk of crop failure by improving moisture retention.

In order to achieve sustainable soil conservation cost-effective programs that encourage farmers, particularly resource poor farmers, to adopt soil management technologies are needed. Costs-effective conservation programs in turn require knowledge of transaction costs market exchange among other factors that induce or otherwise the adoption of conservation measures by farmers. This knowledge in turn helps policy makers to design soil conservation policies that encourage farmers to adopt technologies. In addition, understanding of the factors that influence soil conservation technology adoption highlights deficiencies in farmer knowledge, and hence guides the extension service in setting priorities for conservation training and extension activities.

1.6 Study Area

The study areas comprised of Machakos and Kitui districts. These districts are synonymous with soil conservation efforts in Kenya dating back to the colonial days. It has also been observed that recent work on conservation efforts is going on and this would provide considerable wealth of information needed for data analysis. Moreover, these same districts are in the marginal areas and have substantial proportions of zone 4(see Jaetzold and Schmidt, 1983). In these areas also, there are some farmers who have not invested in soil conservation measures; thus effectively netting out unawareness as a critical issue.

Below we give general brief background of the districts. We start with Machakos district.

Machakos District

This is one of the twelve districts that comprise Eastern Province in Kenya. The district has a total area of 6,051 sq. km and is divided into 11 administrative divisions. There are a variety of topographical features. The landscape is largely a plateau that rises from 700m to 1700m above sea level and is interrupted by an escarpment and a series of hills, the highest of which is Kilimambogo (Ol Donyo Sabuk), which is 2,144 metres above sea level.

In the western part of the district, there are the Kapiti and Athi plains, north there is the Athi River, which flows round the solitary hill of Ol Donyo Sabuk towards the south-east. Rising steeply to the north-east of Athi River is the Yatta Plateau, which is punctuated by isolated hills. This plateau extends into the basin of Tana River. In the Central part of the district is a series of hills that stretch in a roughly north-south axis. This series includes the Ol Donyo Sabuk, Kanzalu ranges, Kangundo, Mua, Mitaboni, Iveti and Kiima Kimwe.

Machakos is generally hot and dry. It has two rainy seasons, the long rains, which start from late March to May, and the short rains that start in late October to December. The annual average rainfall fluctuates between 500mm to 1,300mm. There are significant regional and seasonal variations within the district and rainfall is unreliable. The high altitude areas of Matungulu, Kangundo, Kathiani, Central and Mwala divisions receive much higher rainfall than the rest and hence are good for agriculture. The other areas support ranching and pastoral production activities. Mean temperatures range between 18°C and 25°C. The coldest month is July while October and March are the hottest.

The population in the district has been rising from 765,008 in 1989 to 1,041,989 in 1999. The population is projected to be 1,108,415 by 2001. Women are more numerous than men, especially in the rural areas, implying that they are the major contributors to family farm labor, and thus require empowerment to make critical decisions on production and resource utilization at the household level.

The population of Machakos district is not evenly distributed. The distribution in the rural areas is influenced by availability of water and soils to sustain agriculture. There are big inter and intra-divisional variations in population density and the divisions that consist of the large and relatively fertile hill masses have higher population densities that the rest of the district. Central Division has the highest population for it covers Machakos town, and the Iveti and Mua hills, which have fertile soils and high rainfall. The population in Yatta Division is high partly because of the large land area and partly due to the influence of Yatta Furrow, which, through providing water for irrigation, has enabled agricultural production to prosper in marginal areas.

Although the District is large in area, high and medium potential areas for rain-fed agriculture are limited to the highland areas that have high and reliable rainfall. These areas are covering about 26% of the total area of the district. Irrigation potential is found along Rivers Tana, Athi and the Yatta Furrow. These potential areas cover approximately 11,000 hectares. Land use patterns are based on the agro-ecological zones and are influenced by the soil fertility.

The table below shows the agro-ecological zones in the district.

Table 1.1: Agro-Ecological Zones in Machakos District

Main Zone	Ecological Characteristics	Characteristics of use	% of District Area
AEZ II	Sub-humid	Maize, Coffee	3
AEZ III	Semi-humid	Coffee, Cotton,Maize	9
AEZ IV	Transitional	Maize, Cotton	40
AEZ V	Semi-arid	Livestock, Millet, Sorghum	31
AEZ VI	Arid	Livestock	17

Source: GOK, 1997-2001b, Jaetzold & Schmidt, 1983

Zone II covers the upper slopes of the hill masses of Iveti, Mua and Kangundo. The zone has an average annual rainfall of 1000mm and has the growing potential of maize, citrus, forestry, and dairy as the main activities. It has a fair to good yield potential.

Zone III covers the lower slopes of Iveti, Mua and Kangundo and parts of Matungulu and Mitaboni. The zone has an average annual rainfall of 850mm. The main agricultural activities are growing of maize, beans, pigeon peas, sunflower, citrus, bananas, cowpeas and dairying.

Zone IV is the largest zone in the District. It covers most parts of Mwala, Ndalani, Kinyaata and Katangi in Yatta Division, Kangonde in Masinga, and parts of Ndithini and Matungulu Divisions. Average annual rainfall in this zone is 700-750mm. The zone has a short cropping season with a fair to good yield potential for Katumani maize, Mwezi moja beans, pigeon peas, sorghum, cotton, mangoes and cowpeas. Livestock rearing is also a major activity. This is the ecological zone chosen for this study.

Zone V covers most parts of Masinga and Yatta Divisions, parts of Mwala and Yathui Divisions bordering the Yatta Plateau, Komarock in Matungulu and Mitaboni in Kathiani. The average rainfall in the area is about 600-650mm. The main activities are ranching, bee keeping, growing of pigeon peas, sorghum, maize (katumani), cotton and other drought resistant and early maturing crops.

Finally, Zone VI covers Athi River Division and parts of Central Division on the Athi-Kapiti plains. This is almost exclusively a ranching zone with farming only under irrigation. Table 1.2 below shows the distribution of soils in Machakos district.

Table 1.2: Distribution of Soils by Type and Area in Machakos District

Soil Type	Approx. area (sq.km)	% of Total District area
Vertisol	1392.0	23
Acrisols/Ferralsols	3570	59
Planosols	4233.5	7
Cambisols	363	6
Andosols	121	2
Arenosols	181.5	3
Totals	6051	100

Source: GOK, 1997-2001b

Vertisols are poorly drained, deep, grayish brown to black cracking clays and are generally less eroded. They are boulder and stony in some places and in other places sandy with a moderate to high fertility. These soils are sensitive to erosion, are difficult to manage, and have low infiltration rate. Acrisols/Ferralsols are deep, friable and excessively well drained. They have a moderate to low fertility and are dark in colour. These soils also have strong acidity, low available phosphorus, no reserves of weatherable minerals and easily lost topsoil organic matter demonstrate low resilience and moderate sensitivity to water erosion. Planosols are imperfectly drained, moderately deep, dark grayish, brown to black in colour and very firm. They have a moderate to low fertility.

Cambisols are excessively drained to well drained, deep, dark red to dark yellowish brown, very friable sand clay loams to sandy clay. They are easily eroded forming deep gullies. In some places they have thick and humic topsoils and are of variable fertility. Arenosols on the other hand, are somewhat excessively drained, very deep dark red to brown sandy loam to clay. They are of moderately low fertility. Andosols are somewhat excessively drained, very deep strong brown to dark yellowish brown, very friable and smeary, slightly sodic, gravely sandy clay loam. They are easily erodable.

Because of the nature of the study, which covers transaction costs, a brief overview on roads network is important. The classified road network in the district covers a distance of 1,562.9 km. The road network connects all the major and most of the minor market centers and also provides access to areas of agricultural importance. The distribution network by class and type of surface is given in Table 1.3.

Table 1.3: Classified Road network in Machakos District in kilometers

Class	Bitumen	Gravel	Earth	Total
A	108.6	-	-	108.6
B	35.5	-	-	35.5
C	151.9	82.7	-	234.6
D	-	207.3	69.8	277.1
E	44.7	107.5	519.6	671.8
GOK access	4.1	2.3	12.7	19.1
Rural access	-	216.2	-	216.2
Total	344.8	616.0	602.1	1,562.9

Source: GOK, 1997-2001b

There are also unclassified roads built and maintained by local communities. Despite the extensive network, its distribution is not even and the condition of the roads is not good throughout the year. The tarmac road network is linked by gravel and earth roads, and most of those are impassable during the rainy seasons. The hilly terrain in Kangundo, Ndithini and Kalama Divisions has some of the worst roads. Due to the extensive nature of the district and also to the steep and rocky hill masses, the conditions of the roads deteriorate very fast. Kangundo, Kalama and Ndithini are the divisions greatly affected by the poor road network.

Kitui District

Kitui District is one of the eight districts in Eastern Province. The district occupies an area of about 29,389 square kilometres including 6369 square kilometres under the Tsavo National Park. The rural population occupies an area of 23020 sq. km of the district.

The district lies between 400m and 1800m above sea level and slopes generally from west to east. There is Yatta plateau to the west, which stretches from north to south between rivers Athi and Tana. The central part of the district has a lower elevation (600m - 900m above sea level) and is traversed by hilly ridges. The eastern side of the district is almost flat with shallow widely spaced valleys. The higher parts of the district are in Kitui Central, Mutito Hills and Yatta Plateau. These areas receive higher rainfall and are some of the productive areas in the district.

There are many seasonal rivers which include Nzeeu, Kalundu, Tiva, Ndiangu, Mutendea, Mwita Syano, Kauwi in central region, Kithioko, Kavaini, Tyaa in Mwingi Division, Ndiani, Kivoi, Nziu, Kalenge, Mataka, Mitamisyi, Mivukoni, Kaningo and Thunguthu in Kyuso Division, Mui, Ikoo, Thua, Enziu in Mutitu Division. The rivers flood during the rains and later turn into dry sand beds. Only a few rivers are perennial. These are Tana and Athi.

The geology of the district is characterised by metamorphic and igneous rocks of the basement complex system. The south-eastern side of the district is composed of permian deposits and tertiary volcanics are predominant in the western part. These rocks hold extractable water only in small cells, which generally occur in low areas near stream channels. There is little evidence of large-scale mineralization.

Kitui district is hot and dry for most of the year and can be characterised as an arid and semi-arid area with very unreliable rainfall. The rate of evaporation is very high thus limiting land use greatly when coupled with unreliable rains. The district has two rainy seasons - one with long rains from April to May and one of short rains between November and December. The dry periods are from August to September and from January to February.

The amount of rainfall follows topographical features of the landscape much as it does in Machakos District. The hills such as Mumoni in Central Kitui and Mutito in the western part of the district receive 500-760mm per year. The Endau Hills in the east receive 500-1050mm while the eastern and southern areas receive less than 500mm. In general, most of the district has less than 750mm of rainfall in a year.

The minimum mean annual temperatures in Kitui District vary between 14°C and 18°C in the western parts and 18°C and 22°C in the eastern parts. The maximum mean annual temperatures on the other hand vary between 26°C and 30°C in the western parts of the district and 30°C and 34°C in the eastern parts.

The district is divided into eight administrative divisions. The 1979 population census recorded a population of 463,974 people in the district. It had grown to 645,000 by 1989.

The central part of the district is sedimentary plains, which are usually low in natural fertility.

Because of its higher altitude than surrounding areas, it receives comparatively high precipitation. The eastern parts of the district have red sandy soils, which are also of low natural fertility. This is worsened by the compatively low rainfall in the region. These soils are very rich in sodium and are considered by the people of eastern division and neighbouring Tana River District to be the best grazing grounds in the whole district. Towards the western part of the district, there are clay black cotton soils, which are also generally low in fertility.

The vegetation and land use patterns are governed by rainfall patterns and can be used to delineate four Agro-Ecological Zones in the district. The first is the Arid-Agro-Pastoral, which is normally devoted to extensive livestock farming. The next is semi-Arid Farming zone, which has good potential for agricultural development. This area is either cultivated at present or occupied by savannah woodlands. The third is the Semi-Arid Ranching zone that is less fertile but suitable for drought-resistant food crops and livestock. Finally there is the Arid Pastoral zone with virtually no agricultural development. The people in this zone depend on livestock for livelihood. They are semi-nomadic in that during times of drought, they shift from the drier areas with their herds in groups, to areas with water for their livestock.

The district is in a rainfall deficit region. As a result, only 2.2% of the land receiving between 762 and 1270mm of rainfall is of high potential in terms of agriculture. These areas include Mulango, Kisasi, Miambani, Changwithya, Matinyani and part of Mutonguni and Migwani. Furthermore, 36.6% of the district receiving between 500 and 800mm of rainfall can be classified as medium potential, which is only useful as rangeland and 61.2%, receiving less than 500mm of rainfall is low potential land.

The high and medium potential lands of Kitui are settled and cultivated areas. The district is prone to frequent droughts and crop failures. Most lands in the district can best be utilised by planting drought resistant crops such as sorghum, beans, sunflower, pigeon peas, cotton and green grams which produce substantial yields even in seasons of inadequate or poor rainfall.

Kitui District has a total of 3,373.1 km of classified and unclassified roads. This covers only a small portion of the District. Central Division is fairly well covered by a reasonable road net-work. These are international trunk road (A), national trunk road (B), secondary roads and motorable trucks (C). The table below summarises the information.

Table 1.4: Road infrastructure in Kitui District in kilometres

Class	Bitumen	Gravel	Earth	Total (km)
A	48.8	0.0	94.2	143.0
B	6.5	147.6	9.6	163.7
C	25.5	110.7	74.3	210.5
D	4.2	871.9	162.1	1,038.2
E	1.0	63.2	1,182.6	1246.8
Rural access	0.0	537.1	30.4	567.5
GOK access	2.2	0.0	1.2	3.4
Total	88.2	1,730.5	1,554.4	3,373.1

Source: GOK, 1994-1996

In general, Kitui District is relatively poorly served by transport systems[11]. The District has a tarmac road which connect Kitui Town to Nairobi via Machakos and murram roads provide connections to the Thika-Garissa road, which crosses Mwingi District, and to the rail line from Nairobi to Mombasa at Kibwezi. Most major markets in the district such as Kabati, Kisasi and Mbitini are connected to Kitui Town by murram or earthen roads. During the rainy season, these roads often become impassable.

[11] Kitui District, which comprises largely semi-arid areas, has a road density of 6.7 km/100 km^2 and would require an investment of at least 24 billion Kenya shillings (US $340 million) to bring it to 90 km/100 km^2, the road density of India (MTC, 1998).

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews literature on the most important aspects of this dissertation, namely soil conservation, the concept of transaction costs, and analytical approaches used in sustainable land use. The aim of this literature review on soil conservation is to show the works that have been done in the past relating to factors that influence soil conservation investments by farmers. Additionally, and more important the works that have focused on transaction costs and the analytical tools used. This is meant to show that gaps exist in knowledge of soil conservation with reference to the influence of transaction costs and the method of analysis employed in addition to replication. The contention of this study lies on the dearth of transaction cost studies on soil conservation.

2.1 SOIL CONSERVATION

Soil erosion has received much attention in recent years, especially on fragile lands in the tropics. Government and Development agencies have invested substantial resources to promote adoption of practices to control erosion, and there is a growing literature on soil and water conservation.

Socio-economic analyses of issues concerning soil degradation and conservation date back at least to the 1930's (Cirriacy-Wantrup 1938, Bunce 1942). The widespread interest in soil conservation in the United States of America (U.S) in the 1930's (the 'Dust bowl' era) stemmed from the intensification of agricultural production with technologies and land-use practices that subsequently were recognised as less than wise. Although many of the concepts developed in the 1930's are relevant and still used, their scope has now been broadened. Many of the studies in the past have revolved basically on soil conservation as an input into agricultural production; definition of topsoil as a natural resource that borders between being renewable and non-renewable; and the consideration of soil degradation and its effects within the framework of common property resources (Thampapillai and Anderson ,1994). The authors' caution about the need to distinguish the differences in soils in the tropical areas that are fragile and the robust soils that are typical of temperate regions. This is considered important since the world literature on soil erosion and conservation is dominated by work on the relatively well-buffered soils of North America (e.g. Walker, 1982; Walker and young, 1986; Sinden and King, 1988).

Reardon and Vosti (1992), discuss the effects of policy implemented to protect the long-term fertility of top-soils in developing countries. They find there is more that need to be known about relationships between production choices and the rate at which soils are deteriorating. They further stress the need for policy analysts to focus on incentives at the household level to understand the consequences and implications of such policies. In particular, it is important to be aware of the similarities and distinctions among the sets of productivity and conservation investments, which are available at the household level. The empirical gap identified by Reardon and Vosti is also confirmed in other studies (e.g. Lutz et al., 1994).

The relationship between the effect of soil conservation on output and the factors influencing the adoption of soil conservation is complex. The effect of soil conservation on output and income overtly influences the adoption of soil conservation measures. Yet, there is a distinction between these concepts. The effect on output can be regarded as one that induces movement along a given demand or supply function pertaining to soil conservation. Alternatively the factors influencing the adoption of soil conservation can be conveniently regarded as those that induce shifts in the demand or supply functions. The difficult is in distinguishing between demand and supply, because of the absence of a clearly defined market for soil conservation. This is due to the fact that the very same firm (i.e., farm) that demands soil conservation usually has to provide it. The literature thus avoids the issue of demand and supply for soil conservation; and instead deals with the factors that influence the adoption of soil conservation measures (Thampapillai and Anderson, ibid.).

Several factors that condition adoption decisions of smallholders have been studied in relation to production technologies (e.g. Feder et al., 1985; Kabede et al., 1990; Bellon and Taylor, 1993; Adesina and Zinnah, 1993; Adesina and Baidu-Forsen, 1995). Investigating into factors that influence smallholders' soil conservation investment decisions are however, very limited. Technologies that enhance the conservation of the soil resource may have attributes that significantly differ from production technologies (Reardon and Vosti, 1992). Thus a different set of policies and strategies may be called for to promote the use of these conservation technologies.

Previous studies show that a number of factors may have a profound influence on adoption of conservation technologies (Ervin and Ervin, 1982; Norris and Batie, 1987; Nowak, 1987;

Goud et al., 1989; Sinden and King, 1988; Lee and Stewart, 1983; and Clay et al,1996). The factors can be grouped into four broad categories such as economic, institutional, social and physical. More specifically, they are household characteristics, farming systems, land characteristics, asset endowment, farm orientation, technology characteristics, institutional structure and policy factors, and market failures. Many of these factors are specific to a particular region, village, household and parcel level.

Likewise, labour, capital and land market distortions affect each farm household differently, depending on their endowments of particular factors and assets. There are also imperfections in the product market. Yet there remains little understanding of the factors that are crucial in the determination of farmers' investments in soil and water conservation. Studies on which of these factors explain the Kenya case are rather limited. Moreover, there has been a dearth of studies on transaction costs as a factor influencing soil conservation.

Below we review a number of individual case studies on soil conservation around the world. McConnell (1983) focused on the optimal private and social intertemporal path of soil use when the farmer grows a single crop. The author did not consider choice of crops as an important soil conservation variable and moreover did not incorporate non-linear relation for crop yields and soil losses as a function of soil depth. It appears that different crops have different effects on soil conservation, and thus what will influence crop choice will also have an effect on soil conservation investments. Goetz (1997) incorporates both crop yields and soil losses as a non-linear function of the soil depth within the decision problem of the optimal allocation of land to a mix of crops. The intensity of the use of inputs and the choice of crops are considered the key elements for controlling soil erosion. The study assumed land was homogenous which is unrealistic.

Agricultural prices is one of the factors that influence soil conservation. Pricing policies may influence soil conservation by inducing farmers to choose particular crops and also the level of returns obtained. However, literature shows that its effect will depend on market distortions and household endowments. Contrasting Perrings (1989) and McConnell (1983), where the former finds that lower agricultural prices might cause land degradation is diametrically opposed to the latter in which it is higher prices that have this effect. The lesson to be learnt here is that market failures and subjective poverty condition the range of possible responses to a price change. Barret (1991) pursues these arguments further as he tries to reconcile Repetto (1987) and Lipton (1987). Repetto argues that higher output prices will encourage soil conservation while the latter posit that higher output prices will lead farmers to deplete the soil. Barret (ibid.) finds that the effect of higher output prices on conservation may go either way depending on farmers balancing (at the margin) of present costs against the sum of future benefits appropriately discounted. Nevertheless, he is of the view that price policies have no effect on soil conservation. However, Clarke (1992) argues that profitability alone of investments as a result of price changes is not enough. What is rather much important is the existence of viable soil conservation measures. It also depends crucially on the complementary / substitutability relationships between inputs. The author argues that an increase in product price raises the marginal product of investment in soil quality; hence the farmer has the incentive to invest in soil conservation measures.

Other studies that have focused on the influence of price on soil conservation include Clarke 1992. De la Brière (1999) on a study of the determinants of adoption of sustainable soil conservation practices in the Dominican Republic highlands finds the following factors as important in soil and water conservation: land scarcity, subsistence households, education, subsidies and technical assistance and the perceived security of tenure. In a study of the Adoption of soil Conservation Measures in the Northern Province of South Africa, Anim (1999) finds that awareness of soil erosion problems and increases in long-term profit are significant indicators of the probability of adopting silt traps and contour ploughing as methods of soil conservation. Factors such as age, security of tenure, informal communication, size of land holding and difficult of adopting a particular technology, do not appear to be significant determinants of the adoption of soil conservation measures.

Shiferaw and Holden (1998) on a study of the pay-offs of the different soil conservation measures in Ethiopian Highlands, find that a number of the measures have very low profitability with the exception of grass strips in one of the sites. This indicates that the economic gains to small farmers by switching from traditional land management to soil-conserving practices under the existing production technologies are minimal. The researchers therefore call for the development of low cost soil conservation technologies that provide farmers with immediate benefits to poor farmers, as subsidies are costly and difficult to justify.

Other factors that encourage adoption of soil conservation measures are population pressure and land scarcity (Shiferaw et al., 1999). An econometric study by Shiferaw and Holden (1998) reveals that low or negative initial returns to conservation technologies may undermine households' incentives to invest in conservation technologies.

When it comes to Kenya, only a few studies on soil conservation have been carried out (Figueiredo, 1986; Hedfors, 1981; Holmberg, 1985; Holmgren & Johansson, 1987; Lindgren, 1988; Pagiola, 1993, 1994). These studies document the benefits of investment in soil conservation. Lindgren (1988), for instance, finds that it pays for the average farmer to adopt soil conservation measures in Kangundo division of Kitui district. However, this study was based on a very weak empirical data. The study assumed a zero wage rate for unskilled labour. Kagwanja (1996) and Tiffen et al. (1994) document some factors influencing soil conservation investments. Nevertheless, Kagwanja (1996) focused on the determinants of farm level soil conservation technology adoption in the high rainfall, high populated, steep slopes of Mt. Kenya Highlands, in Embu, Kenya. This area faces very different ecological conditions from those of Machakos and Kitui, which are marginal areas. Moreover, the major focus of the study was on perception of soil erosion problems.

Tiffen et al (1994) document the transition factors in Machakos district, which is a marginal area, focusing on population density and presence of markets. This study, though a major piece, lacked rigorous analysis and is difficult to discern how the conclusions were arrived at. Testing causality between population and environment requires more formal quantitative modelling and comparative case studies. The study is replete with description, but total lacking in this sort of modelling or statistical analysis and with only rudiments of sensitivity testing. Moreover, self-help groups, Christian mission education and expansion of cash crop production are not restricted to Machakos but can be found in many areas that fared less. In fact, Dietz (2000) in a study in Machakos and Kitui discounts population density as a transition factor explaining level of soil conservation investments. His finding is that distance to Nairobi is a better explanatory factor to transition compared to population density.

It appears that population growth under certain conditions may stimulate sustainable intensification while in other cases, may lead to land degradation. The incentive structure and how these are affected by a number of factors including policies appear to have a strong impact whether small farmers are able to choose a sustainable and welfare-improving or are forced onto a non-sustainable and welfare-reducing development path (Holden and Biswanger, 1998). Profitability of soil conservation measures is thus a very important consideration in adoption rates (Shiferaw and Holden, 1998). Gerrits (2000) finds land tenure as a transition factor in Kitui district on investments into sustainable farming and in particular the distinction into mobile and non-mobile types. Pagiola (1994) relates rates of return and adoption of soil conservation measures in Kitui and Machakos using benefit-cost framework. He finds that *fanya juu* terraces are privately profitable in the two districts under a broad range of conditions. However, given the high initial costs of terracing, the investment[12] in soil conservation is not repaid until the 48th year.

Thus in general there is a dearth of studies on determinants of soil conservation investments in Kenya. They are even much more limited on semi-arid or marginal areas. Even more significantly, little or no work has been carried out on the influence of transaction costs on soil conservation in Kenya.

2.2 TRANSACTION COSTS

Transaction costs have been receiving a lot of attention especially with the rise of new institutional economics. The argument being advanced is that for some time, institutions have been taken as given. Yet these institutions affect the allocation and distribution of resources and do adapt to changing conditions. Institutions are a public system of rules that define the kinds of exchanges that can occur among individuals and that structure their incentives in exchange. Such institutions include markets and property rights, systems of land and animal tenure, obligations of mutual insurance within lineage groups, and other systems of exchange that are determined by implicit contracts or social norms (Hoff et al, 1993). Some of the early studies on transaction costs were made by Akerlof (1970), Williamson (1986), and North (1990). Some authors for instance depict social institutions as sets of rules that emerge from the repetitive play of an underlying game by a group of rational agents. Each agent co-operates to maximise the expected pay-off. Non-co-operative actions lead to lower pay-off.

[12] Net returns with the conservation strategy are higher in the seventh year compared to the without scenario. The

Institutional economics appears to be in two strands: governance (organisational) and the institutional environment. The later has received less attention. Putman (1995) argues that social capital has powerful consequences because civic networks and norms ease dilemmas of collective actions. This can be through increase in iteration thus reducing opportunities of opportunism, foster robust norms of reciprocity and social trust, amplify the flow of information and help transmit reputations, and finally provides templates for future political and economic collaboration. Thus societies with high social capital can sustain high investments in sustainable farming.

In recent literature, there has been an increasing interest on transaction costs of rural markets in developing countries. Empirical evidence suggests that transactions in such markets are not costless and may involve information search, negotiations and enforcement among others. Such exchange costs may be potentially great to preclude any trade. This is particularly true in rural areas where transport, communication and enforcement systems are often highly deficient.

Some empirical studies on transaction costs have been carried out by Frank and Henderson (1992), Holden et al (1999), Omamo (1994), Jaffee (1991), De Janvry et al. (1991,1992), Hobbs (1997), and Dijkstra (1997). The focus was on how transaction costs influence output and input marketing of farm households, the choice of marketing channels, the choice of crops and ways of reducing transaction costs. Frank and Henderson (1992) for instance argue that transaction costs motivate firms to use non-market arrangements for vertical co-ordination in production. This is meant to lower these costs considerably. Transaction costs in marketing and processing in Africa typically arise because market prices do not fully reflect the true costs and returns to participation for all market actors, who have unequal initial endowments and for whom market solutions (such as borrowing against receivables or knowing where purchasers can be found) may not be available to all (Holloway et al, 1999). Transaction costs are the embodiment of barriers to access to market participation by poor small holders in some activities undertaken by better-off small operators. Some of the studies have also highlighted the contribution that Transaction Cost Analysis (TCA) makes to our understanding of agricultural markets. However, few studies have focused on the impact of

without conservation case would be unprofitable after 19 year. For details see Pagiola (1994).

transaction costs on investment in the farm. One criticism of TCA is that its theoretical development has not been accompanied by successful delineation of the nature and magnitude of transaction costs. This is because transaction costs are often not easy to disentangle from other costs such as managerial. The complex nature of economic institutions means that the costs of their operation are not easy to quantify. Thus, analysis that delineates a particular case may be a fruitful approach. The present study takes such an approach by focusing on transaction costs of access to the product and input market and social net works and how these influence household investment pattern into sustainable agriculture. More generally, transaction costs such as costs of searching for a buyer or seller, screening costs, costs of negotiating, contract monitoring and enforcement costs and transportation costs may create a wedge between buyer's and sellers's price of a factor or a product, causing it to be "non-tradable" for some range of implicit prices.

A few studies on transaction costs on sustainable land use have been carried out by Shiferaw and Holden (1997, 1999, 2000), Pender and Kerr (1996), Kruseman and Bade (1998), Ruben et al. (1994, 1997), Kruseman et al., (1997); Kruseman, (1998), and Bade et al. (1997). We note a number of limitations with these studies. Most of them are not in semi-arid or marginal areas where soil moisture limitation is very serious. Moreover, none specifically touches on terraces that are durable except for periodic maintenance.

Most theoretical work on soil and water conservation adoption studies follows a cost-benefit framework, while empirical adoption studies implicitly use a broader framework that incorporates farmer-specific conditions. These studies include Pagiola (1993, 1994, 1995), Ekbom (1995), and Shiferaw and Holden (2001).

2.3 ANALYTICAL APPROACHES

A number of approaches have been used for appraisal and evaluation of land use options. Schipper (1996) provides an extensive review of different theories and methods that can be used for land use analysis. They can be grouped into explorative, explanatory and forecasting according to the purpose of the analysis (Rabbinge & Van Ittersum, 1994). Explorative models are used for the assessment of land use potentials in the long run. They explore outer development boundaries under different sets of assumptions and priorities (scenarios). This includes finding possible discontinuities in current trends. Since these models reflect the long-run, many assumptions have to be made about the future developments. This type of models is sometimes exclusively based on biophysical knowledge, with very simple assumptions about economic development, but not including behavioural relationships. Linear programming procedures are widely used in explorative studies (WRR, 1992; Veeneklaas et al., 1991; 1994; Van der Ven, 1996).

Explanatory models try to give a plausible explanation of current land use, based on a variety of variables. Statistical methods are usually applied to determine which variables significantly explain land use. Farming system research (FSR) and farm management analysis are commonly used for explanatory studies (Steenhuijsen Piters, 1995; Upton, 1987). Clay et al (1996), for example, used random-effects generalised Least Squares (GLS) to explain land conservation investments, organic input use, chemical input use, and land use (C-values) in Rwanda.

A different approach is the use of farm household modeling (Sing et al, 1986) and supply response models (Nerlove, 1958; Askari & Cummings, 1976) which explains land use almost exclusively with behavioural variables using econometric techniques. Explanatory models are sometimes used for predictive land use studies by extrapolating from the current land use under the assumption of changing exogenous parameters. In predictive models the rhythm and direction of change is what we want to know, this implies that time has to be explicitly included in the approach, either in a dynamic model or in a comparative approach. In earlier studies, many of these models assumed implicitly or implicitly perfect markets and thus separability of production and consumption decisions. They often ignored transaction costs and intertemporal markets (credit, risks and insurance). Recently, attempts have been made to include market imperfections (De Janvry et al., 1991, 1992; Kruseman et al., 1997, Kruseman and Bade, 1998, De la briere, 1999).

Forecasting models also make use of certain elements of the other two modelling frameworks, because validation of the modeling framework is mostly based on current land use, and the implications of technological change can be assessed with linear programming approaches (Wossink, 1993). However, such are less developed. The main difficulty in such modelling procedures is that they explicitly include time.

Common elements in the ongoing debate on suitable procedures for land use analysis hinge on (i) the time horizon (i.e. short or long-term perspective); (ii) the interaction between biophysical and socio-economic criteria; (iii) the aspects that influence land use decisions (i.e. farm household behaviour); and (iv) the procedures for aggregation (parcel level, farm, region), Kruseman et al, 1997. In recent studies, there has been some attempts to include these issues.

The first group of models to be used in sustainable land use are the so-called *optimal control* models (Burt, 1981; Walker 1982, McConnel, 1983; Goetz, 1997; Barbier, 1990; Barret, 1991; Shiferaw, 1996). They assume perfect markets and thus separability and perfect foresight. These models posit price-taking producers who aim to maximize the net present value of output. The producers' decisions are conditioned in part by a measure of soil quality that captures the effects of past agricultural practices; the farmer's problem is essentially to find the optimal rate of soil depletion.

In Burt (1981), the top soil and soil organic matter are state variables whose current values are determined by past crop choices - especially, the fraction of land planted to wheat, a relatively erosive crop. Farm yields are progressively reduced by topsoil and diminution of soil organic material , so for given prices, and without compensating increases in fertiliser input, the profitability of planting wheat is a declining function of the fraction of land under the crop. One obvious limitation, however, is that the only means to influence the values of state variables is by reallocating land between wheat and the less erosive crop.

Walker (1982) addresses choice technique, introducing as a control variable the time of adoption of a soil-conserving practice. Farmers decide each year whether or not to adopt the practice, based on a damage function recursively comparing the net present value of another year's use of an erosive practice with that of immediate adoption of the soil conserving one. Ceteris paribus, for some rate of erosion-related yield decline it may become profitable to adopt soil conservation even if the current costs of doing so are higher than for the erosive practice - as for example when some land must be set aside to plant grass strips or hedgerows. The author posits that farmers continue to mine the soil and that erosion still exceeds recommended levels for preserving the long-run soil productivity. Farmers continue 'mining' their soil by employing erosive farming techniques, which offer high yields currently but diminish the soil's future productivity. Conservation practices seem more costly than conventional ones in the short run. Higher costs may result from installing and maintaining terraces. No adequate research data exists which quantifies the cost of not controlling erosion. Existing data is also naive: the focus is on linear yield response or a static yield base for assessing the future cost on eroded yields. With these studies of optimal rate of soil loss, one is able to find that optimal private and social rates of erosion are identical due to the assumption of perfect markets.

McConnell 1983 on the other hand develops an economic model for optimal private and social utilization of soil. The focus is on the intertemporal path of soil use including the conditions under which private and social optima diverge. It also gives insight about effective instruments of erosion control. If farmers know that soil loss affects farm resale values, they will conserve it. McConnell major contribution was to observe conditions under which it may be privately optimal for farmers to make production choices in which soil loss exceeds both the natural regeneration rate and the socially optimal rate.

These models capture the key features of the farm-level optimal depletion problem: farmers choose crops and techniques to achieve an optimal soil or soil quality depletion rate for given prices, discount rates and planning horizons. Each study examines the influence of one or more exogenous factors - prices, interest rates, and/or natural rates of regeneration - on the privately optimal rate of land degradation. Each highlights the critical empirical question of the rate at which an erosive practice contributes to land degradation, although only McConnell distinguishes formally between this and the socially optimal rate. As noted by McConnel, when markets are perfect, the private intertemporal path for the soil use mimics the socially efficient path. Thus there are no reasons to be concerned with land degradation when markets are perfect. Barret (1991) developed models of optimal control of soil erosion and soil fertility in order to understand the effect of price policies on soil conservation. He shows that the effect could either be positive or negative although he argues that pricing policies will not affect soil conservation dramatically.

The emphasis in natural resource modelling and management in recent years however, has shifted from optimal depletion to one of 'sustainable use'; the characterisation of land degradation as a problem of the optimal depletion of an abundant resource has been reevaluated. A number of models have been developed that allow for soil-quality improving investments (Barbier 1990; Clarke 1992; LaFrance 1992). The possibility of soil-enhancing investments extends the range of the farmers' options with respect to production and resource allocation; in addition to choosing technologies and crops, the optimisation problem now includes the allocation of resources between current production and future soil quality.

The above may not be an adequate representation of rural economies in the developing world where market imperfection exist. The recursiveness of the model breaks down, and standard results from production and consumption theory may be reversed (Singh et al, 1986; De Janvry et al, 1991). Thus, these kinds of models cannot be used to explain the actual behaviour of farmers in developing countries unless they are modified to include the relevant market imperfections. Moreover, the implications of market imperfections are quite different when transaction costs are primarily household specific (De Janvry et al, 1991) than when most transaction costs are between villages and the rest of the economy (Taylor and Adelman, 1996).

Attempts to include market imperfections in the optimal control models have been made in recent works by Pagiola (1995); Greperrud (1997a), Shiferaw and Holden (1997), Shiferaw et al (1999, 2000), Kruseman and Bade (1998), Ruben and Heerink (1998), Kruseman et al., (1997); Bade et al., (1997)[13]. In Pagiola's model, assumptions of perfect markets and perfect foresight are maintained but subsistence requirements are included to pick out some effects of imperfections on credit/insurance markets. He discusses four cases and shows that under certain conditions (severe poverty) poor farmers may have more incentives to adopt sustainable practices than other farmers because the future disutility of degrading the resource is potentially unbounded. He also looks at the case where subsistence constraints prevent farmers from adopting sustainable practices. They may be so poor and lack the access to credit markets, which would enable them to make the necessary investments. When no sustainable practices exist or are unattainable, poor farmers without migration options would degrade the soil more slowly than households with migration option (ibid). Grreperrud (ibid.) has developed a dynamic model of soil depletion choices under production and price uncertainty. It is a model with one market imperfection only (risk/insurance). The model has

[13] For an excellent review, see Holden and Biswanger, 1998.

three control variables: productivity increasing but degrading input, conservation but productivity reducing input, and <<win-win>>input which both increases productivity and conserves the soil. The model illustrates that risk and risk aversion have ambigous effects on conservation as observed in empirical studies(e.g. Anderson and Thampillai, 1990; Ardilla and Innes, 1993). Detailed knowledge of the farming systems and sources of risks are required to predict the direction of effects. One of the conclusions of the model is that output price uncertainty, risk aversion may induce less use of all inputs. Another is that production uncertainty may induce farmers to use less degrading inputs and more conservation inputs. Thus production uncertainty may be more favourable for conservation than price uncertainty.

Shiferaw and Holden (1997) have developed a farm household model incorporating user costs of land and conservation decisions of farm households in the Ethiopian highlands. The model includes subsistence requirements and liquidity constraints. Short and long run responses for cases when conservation technologies reduce, make no difference, and increase yields, are analyzed. The model is used for testing the efficiency of various policy measures to reduce land degradation and increase conservation investments. Only imperfections on credit/insurance markets are taken into account. Important aspects of imperfections on product, land and labour markets, and other production and conservation input markets such as fertiliser are ignored.

Pagiola (1992) develops a theoretical dynamic model of farmer behaviour for the analysis of soil degradation. Instead of applying this model to Kitui, the author used a benefit-cost analysis to analyze the returns to soil conservation in Kitui district, Kenya due to data limitations. While this is a superb work, transaction costs were not considered in the empirical analysis. Omamo (1995) develops a non-separable household model to analyze the effects of smallholder agriculture under market reforms. He finds that import substitution is a rational response under high transaction costs to the market rather than the vague reference to food security. However, the focus was not on soil conservation and as a result a number of things differ. First of all, in our study it is the amount terracing (soil conservation investment) undertaken each year that introduces an element of dynamicity in the model. Whereas for Omamo (1995), it was livestock units and moreover, a Translog utility function was used. In our case, an AIDS was estimated instead to obtain the initial elasticities.

Shiferaw and Holden (1996) model the conservation process as a two-stage process: recognition of the erosion problem, and adoption and level of use of control practices. An ordinal logit model is used to explain parcel-level perception of the threat of the erosion problem and the extent of use of conservation practices. The findings show the importance of perception of erosion problem in influencing farmers conservation decisions. Other important factors include household, land and farm characteristics, perception of technology -specific attributes and land quality differentials. Shiferaw et al (1999) uses a bio-economic model to examine the linkage between population pressure and poverty, and their impacts on household welfare and land management. The effect of population pressure is incorporated through changing the land-labour ratio of the household at the initial period. The results show that when land is relatively abundant, land users lack the impetus to make significant investments to mitigate soil erosion. However, with land scarcity as a result high population pressure, and if off-farm opportunities are limited; while labour is not in short supply, investment in soil conservation is likely to take place. Availability of credit and fertiliser, however, seemed to discourage labour-intensive conservation efforts. When markets are imperfect, poverty in vital assets (e.g. oxen and labour) limits the ability or the willingness to invest in conservation.

Kruseman et al., (1997) have developed nonseparable farm household models for the analysis of sustainable land use and food security. They have been used for policy analysis in Mali and Costa Rica and incorporate explicitly various market imperfections and policy experiments related to these imperfections (transaction cost reduction, improved access to credit in Mali (Bade et al., 1997). They conclude that structural policies addressing transaction costs and financial markets offer prospects to enhance tradeability and reinforce intersectoral growth linkages with favourable effects on supply response and sustainable practices.

Schipper and Jansen (1999) in a concept methodology paper, present a framework for exploration of land use options at the regional level for policy support which integrates a linear programming model with technical coefficient generator for crops and for livestock activities, used for the quantification of technical coefficients of land use systems, and a geographic information system. It is shown that the methodology is a suitable tool for the analysis of policy options in support of policy makers' decisions, as well to analyse future land use options in view of their effects on income and the environment. It must be stressed that since it is the farmer who decides on, and is responsible for, the actual use of land, finding the "optimal" cropping patterns from a policy viewpoint may not be very useful, unless ways are found to induce farmers to adopt those cropping patterns. There is also a problem of aggregation bias. Since farms are not the same in terms of circumstances and resource endowments, a model should essentially be constructed for every farmer. However this is impossible due to data, manpower, financial and computer limitations. There are two ways out of this. The first is the aggregation of the resources of a region as if it were a single large farm, and secondly; the use of a representative farm household. The latter involves classification of farms into a smaller number of representative groups, mostly on the basis of relative factor endowments or according to the most limiting resource.

Economic models do not usually take into account the agro-ecological processes underlying agricultural production. These processes are treated as a black box and simplified relationships between relevant input parameters and output variables are used (Kruseman, 1999). The bio-economic nature is found in the inclusion of environmental amenities and the use of quantitative models from biophysical sciences for parametrizing production. Indicators of agro-ecological sustainability might be in terms of organic matter and macronutrient balances. Some of the studies that have used biophysical models are Kruseman and Bade (1998), Shiferaw et al (1999, 2000), and Kruseman et al (1997). While bio-economic models may be more useful, our contention is that they are less tractable and may not substantially improve the results a great deal. Moreover, when it comes to the biophysical system, simple indicators such as crop yields, adoption and use of inorganic and organic fertilizers, and even farmers' perception about fertility are quite effective. These can be viewed as "summary variables" for the numerous interacting biophysical factors and processes that they determine and reflect, allowing these factors and processes to be left outside formal models (Omamo et al, 2002). In addition, the level of soil conservation investments made, which is directly related to the soil depth, shows how sustainable the farming system is.

Other researchers have incorporated imperfections on land, labour and credit markets (Pender and Kerr, 1996). It is a two period model incorporating several asset categories. They analyse four cases: perfect market, missing labour market, missing credit market, and both labour and credit markets missing. Output markets are assumed to be perfect and land is non-tradable. They derive comparative statics results and show that conservation investments are independent of labour endowments and savings but may be influenced by fixed asset levels and the initial level of conservation investments. With a missing labour market, investments in conservation will increase with labour endowment of households. The impact of other asset categories is negative or ambiguous. With a missing credit market, investment in conservation will increase with the amount of saving the household has. Effects of labour endowments and other asset categories are ambiguous. If both labour and credit markets are missing, conservation investments will still increase with savings while the impact of labour and other asset categories are ambiguous.

Kruseman and Bade 1998 use a bio-economic model to study the impact of transaction costs on farm household welfare and sustainable land use in the district of Koutiala in Southern Mali. Model simulations are made to analyse the influence of selective failures on factor or commodity markets. The results indicate that reducing transaction costs on commodity markets is most effective to enhance intensification of land use. However, the study did not dwell on terraces that are more durable and different from improved fallows. Moreover, fallows cannot be used to regeneration of soil fertility in Machakos and Kitui due to small farm size that are under threat of further fragmentation due to population increase. In addition, the focus seems to be in how the organic matter balances will respond as a result of transaction costs. No effort is made to know what are these measures albeit soil conservation measures that are put in place, which have an effect on, organic matter balances. In any case, the changes in transaction costs may have an effect on soil mining that influence organic matter balances with or without any investments in soil conservation measures undertaken.

This study is therefore an improvement for it includes most imperfections except credit and land due to the peculiarity of the study area. In addition, the element of social networks is incorporated as an important structure of dealing with market failures. The study extends the dynamic non-separable household model developed by Omamo to model soil conservation decisions.

CHAPTER THREE: RESEARCH METHODOLOGY

In this chapter, three major sub-topics are discussed namely conceptual framework, data and sampling, and methods of analysis.

3.1 Conceptual Framework

Our analysis and modelling approach is firmly based on the transaction costs and imperfect information theories. This theoretical framework draws on neo-classical economics as well as institutional economics and game theory. The core issue in Transaction Cost Analysis (TCA) is an emphasis on property rights, the transaction costs of measurement and enforcement, incomplete information, and the impact of institutions on the cost of transactions. TCA is a line of investigation that departs from but does not abandon neo-classical economics. Ideally, a market economy develops institutions (including markets, contracts, firms of various characteristics, and systems of regulation) that allow the highest value to be attained from its resources. TCA recognises that such institutions may not be in place and that commercial activity does not occur in a frictionless economic environment (Williamson, 1986). The neo-classical assumption of perfect information, complete market and zero or very low transaction costs is not realistic. When this assumption is relaxed, both the nature of impersonal markets (spot market contracts) and the economic significance of relational contracts become obvious (Williamson, 1986; Streeck, 1992). The basic underlying assumptions of our modelling approach are far from those of Arrow and Debreu (1954) model. Instead we assume that there are pervasive transaction costs and information asymmetries leading to severe market imperfections in typical poor rural economies (Greenwald and Stigliz, 1986).

The existence of local markets with endogenous (local market clearing) prices is a consequence of relatively high transactions costs related to trade and communication with the outside world. This may cause price wedges or bands, isolation of markets, or missing markets (De Janvry and Sadoulet, 1994). The role of extra-household village markets in shaping household resource allocations is likely to depend on the level of development (differentiation in production, trade, and services) and internal transactions costs related to seasonality, risk, local institutions, the distribution of natural, manmade and human capital, and cultural and political factors (e.g., land tenure systems).

Our maintained hypothesis is that markets are important and that people produce for home consumption and also for the market. When there is no access to the market, returns to farm produce tend to be very low. This may be due to the use of traditional low yielding technologies and also due to limited demand for produce emanating from thin or shallow village market(s). As soon as there is connection (access to outside markets), returns are bound to rise as farmers search for high yielding technologies and for a better price for produce. This scenario, however, depends to a great extent, on the conditions prevailing on these markets. TCA posits that there are costs to carrying out market exchange. These are transaction costs and they include information search, negotiation, monitoring or enforcement costs. If these costs are high, then it follows that the returns even with the market exchange are bound to be low. When transaction costs are high enough as to exceed the production cost advantages of the market, households may not specialise and would rather engage in subsistence production. This is not to say that there is no investment whatsoever with subsistence production. Investment may be there but very limited only with an objective of meeting local self-sufficiency, which is low by any standards.

In practice, some transaction costs represent social loss of resources, while others represent simple transfers between agents. When transaction costs involve real resource losses, it is immediate that reductions in transaction costs raise welfare and thus investment. In the case in which transaction costs represent pure fees or rents, such costs introduce a wedge between the buying and selling prices of inputs such as capital. If transaction costs represent real resource costs, their reduction has two effects: first, such a reduction raises the - net - of - transactions - cost - productivity of all investment technologies made. Secondly, the magnitude of investments undertaken increase considerably. Thus time and physical resources are used up when undertaking soil conservation measures.

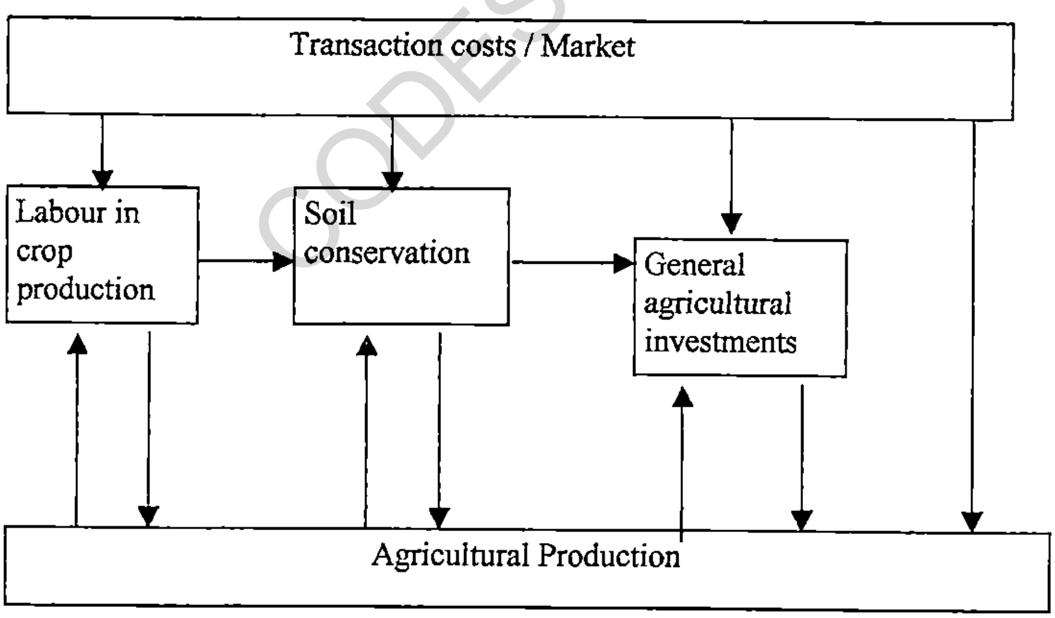
For farmers to increase agricultural output, investments have to be carried out. For the purpose of this study, we distinguish two major investments in agriculture. These are soil conservation investments[14] and general agricultural investments. The former are those that

[14] Soil conservation has long been regarded as an input into agricultural production (Thampapillai and Anderson, 1994). As a result, the analysis of soil conservation decisions has often utilised production functions (for example, Burt 1981, Krammer, McSweeney and Stavros 1983, McSeeney and Kramer 1986). This study takes a similar approach.

influence the productivity of the soil in the medium to the long run and include terrace construction and planting of trees. The latter are those that increase agricultural production but however do not influence the productivity of the soil beyond the short-medium run. These include fertiliser and manure application, changes in crop mix, and use of high yielding crop varieties. Our thesis however, focuses on the first two, as they are the major inputs and fertility enhancement measures in crop production. Further, these measures improve soil productivity as opposed to the latter.

Transaction costs are envisaged to influence investments in soil conservation in about four major ways (see figure 1 below). First, there is the direct way. This concerns the use of labour[15] and capital to construct terraces[16] and to plant trees. The major input here is labour and thus effort is expended to source this labour from the market or otherwise and even supervise it. This effort may include search or transport costs that could be incurred in hiring labour. With proper incentives and supervision, labour can do a good job. There is also use of tools and implements as inputs into terracing, although this is not anticipated to be a major influence.

Figure 1: Household investment in soil conservation, general agricultural investments, and agricultural production



Source: Author's own compilation

[15] Our considered assumption is that farmers operate in Stage I and Stage II of the production function.
[16] Terraces are the predominant soil conservation investments in Machakos and Kitui Districts (Zaal, 1999).

High transaction costs may lead to lower labour use, implying less soil conservation investments made, which in turn lead to less crop production with a further consequent reduction in soil conservation investments.

The second way that transaction costs[17] can influence investments in soil conservation is through general investments in agriculture. This includes things fertiliser and manure application. Household labour, variable inputs and capital are required to contract these inputs used in crop production. In addition, there may be search or transport costs associated with purchasing these inputs. When transaction costs for accessing the market are rather high, it is expected that effective farm gate prices would rise considerably leading to fewer investments in fertiliser and manure. This in turn lead to lower crop output or yields, which will further reduce investments in soil conservation and also general agricultural investments.

The third way is via marketing of agricultural output. Household labour, variable inputs and capital are required to contract for sales of farm output. There may also be search or transport costs involved. High transaction costs in accessing the product market would lead to lower returns from crop production. This has a negative behavioural influence on the investments made in soil conservation and even general agricultural investments.

The fourth way is through labour hiring from the market for ploughing, planting, weeding and harvesting for direct crop production. Hiring and monitoring this labour is quite an expensive undertaking as argued earlier. With high transaction costs therefore, there would be a negative effect on crop production as labour use will fall, with a consequent reduction in soil conservation investments due to the feedback effect. However, labour can also be sourced from self-help groups. This kind incidentally faces relatively low transaction costs for a number of reasons. Hiring costs are effectively non-existent while supervision or monitoring costs are indeed very low since the farmer works together with them. This means that there are hardly very serious incentive problems comparatively apart from in-kind payments such as food. Such labour that reduces transaction costs consequently lead to high crop production with a consequent increase in soil conservation investments due to positive feedback effect.

---

[17]Seasonality is an aspect that may influence transaction costs as activities such as input acquisition are undertaken at specific times of the year. In this study however, seasonality is assumed not to have significant effects.

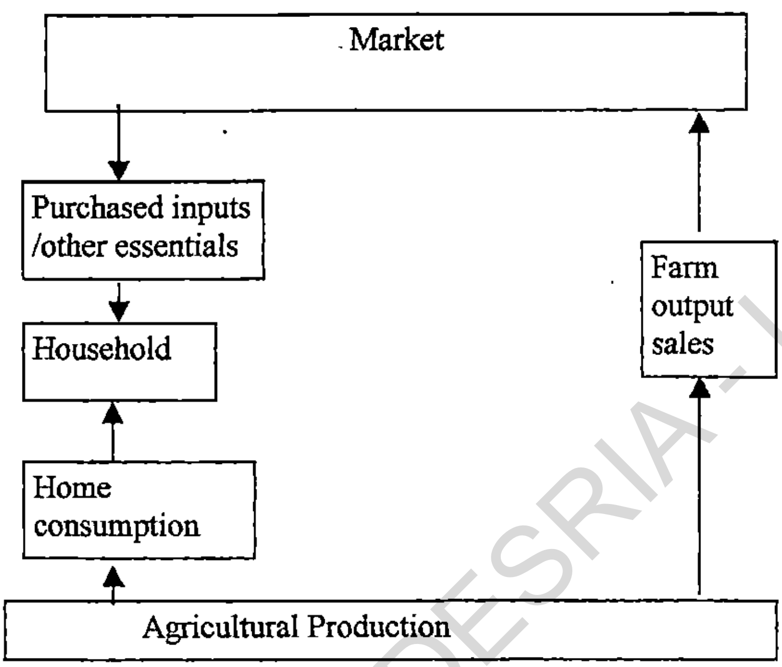
We envisage one way interaction between soil conservation, labour use and general agricultural investments. Inputs such as fertiliser, manure or labour may not be applied if terraces have not been built on a parcel of land. Even if they will be applied, the levels will less than optimal (i.e. sub-optimal) because farmers are aware that the returns expected would be very low. Unterraced fields discourage the use of fertiliser and manure because of runoff. In addition, there will be less moisture in the soils. It is argued that soil conservation either improves soil properties or raises relative returns to fertilizer or manure use (Shiferaw et al. 1999). Besides, soil conservation is positively related with returns to fertilizer use. By holding soil and water in place for delivery to plants, terraces represent long-term investments that complement variable inputs, including organic as well as inorganic fertilizers. In their state-of-the-art review of research on nutrient flows and balances, both Nandwa et al (1998) and Bationo et al (1998) conclude that mineral fertilizers can be effective in increasing yields, but cannot sustain yields in the long run. Only when mineral fertilizers are combined with conservation technologies would productive and sustainable production systems be obtained. We are of the opinion that it is not the level of soil conservation investments that would positively influence labour, manure and fertiliser use but rather whether they have been undertaken or not. This will also reduce a lot the problem of simultaneity. We do not expect an interaction in the opposite direction: from general agricultural investments and labour use to soil conservation. The direction of influence is only through the effect on crop production

We posit that the land and credit markets have not had any discernible influence on soil conservation investments. Even though conceptually transaction costs in these markets can negatively impact on soil conservation, our position is that their effect has been minimal if not zero. Credit markets have collapsed in Kenya and the fact is that none of the sampled farmers have ever received credit. Besides, there is a general fear of taking credit on the basis that their farms would be auctioned if they fail to pay. With the incidence of crop failure, this fear or risk is not misplaced. As for the land market, there has been little buying and selling of land. Moreover, most of the land is either under traditional ownership or formal ownership with title deeds.

On focusing on these transaction costs connected with marketing of various crops and inputs, one is able to find out what limitations and distortions these costs impose on the crop choice facing the farmer. This can then be linked to sustainability of the farming system.

Figure 2 below shows the other important function of rural households - that they are also consumption centres. Households sell goods from their farms to the market and also buy some manufactured goods from the market. These processes involve transaction costs and eventually have a bearing on soil conservation investments. Households also consume what they produce on the farm. This is also largely influenced by market transaction costs[18]. We presume as these costs rise considerably, households tend towards subsistence production

Figure 2: Household agricultural production and consumption with trade

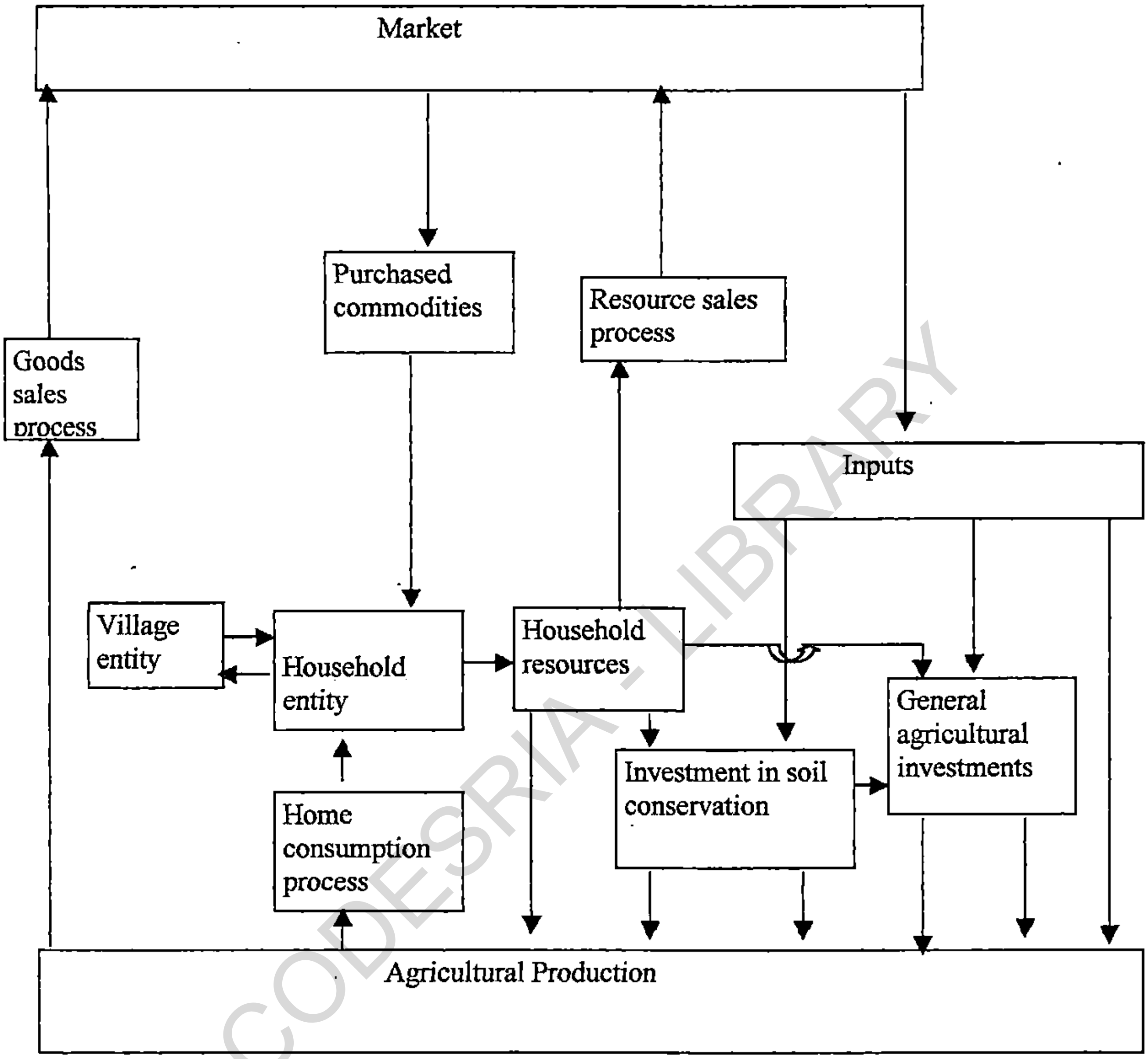


Source: Author's own compilation

As earlier argued, households are both production and consumption centres. It is only when we take the processes occurring simultaneously that we shall get realistic results. As a consequence, the diagrammatic representation of the model combines both production and consumption processes (see figure 3 below).

[18] It also depends on risk reduction strategies as well. Although risk is not considered in this study, the effect is likely to be in the same direction as transaction costs. Basically three transaction costs elements are taken into account in this study: search costs, access costs or transport costs and distance from the homestead to the crop fields.

Figure 3: **Household investment in soil conservation, general agricultural investments, agricultural production and consumption with trade**



Source: Authors own compilation

Although transaction costs primarily influence soil conservation investments through the market, there is also the non-market effect through social networks such as self-help groups. Some farming decisions for example, are simply communal, such as the building and maintenance of village infrastructure. Moreover, households invest in social infrastructure that would be very helpful in bad times, and also useful during the digging of terraces. This is common especially with self-help groups. There are costs involved in organising such labour exchange groups. It takes time and money to organise mutual labour groups and invest in social relations such as drinking beer. Undertaking such activities require variable inputs such as capital, fixed organisational or management cost component, and the time of the household. However, labour exchange groups are much cost-effective than sourcing labour directly from the market. Moreover, social networks guard against market failure that is caused by asymmetric information; and thus are supplementary activities that exploit monitoring devices not otherwise available (Arrow, 1999). This reduces transaction costs considerably, and may thus encourage investments into soil conservation.

Nevertheless, the pursuit of subsistence objectives in the face of high transaction costs may also encourage soil conservation investments. If transaction costs are so high as to cut access to the market, it is theoretically plausible that farmers would invest a great deal so as to meet their subsistence requirements. This would involve the use of family labour or self-help labour to construct terraces. In such a case, we have to have evidence of abundant labour available. Moreover, the investment in soil conservation would only proceed up to the point that subsistence needs are met. Beyond this, there would be no incentives for further soil conservation investments. We posit that this threshold[19] is low compared to those farmers with easier access to the market as they invest to satisfy their needs as well as meet market demand.

While theoretically, households can be wholly subsistence, experience in Kenya shows that all households do participate in the market in one-way or the another. The difference may come in the degree of market orientation. Also households that participate in the market are not necessarily having surplus output. In many instances, high liquidity preference especially during some periods such as when paying school fees, meeting medical expenses and family events; farmers sell their crop produce and later buy food from the market even at very high prices. This is a problem with cash flow. Therefore, no household is truly subsistent.

3.2 DATA AND SAMPLING

Both secondary and primary data were used for this study. For the primary data, a structured questionnaire was used to source information from households. In each district, four sublocations were selected, preferably in Agro-ecological zone 4 (Jaetzold and Schmidt,

[19] It would have been interesting to determine this threshold but was precluded due to data limitations.

1983). These sublocations were chosen on the bases of distance to Nairobi and their population density. Two sublocations, densely populated but near and far from Nairobi were selected from each, and two sparsely populated but near and far from Nairobi were also selected.

The villages selected in Machakos district according to the above criteria[20] were Ng'alalia, Ngumo, Kisaki and Musoka respectively. While the ones in Kitui were Mwanyani, Kitungati, Utwiini and Kyondoni. The villages chosen were showing recent signs of transition to soil conservation measures. From a list of household names provided by the village elder, a random selection of 25 households was made after which the first household survey commenced in 1998 and early part of 1999.

Later on, there was a second field survey[21] from May to July 2000. This second phase of the field survey was necessitated by a number of issues. First, there were serious gaps in the data collected earlier. The gaps became apparent when some modelling attempts were made using the data. For instance, the number of terraces per plot, farm gate prices (useful for aggregating production emanating from various kinds of crops) and the delineation of outside labour into hired labour and self-help group labour was difficult.

Secondly, the data collected in the first phase did not have much information on transaction costs. Since the final dissertation forms part of the *Nederlands Wetenschappelijk Onderzoek/Dutch Scientific Research* (NWO) project output, it was important that a second round of data collection be carried out focusing in detail on this niche.

Thirdly, there was the effect of Elnino in 1997. This influenced a great deal the November-February season. Farmers received a major boost in production during this period. Farmers did not see any need for taking advantage of the continued rains as they had much food. As a result, there was no much production in the March-May season as farmers' fields were covered with bushes. A new survey was thus necessary to get data for a normal year. Lastly, information gathered from village profiles during the first survey was found inadequate. Based on an inventory of the information gathered at the village level (Nyang et al, 2000)

[20] For details, see Zaal (1998).

during the first survey a new village profile was made. This included also specific questions on transaction costs that ought to be gathered at the village level.
However, the second phase also presented some special problems. There might have been changes in the household composition and even characteristics. There might have been new births, some household members may have died or moved to different locations or got new jobs. In addition, plot characteristics may also have changed - new ones may have been acquired, others may have been sold and tenure situation may have been changed, among others. While this is important for one would be in a position to show some of the dynamic elements as far as transition is concerned, it's very easy to confuse and mix up households and plots. If this happens, the results would lose meaning.

To eliminate such problems entirely, after pre-testing and making the final questionnaire, household and plot characteristics were filled in first before going to the field, based on the already filled questionnaires from the first phase. The first three names of the household members together with the way point number and the Geographical Positioning System (GPS) readings for the household location were filled in. Moreover, the village, sublocation and the district were also filled in. This was then followed by filling in plot characteristics such as the slope, way point number, and the GPS readings. This was to make sure that we referred to the same district, sublocation, village, household, plot each time. Where there was no GPS reading for one reason or the other, the farmers' recall of the previous visit by the research team was used.

3.3 Method of Analysis

Modelling adoption, investment levels and benefits of soil conservation measures

Adoption of conservation technologies may be conditioned by a number of factors that may in turn depend on the nature of rural markets. Empirical research and economic theory suggest that household attributes, social capital, institutional and policy variables, household assets, and farm characteristics and orientation, may influence the adoption of soil conservation measures (Shiferaw and Holden, 1998). These factors, enumerated by, among others, Krishna and Uphoff, 2001, Shiferaw and Holden (1996), Gould et al (1989), Nowak (1987), and Ervin

---

[21] This was in some way, panel data though very short.

and Ervin (1982), were used in econometric estimation in this study for the various methods of analysis discussed below.

Before any empirical analysis was done, *descriptive statistics* was employed with a view to understand the data and its distribution. Measures of central tendencies such as means, percentages and frequencies were used to explore types and amount of soil conservation investments; and farm, household, and village characteristics.

(A) Transaction costs, terracing intensity and crop productivity

The impact of crop productivity on terracing intensity may or may not be direct. Alternatively, some factors such as transaction costs may simultaneously affect both productivity and the intensity of terracing. In which case we are dealing with simultaneous equations model in that two or more endogenous variable are determined jointly within the model, as a function of exogenous variables, pre-determined variables and error terms. This simultaneity induces correlation between the regressors and error terms of each equation in the systems, thus causing OLS to be inconsistent in estimating parameters.

As a result, the main estimating techniques are indirect least squares (ILS), two stage least squares (2SLS), limited-information maximum likelihood (LIML), three-stage least squares (3SLS), and full-information maximum likelihood (FIML). ILS, 2SLS, and LIML are essentially single-equation methods in which attention is focused on one equation at a time without using all the information contained in the detailed specification of the rest of the model. In principle, information on the complete structure, if correct, will yield estimators with greater asymptotic efficiency than that attainable by limited-information methods. FIML is computationally more expensive as it involves the solution of non-linear equations, leaving 3SLS as the best estimation technique (Porkomy, 1987; Johnston, 1984; Green, 2000).

Because of the simultaneity of the investment phenomena and a lot of feed back effects, a total of 5 equations were estimated simultaneously as a system using Three Stage Least Squares (3SLS) in SHAZAM Econometric Package. Since manure, fertilizer use, and terracing intensity are censored variables, the Heckman Two-Stage estimating procedure was used to accomplish this model (Maddala, 1983). In the first stage, inverse mills ratio was computed and then added as explanatory variable in the system equation estimation in the second stage.

The Three-Stage-Least Squares system equations were:

$$1. TERACE = f(SLOPE, TENURE, LOC, DISTH, LCROPAC, SEACOS, EDUC, WEALTH, SEX\ FAROR, SELFHG, SHH, FARMCA, INC, AGE, ACESCOS, ERODE)$$

$$2. CROPAC = f(LAB, MAN, FERT, TERACE, LOC)$$

$$3. LAB = f(SLOPE, TENURE, LOC, DISTH, LCROPAC, SEACOS, EDUC, WEALTH, SEX\ FAROR, SELFHG, SHH, FARMCA, INC, AGE, ACESCOS, ERODE)$$

$$4. MAN = f(SLOPE, TENURE, LOC, DISTH, LCROPAC, SEACOS, EDUC, WEALTH, SEX, FAROR, SELFHG, SHH, FARMCA, INC, AGE, ACESCOS, ERODE)$$

$$5. FERT = f(SLOPE, TENURE, LOC, DISTH, LCROPAC, SEACOS, EDUC, WEALTH, SEX, FAROR, SELFHG, SHH, FARMCA, INC, AGE, ACESCOS, ERODE)$$

The description and measurement of the variables that are used in the model presented above and those that follow are given below (Table 3.1). Soil conservation investments (*TERACE*) are proxied by terrace length per hectare since terraces are the predominant soil conservation structures. *ACESCOS* are the transport costs in Ksh to the District main market; which is a major proxy for transaction costs. Transaction costs are made up primarily of transportation costs and information costs (Kruseman and Ruben, 1998). The price differentials between the market and farm gate prices are an indication of these costs. Some of the information costs are incurred but not included in the farm gate price. The consumer price in Nairobi or Kitui or Machakos is the result of supply from various regions, hence it is not a very good indicator for the transaction costs between farm households and the market. The rural collector price only covers a portion of the transaction costs. Hence the justification of using transportation costs of accessing the market as a major indicator of transaction costs. Transport costs are not produce-specific due to desegregation problems and insufficient data sets. The other indicator of transaction costs, though minor is search costs. Other transaction costs components such as handling costs; storage costs and pre-processing costs are precluded due to lack of data, but would only reinforce the point.

Search costs (*SEACOS*) on the hand are calculated as the opportunity costs of farmers labour time spent in searching for a buyer of their farm produce. Market search is costly in terms of labour costs for search activities. For every transaction, the farmer incurs the cost of labour time invested in search. This cost is represented by the opportunity cost of the labour employed in search (Gabre-Madhin, 2001). This variable is considered to include information search and bargaining.

Both *SLOPE*[22] and *TENURE* are indices constructed using the size of individual parcels as weights. *WEALTH* is proxed by the number of rooms for the main house of the household. The Kambas (ethnic group living in Machakos and Kitui districts) often build very good permanent houses even in very remote areas. The sampled farmers show that 80% of them had houses made of bricks and roofed with iron sheets. Thus the type of house is not a good indicator of wealth. Moreover, using the value of livestock as a proxy also creates some bias for very few farmers rear them. Livestock ownership is common in the dry areas. We are of the view that whatever the source of wealth, it is reflected in the houses the farmers live in. We thus decided to use the number of rooms for the main house as a proxy for wealth.

Other variables include: household size (*SHH)*, farm size per capita (*FARMCA)*, characteristics of principle household member (*EDUC, SEX,* and *AGE)*, whether a household participates in self-help group activities (*SELFHG*) or not, distance in metres from individual parcels of land to the homestead (*DISTH*[23]), whether the fields are eroded or not (*ERODE)*, the degree of farm-orientation (*FAROR*) measured by the contribution of farm income to the total household income, household income (*INC*) in KSh, whether a household is in Machakos or Kitui District (*LOC*[24]*)*, crop output per hectare (*CROPAC)*, lagged crop output per hectare(*LCROPAC)*, manure use in KGs per hectare (*MAN)*, fertiliser use in KGs per hectare(*FERT*), labour use per hectare in man-days (*LAB*), net present value of soil conservation benefits in KSh per hectare (*BENEFITS)*, whether soil conservation benefits are

[22] The 5-point slope variable in the questionnaire was re-scaled into three-point variable to make it cardinal or numerical. As for the 7-point tenure, also in the questionnaire, it was arranged according to increasing level of tenure security.

[23] The best would have been time taken to the respective fields both in the wet and dry seasons. Assuming a normal walking speed of 8 Kms per hour (133.34 metres per minute) and finding the opportunity cost of farmers' time, it is possible to get transport costs. However, this would be stretching the data too far since speed is dependent upon the load one carries and also the terrain. In any case, distance is sufficient as an indicator for the purpose at hand. We avoid being crop specific since disentangling is problematic.

[24] Intended to capture differences in the average level of soil conservation investments in the two districts (1 for Kitui, 0 otherwise).

positive or not (*POSNEG)*, land quality (*FERTIL)*[25], and whether household is engaged in self- employment outside farming (*SELFEMP*).

Table 3.1: Description, measurement and expected signs of variables

VARIABLE	DESCRIPTION	MEASUREMENT	EXPECTED SIGN
SLOPE	Slope of land parcels	Simple scale: flat (1), medium slope (2), steep slope (3)	+Ve
TENURE	Land tenure regime	Simple scale of increasing tenure security	+Ve
LOC	Location	Kitui(1), Machakos(0)	-Ve
DISTH	Distance from homestead to crop fields	Metres	-Ve
LCROPAC	Lagged crop output	In Kilograms and in value terms	+Ve
CROPAC	Crop output	In Kilograms and in value terms	?
SEARCO	Search costs	Kenya shillings	-Ve
EDUC	Education of household head	Simple scale: 0 no education, 1 primary, 2 secondary, etc.	+Ve
WEALTH	Wealth of the household	Number of rooms in main house	+Ve
SEX	Sex of household head	Male (1), female (0)	+Ve
FAROR	Degree of farm orientation	Fraction of off-farm income	+Ve
SELFHG	Self help group	Member (1), otherwise (0)	+Ve
SHH	Household size	Number of persons	+Ve
FARMCA	Farm size per capita	Hectares per person	-Ve
INC	Household income	Kenya shillings	+Ve
AGE	Age of household head	Number of years	+Ve
ACESCOS	Access costs to markets	Kenya shillings	-Ve
ERODE	Farm eroded or not	Eroded (1), otherwise (0)	+Ve
TERRACE	Length of terrace	Metres per hectare	
LAB	Labour use	Man-days per hectare	
FERT	Fertilizer use	Kilograms per hectare	
MAN	Manure use	Kilograms per hectare	
BENEFITS	Net benefits of soil conservation	Ksh per hectare	
POSNEG	Whether soil conservation benefits are positive or not	Positive (1), otherwise (0)	
FERTIL	Land quality	Simple scale of increasing land quality	
SELFEMP	Whether engaged in self employment or not	Yes (1), otherwise (0)	

[25] This is the subjective ranking of each plot relative to others by farmers themselves, as a measure of the relative quality or fertility of each plot. The aggregate score is then computed using the area of each plot as weights.

(B) Soil conservation benefits

Benefits of soil conservation are the crops grown and the yields obtained after terracing has been carried out. Investment in terraces will mean higher and stable yields from a given piece of land (Holmgren and Johansson, 1987; Holmberg, 1985; Lindgren, 1988; Figueiredo, 1986; Koinei, 1988 and Mwangi, 1991). The value of this benefit then depends on how much of this yield gets to the market and how much value is realised when it gets there. There are several factors at work such as transaction costs to the market, search costs for finding a buyer and distance from the crop fields to the homestead among others.

Transaction costs affect benefits in at least two ways: the percentage of crop that reaches the market, and the cost incurred in labour time and transport charges of getting various amounts of products home from the fields, and eventually to the market. The former implies that when transaction costs of accessing the market are high, the supply costs are equally high. Farmers respond to the increased supply costs of produce to the market by reducing the amount supplied to the point where marginal revenue is equated to marginal costs. As transaction costs increase therefore, less and less units of output are supplied. Likewise, the effective price received by farmers is reduced or falls. The implication is that high transaction costs are associated with lower soil conservation benefits.

Information was thus sought to make it possible to estimate these factors and thereby construct a valuation of the net benefits from investment as a function of transaction costs and other factors of interest. With this, one would be able to tell whether or not farmers respond to incentives and, more importantly identify which factors such as wealth, family size, and transaction costs affect the response to incentives. Secondly, one would be able to estimate the potential benefits from a reduction in transaction costs such as road improvement in a particular area both with and without the positive feedback from soil conservation investment.

In the construction of soil conservation benefits, it is noted that there are other inputs to farming other than land and labour and differences in these would need to be accounted for in comparing various investment alternatives. Also, the investment problem is intertemporal (benefits coming for several years after costs are sunk) so benefits and costs need to be represented as discounted present values (see the equation below).

$$NPV = (1+r)^{-t}\sum_t Y_t P_t - C_t$$

where,

Y = Agricultural yields (maize and beans) in KGs/ha

P = price of maize and beans per kilogram

C = costs incurred which consists of labour, fertiliser and manure

t = Number of years, representing the chosen time horizon

r = Social discount rate

Application of the above approach requires the adoption of a locally relevant Universal Soil Loss Equation (USLE) to estimate soil losses, and then relate soil losses to yield decline using an experimental derived relationship between top soil loss and yields. Kilewe (1987) in a long-term experiment at Katumani[26] estimated the USLE parameters. Following Pagiola (1994), the yield soil loss[27] equation of maize is given as:

Yield =1.93- 0.13 Soil loss

(0.14) (0.01)

Adj. R Square =0.97

The data is derived from Kilewe (1987) in which an artificial desurfacing experiment was carried out at Katumani to simulate long-term losses from erosion on maize yields. The results for the treatment closely approximate on-farm practices[28]. In this simulation, neither manure nor fertilizer was used. As the equation above shows, a linear specification provides an excellent fit as the high R^2 indicates. The yield decline per unit of soil loss estimated is then converted to a proportional annual yield decline.

However with beans, there have been no experiments of artificial desurfacing to simulate long-term losses from soil erosion on yields. We also do not have sufficient information to re-construct the soil loss – yield relationship for beans. In any case, beans provide a better cover crop than maize. It follows that soil loss under bean crop is low for a farm that has no terraces. We thus assumed a similar soil loss – yield relationship for beans as for that of

[26] Katumani agricultural research station is in agro-ecological zone IV, the same zone as our study area.
[27] Our review of published work shows that various functional forms have been used. Shiferaw and Holden (2001) use a translog, Mitchell (1984) use linear, while Walker (1982) and Ekbom (1995) use variations of the general exponential form. Our borrowing from Pagiola (1994) is dictated by the fact that it is in the same study area and thus have access to the same data. The limitation is that soil loss-yield relationship is often considered non-linear.
[28] Even though no real field experiments have been conducted primarily owing to long gestation period, the results are not far from reality.

maize, as Pagiola (1994) did. We assume pure crop stands due to insufficient data. Allowing for intercropping would complicate the analysis especially in handling the interactions of the crop enterprises.

With unterraced fields, we assume that input use such as manure, fertilizer and labour decline at about 25% every year corresponding to the yield decline. As for terraced fields, yields are assumed to remain stable over a number of years as well as the level of factor use[29]. Studies have shown that crop yields on terraces less than 10 years since being constructed are higher than yields from terraces more than 10 years. Nevertheless, the differences are not significant or yields are rather stable especially when periodic maintenance is adequate (Koinei 1988, Figueiredo, 1986). Crop production costs are thus assumed to remain unchanged[30] over time, but farmers would have to face the initial cost of terracing and the recurrent cost of terrace maintenance including nutrient investment. We also assumed that there is no yield penalty[31] from terracing due to terracing structures. This is because terraces are a form of insurance due to crop diversification. Instead of penalties, it should bring about some form of security and a 5% addition to incomes is usually in order.

A 2% real discount rate was used in this study. This is considered appropriate due to the bequeath motives of farmers; and that real interest rates in Kenya have been negative on average (Lindgren, 1988) before liberalization in 1992. In addition, the economic or population growth ratio has been declining over the years showing the need for increased future savings, necessitating a low discount rate (Ekbom, 1992). Discount rates are those appropriate for discounting future well-being (for a further debate on the appropriate discount rate to use, see Lindgren, 1988; Dasgupta 2001; Ekbom, 1992; 1995).

The relevant time period or horizon is taken to be a 100 years. The best would have been the relevant time the soil conservation structures have a productive effect on the farm. But with

---

[29] This is naturally a simplification, but a necessary one since no data is available on yield and input response of land changes over time.

[30] Works under an assumption of static production function and costs. The best would have been to use a bio economic dynamic model. However due to extensive data requirements, this model was not considered in this study.

[31] Pagiola (1994) assumes a yield penalty of 7% in Kitui, Kenya, while Shiferaw and Holden (2001) make an estimate of 10% and 16 % in two different areas in the Ethiopian Highlands. Our argument is that in practice, the area devoted to production is not entirely lost, since terrace edges can be planted with grass crops for use as fodder or with trees or bananas. Some farmers plant root crops such as cassava in the terrace edges.

periodic and timely maintenance, this time period can extend to positive infinity. As Shiferaw and Holden (2001) argue, where the soil conserving technology may arrest the degradation process and sustain production, the terminal time period may approach infinity. For our case, any time period ranging from 50 to 100 is still fine. This follows from earlier benefit-cost studies, which show that farmers break-even after 48 years (Pagiola, 1994).

Taking a longer time horizon than 48 years will not in any way change or bias the results. The time horizon would only affect the results if it were shorter than the minimum time required to repay the investment in soil conservation. Even though longer periods are essentially problematic since technologies change over farm family generations, simulation of benefits is often done under the assumptions that the same state of affairs will exist for a considerable period of time.

Borrowing also from Pagiola (1994) we take an average annual soil loss of 20.65 tons per acre; which is equivalent to an annual reduction of 3mm in topsoil depth. This will cause an annual decline in yield of 22kg for maize and 15 kg for beans. Within 10 years, yields will have declined by 20%; within 20 years they will drop by more than 40%, assuming no intervention measures are taken to arrest the degradation of the land asset.

Consideration of yield decline alone is not sufficient to determine whether investment in conservation would be profitable from the farmer's perspective. Conservation would only pay if the costs of such investment were lower than the value of averted damage. Although costs decline slightly as lower yields reduce labour requirements for harvesting, revenues decline at a faster rate, so that net returns[32] fall continuously.

We optimally employed a Cobb Douglas[33] functional form as it provided the best fit to the data.

---

[32] It is possible that the flow of net benefits over time is stochastic. However, risk is excluded due to lack of data on technology-specific risk and the need to make the analysis simple.

[33] One drawback of the Cobb Douglas specification is that it does not take account of the interactions between factors hence more restrictive.

$$\ln B = \alpha + \sum_{i=1}^{n} \beta_i \ln X_i$$

Where B and X_{ij} are the net benefits of soil conservation and factors considered respectively. All the variables have already been described adequately in Table 3.1.

(C) Transaction costs and soil conservation investments using an Agricultural Household Model

Boorsma (1990) distinguishes three approaches to modelling the behaviour of farmers: econometric modelling, based on linear regression equations of a data set; mathematical programming; and modelling decision processes based on a number of decision rules. An econometric approach is based on statistical analysis of historical data. The advantage of this approach is that it provides a fairly accurate description of the behaviour of the system in the past. A disadvantage, however, is that it does not always provide insight into the processes that play a role and that it is not very suitable to deal with new phenomena (Wossink, 1993). Moreover, the approach requires a large data set, preferably time series, which are rarely available in developing countries.

Dent et al. (1995) proposes the use of decision rules in simulation models. The behaviour of the farmer is thereby considered as the outcome of interplay between his "disposition to act", his material resources (e.g. soil fertility) and the external context (prices). The "deposition to act" of a farmer should not be viewed as unchangeable but rather as cumulative due to his past experience (Shucksmith, 1993). This approach is meant to overcome shortcomings presented by third approach (mathematical programming). Some authors raise questions as to what extent normative models are an appropriate way to represent decision making (Dent et al., 1995). These authors argue that complexity, insufficient knowledge, and inconsistencies of individual preferences and beliefs render normative methods unsuitable to describe individual decision-making.

However, mathematical programming is an approach that is frequently applied in land use decisions. This method allows determination of an optimal allocation of land, labour, and capital, given a set of goals (e.g. maximization of income and leisure and minimization of risk) and constraints (e.g. labour and land) (Barnett et al., 1992; Kruseman and Bade, 1998).

The study thus used mathematical programming to be able to handle new phenomena, especially with policy simulations. This is meant to beef up and corroborate econometric modelling used earlier.

Theoretical model

The basic assumption underlying the theoretical framework of farm household modelling is that decisions on land use are taken by individual households based on their goals and aspirations, making use of the available resource endowments to undertake specific activities, subject to bio-physical and socio-economic constraints. The strength of an agricultural household model is its ability to analyse a household's production and consumption decisions in a unified manner. It thus gives greater insight into farm household behaviour than do analyses that focus only on the production or consumption side of household behaviour. It also offers a richer array of possible policy experiments than do pure production or consumption analyses. Neo-classical agricultural household models represent the production activities, resource constraints and decision-making processes as a set of equations whose exogenous variables can be changed via policy intervention. The modeler's objective is to predict the responses of "agricultural households" to policy change.

Agricultural household models are derived from neo-classical theories of production and consumption, marrying the theory of the profit-maximising firm with the theory of the utility maximizing consumer. The fact that an agricultural household is neither a firm nor an individual is dealt with a series of assumptions.

Household utility maximization is constrained by the production function, total household income, and the time available to the household. The household maximizes its total utility by minimizing the costs of household production. These costs depend on the technology available to the household; the market prices of purchased inputs, the rate of return to household capital, ad the productivity and "price" of household labour.

There are both separable and non-separable agricultural household models. The former can hold under fairly restrictive conditions such as zero transaction costs. The basic structure of the agricultural household model is an adaptation of traditional agricultural household models (Chayanov, 1923; Barnum & Square, 1978, 1979, Sing et al., 1986; De Janvry et al, 1991, 1992). However, the approach followed here does not assume separability between production and consumption. It has been argued extensively that separability neither holds (De Janvry et al., 1991; Benjamin, 1992), nor is necessary under certain mathematical programming conditions (Delforce, 1994). In addition, by the nature of this study where the emphasis is on the influence of transaction costs, it follows that non-separable models are the appropriate ones. In the current model, non-separability arises due to positive transaction costs.

The following is a deterministic, non-separable dynamic agricultural household model that explicitly incorporates the resource requirements of the household. The model assumes a sort of 'central market place' somewhat distant from the farm household location, where goods and services can be purchased at constant prices. The fact that the 'central market' is some distance from the household, in particular, implies that household resources must be used in order to purchase inputs and consumption goods, as well as to market output or engage in off-farm employment. Transaction costs enter in the model as part of the budget constraint.

MAX Utility: Utility is a function of aggregate consumption of commodities produced in the household and those purchased from the market.

Maximise $U = u\ (C,L)$

Utility is maximized subject to the following constraints:

Budget: Expenditures on purchased commodities C (i.e., goods that are bought from the market that includes consumption goods, inputs for production and for soil conservation activities) and hired labour must be less or equal to income from sales of farm produce (Q^m), wage labour (W), savings (Sa), other household assets (A), and exogenous income (E). Remittances from male or female migration or off-farm enterprise, etc, are included in exogenous income.

$$(p\text{-}tc)Q^m + (w\text{-}tc)L^{\text{off-farm}} + E + S + A \geq (p+tc)C + (w+tc)L^{\text{hired}}$$

Time: The allocation of each household member's time to farm labour, off-farm labour, soil conservation practices, communal activities and leisure must be less than or equal to the time each member has available.

$$L^{\text{farm}} + L^{\text{off-farm}} + L^{\text{conserv}} + L^{\text{comm.act}} + L^{\text{leisure}} \leq T$$

Production: The production of goods (Q) in the farm by the household is a function of labour (L), planted area (N), capital (K) and an index for soil quality (I). The index for soil quality is assumed to be largely influenced by soil conservation measures such as manure application, planting of trees and digging of terraces.

$$Q=f(L, N, K, I)$$

The production function is rendered dynamic by considering soil quality as consisting of stock and the investment that link decisions across successive years. The investment in soil conservation is meant to increase the stock of soil quality. In any given year, the household must decide on how many trees to plant, how much manure to apply and how many terraces to build. Soil quality in year i+1 is equal to soil quality in year i plus the investments made during that year.

$I^{i+1} = I^{i} + Inv$. The investment in a particular year will be assumed to be net investment in order to take into account depreciation of investments already made and also losses resulting from crop production.

Empirical Specification of the Model

The demand side was modelled using two demand systems: Almost ideal demand system (AIDS)[34] and Translog. The AIDS demand system was only used for the computation of the initial elasticities, while the Translog demand system was the one used for the overall. A translog[35] utility function is used because of it flexibility as one can easily derive first and second order coefficients. The AIDS model is usually specified as follows:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(\frac{x}{p})$$

Where **X** is total expenditure on the group of goods being analyzed, **P** is the price index for the group, $\mathbf{P_j}$ is the price of the jth good in the group, **wi** is the share of total expenditure

[34] Deaton and Muelbauer (1980).

[35] A translog function is the most frequently used in empirical work (Green, 2000). This function was introduced by Kmenta (1967) as a means of approximating the CES production function and was introduced formally in a series of papers by Berndt, Christenson, Jorgenson, and Lau, including Berndt and Christenson (1973) and Christenson et al.(1975). The translog function has remained the most popular, however, and the most reliable of several available alternatives.

allocated to the ith good (i.e. $w_i = P_iQ_i/X$), and the price index is defined as:

$\ln p = \alpha_o + \sum_j \alpha_j \ln p_j + \frac{1}{2} \sum_j \sum_i \gamma_{ij} \ln p_i \ln p_j$. The budget constraint implies that $\Sigma_i\alpha_i$ $=1$, $\Sigma_i\beta_i = \Sigma_i\gamma_{ij}$

Using the defined price index often makes estimation of AIDS difficult. Thus, Stone's price index (P*) is often used instead of P where

$\ln p_t^* = \sum_{k=1}^{n} w_{kt} \ln p_{kt}$. The resulting linear approximate almost ideal demand system (LA/AIDS) is then used. As with the Translog, the indirect utility function is modelled as:

$$V = \sum_i \alpha_i \ln(\frac{p_i}{Y}) + \frac{1}{2} \sum_{i,j} \beta_{ij} (\frac{p_i}{Y}) \ln(\frac{p_i}{Y})$$

The corresponding expenditure system is:

$$\frac{p_i c_i}{Y} = \frac{\alpha_i + \sum_j \beta_{ij} \ln p_j / Y}{\alpha_y + \sum_j \beta_{yj} \ln p_j / Y}$$

Where

$$\alpha_y = \sum_i \alpha_i = -1, \beta_{yj} = \sum_i \beta_{ij}, and \beta_{ij} = \beta_{jy}$$

The production side of farm households was modelled using linear programming. A Linear programming (LP)[36] framework was chosen mainly because of its suitability for incorporating multiple goals, modelling multiple production activities in highly constrained production systems, and for its relative ease to carry out policy analysis in relation to resource use and conservation decisions of farm households.

Linear programming has a long tradition in agricultural economics especially in farm management. It has also been used in models to explore the possibilities of technical change at various spatial scales (Veeneklaas et al, 1994; Van der Ven, 1994; WRR, 1992), Recently

[36] The analysis of sustainable land use options has frequently used Linear Programming models (Alberta et al., 1992; Van Keulen, 1992; Rabbinge & Van Latesteijn, 1992; Fresco et al.,1994). These models require quantification of activities describing the technical land use options. These land use activities are well-defined and quantified means of agricultural production in which a unique combination of inputs results in a unique mixture of outputs.

linear programming is being used more extensively for understanding household behaviour and subsequently for assessing policy measures. The explorative studies have demonstrated the strength of mathematical programming to assess the effects of technological change. Where econometric analysis is unable to predict break points in trends, mathematical programming does have that flexibility (Kruseman, 1999).

Considerable difficulties were envisaged in estimating a joint production and consumption system of a nonseparable household using the cross sectional data of either a single or two cropping years. Nevertheless, econometric models also have limited use for policy analysis when conditions are varied beyond the range of the data used for estimation. Similar observations have prompted previous researchers to use an LP for farm household modelling (See Ahn et al., 1981; Singh and Janakiram, 1986; Bezuneh, 1988; and Delforce, 1994).

Econometric Estimation

Since the model is not separable, the estimation of production and consumption must be done simultaneously. Because the structural model can be written in explicit form only with the use of non-observable implicit prices, its estimation is quite complex and for that reason it is not usually done. A pragmatic approach described by Sadoulet and De Janvry (1995. P.163-164) is used to compute the model. It consists of calibrating the model as though it were separable, implying that all prices are observed and credit constraints not effective at the base point, and of simulating responses to changes in the exogenous variables and parameters using the non-separable model. The calibration is made using 2000 database as it was considered a normal year. 1998 data was considered contaminated due to the Elnino rains of 1997 that extended to early 1998.

The household consumes a bundle of goods consisting of six items[37] (see appendix D1). These are:

(a) Maize,

(b) Beans,

(c) Fuel: This includes wood and kerosene,

(d) Other foods (Ofoods): This include milk, meat, salt, sugar, tea and cooking fat

(e) Non food (Nfoods): This includes cosmetics, soap, education, medical expenses clothes, transport, religious activities and family events.

(f) Leisure.

The prices for composite goods are indices constructed using data collected during fieldwork in the study area and from the welfare household survey conducted by CBS in the study districts. The indices are weighted averages of the separate prices, where the weights are the shares of each item in total expenditures. As for leisure, this variable had to be constructed due to insufficient data collected during the survey. It was assumed that the number of days available per adult per year is 260 days (taking into account Sundays, public holidays, local barazas and family events such as funerals and weddings. Each adult engaged in farm work was assumed to have worked for 190 days (The total length of the growing seasons of annual crops in LM4 is 190 days for both Machakos and Kitui (see Schmidt and Jaetzold, 1983). The number of man-days in farm work, off-farm and self-business were subtracted from the total time endowment. The resulting man-days in leisure time were multiplied by the farm wage and adjusted with an average probability of finding work[38] of 0.68.

Instead of choosing initial elasticities from literature as suggested above, an AIDS demand system was used to derive initial elasticities. Because of the adding up constraint in the AIDS demand system, one equation is normally dropped and only the remaining ones are estimated. As for our case, we dropped the one for leisure and later the parameters were recovered through restrictions on the parameters (for details, see Sadoulet and De Janvry, 1995:pp 45). The results of the AIDS demand system are presented in Table A2 (appendix A). The derived price and income elasticities (see Table A3 appendix A) were now taken as the initial elasticities to be used for calibration.

Second, levels for full income, commodity prices, and expenditure shares were specified. Third, the proposed elasticities were calibrated using an algorithm that minimizes, with respect to the Translog demand parameters, the sum of squares of the discrepancies between this initial set of elasticities and a set of new elasticities derived from an Translog indirect utility function. The diagonal elasticity values, in which there was most confidence, were left

---

[37] This was based on budget shares, sample size and convenience of analysis. A smaller number of items are more amenable to analysis. This classification is not based on CBS structure and is meant for convenience for our work.

unchanged. The additivity and symmetry constraints were imposed. The algorithm was solved using Generalised Algebraic Modelling System (GAMS) by non-linear means. The calibrated demand elasticities are shown in Table A4 (appendix A). The signs and magnitudes of the elasticities seem reasonable.

We used linear programming to model the production side instead of the De Janvry procedure (Sadoulet and DeJanvry, 1995: 163). We are of the view that the De Janvry procedure is not the right way to proceed for our case, due to conceptual difficulties on the production side. Omamo (1995) tried to overcome this obstacle by using simple leontief-type functions derived from Jaetzold & Schmidt, (1983). This latter study was apparently done about 20 years ago implying that the input-output ratios reported may have changed. We thus decided to use the averages of our sample in the field and model the production system as linear programming. Although Ray (1985) argues that there is selectivity bias and overestimation with using the sample means, the methods he recommended of minimizing the mean of absolute deviations and of minimizing the maximum absolute deviations may not be appropriate. Moreover, they are also cumbersome.

Tables A5 and A6 (Appendix A) show the farming system information of average or typical households in Machakos and Kitui Districts. The major crops are maize, beans and coffee. Only the most relevant inputs and outputs are given. Both maize and beans are annual crops and hence taken as annual enterprises. With coffee, it is modelled as an already established enterprise in that a farmer harvests coffee annually. It is noted that coffee production influences the overall farm strategy because it is a major cash income source, which can be used to finance inputs for other crops. Moreover, fertilisers supplied in kind by the coffee societies or co-operatives for coffee production are also applied to other crops directly or indirectly by making use of the residual effect of fertiliser nutrients. Coffee, however, does not feature in the farming system of agro-ecological zone 4 in Kitui district. There are significant transportation costs. We thus take transaction costs to be Ksh 6.154 per kilometre while search costs are constant and taken to be Ksh 292.80 (lump some). The data sets were insufficient to allow the use of commodity-specific transaction cost levels.

---

[38] This value ranges from 0.8 in the peak labour demand periods, 0.5 for moderate labour demand period to 0.2 in

Animal traction is modelled for land preparation and weeding and is for duration of six months.

The demand parameters together with the farming system information and the production parameters are combined in a program written in GAMS. The model has a life span of 60 years. The maximisation is done through non-linear means. Farm households are assumed to be impatient and therefore to discount future utility. As a result a discount of 10% is used. The household maximises the present value of full income. This full income formulation is chosen over the utility maximisation because of tractability, as the optimal values are the same.

Full income equals the value of time endowment, plus the value of production, less the value of variable inputs required for production of outputs plus any nonwage, nonproductive income. Each year, the household decides on how many meters of terraces to build and maintain, where the length of terraces built is the control variable. The assumed decay rate is 20% per year. The household therefore chooses a cropping pattern, a consumption bundle, and trade levels. These decisions are made subject exogenous prices and transaction costs, production technology, resource endowments, translog expenditure system, an annual budget constraint, an equation of dynamism for terraces and initial terrace length. If concavity conditions are met, a steady-state terrace level and associated levels for the cropping, consumption, and trade variables are registered.

The economic model determines the optimal use of household resources (land, labour, oxen) together with optimal levels of consumption, production and terrace investments given the resource supply and market constraints. Although everything is endogenous in the long run, for a short time horizon, one may assume that some variables are exogenously given. Prices of tradables and transaction costs are in this category. For other types of variables, their initial conditions (stocks) are given, while their changes during the period for which the model is run, are endogenously determined. Examples of these are terraces. A third class of variables are those endogenously determined in each period, like input use, output and consumption.

---

the off season. For details see Omamo (1995) and Walker and Ryan (1990).

A number of simulations were carried out with and without transaction costs included. The standard approach to policy analysis is applying experimental simulations to a representative household (or households). Household types were specified based on their relative resource endowments and distance to the market. The resource endowments are land, labour and oxen. We have households that are land scarce and those that are land abundant; with large family size and with small family size; with and without oxen; with low and high exogenous income levels, with and without coffee in their farming systems, and those that are near and far from the markets. The thrust is to investigate how they respond to transaction costs with a consequent result in the soil conservation investments. We assume no interaction between crop activities and oxen except for the provision of draught power.

To validate the model, the results of a base run are compared with the measured data of the production structure of the four types of households. That is, the model is calibrated to fit the land and household characteristics of the study area in 2000. The base run is used as a benchmark against which the policy scenarios are assessed. There are always differences between measured and simulated production structures. The measured one is the actual reality. For the simulated production structure, a lot of abstraction has been made in order to make the model simple. Prediction arising from it will never give the actual production structure. Moreover, in reality farmers face a number of multiple goals and yet in our model we assumed one overall objective.

Although the model is validated with empirical data, there are a number of restrictions on the interpretation of the results. Some of the parameters in the model are difficult to quantify and have been estimated in an indirect fashion. As a result, there is a possibility of occurrence of biases. Despite these cautions the model results give us important insights in the rhythm and direction of change.

CHAPTER FOUR: SOCIO-ECONOMIC CHARACTERISTICS OF SAMPLED HOUSEHOLDS

In this chapter, some descriptive statistics are presented and discussed. The main purpose is to understand the data and give some input into modeling in the chapter that follows. These include socio-economic characteristics of farms, households and villages. Finally the important investments into sustainable farming are discussed.

4.1 Farm and household characteristics

A number of farm and household characteristics are discussed in this section. Some of these include parcels of land terraced, land acquisition, land tenure, slope of land, type of use of fields over time (see Appendix B); characteristics of heads of households such as educational level, sex; household size, the distance to the farms or fields from the homestead, soil conservation measures and inputs used. Others include household income and the crops grown.

Of all the individual fields sampled, 68.9% had been terraced, while 31.8 % had not. We thus infer that a substantial amount of land has been terraced in Machakos and Kitui Districts. It does suggest that soil conservation is generally taken seriously in the two marginal Districts. Discussions with farmers and soil conservation officers reveal that terracing is carried out irrespective of whether the land is flat or not[39]. The difference comes in the terracing intensity. On a flat parcel of land, terraces are constructed 25-30 metres apart and hence the total length per hectare would be much smaller. Besides, farmers also believe that good yields or fertile parcels of land are associated with terracing. This idea was supported by about 95% of the sampled farmers.

The mode of land acquisition remains entirely by inheritance (about 70% of all the fields) followed by purchasing (about 27%). This shows that the land market is not very much active in the study area, a phenomenon associated with imperfection. The results also suggest little mobility of people from and to the study villages. Further, even if people migrate, some

[39] This is because terraces conserve both soil and water. They are also helpful in harvesting water from roads and footpaths.

members of the family are left behind thus continuing holding their ancestral land. The results are corroborated by studies both in Kenya and elsewhere in Africa that land markets are inactive (André and Platteau, 1998:18-19). Supply considerations largely explain why land sale markets are thin in Sub-Saharan Africa. Most authors consider the market for buying and selling of land as rather inactive and refer mainly to "distress sales" as an argument for market supply of land (Bardhan, 1984). Landholders are typically reluctant to sell their land, even when they get an employment outside the agricultural sector and they reside in town. This is because land continues to be perceived as a crucial asset for the present and/or future subsistence of the family, all the more so as it is a secure form of holding wealth and a good hedge against inflation. Thus land sales often happen in distress situations as many people working in urban areas use land as insurance against uncertain employment and against landlessness in the next generation of the family, and as a pension fund for their old days (Lawrey, 1993). Such social security considerations often underlie the apparent persistence of indigenous control of land transfers even when they are duly registered. An active land market is advantageous because when land becomes a tradable good, land transfers will gravitate towards those farmers that are able to realise highest marginal returns. In such a scenario, considerable soil conservation investments may be made on the land.

With tenure pattern, we observe that individual parcels having title deeds and those in the process of obtaining title deeds are the most predominant (38.8% and 49.9% respectively). This shows considerable interest in improved or increased tenure security by farmers. This is expected to reduce the incidence of disputes, freeing resources that otherwise would have been used for litigation. On-farm investments in soil conservation can only be made when farmers are assured of internalizing the benefits for a considerable period of time. This is possible with secure land tenure[40]. It gives greater security of land access and has lower discount rate (lower risk aversion). If land is less than secure, a farmer faces lower expected returns from soil conservation because of the probability of being evicted before realizing all the benefits. As Ervin (1986) and Wachter (1992) argue, insecure property rights dissuade farmers from undertaking long-term investments, such as investments in soil conservation, because they may not be able to reap the benefits of such investments. With parcels of land

[40] Titles can only guarantee secure tenure claims if the government effectively enforces them or actually discourages outsiders from usurping them. Moreover, both security of tenure and stability of tenure (which means a low level of turnover, regardless of the tenure rights regime) are also important.

under communal ownership, there is no incentive to control soil erosion due to the free-rider problem (Konzacki, 1978). Lyne and Nieuwoundt (1990) argue that under communal land tenure, resources are over-utilized in the economic sense and investment in conservation measures is low. On the other hand, with restricted access (private property)[41], the incentive to invest is likely to be higher and rates of utilization lower because the cost of resource degradation is internalised. Property rights are also considered to be related to farmers relative risk aversion (Shively, 1997).

The temporal dimensions of a technology or natural resource practice carry implications for tenure security. If property rights, whether individual or held in common, do not offer the resource user sufficient time to reap the benefits of investment in a particular technology, adoption will not be forthcoming. In cases where technologies require long time horizons to generate returns on investment, or there is a long lag time between investment and returns; tenure security needs to be addressed before meaningful uptake can be expected.

However, the relationship between land tenure and investments has two sides especially under communal land ownership and when institutions governing land ownership are weak. On one side, secure land tenure improves investments on land. While on the other side, realisation of investments in land such as terraces and trees is an established procedure for improving defacto ownership rights. In such a situation, insecurity in land tenure may even be an incentive for investments (Otsuka et al, 1997). Matlon (1994) also argues along the same line but with respect to manuring, that it is a method of enhancing security of land use rights in marginal security situations.

With degree of slope of individual parcels of land, lower slope (56.5% of the parcels) is predominant followed by mid slope (24.1%). This has an important bearing on soil conservation investments. As the slope increases, so likewise is the expected intensity of the investments. Thus parcels of land that have high soil degradation potential are associated with high levels of soil conservation (Gould et al, 1989; Ervin and Ervin, 1982). Moreover, farmers whose land is on steeper slopes have a higher probability of identifying the need for

[41] Private property rights however becomes optimal only under conditions of resource scarcity. Communal rights are not necessarily inherently less efficient under resource abundance.

soil conservation and management relative to other farmers. If factor markets are perfect, characteristics that are likely complementary to conservation investments, such as slope, will lead to greater conservation investments (Pender and Kerr, 1996). However, in the absence of perfect markets, the result is not certain.

On use of fields during time of acquisition and during the time of the study, we observe some interesting developments. There seems to be an increase in the number of fields used for growing of food crops for home consumption (52% to 74%), which suggests a reduction in the sourcing of food requirements from the market. This maybe a response to high transaction costs to the market (see Omamo, 1999). Another observation is that there has been a reduction of private grazing, private fallow and bush land or forested area accompanied by an increase in the growing of private food and cash crop. This illustrates that the cash economy has been increasing in importance. The results also suggest an increase in intensification in land use and diminishing land sizes as population grows, implying need for soil conservation investments.

With fertility enhancements procedures, manure use from livestock is the predominant one (73% of all the parcels of land). This is followed by fertilizer with a paltry 11%. This is because fertilizers are prohibitively costly. As Obare (2000) argues, farmyard or organic manure has long been advocated as a substitute for the relatively costly commercial fertilizers in agricultural production. If used in clayey soils, manure improves the texture of the soil, making it easier to cultivate. Similar results are obtained in sandy soils with leaching problems. Besides conserving moisture on poor land, manure improves the microbial life of the soil and helps other nutrients become soluble.

The study also shows that 73.3% of the households were male headed, 14.8% female-operated, and 11.9% were female headed. Female-operated households are those that are headed by men who do not reside in their homes. In this scenario, women operate the households though headed by men. The results are not strange as many households are male headed in Africa. In case a man dies, normally the first borne son assumes headship. The above closely resembles a family life cycle, where the female-operated households are headed by young men who work in towns (mean age of those men 41.7 years). Later they retire and return home giving rise to the male-headed households (mean age of the men 49.3 years) and then the men die early leading to female-headed households (mean age of the women 51.3). Of the sampled households, about 40% had heads that were members of a self-help group. This is in contrast to 60% who were not members. In a household, it is in most cases either the husband or the wife or both who are members of a self-help group. Taking this into account, 66.7% of the households had members involved in self-help group activities against 33.3% who had none. The predominance of collective action[42] suggests that the transition to sustainable farming may depend on the ability of the community to cooperate, learning and copying mechanisms and social norms about good farming.

The study also found that 15.2% of the heads of the households did not reside on their farms as opposed to 84.8% who did. It is clear from the results also that the major occupation is farming 77.7%. This suggests that farming is the major source of household incomes. As a result, farmers do undertake investments in the farm so as to improve their welfare. Thus agriculture still remains the engine or impetus to growth.

With education level, 17.6% of the household heads had never been to school; 49.5% primary school; 21.9% secondary, 6.2% college; university 1%, and adult education 3.3%, form six 0.5%. Education is a very important component. Shultz (1964) argues that investment in schooling facilitates the transition from traditional agriculture, which is characterised by low productivity to modern agriculture where productivity is very high. He further argues that illiteracy does not mean that people are insensitive to the marginal costs and returns in allocating productive factors at their disposal, it nonetheless means that the human agent has fewer capabilities than he would have if he had acquired the skills and useful knowledge associated with schooling.

Education specifically affects farming in four main ways. First, through the worker effect. In this, a farmer becomes more efficient in performing certain tasks. Secondly, the allocative effect where farmers learn how to choose optimal resource combinations. In this scenario, the farmer can make better allocation of resources, which would bring improvement in investments in soil conservation. The innovative effect is the third one. In this, education influences the ability of a farmer to acquire and analyse available information on expected

---

[42] Social capital can help increase peoples' incomes (World Bank, 1994) in addition to facilitating continued

costs and returns, variability, etc. of innovations thus reducing time lags in adoption. Finally, there is the market effect where the farmers capacity to exploit new market opportunities is improved.

Education can also have complex effects, possibly increasing the return to investment or the farmer's access to credit, but also increasing the opportunity costs of the farmer's time (Pender and Kerr, 1996). Education provides farmers with information on conservation measures and the effect of soil erosion on productivity. This in turn implies that farmers are more likely to incorporate soil conservation into their farming operations.

Table 4.1 below shows some descriptive statistics of selected household characteristics. We observe that food expenditure occupies a substantial fraction of the total household expenditure. This is typical for poorer households where food expenditure is the dominant household expenditure item. For wealthier households, food occupies a smaller portion even though the quality differs. The rest (non-food) is shared by family events, church activities, school fees, medical bills, clothes, transport, kerosene and wood among others. School fees and medical expenses are the dominant components in non-food. Manufactured goods include items such as sugar, tea, salt and cosmetics that are sourced from the market thus making their effective farm gate prices higher due to transaction costs of market exchange.

With soil conservation investments (proxed here by terrace length per hectare and area terraced), we find a number of peculiarities. First, we note that the terrace length per hectare varies from 0(zero) to 7410 metres with a mean of 568.72 metres and a standard deviation of 906.7 metres. Likewise, area terraced ranges from 0.00 ha to 12.15 ha with a mean of 0.98 ha and a standard deviation of 1.35 ha. The variability in the two measures is high as the standard deviation is above the mean average. This points out to a number of factors that lead to the differential investment in land improvements, one which includes transaction costs to the market. While area terraced might indeed represent a better indicator for soil conservation investments due to less variability, the length of terrace per hectare is a much better measure since farmers actually dig the terraces and it is what a worker is paid for (digging the terraces) rather than the area terraced. Moreover, the figure for area terraced may have some errors as it is derived from what a farmer says is the fraction of the farm

---

agricultural yield increases (Uphoff and Wijayaratna, 2000; Admassie et al, 1998; Uphoff et al, 1998).

unterraced. The "fanya juu " terraces (if the soil is thrown upslope during construction) are predominant in semi-arid areas than the "fanya chini" type (if the soil is thrown downward). The study shows that over 90% of the farmers have fanya juu terraces, 7% fanya chini, and 3% grass strips. An earlier study (Nixon et al., 1993) supports this finding showing that fanya juu terraces are more popular (60% of the farmers) than the fanya chini ones (23%) because the former conserve both soil and water while the latter are mainly for water conservation.

Table 4.1: *Characteristics of sampled households in Machakos and Kitui districts, Kenya, 2000*

Variables	N	Min	Max	Mean	STD. DEV
Food expenditure	197	3640.0	345956.00	52356.28	35830.81
School fees	157	0.00	120000	11702.89	19356.93
Medicine	186	100.00	80000	6174.14	8538.70
Manufactured goods	197	0.00	49036.00	13876.08	6406.10
Non-food expenditure	197	0.00	359580.00	43862.61	41026.55
Total Expenditure	197	5575.0	400400.00	96218.90	61473.06
Terrace (metres/ha)	197	0.00	7410.00	568.72	906.70
Area terraced (ha)	174	0.00	12.15	0.98	1.35
Number of rooms in main house	197	1.0	9.0	3.0	1.7
Slope of farms	179	.10	4.29	1.82	0.72
Tenure of farms	192	3.0	9.43	6.14	0.85
Farm size per capita	197	0.01	2.29	0.28	0.28
Total value of inputs (Ksh/ha)	193	0.00	26093.08	1792.33	2848.94
Total value of manure and fertilizer (Ksh)	197	0.00	13303.00	656.01	1740.51
Amount of manure (Kgs/ha)	191	0.00	13832.00	335.00	1129.38
Amount fertilizer (Kgs/ha)	195	0.00	347.34	12.27	42.50
Terracing costs (Ksh/ha)	60	0.73	17462.90	2057.42	3471.95
Terracing labour (Man-days/ha)	66	2.20	52403.52	5923.18	10237.62
Labour (man-days/hectare)	191	4.00	1197.13	132.25	141.67
Family labour (terracing)/ha	67	0.00	17477.72	1855.00	3345.24
Hired labour (terracing)/ha	62	0.18	17462.90	1995.38	3436.44
Self-help labour (terracing)/ha	62	0.18	17462.90	1992.31	3435.48
Distance to parcels from homestead (metres)	191	1.0	53302.0	2498.2	6671.4
Distance to district market (Kms)	191	.50	65.00	26.53	15.55
Age of household head	192	23.0	95.0	48.14	14.92
Household size	197	1.0	18.0	6.75	2.9
Number of adults in household	194	1.0	11.0	4.1	2.25
Number of children	194	0.0	9.0	2.8	2.1
Household income (Ksh)	197	865.0	474436.2	49762.5	69942.2
Crop income (Ksh/ha)	191	906.49	161908.50	18455.99	20474.14
Other income (Ksh)	197	0.0	432000.0	27235.7	56929.3

N = Number of households

Slope and tenure figures are indices showing an increasing degree of slope and tenure security

Source: Field Survey, 2000

Farm size per capita mirrors both land scarcity and population pressure. It ranges from 0.01

ha per person to a maximum of 2.29 ha with a mean of 0.28. The standard deviation is also 0.28. The results imply that there are some households that face a high land scarcity compared to others. Those that face a higher land scarcity may react to such a pressure by either adopting high productivity enhancing measures (for example, terracing) or they just migrate to other areas. Another option is to have several parcels of land in different places. For example in Ngalalia village, a number of farmers have grazing land in Yatta and in other areas. The grazing lands ease off population pressure as other members of the households go to those areas and undertake livestock farming instead. Whether land scarcity leads to a downward spiral of soil degradation and yield decline, or to farmers investing in soil improving measures, perhaps eventually triggering sustained growth in productivity and income as suggested by Boserup (1965), might depend in part on the evolution of property rights over land and access to markets.

In general, terracing structures take productive farmland space. In this scenario, a farmer has to consider the trade-off. It makes sense to have a higher terrace level if the loss in output as a result of terraces is more than compensated by increased yields. In some instances, farmers delight in having a better-terraced farm for social purposes. There is pride in that for one gets social satisfaction and recognition as a "good farmer".

Generally, the use of inputs apart from labour is low. This can be inferred from the costs of total inputs used. The mean is about 1792.33 Ksh per hectare. The variability in this case is quite high (2848.94 Ksh/ha). These inputs include manure, fertilizer, seeds, pesticides and planting materials. The table also shows the use of manure and fertilizer. Application of manure varies from a minimum of zero to a maximum of 13832.00 Kgs per hectare. The mean use per hectare is 335.00 Kgs with a standard deviation of 1129.38. However, with fertilizer consumption, the variability is quite low. In general, consumption of fertilizer is low (12.27Kgs /ha). This is because fertilizer is expensive as a fertility enhancement measure. Thus farmers respond by reducing the amount applied as effective prices rise due to transaction costs. Manure is cheap relatively and is often sourced within the farms or just from neighbors a short distance away and in some cases all the way from Kajiado District. This is reinforced by the fact that the major fertility enhancement measure on farms is manure use (Appendix B7). The availability of farmyard manure, however, pre-supposes that the farmers' production system is dual in nature in that it is characterized by the production of both crop and livestock. The relative importance of livestock can only be emphasized by its flexibility in conversion into liquid cash, thereby acting as a consumption smoothening buffer, considering that crop incomes are seasonal.

Labour use on terrace construction per hectare ranges from 2.20 man-days to 52,403.52 man-days, with a mean of about 5,923.18 man-days. In this scenario, we cannot distinguish children and gender. We assume that there is no much difference on the amount of work that a man or a woman can do when it comes to terrace construction and even for crop production activities. While for crop production, labour use ranges from 4.00 man-days per hectare to 1197.13 man-days, with a mean of 132.25 man-days. The standard deviation is 141.67 man-days. This does indicate a lot of variability on labour use among farms. Perhaps this variability has to do with soil type and the crop choice. Family labour is generally not sufficient for both terracing and crop production. About 68% of the farmers acknowledge this, thus necessitating supplementing with hired labour and *Mwethya* (labour exchange groups).

The results also show that average distance to parcels of land is 2498.2 metres (2.5 Kms) from the homestead. The variable ranges from a minimum of 1 metre to a maximum of 53302 metres (53.3 kms) with a standard deviation of 6691.4 metres (6.67 kms). Parcels of land that are more distant are difficult to supervise, control and monitor. Farmers spend much of their time headloading commodities from fields to the homestead and vice-versa for inputs. As a result, the effective input prices such as labour rise considerably making it more expensive to terrace a unit land area. Consequently, soil conservation investments are expected to be lower.

Distance[43] to district markets ranges from 0.5 Kms to 65.00 Kms with a mean of 26.53 Kms and a standard deviation of 15.55 Kms. Although time and distance to markets are often proxies for market access (Njehia, 1994; Obare 2000), time seems to be rather shaky as matatus[44] wait till they fill up and often stop on the way picking passengers and luggage. Ceteris paribus, increasing distance and time to the market imply high transport costs, which have a consequence on the costs incurred in buying farm inputs and the monetary incomes

[43] This is the shortest distance by the road to the market.

that farmers obtain from selling their produce. Transport costs whether from the field to the homestead or from the homestead to the market, affect total production of a crop as well as the marketed quantity of that crop. All these act to reduce crop returns which in turn lower soil conservation incentives. The end result is a reduction in terracing intensity and adoption. Even if crops are not marketed, which may be a rational response to high transaction costs; the acquisition price matters necessitating import substitution (Omamo, 1998).

The age of principle household member ranges from 23 years to 95 with a mean number of 48.14 and a variability of 14.92 years. Age is important most often because young farmers are more innovative, are willing to take risks and have low discount rates of the future periods. Some authors have argued that younger farmers have a likelihood of adopting of soil conservation than older farmers (Hoover and Wiitala, 1980). However, the draw back is that they have less farming experience and are often away in towns working or looking for jobs. Age is often a proxy for farming experience and represents human capital endowment that can be acquired over time. This can increase the potential returns to soil conservation investments. However, Gould et. al, (1989) argues that older farmers usually have a shorter planning horizon, which implies that they have high discount rates. This high discount rate reduces present value of expected long-term benefits from conservation causing older farmers to have a lower likelihood of adopting soil conservation. Therefore, the net effect depends on the strength of the causal mechanisms.

We also find that the average household size of 6.75 is much higher than the average Kenyan household with 5.2 persons. A large household size may imply a number of things. First, it suggests labour availability. This is crucial when viewed against the background that the major input in terracing is labour. The use of some conservation practices such a terraces are very labour demanding. In circumstances of low cash incomes and non-existent or imperfect labour markets, family labour can play a crucial role in the adoption of labour-intensive conservation technologies. Comparing with the adult population and children, we find the former to be higher (4.1 persons) than the latter (2.8 persons) further alluding to labour availability. Secondly, abundant family labour is good. This type of labour has very low transaction costs if not zero. Hence, we do not assume a perfect substitutability between

---

[44] These are minibuses that ply rural areas of Kenya.

family and hired labour. The latter is typical of the principle-agent relationship with lots of problems of asymmetric information, incentive problems and very high sourcing or hiring costs. Supervision costs make hired labour relatively more expensive than family labor because work effort and therefore labour productivity tends to be lower for the former. However, large households imply increased food demand. This has two implications: first, the household has to provide for its own needs, which, means that farm production would be mainly focused on meeting subsistence requirements, and second, the same household has to produce surplus in order to generate enough income to ensure sufficient supply of food from external sources to meet production short falls.

The table also gives information about household income. It varies from Ksh 865 to a maximum of Ksh 474,436.20 annually. The mean income in the two districts is Ksh 49,762.45, which is very high. We thus expect substantial variation in a number of household characteristics that can be linked to household income. A higher household income is essential to finance soil conservation investments. Many authors have argued that income increases the likelihood of adoption of conservation technology (Norris and Batie, 1987; Sinden and King, 1988). Higher incomes provide farmers with the ability to purchase materials and equipment for soil conservation or hire labour if labour market exists. Some even have argued that farmers with higher incomes have a lower discount rate (Featherstone and Goodwin, 1993) and hence make higher long-term investments. On the other hand, poverty may force farmers to discount the future more heavily (Holden et al, 1998) that may limit the ability to invest in conservation of the natural resource base.

Similarly, crop income[45] ranges from 906.50 Ksh/ha to a maximum of 161,908.50 Ksh/ha with a mean of 18,456 Ksh/ha. The variability is also very high at Ksh 20,474.140 per hectare. If we assume that crop yields are a function of input use including terraces, and management; then the variation in yields would be explained by resource endowments and management abilities. The income from other sources ranges from Ksh 0.0 to 432,000 per hectare with a mean of 27,235.70 Ksh/ha. The standard deviation is 56,929.13, which is twice the mean. The variability is accentuated by the different opportunities facing households such as proximity to major towns and education levels of its members. The results suggest the

[45] Farm gate price was used to calculate the value of heterogeneous crop output. The value of output is a good

dominance of farm incomes as a source of household incomes and the varying opportunities facing households that may allude to the differential terracing intensity. Further, terracing is highly labour demanding, which necessitates family labour augmented by hired labour sourced from the market.

Table 4.2 below reveals a number of important issues. The major reasons for some of the unterraced portions of fields are lack of money, shortage of labour and relatively flat land. The results confirm that terracing is an expensive undertaking and very labour demanding. We also observe the importance of land being relatively flat in Kitui District (32.3%)as compared to Machakos district (5%).

Table 4.2: Reasons for unterraced parts of fields in Kitui and Machakos Districts, Kenya, 2000

Reason	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Lack of money	21	52.5	20	29.4	41	38
Shortage of labour	14	35	13	19.1	27	25
Land is flat	3	7.5	22	32.3	25	23
Others	2	5	13	19.1	15	14
Total	40	100	68	100	108	100

Source: Field Survey, 2000

The weighting for other reasons seems to be roughly the same in the two districts. The reasons that fall under "other" are land having recently been acquired or opened, fallow, lack of time and problems with extension service.

4.2 Village characteristics

A lot of input for this section comes from village profiles, and sample data.
Such issues like access to the market, size of village, special features of the village, number of parcels, terracing aspects and community group activities among others are discussed.

There are a number of observations that we can make from Table 4.3 below. Looking at the sample sizes in each village, there is a drastic decrease especially for Ngalalia. These were more or less like panels for the same farmers had been selected in 1998. The intention was to interview the same households in the year 2000 to observe some dynamics. It was difficult to get the same households largely due to migration, death, and the persistently not at home. As

measure of output when dealing with heterogeneous commodities.

a result, about 6.2% (13) of the original sample was lost, leaving 93.8% (197).

Table 4.3: Characterization of sampled villages in Machakos District, Kenya, 2000

Villages	Kisaki	Musoka	Ngalalia	Ngumo	Average
Sample size	26	27	18	24	
Household size	7.69	7.00	5.89	6.25	6.79
	(3.03)	(3.01)	(2.35)	(2.77)	(2.88)
Number of children	3.31	3.23	1.71	2.58	2.81
	(1.89)	(2.42)	(1.40)	(2.12)	(2.10)
Number of adults	4.38	3.92	4.29	3.67	4.05
	(2.10)	(2.24)	(1.83)	(1.97)	(2.04)
Farm size per household	2.15	1.72	1.14	0.90	1.52
(ha)	(1.35)	(2.36)	(1.03)	(0.62)	(1.60)
Farm size per capita	0.30	0.25	0.23	0.17	0.24
	(0.19)	(0.24)	(0.26)	(0.16)	(0.21)
Slope index	2.15	2.02	2.06	1.93	2.03
	(0.55)	(0.72)	(0.71)	(0.75)	(0.68)
Tenure index	5.93	6.13	5.99	6.10	6.04
	(0.93)	(0.85)	(0.57)	(1.25)	(0.94)
Distance from home to	605.24	699.44	6187.79	708.58	1750.04
parcels (metres)	(1617.36)	(1259.73)	(12337.58)	(1166.8)	(5893.49)
Terrace Length (m/ha)	824.76	803.68	580.00	1038.55	826.40
	(548.40)	(1381.17)	(578.69)	(1727.94)	(1192.48)
Crop output per household	25172.81	14060.52	36601.61	8962.29	20084.75
(Ksh)	(27140.09)	(16302.33)	(51260.89)	(7958.58)	(29351.93)
Crop output	16740.86	13906.43	28068.88	12820.56	17091.26
(Ksh/household/ha)	(17760.68)	(14737.06)	(26337.19)	(12519.9)	(18396.89)
Crop output per capita	2510.17	2317.26	6072.65	2362.27	3092.97
	(3631.68)	(2657.76)	(8341.96)	(2809.54)	(4699.07)
Average number of parcels	2.85	2.11	4.50	2.71	2.92
% Households involved in self-help groups	81	67	67	71	71.6
Population Density	103.67	267.90	166.67	450	247.06
Distance to District Market	18.81	40.61	30.13	57.38	36.36
(Kms)	(5.17)	(12.80)	(1.45)	(6.45)	(16.49)
Distance to Nairobi (Kms)	98.81	122.07	110.13	107.38	109.80
	(5.17)	(9.60)	(1.45)	(6.44)	(11.25)
Transport costs to District Headquarters (Ksh)	50	80	100	70	

Figures in parentheses denote standard deviation
Source: Field Survey, 2000

The average household size shows that Kisaki village has a much higher figure (7.7). The smallest household size is in Ngalalia with 5.9. Household size often indicates labour availability and consumption or demand requirements. However, the former appears not the case since the average adult population per household in all the villages is more or less the same. But with the number of children, Ngalalia has the least (1.7). *Ceteris paribus*, more investments in sustainable land use are expected in Kisaki compared to Musoka, Ngumo, and with Ngalalia being the least, as more investments are needed to meet subsistence requirements. However, large households are expected to be poor as more assets are drawn down to finance consumption and pay school fees and medical bills. GOK (1999-2015) contend that poor rural households have an average of 6.5 persons in contrast to the average rural household size of 5.6 persons. As Platteau (1997) argues, poor households are unable to set up viable non-farm businesses, are excluded from patronage relationships that are important in obtaining wage employment, and are usually excluded from rotating saving- and – credit associations (merry-go- rounds) for lack of regular incomes from which to pay their periodic contributions to the common pot. Since membership in these associations gives access to consumption credit, exclusion from them deprives poor households of an important and flexible insurance devise.

The next characteristic is average farm size in the sampled villages. We see that Kisaki village has the highest average farm size (2.15 ha) followed by Musoka (1.72), Ngalalia (1.14), and Ngumo (0.90) in a descending order. Research has so far shown an inverse relationship between farm size[46] and input use (Berry and Cline (1979). In this study, soil conservation is taken as one of the inputs in farm production. One can thus infer that Ngumo village has the highest level of investments in land compared to Kisaki. As land becomes scarce, we often expect more investments to be made so as to raise land productivity. Moreover, opportunities for leaving land fallow to allow for natural regeneration become unavailable.

However, a better measure of scarcity of land is farm size per capita. The results show that Ngumo has the lowest farm size per capita (0.17) while Kisaki has the highest (0.30). However, Musoka and Ngalalia have about the same farm size per capita. We thus expect a higher learning process through 'neighborhood effects' in Ngumo village compared to Kisaki village. With this process, farmers nearby, first adopt terracing technology because they can observe the practice first-hand and also because it is plausible that it will also work on nearby farms. Alternatively, land scarcity could lead farmers to invest in soil conservation, leading to sustained growth in productivity and income (Boserup, 1965).

[46] The inverse relationship seems to lie on lower intensity of land use by larger farms compared to small ones. Its main economic basis is that large farms confront different relative factor prices from small farms which lead them either to (a) to take land as a relatively abundant resource using extensive production methods, or (b) to substitute

On total distance to the farms or fields, Ngalalia village has the highest. A plausible reason can be advanced for this state of affairs. Each household has at least four parcels of land (4.5). An increase in distance implies scattering or dispersion, which increases farmers' abilities to manage income variability efficiently by taking advantage of micro-climate variations. This is because most households have a parcel of land along the river, another at the slope of the hills nearby and others elsewhere (location of niche fields). The results also suggest that it is difficult to find land nearby to buy or may be prices of land are very high. So they have to invest elsewhere where land is cheap and is available. This is because Ngalalia has smaller household size and is relatively rich and thus can afford to invest on more land, which is not available. The other villages have about the same total distance from the homestead to the parcels of land. From this, one can infer that there may be less soil conservation investments in Ngalalia village. This is because of the higher total distance from the homesteads to the plots or fields. As the distance from the farm to the fields increase, more hours are spent in traveling and back loading implying very high opportunity costs. This leaves little labour time to be expended for crop production and soil conservation investments. Thus the greater the distance, the lower the terracing intensity and adoption.

With length of terraces per hectare (a proxy in this study for soil conservation investments) is quite revealing. Ngumo comes top (1038.6 meters/ha), with Ngalalia having the lowest (580 meters/ha). It is difficult to discern why this is indeed the case considering as argued before that Ngalalia with a small household size and with the highest crop income would be capable of financing conservation investments. However, we note that fewer households (67%) are involved in self-help activities in Ngalalia compared to Ngumo (71%) suggesting the importance of social capital and hence collective action in soil conservation investments. As Krishna and Uphoff (1999) contend, technical and financial aspects are usually given overriding importance in soil conservation and land use management plans. However, it is recognized that social and institutional factors also matter. They seem to influence soil conservation investments through peer pressure; and in reduction of transaction costs in information acquisition, and in labour hiring

Further, the results may be attributed to total distance to the individual parcels of land from

---

capital for labour through farm mechanization.

homesteads, population density, and transport costs to the District main market. The village faces high transport costs to the market (Ksh 100) compared to the others. This might be an issue of the condition of the roads, the density of transport carriers and monopolistic competition as the distance to the market is only 30 Kms thus making transport margins rather high.

Table 4.4 below presents descriptive statistics of some selected characteristics on sampled villages in Kitui district. With household size, Mwanyani village has the highest followed by Kyondoni, Kitungati and Utwiini in descending order. Mwanyani is thus expected to have more investments with Utwiini having the least. The rest follow accordingly. However, there is a higher variability in Kitungati and Kyondoni. As argued earlier, a larger household size suggests potential higher labour availability as well as demand requirements provided there is a positive correlation with the number of adults in the households.

On mean farm size in hectares, Utwiini has the lowest with Mwanyani having the highest. A much better measure is farm size per capita that indicates land scarcity and population pressure. According to this factor, Utwiini village has the smallest with Kyondoni having the largest. One can infer that there is more labour application per unit area in Kyondoni compared to Utwiini. This can also be inferred from the adult population in the four study villages.

With farm revenues per hectare, we find that Kitungati has the highest (Ksh 23,734.30) followed by Utwiini (Ksh 22,761.55), Kyondoni (Ksh 12,870) and Mwanyani (Ksh 11,590) in a decreasing order. Farm revenues are a proxy for having the ability to finance terracing (i.e. soil conservation). Though in general this seems to be the case as Kitungati also has the highest terrace length per hectare, the others do not follow as expected suggesting the importance of other factors acting in a combination in driving soil conservation. These factors are slope, tenure, population density, age and education.

With average distances to the fields, the villages show some interesting pattern. Kitungati has the highest (4196.9 metres) with Utwiini village having the lowest (1597.3 metres). In Kitui district, this variable appears weak or inadequate in explaining differences in soil conservation measures among villages. As earlier argued, a higher distance to crop fields is a risk reducing strategy. This is a direct conflict to transaction costs strategies. As to which objective overrides the other is an empirical question and is beyond the present study. Nevertheless, based on casual observations, it appears that risk overrides transaction costs in Kitui District while it is the vice-versa in Machakos District. Another possible explanation is that closer parcels of land may be more secure. Bivariate correlation of analysis of the data suggests so (Pearson correlation coefficient is –0.168 and is significant at the 0.05 level – two tailed tests).

Table 4.4: Characterization of sampled villages in Kitui District, Kenya, 2000

Villages	Mwanyani	Kitungati	Utwiini	Kyondoni	Average
Sample size	25	25	26	26	
Household size	7.16	6.56	5.88	7.08	6.67
	(2.21)	(2.93)	(2.27)	(3.84)	(2.90)
Number of children	2.28	3.28	2.73	2.52	2.70
	(1.4)	(2.5)	(1.99)	(2.22)	(2.08)
Number of adults	5.08	3.28	3.15	4.80	4.07
	(3.01)	(1.51)	(1.67)	(2.66)	(2.4)
Farm size per household (ha)	2.88	1.95	1.11	2.16	2.02
	(5.81)	(1.48)	(0.85)	(1.60)	(3.12)
Farm size per capita	0.35	0.30	0.21	0.39	0.31
	(0.46)	(0.20)	(0.17)	(0.40)	(0.33)
Crop output per household (Ksh)	18076.88	34886.60	18231.39	28139.25	24801.21
	(18021.11)	(42829.90)	(1599.07	(46143.52)	(33967.10)
Crop output per household (Ksh/ha)	11589.96	23734.29	22761.54	12869.98	17740.45
	(10580.69)	(31819.28)	(25493.36)	(10115.24)	(22005.37)
Crop output per capita	1687.91	4507.09	3980.56	2918.24	3276.90
	(1486.10)	(5795.87)	(3789.51)	(4181.09)	(4189.13)
Slope index	1.75	1.25	1.69	1.80	1.64
	(0.56)	(0.84)	(0.60)	(0.73)	(0.71)
Tenure index	6.25	6.19	6.05	6.40	6.22
	(0.83)	(0.57)	(0.82)	(0.79)	(0.76)
Distance from home to parcels (metres)	3957.22	4196.88	1597.32	3062.61	3193.47
	(6924.52)	(10349.34)	(5068.18)	(5995.97)	(7281.83)
Terrace Length (m/ha)	340.99	368.77	267.32	339.83	328.72
	(313.89)	(513.56)	(425.34)	(276.93)	(388.96)
Average number of parcels	3.20	2.28	1.58	2.42	2.36
% Household involved in self-help groups	72	64	38.5	76.9	62.7
Population Density	200	115.38	166.67	102.25	146.08
Distance to District Market (kms)	6.12	21.28	21.00	22.52	17.76
	(1.10)	(1.72)	(3.48)	(3.79)	(7.27)
Distance to Nairobi (kms)	186.12	201.28	200.85	204.00	198.09
	(1.10)	(1.72)	(4.84)	(8.40)	(8.54)
Transport costs to District Head quarters (Ksh)	25	80	80	50	

Figures in parenthesis denote standard deviation

Source: Field survey, 2000

The table above also shows that the mean length of terrace per hectare for Utwiini village is in fact the least followed by Kyondoni, Mwanyani and Kitungati in ascending order. However, the last three villages have comparable investment magnitude. This possibly suggests a number of factors acting together such as tenure, age, education, slope, and farm revenues. As can be observed from the table, Utwiini, which has the least conservation investments, has low farm revenue and is relatively flat.

On the aggregate, Kitui has much less investments compared to Machakos. The average length of terrace per hectare for the four villages in Kitui is 328.72 metres while for Machakos it is 826.40 metres. In fact, Machakos has far much more than double (2.5). While other factors such as slope explains this phenomenon, it is apparent that the distance to Nairobi plays a very significant role. This reasoning stems from the fact that Nairobi is the major market in Kenya where most produce flows pass. The prices prevailing at this market will in most cases determine the prices received by the farmers. Our main assumption is that farmers terrace because of the expected returns accruing from crop sales as a result of improved land productivity. Distance besides other factors to Nairobi thus becomes crucial. Transaction costs, which largely consist of transport and information costs, ceteris paribus, increase as distance to the market increases. This is likely to lower the incentive to invest in soil conservation the further a household is from the market via product prices. Moreover, high transaction costs may lead to high crop production costs that impinge negatively on conservation investments.

With average distance of the households in the sampled villages from homestead to parcels of land, it is higher for Kitui district (3193.5 metres) compared to Machakos (1750 metres). In fact, it is about 1.8 times larger. We theoretically expect those areas far away from Nairobi to be less densely populated, to have bigger fields, and to have fields farther away from the homesteads. This also results in fewer investments in incremental land quality. The results confirm these expectations (see Table 4.4).

Focussing on the length of terrace per hectare with distance to Nairobi, the Pearson correlation coefficient is -0.271, which is statistically significant at 0.01 level. This confirms that as one moves away from Nairobi, the investment in terraces decreases. This is an indirect effect working through product prices. It does suggest that high transaction costs of access to the major market in Kenya reduce the incentives to invest in incremental land quality (or capital). We expect better returns to agriculture to lead to more land conservation and soil fertility investments. Moreover, as market prices do not reflect the actual prices received by farmers, distance and transport costs incurred by the household to the market can both be used to reflect transaction costs. We expect both to be inversely related to investments in agriculture. A correlation between length of terrace per hectare and farm revenue (from crops) per hectare is positive and significant at 0.01 level (0.234). This supports the pattern of conservation investments observed with differential transaction costs. High prices or returns as a result of low transaction costs to the market for agricultural products are likely to result in increased value of agricultural land. This makes investments and maintenance of soil conservation measures more effective.

With proportion share of source of household incomes (Table 4.5), remittances form a significant portion for villages in Machakos as compared to those in Kitui. Being quite close to Nairobi, Machakos has more opportunities for off-income relative to Kitui district for those working away from home.

Table 4.5: Proportion of household incomes according to the sampled villages in Kitui and Machakos Districts, Kenya, 2000

Villages	Remittances	Off-farm	Livestock	Business	Crop
Kisaki	.09	28.12	8.34	16.73	46.72
Musoka	36.34	21.90	6.85	3.84	31.11
Ngalalia	9.50	18.50	3.05	14.03	54.91
Ngumo	18.92	44.49	6.93	9.47	20.19
Average (Machakos villages)	15.55	27.77	6.36	11.26	39.05
Mwanyani	19.7	12.35	10.95	4.74	52.26
Kitungati	7.47	0	10.33	10.74	71.46
Utwiini	4.85	1.28	4.95	52.78	36.14
Kyondoni	9.04	3.0	8.63	31.20	48.13
Average (Kitui villages)	9.41	3.44	8.48	27.22	51.45

Source: Field Survey, 2000

Off-farm incomes, from activities that are close to the villages, also form a substantial portion of household incomes. In Machakos, the proportion is 27.7% as compared to 3.4 percent for Kitui. On the other hand, in both areas, crop income is still predominant. Combining livestock and crops, the share of household incomes in the sampled villages in Kitui is 60% and for Machakos 45.4%. This confirms the pivotal role the agricultural sector plays in economic growth.

The existence of self-help groups happens to be an important component explaining investment behavior in soil conservation. These are part of social networks and are essential in risk pooling and risk sharing. Table 4.6 below shows the involvement of household members in various forms of self-help groups in the sampled villages. The table shows that merry-go-round is the predominant activity. This is crucial in mobilizing rural savings and greatly eases credit constraints. The other activities are tree nurseries, group farm, school activities, ploughing on members' fields and terracing. Though not having the largest share, terracing is still seen as an important aspect to be focused on. Moreover, tree nurseries show that farmers are aware of soil degradation problems and see the need to plant trees on their farms. It's also likely to be an indication of high fuel and construction prices experienced by farmers due to increasing distances to forests occasioned by deforestation, in which case, soil conservation becomes an indirect or secondary benefit. Apart from merry-go-round and school activities, the rest show that labour is really an important constraint in the marginal areas of Kenya. In these areas, the solution lies on investing in social capital so that labour exchange groups could thrive.

Table 4.6: Self-help group Activities in the selected villages in Machakos and Kitui Districts, Kenya, 2000

Self-help group activity	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Merry go round	34	37.4	17	16.5	52	26.8
Tree nursery	13	14.3	28	27.2	41	21.1
Group farm	8	8.8	20	19.4	28	14.4
School activities	4	4.4	12	11.7	16	8.2
Ploughing of members' fields	14	15.4	2	1.9	16	8.2
Terracing on members' fields	8	8.8	3	2.9	11	5.7
Terracing on non-group member fields	2	2.2	0	0	2	1.1
Church activities	1	1.1	9	8.7	9	4.6
Road repair	3	3.3	3	2.9	6	3.1
Shallow wells	0	0	5	4.9	5	2.6
Others	4	4.4	4	3.9	8	4.1
Total	91	100	103	100	194	100

Source: Field Survey, 2000

Self-help labour faces low transaction costs compared to hired labour. Since own labour is probably not sufficient, it is augmented with self-help labour, which is appropriate and handy. It is argued that family farmers are said to have more direct motivation, more intrinsic grasp of the agronomic attributes of their land and flexibility in seasonal labour deployment (Ellis, 1988). The author further argues that hired labour has supervisional and motivation problems, rigidities of seasonal employment, and less detailed knowledge of the land and its capabilities. Although incentives for shirking or opportunistic tendencies exit, monitoring and enforcement is easy within a self-help group.

The size of self-help groups and their manner of operations vary considerably (Pearson et al, 1995). Some operate purely as labour exchange groups[47], working on each member's field in turn; others charge members for work done at a nominal rate and may also work for nonmembers (generally at a higher rate than that charged to members). Many of these groups also have functions other than labour exchange; for example, many work on community projects or operate as rotating savings associations. Some provide credit to their members. Self-help groups make labour sourcing and supervision rather cheap for both terracing and crop production.

The existence of collective action is an apparent sign of the presence of imperfect markets in credit and labour. Self-help groups can also be used for other purposes. They can offer an insurance mechanism against income shocks, provided that these shocks are not correlated among participants. If groups are already formed around a common purpose and share a common set of norms and values, this reduces the information and coordination costs of their organizing around another purpose having already established a history of coordination and trust (Balland and Platteau, 1996).

On the weights of distribution between the two districts, we note that there are more activities in tree nurseries and group farm in Kitui than Machakos. Perhaps this indicates the use of family or self-help labour for farming activities in Kitui. We suppose that Machakos relies more on hired labour compared to Kitui. For Machakos, we observe that there are more merry -go-rounds activities (rotating activities among members) and ploughing on members fields compared to Kitui. Perhaps the exposure and proximity to Nairobi has made them aware of the importance of saving schemes and the need to raise money for various activities.

Risk aversion, an issue of idiosyncratic risk, is the major reason for the formation of self-help

[47] These social arrangements can be seen as cooperative outcomes of repeated Prisoner's Dilemma games, as members participate as long as they expect future help from the other members.

groups (see Table 4.7). Farmers often fall back on this in the event of illness, death and other calamities that might strike. This is perhaps more pronounced since people in the rural areas rarely have any kind of insurance to guard against possible adverse effects. This is followed by the "normal thing to do". It is part of the social structure of a group of people. This is then followed by "expensive to hire labour". Perhaps this reflects the labour problems inherent in the study area. Thus, a way out of this is by joining self-help labour groups (mwethya). Helping each other, which is a social aspect especially in the rural areas, is also important, although minor.

Table 4.7: Reasons for being a member of self-help group in the selected villages in Machakos and Kitui Districts, Kenya, 2000

Reason	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Risk aversion	21	25.3	17	24	39	25.3
Normal thing to do	22	26.5	12	17	34	22.1
Labour shortage	13	15.7	17	24	30	19.5
Expensive to hire labour	9	10.8	5	7	14	9.1
Help each other	3	3.6	8	11	11	7.1
Others	15	18.1	12	17	26	16.9
Total	83	100	71	100	152	100

Source: Field Survey, 2000

Another important aspect or element is how hired labour is monitored or supervised with a view to making it as productive as family labour. It is generally acknowledged that hired labour has a tendency to shirk or has opportunistic tendencies and may even mismanage farm assets. These moral hazard problems can be controlled only through continuous and tight monitoring, thus increasing the effective costs of labour dramatically. Family labour, however, does not shirk since it is the claimant to residual farm profits. Labour monitoring strategies are shown in Table 4.8 below.

We observe that where farmers "regularly check on the amount of work done" is the predominant (53.3%). This is followed by "working together with the worker" (31.1%). Having another "family member check on the worker", perhaps, a brother is 9%. The first case possibly implies that heads of households have other tasks to do and thus cannot always work together with hired labour. Moreover, some of the heads of households are not resident on their farms. This constant monitoring entails extra costs for hired labour, yet it is necessary if its productivity is to be close to that of family labour. The two dominant choices seem to entail the principle-agent relationship. This means that a worker has less to fear from another family member than the real employer. Perhaps this explains why this strategy is less employed (6.6%).

On the weight distribution of the monitoring strategies in the two districts, we observe that Machakos has a higher percentage for the first strategy (68.1%) than Kitui (44%). This gives an indication that farmers in Machakos are more involved in off-farm activities relative to those in Kitui. It also shows that farmers in Machakos often use hired labour for farming activities relative to those in Kitui. In any case farmers in Machakos have higher household incomes and thus can afford to hire labour both for terracing and crop production.

Table 4.8: Labour Monitoring in Kitui and Machakos Districts, Kenya, 2000

Monitoring strategy	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Check on amount of work Regularly	32	68.1	33	44	65	53.3
Work with him in most cases	12	25.5	26	34.7	38	31.1
A family member checks him	3	6.4	8	10.7	11	9.0
Others	0	0	8	10.7	8	6.6
Total	47	100	75	100	122	100

Source: Field Survey, 2000

When it comes to how labour was sourced in the sampled areas (Table 4.9), we observe that the "labour coming to look for work" is predominant with 50.8%. This leaves the next major one - "sending information through relatives and friends" with 41%. The ones among "others" mainly include the "farmer going to look for the worker". It is interesting to note that with labour sourcing, the strategy adopted by farmers is to reduce transaction costs significantly. The two dominant sourcing strategies have marked reduction in hiring costs. As for the relative distribution in the two research areas, it is worthy to note that the "others" for Machakos is zero. Perhaps farmers in Machakos are more sensitive to transaction costs and thus are more responsive. The result is undertaking measures that greatly reduce transaction costs. Perhaps this also explains the fact that the option of labour itself looking for work as the highest (68.8%) as depicted in Table 4.9 below.

Table *4.9: Labour sourcing strategy for farm work in Kitui and Machakos districts, Kenya, 2000*

Strategy of sourcing	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Came over searching for work	33	68.8	29	39.2	62	50.8
Sent information to relatives/ Friend to look for worker	15	31.2	35	47.3	50	41.0
Others	0	0	10	13.5	10	8.2
Total	48	100	74	100	122	100

Source: Field Survey, 2000

"Sent information" imply there is plenty of idle labour around. It only needs to be notified. "Looking for job" imply that there is a stiff competition in the labour market coupled with commercialized and changed lifestyles where one has to "seek for the job". They both depict different scenarios on monetization of the village economy.

On where labour was sourced (Table 4.10) we note that "another village" and "same village" are dominant. Again this strategy is geared towards transaction costs reduction. Moreover, even with hiring from another village, in most cases refers to the neighboring one. It is thus becoming clearer that farming households do undertake strategies to reduce transaction costs. Sourcing labour nearby is cost-effective as information flow is fairly symmetrical.

Table 4.10: Where labour was sourced for work in Kitui and Machakos Districts, Kenya, 2000

Place of sourcing	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Another village	28	57.1	22	31.4	50	42.0
Same village	12	24.5	31	44.3	43	36.1
Local town	4	8.2	13	18.6	17	14.3
Others	5	10.2	4	5.7	9	7.6
Total	49	100	70	100	119	100

Field Survey, 2000

When it comes to the tasks of the workers employed in various households (Table 4.11) we find that the majority are farm workers. This suggests that family members perform household chores by themselves as opposed to the situation in urban centers.

Table 4.11: Task of workers employed in Kitui and Machakos districts, Kenya, 2000

Task of worker	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Shamba boy	27	56.3	51	67.1	78	63
Herder	10	20.8	17	22.4	27	22
Maid/houseboy	3	6.3	5	6.6	8	7
Others	8	16.7	3	3.9	11	8
Total	48	100	76	100	124	100

Source: Field Survey, 2000

4.3 Types of investments in Sustainable Agriculture

There are different types of investments that have been made in the sampled households in Machakos and Kitui districts. However, terracing appears to be the dominant one (Table 4.12). At the parcel level, we find that 70.5% of the parcels are terraced while 29.5% are not.

Table 4.12: Types of Investments in Sustainable Agriculture at the parcel level in Machakos and Kitui Districts, Kenya, 2000

Types of investments	Machakos		Kitui		Combined	
	Frequency	%	Frequency	%	Frequency	%
Terracing	182	65.7	117	46.8	299	56.7
Grass strips	32	11.6	31	12.4	63	12
Grass terrace border	45	16.2	7	2.8	52	9.9
Trash lines	11	4	35	14	46	8.7
Agro-forestry	5	1.8	5	2	10	1.9
Open ridges	2	0.7	1	0.4	3	0.6
Cover crops	1	0.4	2	0.8	3	0.6
Stone terrace	-	-	2	0.8	2	0.4
Cut-off drains	-	-	1	0.4	1	0.2
Total	278	100	201	100	479	100

Source: Field survey 2000

Other measures of soil conservation are trash lines (8.7%), grass strips (12%), grass terrace border (9.9%), cover crops (0.6%), open ridges (0.6%), agro-forestry (1.9%), stone ridges (0.4) and cut-off drains (0.2%). These measures are most often made together with terracing. For instance, for those parcels that were terraced (299), other measures undertaken in the same parcels are trash lines (9.7%), grass strips (14.7%), grass terrace border (14.7%), cover crops (0.7%), open ridges (0.3%), agro-forestry (3%), stone terraces (0.3%) and cut-off drains 0.3%).

It is also true that some of the unterraced parcels (125) also had the other measures of soil conservation. These measures are trash lines (11.2%), grass strips (4.8%), grass terrace border

(0.8%), cover crops (0.8%), open ridges (1.6%), agro-forestry (0.8%), and stone terraces (0.8%).

The table generally shows that Machakos has a higher proportion of grass terrace border compared to Kitui. It also shows that Kitui has more farmers using trash lines as investment measure compared to Machakos. This might be an aspect of either land being relatively more flat in Kitui or lack of hired labour or perhaps due to low household income or education. We also note that Machakos has more terraces (65.7%) than Kitui (46.8%). We are of the opinion that the differences in terracing levels in the two districts has to do with locational factors. Either historical reasons or proximity to Nairobi are the main reasons. Dietz (2000) makes an interesting argument about proximity to Nairobi. The author argues that this may have to do with either the significance of distance-related transport costs or urban political or cultural influences which involve state projects, non-governmental activities, and churches that have more impact.

Summary

A number of conclusions could be gleaned from this chapter. First of all, the chapter has shown that terracing is the dominant soil conservation investments undertaken in the study area. Secondly between the two study districts, Machakos appears to have a higher number of individual parcels of land terraced (65.7%) compared to 46.8% for Kitui district. We also find that crop income is the major source of household income and that households undertake some measures to reduce transaction costs by using household labour and sourcing additional farm labour nearby. We also find that factors such as tenure, age, education, population density, membership in self-help groups, distance from the homestead to crop fields besides transaction costs to the market are important in explaining differential soil conservation investments among farmers.

The next chapter examines the determinants of terracing intensity using Three Stage Least Squares (3 SLS) because of endogeneity problems.

CHAPTER FIVE: **DETERMINANTS OF SOIL CONSERVATION INVESTMENTS**

In this chapter, the determinants of the level or magnitude of soil conservation investments are analysed using Three Stage Least Squares (3SLS)[48]. This is considered important due to simultaneous effects that exist in the whole investment phenomena. First the analysis[49] is carried out with aggregate crop output in the first section. The results in the first section are also corroborated through the use of an agricultural household model. In the second section, a Cobb-Douglas regression function is used to assess incentives for soil conservation. Since terracing intensity, manure and fertilizer use are censored variables, Heckman Two Stage estimating procedure was used. In the first stage, inverse mills ratio (*IMR*[50]) was computed and then added as an explanatory variable.

The analysis was done at the household level. This is because it is at the household level that final decisions are made about land use, crop and technology choice (Kruseman and Bade, 1998). It is worthy to note also that some variables have different effects at different levels depending on scale effects.

5.1 Determinants of soil conservation investments with aggregate output

The regression functions reported in Table 5.1 below were obtained by running simultaneously five systems of equations using Three Stage Least Squares (3SLS) with SHAZAM Econometric Package. This is due to the simultaneity[51] and endogeneity[52] of the investment phenomena. Some of the variables like manure, fertiliser and terraces have a number of zero observations. In order not to loose too many observations, we transformed[53] these into natural logs by adding 1.01. This method is found elsewhere in studies such as Deolalikar and Vijverberg (1987), Jacoby (1993) and Linde-Rahr (2000).

---

[48] The analysis was also carried out using Logistic and Tobit regression models. The results were however similar and are thus not reported in this study. Moreover, one cannot make a decision and fail to invest in soil conservation.

[49] Households from Ngumo village in Katheka sublocation, Machakos District, were removed from the analysis due to little or no connection with Machakos District main market. Most of the produce flows for this village go through Tala to Nairobi. Their inclusion would have brought some bias.

[50] *IMR* whenever it appears in the results presented is the inverse mills ratio.

[51] Simultaneity bias would result in error terms being not independent (asymptotically biased estimators). Solution is to apply duality theory, a solution that fails to use all available information and is statistically inefficient (Mundlak 1996). This issue generally plagues the estimation of production functions.

[52] For more details, read chapter 3.

[53] The spread between individual observations remains the same. For details, see Marsh (1988).

Table 5.1 shows that investment in terraces is significantly influenced by slope, tenure, location, distance to the crop fields, education, wealth, degree of farm orientation, membership in self-help groups, household size, farm size per capita, household income, age, erosion status of the farms (fields) and transaction costs (access costs).

Slope of the farms appears to have a significant negative direct effect on soil conservation investments while the indirect effect is positive and significant through manure use. Steeper parcels of land are more susceptible to erosion and it is expected that steepness discourages the use of chemical and organic inputs because of run-off. However, the results show that manure and fertilizer application increase with slope suggesting that farmers sometimes increase their use even on steep slopes in order to maintain production levels possibly due to food security concerns. The negative correlation shows that the relationship between conservation investments and field slope is complex. Farmers invest most heavily on slopes of medium steepness (those steep enough to need conservation investments), but not so steep as to discourage investments, as their maintenance is very costly (Clay et al, 1996). In our case the net effect of slope is negative, due to the difficulty of manoeuvring draft animals, and the likelihood of terrace walls collapsing as slope increases farther. The results thus suggest that farmers may be focusing on the gentle slopes first and that too steep lands may not be the right place to cultivate. Farmers often leave land with very steep slopes uncultivated. Moreover, terraces are made even on flat land and as argued earlier this is to conserve and harvest water run-off from roads and footpaths. In the semi-arid areas, the purpose of water conservation is more pronounced. Econometric evidence from Rwanda and the Philippines show that the net benefits of soil conservation are highest on fields of medium steepness (Clay et al., 1995; Templeton, 1994). In the past, farmers placed their steepest slopes under pasture, woodlot, and perennial crops because these slopes easily erode. In addition, the soils on steep slopes are light and thin making them prone to erosion; keep yields low, and lower long-term returns to investments. Thus a spiral of low production and low investment is set into motion as these marginal lands are taken out of their traditional uses and put under intensive cultivation. Besides, the soils are shallow and the places rocky, thereby making it more expensive to construct the same unit length of terraces. The results may also be linked to population pressure, as farmers may not see the need of cultivating steep areas if there is enough land with gentle slopes. However, under high population pressure, steep areas are brought into cultivation through closer spaced terraces.

Table 5.1: *3SLS regression results for determinants of soil conservation investments (m/ha) in Machakos and Kitui districts, Kenya, 2000*

Equations	1	2	3	4	5
	(TERACE)	(MAN)	(FERT)	(LAB)	(CROPAC)
ln *SLOPE*	-0.235	0.639	0.154	-0.793E-01	
	(-1.742)**	(4.193)***	(1.178)	(-0.936)	
ln *TENURE*	0.754	-0.350	1.401	-0.247	
	(1.450)*	(-0.598)	(2.776)***	(-0.751)	
LOC	-0.936	-0.135	-0.986	-0.549E-01	.341
	(-5.659)***	(-0.721)	(-6.202)***	(-0.394)	(.959)
ln *DISTH*	-0.800E-01	-0.130E-02	0.575E-01	-0.118E-01	
	(-2.639)***	(-0.380)	(1.962)**	(-0.614)	
ln *LCROPAC*	-0.273E-01	-0.377E-01	0.150E-01	0.254E-01	
	(-0.478)	(-0.587)	(0.275)	(0.709)	
ln *SEACOS*	0.288E-02	-0.461	0.527E-01	0.554E-02	
	(0.535E-01)	(-7.593)***	(1.011)	(0.163)	
ln *EDUC*	0.311	-1.059	1.096	-0.288	
	(1.558)*	(-4.730)***	(5.706)***	(-2.211)**	
ln *WEALTH*	0.552	0.526	0.496E-01	0.136	
	(3.667)***	(3.101)***	(0.341)	(1.385)*	
SEX	-0.819E-01	0.994	-0.540	0.104E-01	
	(-0.321)	(3.461)***	(-2.186)**	(0.649E-01)	
ln *FAROR*	0.326	0.868	-0.285E-01	0.597	
	(2.863)***	(6.784)***	(-0.260)	(7.711)***	
SELFHG	0.202	0.329	-0.346E-01	-0.144E-01	
	(1.387)*	(2.005)**	(-0.246)	(-0.159)	
ln *SHH*	-0.525	0.402	-0.482	-0.619	
	(-2.675)***	(1.828)**	(-2.554)***	(-4.889)***	
ln *FARMCA*	-0.554	0.117	0.542E-01	-0.793	
	(-5.159)***	(0.974)	(0.529)	(-9.033)***	
ln *INC*	0.554	0.814	0.133	0.540	
	(6.484)***	(8.498)***	(1.621)*	(9.478)***	
ln *AGE*	1.178	-1.362	1.057	-0.161	
	(3.704)***	(-3.831)***	(3.455)***	(-.803)	
ln *ACESCOS*	-0.567	-0.960	-0.157E-01	0.395E-02	
	(-2.664)***	(-4.009)***	(-0.766)	(0.294E-01)	
ERODE	-0.352	-0.935	-0.401	0.245E-01	
	(-2.470)***	(-5.821)***	(-2.908)***	(0.273)	
ln *TERACE*					-0.231E-03
					(-0.786E-02)
ln *LAB*					1.056
					(6.791)***
ln *FERT*					0.596E-01
					(1.053)
ln *MAN*					0.206E-01
					(0.868)
IMR	3.402	3.364	1.704		
	(30.25)***	(31.76)***	(15.35)***		
(*CONSTANT*)	-3.926	1.895	-6.433	-2.366	4.490
	(-1.728)**	(0.744)	(-2.947)***	(-1.640)*	(5.869)***
N	148	148	148	148	148

* significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01

Figures in parentheses are t-statistics that the probabilities of respective coefficients are zero

Source: Field Survey 2000

Tenure regime or system has a direct and a positive effect on soil conservation investments. Tenure also positively influences the use of fertilizer. This implies that as tenurial arrangements improve, so does fertilizer use increases. Perceived security of tenure is important in investing in soil conservation measures because of sunken costs, both in physical infrastructure (terraces, ditches) and in knowledge acquisition. Without such rights, the 'tragedy of the commons' is a distinct possibility as farmers may not be able to reap the full benefits[54]. With security of tenure, incentive for terrace construction increases because farmers are able to realize or recoup the benefits of terracing that flow or occur over time. Pagiola (1994) finds that in Kitui and Machakos, it takes about 48 years for a farmer to beak-even once soil conservation structures are constructed. With such a time horizon, it would make sense for farmers to participate in terrace construction if they are assured of ownership of the land for at least 48 years. In addition, due to the bequest motives of many African farmers, secure tenure ensures that such goals are realized. Furthermore, if land tenure is less than secure, a farmer faces lower expected returns from soil conservation because of the probability of being evicted before realizing all the benefits. Land titling and other mechanisms of increasing security of access to land are thus important for soil conservation investments, which have a large sunk cost dimensions, both as an investment in labour and capital and in knowledge acquisition (De la briere, 1999). Tenure reflects what Feder et al. (1985) term degree of "confidence in the long term". Tenure status also influence risk behaviour. We expect farmers to make fewer longer-term land improvements such as terraces on holdings that are rented in. These holdings have short-term use rights, and as such make long-term investments at risk of reappropriation by the owner (Place and Hazell, 1993; Migot-Adhola et al, 1990).

Studies in the past have shown that traditional tenure regimes are not a hindrance to farm investments in Sub-Saharan Africa (Bruce & Migot Adhola, 1994). However, with the rapid flux (i.e., movement of people) and rapid economic growth, tenure security is increasingly becoming important. We are of the view that in the past, since people were more sedentary, village level institutions could easily ensure security of individual properties. But as people

---

[54] This can be depicted as a *Prisoner's Dilemma game*, in which it is a dominant strategy for each farmer not to invest in terraces, because the private benefits do not outweigh the social cost. However, if farmers interact in a repeated Prisoner's Dilemma game, it has been shown that cooperation is sometimes possible, implying that other forms of institutions than property rights can be developed which limit soil mining to socially acceptable levels (Balland and Platteau, 1996). Nevertheless, this does not reduce the need for improved tenure security in order

migrate and become mobile, such structures are no longer adequate. The traditional institutions are also not able to adjust tenures to accommodate population growth, changing technology and fluctuating market conditions (Dasgupta and Maler, 1997). Thus formal institutions at the country level become crucial. As Tiffen et al (1996) argue, secure land tenure is important to farmers' willingness to invest in land improvement, most particularly in long term measures such as soil and water conservation. Investments in soil conservation measures can only be undertaken when sufficient returns are expected or guaranteed. This is possible with secure tenure especially with soil conservation that has long gestation period. Hence the crucial role of tenure security in resource management and conservation (Hayes et al, 1997; Readon and Vosti, 1992; Nowak, 1987). Thus strong property rights are necessary to provide the incentives to terrace.

Location is negative and significant. It is also significant indirectly through fertiliser use. There appears to be some locational related factors that favour Machakos with regard to fertiliser use. This is likely to be linked to the proximity to Nairobi, which makes fertilizers cheap, and diffusion of knowledge much higher compared to Kitui district. The results also show that Machakos has significantly higher level of soil conservation investments compared to Kitui. This reflects a greater propensity for Machakos farmers to undertake investments to prevent soil erosion and conserve moisture. This may have to do with learning and copying social dimensions. In Machakos, some of this learning was in the form of an exogenous shock (Tiffen et al. 1994). In the 1940's, the colonial authorities organized compulsory terracing programs, led by chiefs, government officials or those whom the government regarded as elders. Most likely, these activities generated new information about the effectiveness of terracing for soil conservation. These activities are likely to have had more impact in Machakos district compared to Kitui due to higher population density and proximity to Nairobi and to the Kenya highlands[55]. Other exogenous learning shocks were World War I and II, with Akamba soldiers returning home with new ideas from other countries. However, this affected both districts. Terrace construction also started much earlier in Machakos compared to Kitui, in which case there was enough time for diffusion to spread the technology to other farmers. This is probably related to ALDEV programme by the colonial

---

for farmers to internalise their benefits.

[55] Some areas of the then Machakos District were part of the "White Highlands" and thus the District received more attention.

government to improve agriculture in the 'African reserves'. Data for this study shows terrace construction started in Machakos in the 1950's and in Kitui in the late 1960's[56].

The differential intensity of conservation may also simply be due to the conservation ethics of farmers or just being closer to Nairobi, to which Machakos District is. Dietz (2000) posit two causal mechanisms for the latter. First, there is the distance-related transport costs, for which products (and hence agricultural income to be used for investment) or for labour (and hence remittances that can be used for investments). Secondly, it could mean that urban political or cultural influences (state projects, NGO activities, church influence) have more impact. However, the village profiles show that the actual 'density' of projects is rather low. Although there are numerous NGOs in Kenya, their village-level representation is generally low. What matters is the overlap of networks between representatives of these state and non-state institutions on the one hand and villagers on the other. Many villagers do have profitable contacts with often well-educated ex-villagers in influential positions elsewhere. It seems that nowadays the linkages with the cultural elite (church leaders in particular) are as important as linkages with the political or administrative elite. Moral leadership extends to 'good farmership' and a premium on church-mediated social cohesion. Dietz (2000) farther suggests that in the adoption of innovations in sustainable land use, it is probably wise to go beyond a technical 'diffusion of innovation' approach and accept that it is more about 'diffusion of lifestyles' and 'moral codes of conduct'. If cultural leaders accept certain practices and if their leadership is acknowledged by many people in a village, the chances of follow up can be expected to be high.

Distance to crop fields has a negative and significant direct effect on soil conservation investments. As argued in chapter four, more distant parcels of land are difficult to supervise, control and monitor. Moreover, such parcels face high effective input costs at all levels of input use. Thus it is theoretically plausible for a rational farmer when faced with high input costs, ceteris paribus, to respond by lowering input use at all levels for distant parcels of

[56] Until about the 1970 it was a trickle of new terraces in a few villages. This changed in 1970-72 especially in Machakos. After the 1973/76 drought, a major wave followed in 1976-78, now also in Kitui. This boost of activity preceded the big foreign-funded integrated development programmes, which started in Machakos in 1978 (Machakos Integrated Development Programme; EEC-funded), and in Kitui in 1981 (USAID- funded ASAL programme, but without a lot of activity on the ground). The soil conservation departments in both Machakos and Kitui probably played a considerable role in the late 1970s. Another period of major investments was probably triggered by the 1984 drought. It was at its peak in 1988.

land[57]. The same applies to soil conservation, which requires mainly labour input. Even indirectly, soil conservation investments reduce when other complementary inputs used in the production process are reduced. Farmers go to some of the parcels of land often at critical times, when labour demand is high; which is costly in terms of labour time foregone. Even during the low labour demand periods, there is often direct competition with leisure resulting into health problems. Moreover, farmers fear theft and pilferage of produce from parcels of land farther away, which is another form of transaction costs, hence less investments. Strategies[58] to control theft and pilferage such as having workers or some family members stationed there until the harvest is brought home besides fencing are clearly costly. Workers require supervision thus entailing higher costs. These costs are likely to be higher the farther the parcels are from the homestead.

Discussions with extension officers point out that parcels of land closer to the homestead are better managed. These parcels of land are also likely to have been acquired much earlier (our study shows that this is indeed the case). This is because one has to settle first before thinking of expanding or acquiring other parcels of land. Resources are likewise concentrated first in the parcel of land where the homestead is. One then can acquire other parcels of land possibly after exhausting most of the production opportunities available through intensification. It is also more expensive on a per unit basis for any input applied on far off parcels of land and also more costly relatively to manage such land. Another compelling factor is social recognition or prestige linked with being a "good" farmer. In most cases, farmers are associated with the land closer to the homestead or if the homestead is in a farm, the land on which the homestead is. Consequently, land closer to the homestead has high input application and also high terracing density so as to derive social satisfaction besides other objectives. Indirectly, the effect of distance to the crop fields is also negative but weak through labour and manure use. However, with fertiliser use, the results are surprising as the correlation is positive and significant. But as Grabowski (1990)[59] argues, plot scattering or dispersion takes advantage of micro-climate variations, and reduce the possibilities that a farmer's full range of crops will be lost to pests or weather problems. This suggests that

---

[57] Although donkeys can greatly reduce the effect of distance to crop fields, their availability is limited as only about 18.3% of the households have donkeys.

[58] Traditional witchcraft (kathitu) is sometimes used to instil fear to "would be" thieves. However, this is only to supplement labour that act as watchmen.

[59] About 93% of the farmers acknowledged that it is better to have land in various places so that when crops fail

sometimes risk considerations may conflict with a rational response to increased distance to the crop fields. Some studies view fertilizer use in a high-risk environment (semi-arid areas) basically as a risk-reducing device (van den Berg, 2002; Antle and Crissman, 1990). Besides, chemical inputs such as fertilizer are easier to transport compared to manure, which are bulky. Hence the positive sign of distance to crop fields with fertilizer use.

Lagged crop income generally has very weak effects both directly and indirectly on soil conservation investments. We expected powerful direct and indirect effects of the feed back mechanism emanating from crop income to soil conservation investments. A negative lagged crop output is likely to be due to a yield penalty (Shiferaw & Holden, 2001; Pagiola, 1994). Terracing structures take space, implying that further terracing can only occur under reduced yields. The extra productivity due to terracing cannot meet the yield short fall created by reduced effective planting area[60]. Besides, constructing terraces often moves the earth in ways that bring unproductive soil to the surface. In addition, the lagged crop income data was from the period of the Elnino rains in Kenya when harvest was abundant. As a result of the heavy rains, a number of terraces were destroyed which necessitated repair.

Search costs do not have significant direct effects on soil conservation. These are costs to finding a buyer of farm output. We assume these search costs are of a similar magnitude to those of searching for sellers of inputs like manure. This is because in both cases, it is an issue of information costs. The lack of significance may arise from the fact that search costs are lump-some and can be reduced over time. As time goes by, farmers are able to establish contacts or networks with buyers. It is also plausible that traders are within reach and are locals in which case search costs are very low. It is the indirect effect through manure use that is strong (significant at 1%). Manure can be sourced from neighbours and sometimes all the way from Kajiado district. Thus the higher the search costs, the lower the use of manure at the household level. Moreover, there is a strong relationship between search costs and transport costs (Pearson correlation coefficient is 0.222 significant at 0.01 level). Thus it appears to be more of transport costs rather than search costs as the causative factor. However, for labour and fertilizer, the effects are weak. As argued earlier, labour consists mostly of family labour, while the rest is hired from nearby, rendering search costs for labour

in one place, one has at least some harvest.

insignificant. As for fertilizer, farmers often buy from local well known stockists.

Education of heads of households is equally important. Direct influence on soil conservation investments is positive and significant. Education, which is a proxy for information flow, may overcome many characteristics of farmers that act as obstacles to soil conservation such as unreceptiveness to new ideas, fear of change and lack of incentives. The indirect effect is also strong through manure, fertiliser and labour use. Manure use is often associated with the less educated. Thus the coefficient for education level of principle household member is negative and significant. The implication is that those heads of households with little education tend to have less income. As a result, they use more of manure, which is relatively cheap. Moreover, it is logical that the lower the education level, the less the level of awareness about fertilisers and possibly only more knowledge of manure which is locally available. The results also show that fertiliser use is significantly influenced by education level of principle household member. Education leads to better resource allocation and is a form of human capital (Shultz, 1964; Pudasiani, 1983; Welch, 1978 and; Idachaba, 1994), besides improving the farmer's management capabilities (Gould et al, 1989). Other studies have also found a positive association between education and adoption of conservation technology (Earle et al, 1979; Ervin and Ervin, 1982). Thus a sufficient level of education increases the intensity of soil conservation. In addition to the capital returns generated by education it also results in a positive externality by increasing participation in social activities. Lall et al, (2002) find that if a household head has high school education level, his or her probability of participation is increased by nearly 6%. Education is a variable that is within the control of policy maker. Efforts can thus be made to improve the education standards of farmers, possibly through the extension service and through local non-governmental organizations. Training of adopters may need to go beyond simple information for the adoption of new practices, to include training in farm management to run a successful farm operation using the more complex soil conservation practices.

Wealth is positive and significant directly. The indirect effect is also significant through manure and labour use. With fertilizer, the sign is as expected although not significant. Our considered inference is that wealth is conspicuous for there is prestige in having well laid

[60] Thus adoption of any conservation technique is often costly indirectly in production foregone.

down terraces, as it is what constitutes "a good farmer". Thus, wealth is likely to influence soil conservation through prestige or attitude. The results also point out to financial constraint due to imperfect credit markets (Shiferaw and Holden, 1996; Pender and Kerr, 1996). When credit markets are imperfect which is the norm in Kenya, wealth may ease investment cash constraints, reduce the rate of time preference and also provide a sense of security (lower risk) to the household, which may enhance adoption of conservation and the increased use of manure, fertilizer and labour. Wealthier households may have greater access to capital and thus increasing soil conservation investments. We thus infer that efforts to slow or arrest soil degradation through adoption of soil conservation techniques can be costly, either directly in terms of investment requirements or indirectly in terms of forgone production. There is also a possibility that it is easy for a wealthy person to attract, hire and retain labour. Also due to familiar life income insecurity, people may stick to a wealthy person as security during famines and as a sure way of meeting school fees and other financial obligations such as medical bills. The converse is true that missing or imperfect credit markets, cause particularly poor households to be rationed out of credit markets and may contribute to high discount rates (Holden et al., 1998).

The level of one's assets (wealth) also affects the degree to which one discounts possible future gains. Those who posses a higher quantity and quality of endowments will place a higher future value on the medium and long-term benefits produced by investment technologies. This is because they are less constrained by food insecurity and risks, which undermine the ability to meet basic needs as compared to low-wealth households. Poverty therefore may lead to high rates of time preferences and inability to forgo immediate consumption to improve the future productivity of environmental resources (Holden et al., 1998). Moreover, the poor depend more on annual crops, which typically degrade soils more than other crops. They also lack sufficient assets to undertake the land husbandry and investment necessary to maintain or increase productivity (Malik, 1998). Social structures and power distribution furthermore bias technologies and the flow of technical information in favour of the wealthy, thus shaping adoption outcomes (Grabowski, 1990). Moreover, even the extension service has often favoured the wealthy (Knox et al, 2002).

With sex of the principle household member, we find that it is only positive and significant on manure use. The variable also has a negative effect on fertiliser use. All other effects, whether directly or not, are weak. We are of the view that men are physically strong, hence are able to source and apply more manure, which is often bulky and cumbersome. Moreover, women have extra burdens of home and childcare they face especially when they have to fend for their households single-handedly. Besides, discussions with extension staff reveal that women do not own livestock from which a substantial proportion of manure used is sourced. With fertiliser use, however, it is the female-headed households who use more. This suggests that women are more concerned of household welfare and would make efforts to achieve this goal. One way is to apply more fertilizer on their farms that will lead to increased output. Moreover, fertilizer is easier to transport since it is not bulky. Descriptive analyses show that female-headed households have lower search costs and higher degree of farm orientation. Thus the apparent anomaly may be explained by lower search costs and a higher degree of farm orientation. It is also possible that women are reached more by traders and extension agents. However, Bird-David et al, (1998) argue that female-headed households tend to enjoy a broader basis of labour division and contribution of resources by members of the household. They also have greater degree of control over the household resources and feel a greater degree of security. In addition, the authors argue that there are no significant differences in the extent to which extension agents visited different household types. Nevertheless, in discussions with extension staff, it emerged that women are exposed to extension services more than men. This is because they are often members of women groups. Men groups are rare. Yet, groups are the entry points of extension service. The extension service in Kenya more often uses groups to pass extension messages. Usually, extension staff participate in barazzas[61], which have been called by the provincial administration. Most of the people who attend are women. Women are also better managers in terms of land husbandry and also better in terms of listening to extension messages. Thus they are likely to have a higher uptake of extension messages. Women are also keen to learn and in making use of the knowledge gained.

The degree of farm orientation[62] is positive and significant both directly and indirectly. It is only with fertilizer use that this effect is negative although not significant. We can infer that if income from the farm is the predominant source of household income, there will be more efforts made to either maintain or improve this source of income. Hence the drive to invest in

[61] These are public meetings usually called by the provincial administration

soil conservation measures in expectation of better incomes. Expectations about future income and household welfare depend on the farmer's planning horizon and discount rate (Solow, 1974). It is believed that in developing countries, the rate of discount rate is high and the length of planning period is short (Dasgupta and Pearce, 1984; Markadya and Pearce, 1988). If farmers expect net returns without conservation to be higher than those with conservation, they are likely to postpone adoption of conservation practices. Similarly, if the effects of degradation are perceived unlikely in the future, adoption of soil conservation technology will remain correspondingly unlikely. The negative effect of degree of farm orientation with fertilizer use suggests two things. First, the presence of imperfect credit[63] markets; and secondly, that it is off-farm income that encourages fertilizer use. As Pender and Kerr (1996) argue, a negative coefficient of the share of income earned from farming (which suggests that off-farm income has a positive effect on fertilizer use) is due to financial constraints. The degree of farm orientation also gives an indication of allocation of resources within the household. If capital investments can be replaced by family (or wage) labour, low levels of capital investment may pose no obstacle to accumulation.

We also find that membership to self-help groups is important with transaction costs to the main district market outlet. These groups are based on the principle of reciprocity and are helpful when the option of hiring in labour is limited by liquidity constraints especially when farmers cannot borrow against their future income (Oostendorp, 1998). As Lindgren (1988) argues, most of the terraces have been built by the farmers themselves or by self-help groups. The direct effect of self-help group is positive and significant besides the indirect effect through manure use. Membership in self-help group is a form of social capital and is quite instrumental in the reduction of transaction costs especially with information acquisition. Moreover, it is a form of peer pressure bearing on the farmer making him see the need to terrace in order to gain acceptability in the society. Manure is often bulky and hence its use is positively correlated with social capital. Self-help groups are non-market institutions and are more appropriate if adoption of better technologies has certain fixed costs, which can be met through group labour inputs. The cost of time spent organizing and participating in collective action decrease if wages fall or a given number of people live together. In addition, there is less tendency to shirk due to other benefits of social capital such as risk sharing and pooling.

---

[62] Fraction of farm income in the total household income.

By serving as a risk sharing device, Knox et al (2002) argue that collective action can alleviate food insecurity and other survival risks borne disproportionately by the poor to lower the degree of future discounting and therefore positively influence technology adoption. Thus societies with high social capital are likely to sustain high investments in sustainable farming. Descriptive statistics show that households that do not have members who participate in self-help group activities have lower crop output, lower household incomes and higher search costs. This confirms the importance of self-help groups as being critical to information flow or help reduce significant information gaps, thus reducing transaction costs linked to sourcing for relevant information. The same households also have farms that are relatively flat.

Household size[64] also has a strong negative direct effect on soil conservation investments. The indirect effect is strong also through manure, fertiliser and labour usage. It seems therefore, that large household size discourages the investment in soil fertility maintenance. If some of the adults are not active in farming but instead are engaged in other occupations, then this variable may not be a useful measure of labour availability. However, with manure use, the sign is positive. Manure is often bulky and thus more labour effort is expended in its transportation and eventual application on the farms, hence its positive sign. We are of the view that a large household size[65] implies higher consumer-worker ratio[66], which further implies high dependency ratio. This suggests that the constraints imposed on the household by having more dependents materially affect labour availability. The negative relationship between terracing and household size suggests that in large families, resources may be shifted towards maintaining the family rather than improving the farm. There is thus a drag on household asset position in order to meet consumption requirements and also payment of school fees[67] and medical bills; hence the apparent negative sign of household size with soil conservation, fertilizer and labour. Moreover, the necessity to support a large family may shorten the planning horizon of the poor and hence discourage soil conservation (Shiferaw and Holden, 1996). Household size also is a proxy for labour endowment, which is useful for

[63] Even though merry-go-rounds are an important source of investments funds, they are hardly sufficient.
[64] Attempts were made to use the number of adults but the results were not encouraging.
[65] The sample data shows that as the household size increases, the number of children also increases (Bivariate correlation between household size and number of children is 0.628, which is significant at 0.01 level).
[66] An increase in the consumer-worker ratio reduces the ability of households to meet subsistence needs especially where land pressure is high (Holden, 1991) and may subsequently lead to a reduction in terracing density.
[67] About 66.3% of the sampled farmers said they would rather spend money on education of their children than on soil conservation. Thus low terracing levels maybe as a result of lack of money due to payment of school fees.

both terracing and crop production. This ought to have a positive effect. The inference is that with household size, there are two effects occurring at the same time but in different directions: consumption requirements, which is negative; and the labour endowment, which is positive. The net effect depends on the relative magnitude of these forces and for our case; the former appears to be stronger. Pender and Kerr (1996), however, offer a different explanation, that a negative labour endowment with investment occurs when the coefficient for absolute risk aversion in the present period is less than that of the future period.

On one hand the results could be interpreted, at least superficially, as a case in which the contribution of household size in soil conservation may be undermined by the cost of supporting the family[68]. On the other hand, the result could indicate circumstances in which labour is preferred to soil conservation. Some of the perceived need to undertake soil improvements may be lessened by the availability of family labour. This hypothesis is consistent with the notion that farmers with insecure property rights may be more willing to substitute labour for soil capital.

A question always remains of whether results are contaminated by unobserved factors such as knowledge, effort and management that differ with households even in the same village. However, Pender and Kerr (1996) argue, the impact of many variables is conditioned by the nature of factor markets, the extent of complementarics between those variables and other productive inputs, and the nature of preferences of households. Variables that have no effect on investment if factor markets are functioning costlessly and perfectly can have complicated effects if those markets do not function perfectly.

Farm size per capita is negative and significant. This is an indication of land scarcity as well as population pressure. We thus infer that land scarcity significantly increases terracing intensity. This is especially true when the household derives its sustenance or livelihoods from the land. The implication is that farmers, when confronted with declines in production and enjoying no access to alternative agricultural land or migratory networks, may be forced to increase terracing intensity. The goal is to increase land productivity, which can be achieved through increased terracing and labour use on crop production. It is also logically

[68] A possible causal effect through lower educational levels and household income is not supported by data.

possible that those with large parcels of land have opportunities for crop rotation and leaving the land fallow instead of using costly soil conservation techniques. Moreover, such farmers are under less "livelihood pressure" to husband their land. The indirect effect is strong through labour use.

We also find that household income[69] has a positive and significant direct effect on soil conservation investments. This finding is consistent with other studies in the past (Norris and Batie, 1987 and Sinden and King, 1988). The indirect effect is also strong through manure, fertilizer, and labour use. The significance of household income in input use such as manure, fertilizer and labour suggests the existence of imperfect credit markets (Pender and Kerr, 1996). Moreover, even where the credit market is functioning but underdeveloped, Reardon and Vosti (1992) contend that the least likely investments to receive credit are land conservation measures. The results also show that terrace construction is an expensive undertaking. Higher income enables farmers to purchase materials and equipment for soil conservation or hire labour. A further explanation is that there is a greater willingness to take risks with increasing income levels (Binswanger, 1982; Antle, 1987, 1989; Myers, 1989) and thus higher soil conservation investments. Besides, risk is closely related to other factors such as wealth and education (Norris and Batie (1987). It is also plausible that farmers with high incomes may have lower discount rates and hence make higher long term investments (Featherstone and Goodwin, 1993).

Age of principle household member is another important factor in soil conservation investments. The direct effect is positive and significant. Indirectly, it is strong through manure and fertiliser use. The effect through manure is negative. It seems that households with older heads use less manure than those who are younger. It is argued that older people have accumulated wealth in most cases and thus tend to use fertilisers more. Further, older people are less strong physically implying less use of manure, which is often bulky. The fact that age strongly correlates with soil conservation investments possibly shows that terracing is a very expensive undertaking. The argument advanced is that older people have more farming experience[70] and also have accumulated more wealth (Nyang, 1999) and thus able to

[69] We tried to use expenditure as a proxy for household incomes but the results were not satisfactory. Despite the difficulties of getting accurate household income figures, efforts were made to reduce envisaged errors.
[70] This suggests that farmers have to learn about the effects of a new technology before adopting it entirely. This

finance terrace construction and fertilizer use. A bivariate correlation of age of principle household member and number of rooms (a proxy for wealth) shows that it is positive (0.208) and significant at 0.01 level. But where land markets are absent and poverty is rampant, age raises the time preference (i.e. high discount rate) of the poor, which may lower the desire for further conservation (Shiferaw and Holden, 1998).

The erosion status of the farms (*ERODE*) is negative and significant directly on soil conservation investments. This suggests that farms that have been eroded are likely to have lower terracing levels. As far as farmers are concerned, the priority is terracing farms where returns (pay-offs) are higher, which is often on farms that have not been eroded and are fertile. Indirectly, the variable (*ERODE*) is also strong through manure and fertilizer usage. The results also suggest the interaction between soil conservation investments (terraces) and ordinary input usage. Farms that are eroded are often the ones with no terraces constructed. Then it shows that farmers with such fields use less manure and fertiliser, leading to a much lower incentive to terrace due to behavioural feed back effects. Where soil conservation investments have been made, there is less erosion or loss due to runoff and thus more effective use of inputs. Moreover, there is a relationship between land conservation investments on one hand, and the use of organic and chemical inputs on the other. Again, the former guards against run-off, thereby enhancing the effectiveness of the latter. Finally, there is a relationship between organic input use and chemical input use: agronomic recommendations are for the two to be used together. Descriptive statistics also show that households that have parcels showing evidence of soil erosion (eroded) have higher search costs, higher crop output and higher household incomes. This suggests that these farmers are concerned about immediate benefits. As the time path of soil conservation shows, degrading the soils is more profitable in the short run than the conservation path, but after some point, the benefits start declining rapidly as further soil loss brings significant changes in crop yields. The results also have a bearing on the time preference of the farmers. Perhaps due to large initial expenses to be incurred, farmers would rather invest first in areas where the returns are quicker and much higher; which are fields that are relatively less eroded. As for fields that have gullies, or with clear evidence of erosion, it takes relatively long time to restore their productivity assuming terracing takes place.

---

is important if risks of the new technology are unknown and hence the need for knowing its risk profile. About

Eroded fields also indicate the priorities of farmers. If they could sell land to invest in education of children in the expectations of better returns and security during their old age, why then wouldn't a farmer then sell land in order to invest in improved productivity of his farm? It may possibly be that returns from terracing are not high or rather not secure and thus cannot be dependent upon. In addition, by having parcels of land that are eroded, farmers have already internalised this within their decision making process. They may thus see no need of farther wastage of scarce financial resources.

The direct effect of transaction costs (access costs) on soil conservation investments is negative and significant, illustrating the disincentives of transaction costs. Indirectly, the strong effect is through manure use. Since we do not have a purely subsistence production nowadays, farmers do invest with an objective of meeting household consumption requirements and for sale to obtain money to meet some household expenditure requirements. Higher transaction costs to the market implies lower returns to crop production because farmers are price takers. Farmers thus form expectations about future returns to produce sales. This has an effect of creating disincentives to soil conservation investments, which is an input to the crop production process. Thus the higher the transaction costs faced, the lower the expected returns and consequently, lower investments in soil conservation. Besides, this is also likely to be an issue of enterprise selection versus food security. Farmers tend to select enterprises that minimize food insecurity and this happens to be low-priced commodities whereby the net-returns for a profit maximizer appear ridiculous. Besides, about 76.8% of the sampled households said that it was better to have a greater portion of land under food crops than to cash crops[71] because the prices for cash crops fluctuate too much. This is because market transaction costs such as transport and handling charges and time spent traveling to and from markets create divergences between market and farm gate prices leading to imperfect substitutability between domestic and market supplies of food. If, as Fafchamps (1992) argues, basic staples account for large shares in the total expenditures of rural households, then high transaction costs in food markets raise returns to food self-sufficiency. Further, the more cash constrained rural households are, the more likely they will seek to avoid market transactions by meeting significant portions of their food requirements from

73.1 % of the sampled farmers said that they try new things on small portions of land first to avoid large losses.

[71] Smallholder farmers in Kenya often choose to grow low-value food crops rather than significantly more profitable cash-crops (Argwings-Kodhek et al., 1990; Heyer and Waweru, 1976; Pagiola et al., 1990; Sellen et al.,

domestic production.

The inference is that farmers' behaviour is influenced by the expected profitability of any investment made. The returns of terrace construction are the crops grown after the investment has been undertaken. When the costs of access to the market are higher, the net returns to the farmers' decrease significantly thus reducing the incentive for further terracing. Prior to making any investments in soil conservation measures, it appears that farmers have a definite understanding of the transaction costs to the market. It implies that the decision to invest is arrived at after taking into account the transaction costs faced. This is one possible explanation why some farmers do not terrace their farms is that they face higher transaction costs, ceteris paribus, so that they do not realise a net benefit by terracing. That is, they face a threshold, which can only be surmounted at a cost that exceeds the net benefit realised by terracing.

The strong indirect negative effect of transaction costs through manure use suggests that manure is often not obtained from the farmer's farm. It implies that a lot of manure comes from either neighbours or from a place a distance away from the households. In some instances, manure is sourced from Kajiado district. Our main thesis is that negative influence of transaction costs on manure use will have a consequent low output in crop yields, which in turn will reduce further incentives for soil conservation investments through the feed back behavioural effects. The correlation with fertilizer though not significant has the expected sign. As with labour use, the correlation is unexpected (positive), though not significant. We are of the view that as a response to high transaction costs, farmers either use family labour or source labour nearby.

The above results on the effect of transaction costs (access costs) on soil conservation investments using 3SLS are also supported through the use of an agricultural household model. The base solution results are given in Table 5.2 below.

We generally note a number of salient points with the results. First, that transaction costs indeed reduce soil conservation investments. Clear differences between household types are

---

1990; Winter-Nelson et al., 1990).

registered. The difference between households type 1 and type 2 is the distance from the market and so are transport costs. All other factors are the same. We observe that terrace length (totals) decrease from 1268.3 metres per hectare to 709.5 metres per hectare. This is a substantial reduction (about 44.1%). We also observe another reduction between households' types 5 and 6 (about 42.8%). Household types 3 and 4 on one hand, and 7 and 8 on the other hand are meant to show the importance of resource endowments. Thus the trade-off between household consumption, production and investment are conditioned by asset endowments. These households do not have oxen in their farming systems. Comparisons of household 5 and 7, which differ only in terms of oxen, show that soil conservation investments drop from 323.9 metres to 311.0 metres per hectare (about 4 %). There is also a drop between household 2 and household 4 (38.7%), between households 6 and 8 (27.2%) and between household types 1 and 3 (15.7%). The general reduction comes about for a number of reasons. Oxen reduce labour requirements, and thereby increasing household labour available for terrace construction. Secondly, a household can hire out oxen to neighbours within the same village or neighbouring village and thus get some draught revenue, which can be used to finance terracing activities. Poverty and subsistence requirements may thus limit the ability to invest in conservation of the soil resource base.

Table 5.2: The impact of transaction costs on household soil conservation investments (terracing in metres per hectare) in Machakos and Kitui Districts, Kenya, 2000

Household Type	Land	Labour	Oxen	Distance to market	Farm size per capita	Terraces
H1	2	5	2	0	0.4	1268.3
H2	2	5	2	50	0.4	709.5
H3	2	5	0	0	0.4	1068.5
H4	2	5	0	50	0.4	434.8
H5	10	7	2	0	1.4	323.9
H6	10	7	2	50	1.4	185.4
H7	10	7	0	0	1.4	311.0
H8	10	7	0	50	1.4	135.0

Source: Author's computation

Household types 1 to 4 have a farm size per capita of 0.4 while household types 5 to 8 have a farm size per capita of 1.25. We generally note that the higher the land scarcity (0.4 for households 1 to 4) the higher the terrace construction. Households with more land per capita (1.4 for households 5 to 8) have lower terrace construction. The more land available, the more the opportunities for crop rotations and more importantly, land can be kept fallow to regain its fertility.

A higher level of land scarcity also implies a high population pressure. The results thus show that under high population pressure, land becomes dearer relative to labour, which induces conservation investments especially when conservation technologies do not take land out of production. This is in line with Boserup (1965) in which intensification of land use and investments to enhance its productivity will be limited when land is more abundant relative to labour. This suggests that smaller families with large farms will have lower incentives to increase intensity of labour and other inputs per unit of land to enhance productivity. Shortage of labour relative to land also means that the labour-scarce household may have to hire labour to construct the labour-intensive soil conservation investments (terraces). The cumulative effect of scarcity of labour and land abundance is lower soil conservation efforts.

To obtain the direction of change as a result of policy simulations, we calculate response multipliers, which are defined as the percentage change in an indicator variable as the result of a discrete change in a policy variable or parameter. The absolute value of change or the rhythm gives an indication of the effectiveness of change. It is especially relevant when the implementation of policy measures is costly either for the implementing agencies in terms of direct costs or for all the stakeholders in terms of opportunity costs.

In Table 5.3 below, the results of an experimental simulation of a 10% reduction in transaction costs on soil conservation investments (i.e. terraces) are presented. There is a general increase in the length of terraces constructed per hectare. Comparison of household types across shows indeed that it is the case with the exception of household type 2. The percentage changes are shown in Table 5.3.

Table 5.3: Simulation results of a 10% reduction in transaction costs on household soil conservation investments (terracing in metres per hectare) in Machakos and Kitui District, Kenya

Household Type	Land	Labour	Oxen	Distance to market	Farm size per capita	Terraces	% Δs
H1	2	5	2	0	0.4	1301.4	2.6
H2	2	5	2	50	0.4	665.4	-6.2
H3	2	5	0	0	0.4	1068.6	0.01
H4	2	5	0	50	0.4	442.0	1.7
H5	10	7	2	0	1.4	324.0	0.03
H6	10	7	2	50	1.4	187.0	0.9
H7	10	7	0	0	1.4	311.4	0.13
H8	10	7	0	50	1.4	135.2	0.15

Figures in parentheses are response multipliers indicating percentage change compared to the base run
Source: Author's computation

Some of the percentage changes though generally positive and as theoretically expected are very marginal. However, as Bade et al (1997) argue, the direction of change is more important than the absolute value of change. With household type 2, reduction in transaction costs actually reduces soil conservation investments. The apparent contradiction with economic theory perhaps, is due to the concept of a backward bending supply curve. Another possible explanation could be that under high population pressure or land scarcity coupled with high transaction costs, as is the case with household type 2, farmers may be forced wholly to pursue subsistence objectives. Such farmers are likely to invest in soil conservation measures in order to improve land productivity in the absence of alternative opportunities such as out-migration and off-farm work. But with households that have oxen, labour drudgery is reduced and they can be hired out to obtain draught revenue. A reduction in transaction costs to the market may cause a sudden disequilibria and make farmers reduce terrace investments due to the existence of an alternative option (draught revenue), perhaps more viable comparatively, to meet subsistence objectives. Moreover, increasing soil conservation investments under population pressure has a yield penalty since the structures take some land, however little, from production.

Whether the results discussed above on the impact of transaction costs on soil conservation investments can be consistently replicated for specific crops is the subject of further empirical investigation (see Tables C1 and C2 in Appendix C). The results are basically similar with the exception of distance to crop fields, wealth, household size, membership to self-help group, and age of principle household member. Distance to the fields for maize is generally negative but not significant. It is only the indirect effect through manure use, which is negative and significant. This contrasts with beans, which shows the same variable to be negative and significant directly and indirectly through manure usage. The result is plausible given that maize is the more dominant staple, rendering it the more likely focus of self-sufficiency (that is, food import substitution) in response to high transaction costs to the market. As a result, subsistence requirements outweigh high effective input costs considerations as distance from the homestead to the crop fields increase. As for beans, it is not a dominant staple, hence influenced by apparent costs of input usage. These costs increase as distance to the fields increase making farmers invest less in soil conservation measures on bean fields.

With wealth, we find that it is strong and positively correlated with soil conservation investments both directly and indirectly on maize crop. As argued earlier, wealth eases financial constraint and its significance suggests imperfect credit markets. Wealth has a tendency of reducing risk and is very much crucial especially in the presence of imperfect credit markets. It can easily be converted to a flow variable through selling livestock and other assets. With beans, wealth also has similar effects with the exception of fertilizer and labour use that have the expected sign (positive) although not significant. A possible explanation could be that wealth is often expended to meet subsistence needs and welfare of the households that are largely associated with maize.

With self-help group, it is negative and significant with labour use for maize crop, while for beans; it is negative and significant with manure use. Although self-help group is social capital, it is essentially a labour-exchange group. Perhaps the differential effect suggests that labour exchange groups put more emphasis on major staple food crops.

Household size has differential effects in the two crops. With maize, the direct effect is negative and significant. With beans, the variable is positive though not significant. It is difficult to discern why this is indeed the case. One possible explanation is that a large household size implies high subsistence requirements. Even though this ought to impact positively on soil conservation investments, it may have a negative impact because of the immediate household needs. We don't find this problem with beans, as it is not the major staple crop. Indirectly, household size under maize crop has a strong influence through labour usage (negative). As for beans, the effect is negative and significant for both fertilizer and labour usage. Often a large family size implies an increase in consumption requirements. Consequently, there is a drag on household income, which is diverted to meet consumption requirements leading to lower use of fertiliser.

Age of principle household member also has differential effects in the two crops. We observe that the direct effect on soil conservation is positive and significant on maize. With beans, the effect is weak though negative. As previously argued, age reflects farming experience and an accumulation of wealth. Thus, more emphasis on terracing most often on fields under food security crop. Indirectly, the general observation is that age has a negative effect on manure use and a positive effect on fertilizer use for the two crops. There is a connotation of farming experience and accumulation of wealth with age. As such, one is able to afford to buy fertiliser; which implies less use of manure.

Comparing between maize and beans, we find that transaction cost elasticities of beans are relatively more elastic compared to those of maize. This suggests that farmers attach food security perspective to maize. Hence the incentive to invest in soil conservation measures on maize fields even in the face of higher transaction costs. It also suggests that that even if transaction costs increase the accompanying reduction in soil conservation investments and input usage is far much less for maize. The vice-versa is true for beans. The results indicate that beans are considered more as a cash crop or that it is less a food security crop relatively to maize. The same applies for household size, slope, tenure and location. However, with wealth variable, the elasticities are higher for maize than for beans. We thus infer that wealth seems to be expended to improve the production of staple crops. This can fulfill an important social objective. It looks absurd if a rich man cannot be self-sufficient in food staples.

Summary

The results indicate that transaction costs both directly and indirectly reduce soil conservation investments. Despite the inconsistencies in some instances, the consensus generally is that transaction costs are indeed important and negatively influence terrace construction and the use of manure and fertiliser. Consequently, lower manure and fertiliser use leads to a reduction in soil conservation investments through behavioural negative feed back effect via crop output or yields. Our results also suggest the presence of imperfect markets in credit, land and labour. The results also show an increase in labor use although not significant. Perhaps this is farmers' response when faced with high transaction costs. The transaction costs results are corroborated by using an agricultural household model under differential resource endowments such as land size, family size and oxen. The implications of the high transaction costs for the possibilities to enhance more sustainable land use are thus evident.

Thus the results show optimism that indeed transaction costs have a negative impact on soil conservation investments both directly and indirectly. These results are also consistently replicated for specific crops such as maize and beans. Transaction costs may not necessarily differ between crops as most inputs are sourced from the same place or traders and even produce delivered to the same markets. Thus transaction costs are largely neutral between crops. The differences observed as to the effects of other variables between maize and beans, are largely attributed to the fact that maize is the dominant staple food crop.

5.2 Transaction costs and soil conservation incentives

The previous section has shown that there is some correlation between investments in soil conservation and factors such as transaction costs among others. In this section, monetary incentives for soil conservation for each farmer are thus obtained. These are the net present values of benefits of soil conservation and we are interested to see how individual farmers respond to these incentives as a function of transaction costs, farm characteristics and demographic factors. The major thrust is to understand much further the role of transaction costs in the soil conservation investment phenomena.

We first carried out some descriptive statistics with the benefits of soil conservation. We find that 34.4% of the sampled farmers[72] had negative benefits of soil conservation on maize crop. These results contrast sharply with those of past studies (Pagiola, 1994; Ekbom, 1992, 1995) that just carried out cost-benefit analysis and found that it was indeed positive. Perhaps this was because they focussed on a representative or model farmer that was far from reality. The farmers (in our study) that had positive benefits of soil conservation on maize crop were 65.6%. As for beans, 34% of sampled farmers had negative net soil conservation benefits,

[72] Total sample size of maize farmers was 125 while for beans the sample size was 47. The farmers are thus not necessarily the same in both cases. Even though maize and beans in most cases are intercropped, the emphasis was on the dominant crop in each parcel of land.

while 66% had positive net soil conservation benefits. Thus a significant proportion of farmers have negative soil conservation benefits. The results of cost benefit analysis by Shiferaw and Holden (2001) on work done in Ethiopia seem to lend credence to our results. However, our work is a step further for we are able to carry out some econometric analysis of the benefits as a function of household characteristics and transaction costs.

Tables D1 and D2 (Appendix D) show clearly some characteristics of these two groups of farmers (those that have negative benefits and those that have positive benefits). The difference in some characteristics between these two groups is significant. It is difficult to understand why some farmers have negative soil conservation benefits. It suggests that farmers terracing drives are sometimes influenced by social status rather than economic reasons. In addition, there are some other benefits of soil conservation that were not valued and included such as scenic beauty (intangible benefits). Their inclusion if possible might give a different picture.

We later carried out some t-tests on some of the characteristics of these two groups of farmers. We noted a number of peculiarities. There are no significant differences in slope, tenure, distance to the crop fields, household size, wealth, farm size per capita, age of head of household, transaction costs, size of maize fields, and fertilizer use. However, there is a higher and a significant use of manure and labor on fields of those farmers having negative benefits. In addition to that, their terrace length per hectare, search costs and household income are also significantly higher (see Table D3 Appendix D). This seems to suggest that negative soil conservation benefits are not an indication of rampant poverty among the population but rather perhaps non-economic inclined. We are also of the view that it is related to over investments and low value of production. It is likely that due to the fragile ecosystem, the preoccupation of conservation cannot be assessed solely on crop value. Intangible benefits such as scenic beauty, moisture conservation, and social status may need to be considered. This suggests that preferences of a community or group affect the preferences of individual farmers, in particular, if there are social norms as to what amounts to being a 'good farmer'. If deviation from this norm entails private costs to the farmer, for instance in the form of social sanctions, guilt feelings, low self-esteem or loss of prestige, over investment is plausible. We are also of the view that the farmer may never know his or her real costs considering that soil conservation investments are made over a number of years. In addition and more importantly, if costs of acquisition of food from the market are considered along with risks associated with its adequate availability, cash flow problems of farmers, and information flow problems, it is likely that all costs linked to import substitution are lower. This points out to the underdevelopment of the marketing system in Kenya. This suggests that the market or trading system cannot process adequately the quantities and qualities of commodities demanded in various markets. Further, this is a region prone to high levels of food insecurity implying that self-sufficiency may override other objectives given that agriculture is the mainstay of the economy. Agricultural incomes are very uncertain due to drought besides the market. Given this observation, it is not puzzling to find that some farmers have negative soil conservation benefits[73] on maize fields. Moreover, most people are poor who almost live from hand to mouth and with no "reserve" funds for tomorrow. Thus when transaction costs and risk considerations are incorporated into efficiency calculations, the livelihood strategies employed by the poor can be understood as economically rational.

On bean crop (Table D4 Appendix D), we observe that the two groups of farmers do not have significant differences in slope, search costs, household size, household income, size of bean fields, wealth, transaction costs, fertilizer use and education levels. However, significant differences are noted in labor and manure use[74], length of terraces per hectare, age of principle household members, bean yields, farm size per capita, tenure, and distance to crop fields. Farmers with positive net soil conservation benefits have higher levels of distance to crop fields, more tenure security, higher farm size per capita, are much older and have higher bean yields. They also have at the same time, lower use of manure and labor and lower terrace length levels. The emerging picture with beans is generally consistent with the exception of higher distance to crop fields. This once more suggests that though both maize and beans are food crops, with the former playing a dominant role.

Nevertheless, the existence of farmers with negative soil conservation benefits on bean fields

[73] Since terraces are expensive mechanical structures, planting high value crops is one way of increasing soil conservation benefits. However, for the case of marginal areas, prevailing food insecurity makes farmers to focus on maize and beans, which are low value crops. This rather explains the apparent negative benefits of soil conservation investments.

[74] Farmers in Machakos and Kitui districts use manure on beans. The much over emphasized nitrogen fixation is doubtful. This is because legumes use phosphorus to fix nitrogen. To enhance nitrogen fixation, phosphate fertilizers are applied. As a result, the balance or the net gain sometimes does not add much. Moreover, most of it

is still puzzling considering that beans do not constitute the predominant food crop. We are of the view that a number of factors are at play as farmers engage in soil conservation. There appears to be policy-induced distortions or market failure. This points towards the rather heavily emphasized government policy of self-sufficiency and food security[75]. Farmers may feel obligated to do anything that might further this objective whose end result is inefficiency. Moreover, coupled with poverty and risk objectives, farmers tend to realize sub-optimal outcomes.

Table D5 (Appendix D) shows the descriptive statistics for some selected variables for maize crop, while Table D6 (Appendix D), the descriptive statistics for bean crop. All these variables were represented in the econometric model. Most of the variables have low variability with the exception of distance to the crop fields and search costs. The high standard deviation is as a result of the wide variation between minimum and maximum sample values. This high variability will reduce the precision of the estimated coefficients.

Table 5.4 below shows the regression results of a Cobb-Douglas[76] type of a functional form for soil conservation benefits on bean fields. All the variables are in natural logs with the exception of the dummy variables. The most significant variables are slope and whether one is engaged in self-employment or not. Other variables such as tenure, age of principle household member, erosion status of the fields, and fertility of the fields were however significant under transaction costs to Nairobi (see Table D7 Appendix D).

First, we note that the coefficient for slope bears a positive sign. The implication is that as slope increases so are the benefits of soil conservation. This is because averted damages increase as slope increases. Unconserved farms on steeper slopes face higher rates of erosion. As a result, yields decline rapidly. Steeper slopes require closer spacing of terraces, hence higher construction and maintenance costs. This is because the optimal spacing of terraces is a function of slope. On lower slopes, the cost of terracing outweighs the relatively small benefits of avoiding a low rate of erosion. As slope increases, however, the damages caused

will be in the bean pods, which is often removed through harvesting.

[75] Recent evidence suggests that typical policy distortions in developing countries tend to encourage degradation (Panayotou, 1993).

[76] Other functional forms were tried but gave less significant fits. A function like Translog had many insignificant estimates due to multicollinearity introduced by the interaction terms.

by erosion increase faster than the cost of terracing, and conservation becomes increasingly profitable.

Table 5.4: Cobb-Douglas regression results of determinants of soil conservation benefits for beans in Machakos and Kitui Districts, Kenya, 2000

Variable	Coefficient	t-statistic
SLOPE	1.826	1.771*
TENURE	1.538	1.520
LOC	0.529	0.716
DISTH	0.145	0.932
SEACOS	0.311	1.269
SHH	-1.025	-1.487
INC	0.397	1.201
AGE	2.228	1.566
ACESCOS	-0.242	-0.223
ERODE	0.992	1.540
FERTIL	0.846	1.497
SELFEMP	-1.320	-2.082**
POSNEG	0.972	1.371
(CONSTANT)	-2.675	-0.397
R2	0.242	
N	47	

*significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01

Source: Estimates from field survey, 2000

Tenure, although not significant at 10%, is significant at 13.8 %. As Quisumbing et al, (2001) argue, land tenure rules affect the expected future benefits to those who invest in land improvement. The results show that as property rights improve, soil conservation benefits increase because of the long gestation period of the investments. Farmers are thus able to recoup their benefits with secure tenure. The length of time required to break even provides an important indicator of the likely severity of tenure insecurity. Farmers with insecure tenure may doubt that they will be able to enjoy the benefits of adopting conservation measures that will accrue in the distant future. As Pagiola (1994) argues, it takes 48 years to breakeven once soil conservation structures are constructed. A tenure regime that ensures uninterrupted and exclusive benefits of soil conservation for at least 48 years implies that it is secure. Further, there are the bequest motives of many farmers that can only be achieved through secure tenure. Tenure that lasts less than the expected repayment periods imply lower soil conservation benefits. In such a scenario, farmers are unlikely to undertake such investments. Conditions under which adoption of soil conservation practices is less profitable also have increasingly long repayment periods. Insecure tenure or uncertain tenure may also imply a high discount rate leading to low soil conservation benefits. The converse is true, that secure tenure strongly suggests a low discount rate leading to higher net soil conservation benefits. Another plausible explanation is offered by Besley (1995). The author argues that it is reasonable to postulate that work effort is critically affected by land tenure security, which influences the expected future benefits of soil conservation investments (for our case). Thus if one controls for quality of land, the difference in residual net benefits among different tenure regimes, if any, can be attributed to the incentive effects of land tenure institutions on work effort. Which implies a greater labour productivity both on soil conservation investments and crop production, with a consequent higher net soil conservation benefits. Tenure security also influences cultural attachment to the land as well as economic considerations (Besley, 1995).

Erosion status of the fields is positive but only significant at 13.3%. The implication is that marginal returns to soil conservation are higher on eroded fields than those that are not. This is because averted damages on eroded fields are higher. The results also show that age is an important variable. It is significant at 12.7%. As argued earlier, older people have more farming experience and have accumulated wealth. Moreover, it does also indicate that the older one is, the likelihood of recouping all the benefits of soil conservation. Further, this may be associated with strategic behaviour, where some farmers not wanting to incur costs of learning- by-doing would wait to acquire information from their neighbours. Thus, an older farmer may become more proficient with his technology as he accumulates information (Feder et al, 1985). These reasons coupled with bequeath motives of farmers tend to lower the discount rate therefore leading to higher net benefits of soil conservation investments.

Fertility is also another important factor, showing that returns to soil conservation are higher on fertile soils than those that are not. The variable is however significant at 14.4%. Fertile fields have less costs involved especially in fertilizer application and also that crop yields are likely to be higher. Therefore, the pay-offs of soil conservation are higher on fertile parcels of land. The dummy variable *POSNEG* shows that farmers with positive and negative soil conservation benefits are essentially different or have different characteristics. As has been shown by t-tests, farmers with negative soil conservation benefits use more inputs such as manure and fertilizer and yet their productivity is not significantly higher. This might be resulting from a drive by farmers to receive social approval and also to be food secure irrespective of the attendant costs. In fact, about 95% of the sampled farmers believe crop yields fall significantly if land is not terraced. Another dummy variable *SELFEMP* (whether involved in self-employment or not) is negative and significant. A possible explanation is that engaging in self-employment potentially competes (as a destination) for resources such as capital and labour with farming leading to lower crop yields with consequent lower soil conservation benefits.

We find that transaction costs, access costs (*ACESCOS*) are generally negative as expected although not significant. Transaction costs are reflected in lower returns to conservation to the extent that they affect the effective prices faced by farmers. This suggests that transaction costs to the market reduce incentives for soil conservation. As transaction costs increase, there is a dis-incentive to undertake soil conservation investments. The lack of significance may imply that farmers have copying strategies of reducing transaction costs so that eventually the effect may not be that substantial. Moreover, the supply and demand curves for staple crops are usually fairly inelastic due to cash needs of households and the absence of adequate storage facilities. But the fact that the sign is the expected one – negative - illustrates that transaction costs have a negative influence on incentives for soil conservation. It is also possible that when farmers decide on soil conservation investments, they base their decision on a large information set, potentially larger than contained in the data set at hand. It is therefore possible that we are unable to control for all variables that are part of the farmer's information set. It might even be possible that an unobserved systematic pattern over the whole sample is inflicting our farmer's decision.

We now turn to soil conservation benefits for maize fields (Table 5.5 below). We find that there are relatively many significant variables comparatively (4). We find that household size, education, sex and a dummy whether benefits are negative or not, are significant.

Access costs, search costs and distance to the crop fields are negative as expected. As distance to the crop fields' increase, returns to soil conservation decrease. This variable is significant at 11.9% but with transaction costs to Nairobi, it is significant at 10%. Distance to the crop fields works through reduced input use at fields far away from the homestead because effective input costs have increased. The benefits of terracing which are the yields of the crops also decrease due to low input usage. It is also less profitable to cultivate distant parcels of land. All these tend to reduce soil conservation benefits. Search costs are equally negative although not significant, also showing that they tend to lower soil conservation benefits. As argued previously, the benefits of soil conservation are the crops grown. If the search costs are high, then the expected revenue will fall implying lower soil conservation benefits. Access costs to the market are negative as expected although not significant[77]. This is likely to be related to food security (that is subsistence) objectives of farming households. Even though the effect of transaction costs is weak, soil conservation investments are further reduced by the expected lower soil conservation benefits. The low value for maize does not necessarily imply misspecification but may simply point out a very narrow range of variation in soil conservation benefits with respect to the explanatory variables. Thus suggesting or alluding to subsistence objectives with regards to maize.

Table 5.5: Cobb-Douglas regression results of determinants of soil conservation benefits for maize in Machakos and Kitui Districts, Kenya, 2000

Variable	Coefficient	t-statistic
DISTH	-7.45E-02	-1.573
SEACOS	-9.38E-02	-1.024
EDUC	0.436	1.673*
WEALTH	-0.334	-1.333
SEX	1.116	2.8***
SHH	0.533	1.895*
FARMCA	0.157	1.127
INC	-0.136	-1.233
ACESCOS	-0.230	-0.631
ERODE	0.345	1.529
SELFEMP	0.402	1.476
POSNEG	0.895	3.615***
(CONSTANT)	14.675	7.637***
N	125	
R2	0.165	

*significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01

Source: Estimates from field survey, 2000

Household size turns out as expected with a positive sign. It has a significant effect on net benefits of soil conservation. An increase in household size increases labour available for both soil conservation and crop production. Family labour is relatively cheap, as it does not face incentive and motivational problems. Moreover, it does not necessarily require supervision. As a result, soil conservation benefits increase. Sex also has a positive influence on benefits. We are of the view that men are physically strong and thus use more manure,

[77] Using transaction costs to Nairobi market outlet, the variable was found to be significant (see Table D7, Appendix D).

which is relatively cost-effective, and thus able to obtain higher crop yields. Likewise, education has a positive impact on soil conservation benefits. Education improves resource allocation and reduces a lot of information problems resulting in higher soil conservation benefits. Moreover, one would be able to make the terrace layout without the need of a soil conservation officer or hiring an expert at a fee. In addition one is likely not to over invest in soil conservation measures. Thus, we anticipate that it might be difficult to optimise on all accounts for a poor, relatively uneducated household suffering from inadequate information. There are unexpected signs however with wealth and household income. Nevertheless, they are not significant.

In general we observe substantial differences on soil conservation benefits between beans and maize. There are many significant variables with maize but much less with beans. We suppose this springs from the fact that maize is the most dominant staple (that is, food security crop) in which case, there is an interaction between pure soil conservation benefits and subsistence incentives. It is this interaction that is much pronounced in maize compared to beans. It appears that beans are not paramount as far as food security is concerned.

Summary

Despite lack of significance on some transaction costs variables, the apparent negative sign is adequate to conclude that indeed transaction costs negatively influence net benefits of soil conservation investments and consequently incentives. Other important variables that have a significant effect are tenure, household size, slope, and erosion status of parcels of land.

The next chapter presents summary, conclusions and policy implications.

CHAPTER SIX: SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

In this chapter, summaries are made, followed by conclusions after which policy implications are given.

6.1 Summary of Results

In Kenyan rural areas where much of the population resides, about 80% of the people derive their livelihood from agriculture. However, about 80% of the total land area in Kenya is marginal for agricultural production. These areas are ecologically vulnerable and face very serious problems of soil erosion. Soil erosion is a serious problem in Kenya's marginal areas. The resultant effect has been a decline in agricultural productivity with consequent increase in food insecurity.

Soil and water conservation in these marginal and fragile areas are thus key ingredients for sustainable agricultural development and consequently improvement in food security. The transaction costs underpinning the success or otherwise of these measures have had little or insignificant attention in the body of empirical literature. This is even more apparent in relation to their effects in land and resource management in ecologically fragile areas for agricultural land use, that are often far away from major markets.

The study was carried out in Machakos and Kitui districts. Although these districts are not a representative of all the marginal areas in Kenya, they share many characteristics with other marginal areas and illustrate the types of problems these areas are facing. A multi-stage random sampling was used to collect cross-sectional data from farming households with the help of a structured questionnaire.

This study therefore examined the influence of transaction costs on farm level soil conservation investments. Descriptive statistics, correlation analysis, Three Stage Least Squares (3SLS) estimated using the Heckman Two Stage procedure, Cobb-Douglas regression analysis and agricultural household model were used to analyze the data. The results are summarized below.

Transaction costs, terracing intensity, and crop productivity

Three Stage Least Squares method was used because the soil conservation investment phenomena were plagued with feedbacks and simultaneous effects resulting in some variables being endogenous. Due to the fact that the study is dealing with censored variables, the 3SLS was estimated using the Heckman Two Stage Estimation procedure.

We glean from the results that transaction costs both directly and indirectly reduce soil conservation investments. Despite inconsistencies in some instances, the consensus generally is that transaction costs (access costs or transport costs) to the market are indeed important and negatively influence terrace construction, and the use of manure and fertiliser. Consequently, lower manure and fertiliser use lead to a reduction in soil conservation investments through negative behavioural feed back effects via aggregate crop output or yields.

The results further suggest that in general, labour use increases with transaction costs. This appears to be a response by farming households in the face of subsistence needs and high transaction costs. We are of the view that smallholders with low resource endowments tend to use more of labour when faced with high transaction costs. Most of this labor is basically family labor that has no tendency to shirk since it is the residual claimants of farm profits. Moreover, the use of more labor is likely due to the need to meet subsistence needs. As Pagiola (1993) argues, where problems exist, economic agents have substantial incentives to seek ways to overcome them. Mechanisms often develop that allow the impact of many types of market failures or imperfections to be reduced.

It was found that the results could consistently be replicated for specific crops such as maize and beans. Transaction costs are found to have a negative impact on soil conservation investments directly on maize and bean fields. Indirectly, transaction costs influence negatively general agricultural investments such as manure and fertiliser. However, there are some effects that differ between maize and beans. The differential effects in the two crops arise in that maize is the main staple crop (that is, main food security crop). As regards labour use, the effects seem to be positive in relation to transaction costs although not significant. It is plausible that this is linked to the presence of imperfect labour markets.

Application of Agricultural Household Model

We have applied a dynamic non-separable household modeling approach to trace some important relationship between transaction costs and farm level soil conservation investments where farm households are key decision-making units. Our objective was to examine the interlinkages between transaction costs, household resource endowments and soil conservation investments. The imperfect information and transaction cost theories form the theoretical basis of the model. Market imperfection lead to non-separability of production and consumption decisions of farm households. Farm households are assumed to maximize their discounted utility over the planning horizon in a multi-period model where the management of the resource base has feed back effects on the stock of the resource base. The model traces the dynamic interaction between crop production, the resource base, consumption preferences, and partial integration of the household economy into markets.

Transaction costs are found to reduce soil conservation investments. Resource endowments are also found to be crucial. Under land scarcity (brought by high population density), land becomes dearer relative to labor. This is likely to induce conservation investments with a view to increase land productivity. When markets are imperfect, poverty in vital assets (e.g., oxen and labor) limits the ability or the willingness to invest in conservation.

Soil conservation benefits

With a discount rate of 2 % and a time horizon of 100 years, the net present value of soil conservation benefits was computed for both maize and beans crop enterprises. The results indicate that about 66% of the farmers had positive benefits while 34% had negative benefits. Using a Cobb-Douglas regression function, the results show that transaction costs have a negative influence of soil conservation benefits for the two enterprises. The lack of significance may arise from the fact these crops are food security crops. With bean enterprise, other important factors include slope, tenure, household size, involvement in self-employment, fertility, and erosion status of fields. While for maize enterprise, other key factors include: distance to crop fields, household size, educational level of principle household member, erosion status of the fields, involvevement in self-employment and a dummy variable for positive and negative soil conservation benefits.

6.2 Conclusions

Transaction costs have been found to reduce soil conservation investments. Directly transaction costs reduce soil conservation investments. Indirectly, transaction costs reduce manure and fertilizer use with a consequent negative feed back effect on soil conservation investments through crop output or yields. However, the results show that there is an increase in labor use. Perhaps this is farmers' response when faced with high transaction costs. It is worthy to note that this labor is largely family labor, which has less opportunistic tendencies since it is the residual claimant of farm profits.

According to the analysis carried so far, the results strongly suggest that indeed transaction costs impact negatively on soil conservation investments and likewise soil conservation benefits (incentives). However, the envisaged strong impact or influence is not observed partly due to strategies farmers undertake to reduce market participation transaction costs and partly due to subsistence and risk objectives that farmers pursue. Moreover, there is also the likely poverty interaction effect coming into play. In the face of fewer survival opportunities, poor farmers are likely to have a greater incentive to undertake soil conservation investments.

The results also show that other factors besides transaction costs are also important determinants of soil conservation investments. These are degree of farm orientation, age, household size, distance to crop fields, household income, farm size per capita, and wealth. The study has also established that self-help groups are indeed important in soil conservation investments. Another variable that is indeed essential also in the whole investment phenomena is land scarcity. It appears that as land scarcity increases, it then indirectly triggers decision-making. Our results also suggest the presence of credit, land and labour market imperfections.

The explanation of transaction costs does not invalidate other explanation of reduction in soil conservation investments that link the phenomenon with uncertainty and risk aversion. However, the econometric, analytical and simulations with an agricultural household model indicate that transaction costs matter and are sufficient to explain the soil conservation investment pattern in a deterministic setting.

6.3 Policy implication towards sustainable land use in marginal areas

The results of this study indicate that transaction costs to the market impose significant burdens on smallholder farmers in the study region and, by extension, elsewhere in Kenya and in other parts of Africa where similar conditions exist. Farmers faced with high farm-to-market transaction costs invest less in soil conservation measures and commit less manure and fertilizer to crop production. However, with labour use, it appears that more is committed. Higher transaction costs are also associated with more resources devoted to maize, which is the region's, Kenya's, and Africa's major staple food crop. The results also lend credence to arguments that subsistence-oriented production patterns on small farms are rational responses to high farm-to-market transaction costs (Omamo, 1998).

Thus efforts to develop conservation practices with lower costs or higher net returns should continue to be encouraged. Conservation investments are likely to be made (ceteris paribus) if they are less costly to farmers, both in terms of monetary costs as well as labour and animal power requirements. This is true regardless of the nature of factor markets; however, if credit or labour constraints are binding, such costs may prohibit even highly profitable investments from occurring.

Various strategies thus need to be taken in order to reduce transaction costs. To lower transaction costs, structural policies need to be implemented that reduce the costs of transportation and access to information. One of the strategies is the generic policy of improvement of rural road infrastructure[78] and market information systems. However, governments are faced with severe budgetary constraints. Few can afford the high costs of major rural road infrastructure investments. For example, the expenditure required to bring Kenya's road density (which currently stands at just above 11 km/100 km^2) to that of India (90 km/100 km^2) is at least US $7 billion - assuming gravel roads only - and could be as high as $88 billion - assuming paved roads (MTC, 1998). By way of comparison, Kenya's entire gross domestic product currently stands at slightly over US $6 billion.

[78] This is likely to create economies of scale which may the in the form of reduced transaction costs, lower operation and maintenance costs of equipment, enhanced diffusion of technology; new mixes of inputs and outputs; favorable input and output prices at the farm level; and increased specialization and commercialization.

In the expected continued absence of major investments in rural infrastructure, the policy challenge is to identify and mobilize a number of stakeholders in the provision of rural road infrastructure. For instance, with the assistance from government institutions and non-government organizations, rural communities can be mobilized to grade or upgrade and maintain rural access roads. Communally upgraded and maintained rural roads will reduce transaction costs and thus increase farm gate prices, often for more sustainable crops. They also connect people with new ideas and extension agencies, thus raising their range of known land use options; besides improvement in farmers' marketing margins. Improved marketing margins will attract private input traders, leading to a more competitive and input supply system (Hassan, 1996; von Oppen et al, 1985), and thus increasing the choice of markets and inputs for rural enterprises (Islam, 1997). The expected result will be enhanced soil conservation in marginal areas.

Another strategy is the increase of social capital. For example: support for, and active participation in, formation and functioning of farmers' associations (Dorsey and Muchanga, 2000); support for, and active participation in, formation and functioning of trader associations (Fafchamps and Gabre-Madhin, 2001); support for, and active participation in, formation and functioning of industry associations, comprising not only producers (farmers) but also traders, manufacturers (processors), and scientists (Sabel, 1994); support for organizations that link farm input supply with information dissemination (Seward and Okello, 2000). Others include marketing groups or cooperatives. Such measures are essentially institutional innovations that aim to reduce a range of transaction costs (e.g., enforcement, coordination, and handling costs), and also reduce risk. As Delgado (1995) argues, once again, there is a tremendous interest in local organizations, and other forms of participatory mobilization of rural people. It is this interest that has led to a new conceptualization of how the process forming nongovernmental organizations contributes to the agricultural development process, based on the "new institutional economics"(De Janvry et al., 1993). In an on going study, Mwakubo et al (forthcoming) finds that in a village in Kalama Division of Machakos district, there is council comprising of all the elders which meet once a week to deliberate on village matters. This council has a management committee. The village chairman also attends the meetings. All the other social networks or groups constantly receive advice from this council of elders. Besides, any acrimony between groups can also be resolved through this body. We are of the view that such an institutional arrangement[79] should be spearheaded in order to increase social capital. A caveat however, is in order that efforts to increase social capital do not result in crowding out effect of non-participating households. Policy design should require study of the informal links that exist between the two groups of households so that disparities are not enhanced.

The other policy measure is to improve education levels through effective extension[80] service by the government and complemented by non-governmental organizations. Active involvement rather than compulsion together with perception of personal benefits are clearly important in fostering long-term changes to attitudes and practices. A key role for governments is to transmit pertinent information on soil problems and possibilities through education generally, and through targeted extension programs. To have success, soil conservation officers should visit farmers regularly and must keep appointments with farmers, who have multiple activities and responsibilities. Carrying out promises generates companionship, sincerity, appreciation of the farmers, and greater participation. Extension officers should not avoid friendship with farmers solely because their academic backgrounds differ, since this hurts the farmers' dignity. The best way to work is through dialogue, which allows extension staff and farmers to exchange knowledge and experience.

Discussions with extension officers reveal that a number of measures are needed to jumpstart the system. Some of these include: effective facilitation through provision of transport facilities, allowances, and equipments; periodic refresher courses; regular seminars and workshops to facilitate exchange of ideas with relevant stakeholders[81]. There is also need for additional extension staff especially at the lower cadres who will be in contact with farmers[82]. The extension staff can also be facilitated through car loans to buy appropriate[83] vehicles and also given a mileage allowance.

---

[79] This should be followed with training on leadership, project management, and book keeping skills.
[80] An excellent review on policy research by Omamo (2003) stresses the need to go beyond the "what" question to the "how" question in order to generate viable policy options.
[81] These include staff from KARI, Universities, NGO's, and farmers.
[82] Improving agricultural extension service to dispersed smallholder farmers under severe budgetary constraints and retrenchment is a gigantic task.
[83] For example, Suzuki's are cheap and hardy and thus can reach areas with difficult terrain. The usual vehicles such as Pajero's are expensive to maintain.

It is worthy to note that the extension service has moved away from training and visit approach and it is now demand driven[84]. In this approach, farmers come to ask for service and would be required to cost share in the provision of this service such as meeting fuel costs. However, it appears that most farmers are not aware that the extension approach has changed and instead wait to be visited. Moreover, for uptake of extension messages to be effective, farmers must have the necessary capital to buy key inputs. A scenario hindered with the prevailing poverty among smallholder farmers. However, there are copying mechanisms that the extension service is trying in order to be effective inspite of the teething problems. These include cost-sharing in the provision of service with farmers and meeting farmers in groups. Field days, barazzas and women groups are now becoming entry points of the extension service. Through these, they manage to reach many people at the same time. Another suggestion might be to borrow a leaf from the concept of Training of Trainers (TOT). For example, groups or committees can and actually have been trained on how to lay terraces. These people are then able to lay terraces for the others. The same can also be done for other areas or services. Extension messages can be simplified so that they can easily be passed over. However, there are some matters that are too technical and would rather be left to the subject matter specialists.

Hand in hand with extension, the government should ensure that constraints such as insecure tenure do not prevent farmers from adopting soil conservation measures. However, equating land titles with secure tenure and thus with increased investment is too simplistic. Unless numerous improvements are made to the legal system and government institutions, land titles often prove to be too costly to obtain or enforce for most farmers. Moreover, unless access to credit is improved for farmers holding titles, the desired investment effect may not materialize.

Another policy implication would lie on sustained efforts to improve crop productivity, which include the growing of high value crops or use of improved crop varieties. This is envisaged to continuously cut down production costs.

[84] This strategy envisages a market for extension services. However, its efficacy is in doubt given the current experience with agricultural market liberalization under conditions of poor infrastructure, weak institutions, and poverty.

7.0 BIBLIOGRAPHY

Adesina A.A. and M.M. Zinnah. (1993), "Technology Characteristics, Farmer Perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone", *Agricultural Economics*, 9, 297-311.

Admassie, Y., L.I. Mwarasombo, and P. Mbogo (1998). *The sustainability of the catchment approach-induced measures and activities*. Nairobi: National Soil and Water Conservation Programme, Ministry of Agriculture.

Ahn, C.Y., L. Singh, and L. Squire. (1981). "The model of an agricultural household in a multi-crop economy: The case of Korea." *Review of Economics and Statistics* 63:520-525.

Akerlof, G. (1970). "The Market for Lemons: Quality Uncertainty and the Market Mechanism". *Quarterly Journal of Economics*, 84(3), pp. 488-500.

Alberta, Th., H. van Keulen, N.G. Seligman & C.T. de Wit (1992). *Food from dry lands. An integrated approach to planning of agricultural development*. Kluwer Academic Press.pp.211.

Anderson, D.M. (1984). 'Depression, dustbowl, demography and drought: the colonial state and soil conservation in East Africa during the 1930s'. *African Affairs*, 83(332), 321-343.

Anderson, J and J. Thampillai .(1990). Soil conservation in developing countries: projects and policy intervention. *Policy and research series* No.8. Washington, D.C.: The World Bank.

Anim, F.D.K. (1999). "A note on the Adoption of soil Conservation Measures in the Northern Province of South Africa". *Journal of agricultural Economics*. Vol (50). No2: pp336-345

Antle, J.M. (1987). "Econometric estimation of producers' risk attitudes." *American Journal of Agricultural Economics* (69): 509-522.

Antle, J.M. (1989). "Nonstructural risk attitude estimation." *American Journal of Agricultural Economics* (71): 774-783.

Antle, J.M. and C.C. Crissman. (1990). "Risk, efficiency, and the adoption of modern crop varieties: evidence from the Philippines". *Economic Development and Cultural Change*, 38:517-537.

Ardilla, S. and R. Innes. (1993). "Risk, risk aversion, and on-farm soil depletion." *Journal of*

Environmental Economics and Management, Vol. 25: 27-45.

Argwings-Kodhek G.; M. Mutua; and G. Okumu.(1990). *PAM Analysis of Agriculture in Kisii and Siaya Districts. Policy Analysis for Rural Development* Working Paper No. 5. Njoro: Egerton University.

Arrow, K. (1999). *Observations on Social Capital.* in Dasgupta P., & Serageldin I. (1999). *Social Capital: A Multifaceted Perspective.* World Bank

Arrow, K., and G. Debreu. (1954). Existence of equilibrium for a competitive economy. *Econometrica*, 22:265-290.

Askari, H. & J.T. Cummings. (1976). *Agricultural supply response: a suvery of the econometric evidence.* Praeger Publishers, New York.

Bade, J., H. Hengsdijk, G. Kruseman, R. Ruben. and P. Roebeling. (1997). *Farm household modeling in a regional setting: The case of Cercle de Koutiala, Mali.* DLV-Report No. 6. AB-DLO/WAU, Wageningen.

Balland, J.M., and J.P. Platteau. (1996). *Halting Degradation of Natural Resources.* FAO, UN and Clarendon Press, Oxford.

Barbier, E. B. (1990). "The farm-level economics of soil conservation: the uplands of Java." *Land Economics*, Vol. 66 (2): 199-211.

Barber, R.G. (1983). "The Magnitude and Sources of Soil Erosion in some Humid and Semi-arid Parts of Kenya, and the Significance of Soil Loss Tolerance Values in Soil Conservation in Kenya." in: Thomas and Senga (eds.) *Soil and Water Conservation in Kenya. Institute for Development Studies.* Occasional Paper No. 42. University of Nairobi.

Bardhan, P. (1984). *Land, Labour and Rural Poverty.* New York. Columbia University Press.

Barnet, D., B. Blake and B.A. McCarl .(1992). "Goal programming via multidimensional scaling applied to Senegalese subsistence farms." *American Journal of Agricultural Economics*, 64:pp720-727.

Barnum, H.N. & L. Squire. (1979). *A model of an agricultural household: theory and evidence.* Baltimore: John Hopkins University Press.

Barnum, H.N. & L. Squire. (1978). "Technology and relative economic efficiency." *Oxford Economic Papers* (30): 181-198.

Barret, S. (1996). "Microeconomic responses to macroeconomic reforms in the optimal control of soil erosion." in P. Dasgupta and K.G. Maler, eds., *The Environment and Emerging Development Issues.* Oxford: Clarendon Press.

Barret, S. (1991). "Optimal soil conservation and the reform of agricultural pricing policies." *Journal of Development Economics* 36(2): pp 167-187.

Bationo, A., F. Lompo and S. Koala. (1998). "Research on nutrient flows and balances in West Africa: state of the art". *Agricultural Ecosystems and Environment* 71,19-36.

Bellon, M.R. and J.E. Taylor. (1993). "Folk soil taxonomy and the partial adoption of new seed varieties". *Economic Development and Cultural Change*, Vol. 41: 763-786.

Benjamin, D. (1992). "Household composition, labour markets and labour demand: testing for separation in agricultural household models." *Econometrica* 60, 287-322.

Berndt, E., and L. Christensen. (1973). "The Translog function and the Substitution of Equipment, Structures, and Labour in U.S. Manufacturing, 1929-1968." *Journal of Econometrics*, (1): pp 81-114.

Berry, R.A. & Cline, W.R. (1979). *Agrarian Structure and Productivity in Developing Countries*. Baltimore: John Hopkins.

Besley, T. (1995). "Property Rights and Investment Incentives: Theory and Evidence from Ghana". The *Journal of Political Economy*, Vol.103 (5): pp903-937.

Bezuneh, M., B.J. Deaton, and G.W. Norton. (1988). "Food impacts in rural Kenya." *American Journal of Agricultural Economics* 70(1):181-191.

Binswanger, H.P.(1982). "Econometric estimation and the use of risk preference." American *Journal of Agricultural Economics* (64): 391-393.

Boorsma, A. (1990). *Possiblities for arable farms in the Dutch Peat Soil district.* PhD thesis, Rijls Universiteit Groningen, the Netherlands

Boserup, E. (1965). *The Conditions of Agricultural Growth.* Chicago: Aldine Publishing Company.

Boserup, E. (1981). *Population and Technology Change.* Chicago: The University of Chicago Press.

Bunce, A.C. (1942). *The economics of soil conservation.* Ames, IA: Iowa State College Press.

Bird-David, N., W. Karugu, M. Oduol, and S. Wandibba. (1998). *Technological Change and Rural Third World Women: An Impact study in Machakos District, Eastern Kenya.* NIRP Project No. 92-3.1. Final Report, 31 August 1998.

Burger, K and R. Oostendorp. (1998). *Report on the Opening Workshop, NWO program on Environment and the Economy,* held in Machakos, Kenya.

Burt, O.R. (1981). " Farm-level economics of soil conservation in the Palouse area o the Northwest." *American Journal of Agricultural Economics* 63(1), 83-92.

Chayanov (1923). *The Theory of Peasant Economy.* (D. Horner, B. Kerblay & R.E.F. Smith (eds.)), Homewood, III, 1966.

Christen, L., D. Jorgenson, and L. Lau. (1975). "Transcendental Logarithmic Utility Functions." *American Economic Review*, (65): pp 367-383.

Ciriacy-Wantrup, S.Von. (1938)."Soil conservation in European farm management". *Journal of Farm Economics*, 20(1),86-101.

Clay, D.C., F. Byiringiro, J. Kangasniemi, T. Reardon, B. Sibomona, and L. Uwamariya. (1995). *Promoting food security in Rwanda through sustainable agricultural productivity: meeting the challenges of population pressure, land degradation, and poverty.* Staff Paper No. 95-08 (March). Department of Agricultural Economics, Michigan State University, East Lancing, Michigan.

Clay, D., R. Reardon, and J. Kangasniemi. (1996). "Sustainable Intensification in the Highland Tropics: Rwandan Farmers' Investments in Land Conservation and Soil Fertility." *Economic Development and Cultural Change*, 96(2): 351-77.

Clarke H.R. (1992). "The supply of non-degraded Agricultural land", *Australian Journal of Agricultural Economics.* Vol. 36(1), April 1992: 31-56.

Cogle, A.L., M. Littleboy, K.P.C. Rao, G.D. Smith and D.F. Yule. (1996). "Soil management and production of alfisols in the semi-arid tropics. Part III: Long-term effects on water conservation and production." *Australian Journal of Soil Research* 34.

Dasgupta, P. (2001). *Human Well-Being and the Natural Environment.* Oxford University Press.

Dasgupta, A.K. and D.W. Pearce. (1978). *Cost Benefit Analysis.* Basingstoke: Macmillan.

Deaton, A. and J. Muellbauer. (1980). *Economics and Consumer Behaviour.* Cambridge University Press.

De Janvry, A., & E. Sadoulet. (1994). "Structural Adjustment under Transaction Costs." in F. Heidhues & B. Knerr (Eds.) *Food and Agricultural Policies under Structural Adjustment.* Frankfurt: Peter Lang Verlag.

De Janvry, E., E. Sadoulet, and E. Thorbecke. (1993). "Introduction to a special section, State, market, and civil organizations: New theories, new practices, and their implications for rural development." *World Development* 21(April): 565-575.

De Janvry, A., M. Fafchamps, and M. Raki. (1992). "Structural Adjustment and the Peasantry in Morocco: A Computable Household Model." *Eur. Rev.Agr. Econ.* 19(1992), pp. 427-453.

De Janvry, A., M. Fafchamps; and E. Sadoulet. (1991). " Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained." *Economic Journal*, vol.101.

De la Briere, B. (1999). Determinants of sustainable soil conservation practices' adoption: An analysis for the Dominican Republic highlands. Paper presented at the Economic Policy Reforms and Sustainable Land Use in LDCs: Recent Advances in Quantitative Analysis, Wageningen, 30 June - 2 July 1999.

Delforce, J.C.(1994). Separability in farm-household economics: An experiment with linear Programming. *Agricultural Economics* 10: 165-177.

Delgado, C. (1998). "Sources of Growth in Smallholder Agriculture in sub-Saharan Africa: The role of Vertical Integration with processors of high-value items". Agrarekon (*Journal of the South African Agricultural Economics Association*). Special issue, Proceedings of the International Association of Agricultural Economists, Badplaaas, South Africa, August 10-16.

Delgado, C.L. (1995). *Africa's changing agricultural development strategies: Past and present paradigms as a guide to the future.* Food, Agriculture, and the Environment Discussion Paper No. 3. Washington DC: International Food Policy Research Institute.

Dent, J.B., G. Edward-Jones and M.J. McGregor. (1995). "Simulation of Ecological, Social and Economic Factors in Agricultural Systems." *Agricultural Systems* 49: pp337-35.

Dietz, Ton (2000). *Transition to sustainable land use: who or what is pushing? Mid-way assessment of findings from eight villages in Kenya.* Paper for the Symposium Environment and Economics, June 9, 2000, Utrecht

Dijkstra T. (1997). *Horticultural Marketing Channels in Kenya.* Ph.D. Dissertation, Wangenigen Agricultural University.

Dorsey, J. and Muchanga, S. (2000). Best practices in farmer association development in Mozambique." Report presented to USAID/Mozambique. Arlington: ARD-RAISE Consortium.

Earle, T.R., C.W. Rose, and A.A. Brownlea. (1979). "Socio-economic Predictors of Intention Towards Soil Conservation and Their Implication in Environmental Management". *Journal of Environmental Management* 9(3): 225-236.

Eggertsson, T. (1990). *Economic Behavior and Institutions.* Cambridge: Cambridge University Press.

Ekbom, A. (1995). The Economics of Soil Conservation – A Case Study of the Economic and Agro-Ecological Implications of Soil Conservation on Maize Cultivation in Muranga

District, Kenya. *EEU Working Papers*, Gothenburg University, Sweden.

Ekbom, A.(1992). Economic Impact Assessment of Implementation Strategies for Soil Conservation - A comparative Analysis of the On-Farm and Catchment Approach in Trans Nzoia, Kenya. *EEU Working Papers*, Gothenburg University, Sweden.

Ellickson C. R. (1996). "Comment on Contracting, Enforcement, and Efficiency: Economics beyond the Law by Avner Greif." in Bruno, M. & Pleskovic, B. (ed.), Proceedings of the *Annual World Bank Conference on Development Economics*. The World Bank, Washington D.C.

Ellis Frank (1988). *Peasant Economics: Farm households and agrarian development*. Second Edition, Cambridge University Press.

English, J., M. Tiffen, and M. Mortimore. (1994). *Land Resource Management in the Machakos District, Kenya 1930-1990*. World Bank Environment Paper 5. Washington, D.C.

Eriksson, A. (ed.) (1992). *The Revival of Soil Conservation in Kenya*. Regional Soil Conservation Unit Report No.1. SIDA, Nairobi.

Ervin, David E. (1986). "Constraints to Practicing Soil Conservation: Land Tenure Relationships." In Stephen B. Lovejoy and Ted L. Nappier, eds., *Conserving Soil: Insights from Socio-economic Research*. Ankeny, Iowa: Soil Conservation Society of America.

Ervin, C.A. and E.D. Ervin. (1982). Factors affecting the use of soil conservation practices: Hypothesis, evidence and policy implications. *Land Economics*, 58(3): 277-292.

Fachamps, M. and E. Gabre-Madhin. (2001). Agricultural markets in Benin and Malawi: operation and performance of traders. Unpublished IFPRI manuscript. Washington DC: International Food Policy Research Institute.

Fafchamps, M. (1992). "Cash Crop Production, Food Price volatility, and Rural Market Integration in the Third World." *AJAE*, February 1992, pp. 90-99.

Featherstone, A.M. and B.K. Goodwin. (1993). "Factors influencing farmer's decision to invest in long-term conservation improvements." *Land Economics* 69(1).

Feder, G., R.E. Just, and D. Ziberman. (1985). "Adoption of Agricultural Innovations in Developing Countries: A survey." *Economic Development and Cultural Change*, 33, 255-298.

Figueiredo, P. (1986). *The Yield of Food Crops on Terraced and Non-Terraced Land, A Field*

Survey of Kenya. Working Paper No. 35, Swedish University of Agricultural Sciences, International Rural Development Centre, Uppsala, Sweden.

Frank S.D., & D.R. Henderson. (1992)." Transaction Costs as Determinants of Vertical Co-ordination in the U.S.." American Agricultural Economics Association.

Fresco, L.O., L. Stroosnijder, J. Bouma & H. van Keulen (eds.) (1994). *The future of the land: Mobilizing and integrating knowledge for land use options.* Chichester, John Wiley & Sons. pp.409 .

Gerrits, M. (2000). *Prime Property: The influence of land tenure security on investment strategies of small-scale farmers in Kitui District, Kenya.* M.A. thesis, University of Amsterdam.

Gichuki, F.N. (1991). *Conservation profile. Environmental change and dryland management in Machakos District, Kenya.* ODI Draft working paper.

Goetz R. U. (1997). Diversification in Agricultural Production: A Dynamic model of Optimal Cropping to Manage Soil Erosion. *American Journal of Agricultural Economics,* 79(May 1997): 341-356.

GOK. (2002-2008). National Development Plan, 2002-2008. Government Printer, Nairobi.

GOK.(1999-2015). National Poverty Eradication Plan, 1999-2015. Government Printer, Nairobi.

GOK. (1997-2001a). *National Development Plan 1997-2001.* Government Printer, Nairobi.

GOK. (1997-2001b). *Machakos District Development Plan 1997-2001.* Government Printer, Nairobi.

GOK. (1994-96). *Kitui District Development Plan 1994-96.* Government Printer, Nairobi.

Gould, B.W., W.E. Saupe, and R.M. Klemme. (1989). Conservation tillage: The role of operator characteristics and the perception of soil erosion. *Land Economics,* Vol 65: 167-182.

Grabowski, R. (1990). "Agriculture, mechanization and land tenure." *Journal of Development Studies* 27(1): 43-53.

Greene W. (2000). *Econometric Analysis.* Prentice Hall.

Greenwald, B., and J. Stiglitz. (1986). "Externalities in economics with imperfections and incomplete markets." *Quarterly Journal of Economics* (101):229-264.

Greif, A. (1996). "Contracting, Enforcement, and Efficiency: Economics beyond the Law." in Bruno, M. & Pleskovic, B. (ed.), Proceedings of the *Annual World Bank Conference on Development Economics.* The World Bank, Washington D.C.: pp239-262.

Greperrud, S. (1997a). *Soil depletion choices under production and price uncertainty.* Discussion paper, No.186 Statistics Norway, Oslo.

Greperrud, S. (1997b). "The impact of Policy on Farm Conservation Incentives in Developing Countries: What can be learnt from Theory?. *Quarterly Journal of International Agriculture*, vol.36:59-80.

Hassan, R.M. (1996). Planting strategies of maize farmers in Kenya: a simultaneous equations analysis in the presence of discrete dependent variables. *Ag. Econ.*, 15: 137 – 149.

Hayes, J., M. Roth, and L. Zepeda. (1997). Tenure security, investment and productivity in Gambian agriculture: A generalized probit analysis. *American Journal of Agricultural Economics*, Vol 79(2): 369-382.

Hedfors, L. (1981). *Evaluation and Economic Appraisal of Soil Conservation in a Pilot Area.* Ministry of Agriculture Soil and Water Conservation Branch, Nairobi.

Heyer, J. and J. Waweru.(1976). " The development of Small Farm Area." In J. Heyer, J. Maitha, and W. Senga (Eds.) Agricultural Development in Kenya: An Economic Assessment. Nairobi: Oxford University Press.

Hobbs J.E. (1997). "Measuring the Importance of Transaction Costs in Cattle Marketing, American *Agricultural Economics Association*, 79:pp1083-1095.

Hoff K, A. Braveman, & J.E.Stiglitz. (eds.), (1993), *The Economics of Rural Organization: Theory,Practice, and Policy*, Oxford University Press, Inc. New York.

Holden, S.T. (1991). *Peasants and Sustainable Development – the Chitemene region of Zambia. Theory; Evidence and Models.* PhD Dissertation, Agricultural University of Norway, Department of Economics and Social Sciences, Ås.

Holden S.T., J.E. Taylor, & S. Hampton. (1999), "Structural Adjustment and Market Imperfections: A Stylized Village Economy-wide Model with Non-Separable Farm Households, *Journal of Environment and Development Economics*, " Vol. 4(1): pp. 69-87.

Holden, S.T., & H.P. Binswanger. (1998), *Small Farmer Decision-Making, Market Imperfections, and Natural Resource Management in Developing Countries*, Discussion Paper #D-05/1998, Department of Economics and Social Sciences, Agricultural University of Norway.

Holden, S.T., B. Shiferaw, and M. Wik.(1998). "Poverty, credit constraints, and time preferences: of relevance for environmental policy? ". *Environment.and Development Economics* 3, 105-130.

Hollow G., Nicholson C., Delgado C., Ehui S., and Stalls. (1999). Emerging Markets for Dairy Products in Africa: Transactions costs, choice of Technique and Market Surplus in Peri-Urban Dairy Systems in the East-African Highlands. Paper presented at the Agroindustrialization, Globalization, and Economic Development Workshop, August 6-7, Renaissance Hotel, Nashville, Tennessee.

Holmberg, G. (1985). *An Economical Evaluation of Soil Conservation in Kalia Sublocation, Kitui District*. Soil and Water Conservation Division, Ministry of Agriculture and Livestock Development, Nairobi-Kenya.

Holmgren, E., & G.Johansson. (1987). " Comparison Between Terraced and Non-terraced Land in Machakos District, Kenya." Soil and Water Conservation Branch, Ministry of Agriculture, Nairobi.

Hoover, H. and M. Wiitala. (1980). *Operator and Landlord Participation in Soil Erosion Control in the Maple Creek Watershed in Northeast Nebraska*. Washington, D.C.: U.S. Department of Agriculture.

Idachaba, F.S.(1994). *Human Capital and African Agricultural Development*. Paper presented at the XXII International Conference of Agricultural Economists, August 22-29, Harare, Zimbabwe.

Ijaimi, A.M. (1994). Efficiency and equity effects of market access on agricultural productivity in Sudan: a case study of smallholders along the River Nile, north of Khartoum. Berlin, Verlag Dr. Köster.

Intriligator, M., R. Bodkin and C. Hsiao. (1996), *Econometric Models, Techniques and Applications*, (Second Edition), Prentice Hall International Editions, New Jersey.

Islam, N. (1997). The nonfarm sector and rural development: review of issues and evidence. Food, Agriculture and the Environment Discussion Paper No. 22. Washington DC: International Food Policy and Research Institute.

Jacoby, H.G. (1993). Shadow wages and Peasant Family Labour Supply: An Econometric Application to the Peruvian Sierra. *Review of Development Economics*, 37(1-2), November 1991, pp. 265-87.

Jaetzold R.,& H. Schmidt.(1983). *Farm Management Handbook of Kenya: Vol. II Natural Conditions and Farm Management Information, Part C: Eastern and Coast Provinces*. Ministry of Agriculture.

Jaffee S. (1991). "Kenya's Horticultural Export Marketing: A Transaction cost perspective."

A paper presented at the workshop on the Globalization of the Fresh Fruit and Vegetable System at the University of California, Santa Cruz, December 6-9.

Johnston, J.(1984). *Econometric Methods*. New York: McGraw-Hill.

Kagwanja J.C. (1996). *Determinants of Farm Level Soil Conservation Technology Adoption: Lessons from the High Rainfall, High Populated, Steep Sloped Mt. Kenya Highlands, Embu, Kenya*. Unpublished Ph.D. Dissertation, University of Missouri-Columbia.

Kazianga H. and W.A. Masters. (2002). "Investing in soils: field bunds and microcatchments in Burkina Faso." *Environment and Development Economics* 7:571-591

Kilewe, A.M. (1987). *Prediction of Erosion Rates and the Effects of Topsoil Thickness on* Soil *Productivity*. Ph.D. Dissertation, University of Nairobi.

Kmenta, J. (1967). "On estimation of the CES production." *International Economic Review* (8): pp. 180-189.

Knox, A., R. Meinzen-Dick, and P. Hazell. (2002). Property Rights, Collective action and Technologies for Natural Resource Management. IFPRI at http://www.capri.cgiar.org.

Koinei P.K. (1988). *Taita-Taveta Report: Measurement of Yields from terraced and Non-Terraced fields 1987/99*. Soil and Water Conservation Branch, Ministry of Agriculture, Nairobi.

Konzacki Z.A. (1978). *The Economics of Pastoralism: A Case Study of Sub-Saharan Africa*. Frank Cass, London, p.145.

Krishna A., & N. Uphoff. (1999). *Social factors in sustainable land-use management: social capital and watershed development in Rajasthan, India*. Paper prepared for an International workshop Economic policy reforms and sustainable land use in LDCs Recent Advances in Quantitative Analysis, 30 June - 2July 1999- Wageningen.

Krishna A., & N. Uphoff. (2001). Mapping and measuring social capital through assessement of collective action to conserve and develop watersheds in Rajasthan, India. In: Grootaert, C. And T. van Bastelaar (eds.), *The Role of social capital in development: An empirical assessment*. Cambridge University Press.

Kramer, R.A., W.T. McSweeney, and R.W. Stavros. (1983). "Soil conservation with uncertain revenues and input supplies." *American Journal of Agricultural Economics* 65(4), 695-701.

Kruseman, G. (1999). Household technology choice and sustainable land use. Paper presented at the workshop on Economic Policy Reforms and Sustainable Land Use in LDCs : Recent Advances in Quantitative Analysis, Wageningen, 30 June - 2 July, 1999.

Kruseman, G., and J. Bade. (1998). "Agrarian policies for sustainable land use: bio-economic modelling to assess the effectiveness of policy instruments." *Agricultural Systems* 58:pp465–481.

Kruseman, G. , H. Hengsdijk, Ruben R., Roebeling, and J. Bade. (1997). *Farm household modelling system for the analysis of sustainable land use and food security: Theoretical and mathematical description.* DLV-Report No. 7. AB-DLO/WAU. Wageningen: pp13.

Kruseman, G., & R.Ruben. (1998). *Transaction Costs and Incentives for Sustainable Land Use: A farm household modelling approach for southern Mali.* Department of Economics and Management. Wageningen Agricultural University.

LaFrance, J.T.(1992). "Do Increased Commodity Prices Lead to More or Less Soil Degradation?" *Australian Journal of Agricultural Economics*, Vol. 36(1): 57-82.

Lall, S.V., U. Deichmann, M.K.A. Lundberg and N. Chaudhury. (2000), "Tenure, Diversity, and Commitment: Community Participation for Urban Service Provision." World Bank Policy Research 2862. Development Research Group, The World Bank.

Lawry, S.W. (1993). *Transactions in Cropland held under Customary Tenure in Lesotho.* In: T.J. Bassett & D.E. Crummy (eds) *Land in African Agrarian Systems.* Madison. University of Wisconsin Press. Pp. 57-74.

Lee, L.K. and Stewart, W.H. (1983)."Land Ownership and the Adoption of Minimum Tillage." *American Journal of Agricultural Economics*, Vol.65 No.2, May, pp.256-264.

Lipton, M.(1987). "Limits of price policy for agriculture: Which way for the World Bank?" Policy Development Review 5, 197-215.

Lindgren Brit-Marie. (1988). *Machakos Report 1988: Economic Evaluation of a soil Conservation Project in Machakos District, Kenya.* Ministry of Agriculture.

Linde-Rahr M.(2000). *Rural Shadow Wages and Efficient Household Production: Evidence from Viet Nam.* Paper presented at the Environment and Development Second Conference held in Stockholm, Sweden.

Lutz, E., S. Pagiola, and C. Reiche. (1994). "The Costs and Benefits of Soil Conservation: The Farmer's Viewpoint". *The World Bank Research Observer*, Vol.9(2):273-295.

Lynne, M.C. and W.L. Nieuwoudt.(1990). "The Real Tragedy of the Commons: Livestock Production in KwaZulu". *Journal of Agricultural Economics*, 70,12-19.

Maddala G.S. (1983). *Limited-Dependent and Qualitative variables in Econometrics.*

Cambridge University press.

Malik, S.J.(1998). Rural poverty and Land degradation: What does the available literature suggest for priority setting for the Consultative Group on International Agricultural Research? Report prepared for the Technical Advisory Committee of the CGIAR February, Draft.

Markandya, A. and D. Pearce. (1988)." Environmental Considerations and the Choice of the Discount Rate in Developing Countries". *World Bank Environment Department Working Paper 3,* Washington D.C.: The World Bank.

Marsh, Catherine. (1988). *Exploring Data: an Introduction to Data Analysis for Social Scientists.* Polity Press: pp209.

Matlon P.(1994)."Indigenous land use systems and Investments in soil fertility in Burkina Faso." in *Searching for Land Tenure Security in Africa.* Bruce J.W. and Migot-Adhola S.E., (eds.). Kendal/Hunt Publishing Company

McConnell, K.E. (1983). "An economic model of soil conservation." *American Journal of Agricultural Economics,* Vol.65(1): 83-89.

McSweeney, W.T. and R.A. Kramer.(1986). "Soil conservation with uncertain revenues and input supplies." *American Journal of Agricultural Economics* 68(2), 361-3.

Migot-Adhola, S.E., P.B. Hazell and F. Place. (1990). Land Rights and Agricultural Productivity in Ghana, Kenya and Rwanda: A Synthesis of Findings (Washington, D.C.: The World Bank, Agriculture and Rural Development Department, 1990).

Mitchel A.J.B. (1984). *Kenya population supporting capacities study – soil erosion and soil Conservation.* Consultants report to Soil Resources, Management and Conservation Service, Land and Water Development Division, FAO, Rome; Land Resources Development Centre, Surrey, England.

MTC. (1998). Official unpublished data on road length and density in Kenya. Nairobi: Ministry of Transport and Communication of the Government of Kenya.

Mundlack, Yair. (1996). "Production function Estimation: Reviving the primal." *Econometrica,* Vol.64, No.2, March: 431-438.

Mwangi C.M. (1991). Kwale *Report: Soil Conservation Profile Kubo-Kwale.* Soil and Water Conservation Branch, Ministry of Agriculture, Nairobi.

Mwakubo, S.M., G.A. Obare, J.M. Omiti & L. Muhammad. (forthcoming). The Influence of Social Capital on Sustainable Agriculture in the Marginal Areas, Kenya: A case Study of Machakos and Taita-Taveta Districts. IFPRI Research Report.

Mwakubo, S.M.(1994). Factors Influencing Food Production in Kwale District, Kenya. MSc. Thesis, Egerton University.

Myers, R.J. (1989). "Econometric testing for risk averse behaviour in Agriculture." *Applied Economics* (21): 541-555.

Nakijama, C. (1986). *Subjective Equilibrium Theory of the Farm Household.* Amsterdam: Elsevier.

Nandwa, S.M. and M.A. Bekunda. (1998). "Research on nutrient flows and balances in East and Southern Africa: state –of-the-art". *Agricultural Ecosystems and Environment* 71, 5-18.

Nerlove, M.(1958). *The Dynamics of Supply: estimation of Farmers' Response to Price.* Baltimore: The John Hopkins University Press. 289pp.

Nixon, D.J., J.K. Itabari, S.C. Simiyu, M. Gatheru, and C. Bishop. (1993). Soil and Water management practices in semi-arid Kenya: an overview paper presented at the Fourth National Land Water Management workshop held in Nairobi, 15th –19th February 1993.

Njehia, B.K. (1994). *The Impact of Market Access on Agricultural Productivity: A case study of Nakuru District, Kenya.* Ph.D. Dissertation, Verlag Dr. Koster, Berlin.

Norman, Hudson. (1981). *Soil Conservation.* English Language Book Society and Bata Ford Academic and Educational, London.

North D.N. (1990). *Institutions, Institutional Change and Economic Performance.* Cambridge University Press.

Norris, P.E., and S.S. Batie. (1987). "Viginia's Farmers' Soil Conservation Decisions: An Application of Tobit Analysis." *Southern Journal of Agricultural Economics,* 19:79-90.

Nowak, P.J. (1987). The adoption of agricultural conservation technologies: Economic and diffusion explanations. *Rural Sociology,* 52(2): 208-220.

Nyang, F.O. (1999). Household Energy Demand and Environmental Management in Kenya. Ph.D. Dissertation, University of Amsterdam.

Nyang, F.O., S.M. Mwakubo, M.K. Bowen, F. Zaal, W.K. Yabann, and T. Dietz.(2000). The Context of Transition to Sustainable Land Use: A Comparison of Eight Villages in Machakos and Kitui Districts, Kenya (draft report Amsterdam: University of Amsterdam/Eldoret: MUSES).

Nyoro J.K. & Jayne T.S. (1999). "Trends in Regional Agricultural Productivity in Kenya." in proceedings of the conference on *Kenya Agricultural Monitoring and Policy Analysis*, Karen, Kenya.

Omamo S.W. (2003). *Policy Research on African Agriculture: Trends, Gaps, and challenges.* ISRAR Research Report 21. The Hague: International Service for National Agricultural Research.

Omamo, S.W., J.C. Williams, G.A. Obare, & N.N. Ndiwa. (2002)."Soil fertility management on small farms in Africa: Evidence from Nakuru District, Kenya". *Food Policy*, 27: pp159-170.

Omamo, S.W. (1999). Are Kenyan Small-Scale Farmers Irrational? Proceedings of the Second KARI Socio-Economic Conference, held at Parafric Hotel, Nairobi, 17th-19th November, 1997, Waithaka, M., Wangia, S., Njue, E., and Mwangi, P. (Eds.): KARI.

Omamo, S.W. (1998). "Transport Costs and Smallholder Cropping Choice: An Application to Siaya District, Kenya." *American Journal of Agricultural Economics* (80): pp 116-123.

Omamo, S.W. (1995). *Smallholder Agriculture under Market Reform: The Case of Southern Siaya District, Kenya.* Ph.D. Dissertation, Stanford University.

Omamo, S.W. (1994). "The Impacts of Agricultural Marketing Reform on Mixed Farmers in Southern Siaya District, Kenya." *Proceedings of the Conference on Market Reforms, Agricultural Production and Food Security*, Nairobi, June 22-23, 1994.

Oostendorp, R.H. (1998). "An Exploration of Alternative Modeling Approaches to the Mathus/Boserup Bifurcation". Paper presented at the NWO Workshop on Agricultural *Transition towards Sustainable Tropical Land use*, Machakos, Kenya, 25 - 28th March.

Otsuka, K., S. Suyato & T. P. Tomich. (1997). *Does Land Tenure Insecurity discourage Tree Planting? Evolution of Customary Land Tenure and Agroforestry Management in Sumatra.* Washington, IFPRI EPTD Discussion Paper No. 31.

Pagiola, S. (1995)." The Effect of Subsistence Requirements on Sustainable Land use Practices." Paper presented at the American Agricultural Economics Association, Indianapolis, August 6-9, 1995.

Pagiola, S. (1994). Soil Conservation in a Semi-Arid Region of Kenya: Rates of Return and Adoption by Farmers, in: Naapier, T, S. Cambuni, and S. El-Swoufy (eds.) *Adopting Conservation on the Farm,* Soil and Water Conservation Society, Anlenng, Iowa.

Pagiola, S. (1993). *Soil Conservation and Sustainability of Agricultural Production.* Ph.D.

Diss., Food Research Institute, Stanford University.

Pagiola, S., M. Mukumbu, M.Mutua, and G. Okumu.(1990). *Kitui District: The effects of Environmental Degradation and Agricultural Policy on a Semi-Arid Area.* Policy Analysis for Rural Development Working Paper No. 7. Njoro: Egerton University.

Panayotou, Theodore. (1993). Green Markets: The Economics of Sustainable Development. ICEG Sector Studies 7. San Francisco, Calif.: ICS Press.

Pearson, S., E. Monke, G. Argwings-Kodhek, F. Avillez, M. Mukumbu, S. Pagiola, D. Sellen, and A. Winter-Nelson. (1995). "Agricultural Policy in Kenya: Applications of the Policy Analysis Matrix." in Food Systems and Agrarian Change. F.H. Buttel, B.R. DeWalt, and P. Pinnstrup-Andersen,eds. Cornell University Press:pp214-244.

Pender J. & Kerr J. (1996). *Determinants of Farmers' Indigenous soil and water conservation investments in India's semi-arid Tropics.* Environment and Production Technology Division, International Food Policy and Research Institute; EPTD Discussion paper No: 17.

Perrings, C. (1989). "An optimal path to extinction? Poverty and resource degradation in the open agrarian economy". *Journal of Development Economics* 30,pp.1-24.

Place, F. and P. Hazell. (1993). "Productivity Effects of Indigenous Land Tenure Systems in Sub-Saharan Africa".*American Journal of Agricultural Economics*, 75:pp 10-19.

Pokormy, M. (1987). *An Introduction to Econometrics.* Blackwell Publishers, PP308-309.

Pudasiani, S.P.(1983)."The effect of Education in Agriculture: Evidence from Nepal." *Journal of American Agricultural Economics*, 65 FEB-AUG pp.509.

Putman D. R. (1995). "Comment on The Institutions and Governance of Economic Development and Reform." in Bruno M. & Pleskovic B. (Eds.) *Proceedings of the World Bank Annual Conference on Development Economics 1994*, Washington, D.C: pp198-200.

Quisumbing E.R., Otsuka K., Suyanto s., Aidoo J.B., and E. Payongayong.(2001). *Land, trees, and women: Evolution of land tenure institutions in western Ghana and Sumatra.* IFPRI Research Report 121.

Rabbinge, R. & H. van Latesteijn. (1992). "Long-term options for land use in the European Community." Agric. Systems 40(1992) 195-210.

Rabbinge, R. & M. Van Ittersum.(1994). "Tensions Between Aggregation Levels". In: Fresco, L.O., J. Stroonsnijder, J. Bouma and H. Van Keulen. *The future of the Land: Mobilizing and Integrating Knowledge for Land Use Options*. Chichester: john Wiley and sons, pp.31-40.

Ray S.C.(1985). "Methods of Estimating the Input Coefficients for Linear Programming Models. " *American Journal of Agricultural Economics*: pp661-665.

Reardon, T. and S.A. Vosti. (1992). "Issues in the analysis of the effects of policy on conservation and productivity at the household level in developing countries". *Quarterly Journal of International Agriculture*, Vol. 31(4): 380-396.

Repetto, R. (1987). Economic incentives for sustainable production. The annals of Regional Science 21, 44-59.

Rindfleisch A. & Heide. (1997). "Transaction Cost Analysis: Past, Present, and Future Applications." *Journal of Marketing* Vol.61, pp.30-54.

Romero, C. (1993). *A research on Andalusian farmers' objectives: methodological aspects and policy implications*. Paper presented to VII EAAE Congress, Stresa, Italy.

Ruben R. & N. Heerink. (1998). "Policy Incentives for Land Use Intensification: Bio-Economic Modeling at Farm Household and Regional Level". Paper presented at the NWO Workshop on Agricultural *Transition towards Sustainable Tropical Land use*, Machakos, Kenya, 25 - 28th March.

Ruben, R., G. Kruseman, and H. Hengsdijk. (1994). *Farm Household Modelling for Estimating the Effectiveness of Price Instruments on Sustainable Land Use in the Atlantic Zone of Costa Rica*. DLV Report No. 4. AB-DLO/WAU, Wageningen.

Sabel, C. (1994). Learning by monitoring: The institutions of economic development. In: N. Smelser and R. Swedberg (eds.), The Handbook of Economic Sociology. Princeton: Princeton University Press, pp. 137-165.

Sadoulet, E., and A. De Janvry . (1995). *Quantitative Development Policy Analysis*. John Hopkins University Press, Baltimore and London.

Sanchez, P.A., A-M Izac, R.J. Buresh, K.D. Shepherd, M. Soule, A.U. Mokwunye, C.A. Palm, P.L. Woomer, and C.G. Nderitu. (1997). "Soil Fertility Replenishment in Africa as an Investment in Natural Resource Capital ". ICRAF Draft Manuscript. Nairobi: International Centre for Research on Agroforestry.

Schipper, R.A. (1996). *Farming in a fragile future: economics of land use with applications in the Atlantic Zone of Costa Rica*. Wageningen Agricultural University: Ph.D. thesis.

Sellen, D.; G. Argwings-Kodhek; A. Chomba; F. Karin; and M.Mutua.(1990). *Agriculture in*

Nyeri: Farm Income,Efficiency, and Agricultural Policy. Policy Analysis for Rural Development Working Paper No. 11. Njoro: Egerton University.

Seward, P. and D. Okello. (2000). SCODP's mini-pack method: the first step towards improved food security for small farmers in Western Kenya. Paper presented at the 68th Annual Conference of the International Fertilizer Industry Association. Oslo, Norway, May 22-25, 2000.

Shaxson, T. F., N.W. Hudson, D.W. Sanders, E. Roose, and W.C. Moldenhauer. (1989). *Land Husbandry: A Framework for Soil and Water Conservation.* Soil and Water Conservation Society, Ankeny, Iowa.

Shiferaw, B. & S.T. Holden. (2001). Farm-level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia. *Environment and Development Economics*, Vol.6, Cambridge University Press.

Shiferaw, B., S. Holden, and J. Aune. (2000). *Population Pressure, Poverty and Incentives for Soil Conservation: A Bio-Economic Modeling Approach.* Paper presented at the Second International Conference on "Environment and Development." Stockholm 6-8 September, 2000.

Shiferaw, B., S. Holden, and J. Aune. (1999). *Population pressure and land degradation: a bio-economic model with endogenous soil degradation.* Paper presented at the "Economic Policy Reforms and Sustainable Land Use in LDCs: Recent Advances in Quantitative Analysis." Wageningen, 30 June - 2 July, 1999.

Shiferaw, B., & S. Holden. (1998). *Investment in soil and water conservation in the Ethiopian Highlands: Does it pay Small Farmers*? Paper No. D-32/1998, Department of Economics and Social Sciences, Agricultural University of Norway.

Shiferaw, B. & S.T. Holden . (1997). *A Farm Household Analysis of Resource Use and Conservation Decisions of Smallholders: An Application to Highland Farmers in Ethiopia.* Discussion Paper #D-03/1997, Department of Economics and Social Sciences, Agricultural University of Norway.

Shiferaw B. & S.T. Holden. (1996). Resource Degradation and Adoption of Land Conservation Technologies by Smallholders in the Ethiopian Highlands: A Study in Andit Tid, North Shewa. Discussion Paper #D-31/1996, Department of Economics and Social Sciences, Agricultural University of Norway.

Shively, G.E. (1997). *Assets, Attitudes, Beliefs and Behaviours: Explaining Patterns of Soil*

Conservation Adoption among low-income Farmers. Internal Paper Dept. Agricultural Economics, Purdue University.

Shucksmith, M. (1993). "Farm household behaviour and the transition to post-productivism. " *Journal of Agricultural Economics* 44:pp466-478.

Shultz T. (1964). *Transforming Traditional Agriculture.* Yale University Press.

Sinden, J.A., and D.A. King (1988). "Land Condition, Crop Productivity, and the Adoption of Soil Conservation Measures." Paper presented at the Australian Agricultural Economics Society Conference, Melbourne, Australia.

Singh, L., and S. Janakiram. (1986). Agricultural household modelling in a multicrop environment: Case studies in Korea and Nigeria. in Singh, I.; Squire; and J. Strauss (eds.), (1986), *Agricultural Household Models: Extensions, Applications, and Policy.* Baltimore: John Hopkins University Press, pp 95-115.

Singh, L., L. Squire and J. Strauss (eds.), (1986). *Agricultural Household Models: Extensions, Applications, and Policy.* Baltimore: John Hopkins University Press.

Smalling, E.M.A., S.M. Nandwa, and B.H. Jansen. (1997). Soil fertility in Africa is at stake. In *Replenishing soil fertility in Africa*, eds. Buresh et al. SSSA Spec. Publ. 51. SSSSA, Madison, WI: pp.47-61.

Solow, R.M.(1974). "The Economic of Resources or the Resources of Economics". *American Economic Review* 64(2):1-14.

Staal S., C. Delgado, & C. Nicholson. (1997). "Smallholder Dairying Under Transaction Costs in East Africa." *World Development*, Vol.25, No.5, pp779-794.

Steenhuijsen Piters, B.(1995). *Diversity in fields and farmers: explaining yield variations in Northern Cameroon.* Wageningen Agricultural University: PhD thesis.227 pp.

Streeck, W. (1992). *Social Institution and Economics Performance: Studies of Industrial Relations in Advanced Capitalist Economies.* London, Newbury Park and New Delhi: SAGE Publications Ltd.

Taylor, J.E. and I. Adelman (1996). *Village Economics: the Design, Estimation, and Use of Village wide Economic Models.* Cambridge and New York: Cambridge University Press.

Templeton, S. (1994). *Microeconomic analysis of land management: the control of soil erosion and an empirical analysis of non-paddy terracing in the Philippines.* Ph.D. Dissertation, University of California, Berkeley, May.

Tiffen M, R. Purcel, F. Gichuki, C. Gachene, and J. Gatheru. (1996). *National Soil and*

Water Conservation Programme, SIDA Evaluation 96/25. Department for Natural Resources and the Environment, SIDA, Sweden.

Tiffen, M., M. Mortimore, and F. Gichuki (1994). *More People, Less Erosion.* New York: Wiley, Walker.

Timmer, C.P., (1996). "Liberalized Agricultural Markets in Low-income Economies: Discussion." *American Journal of Agricultural Economics,* 78:830-832.

Thampapillai D.J. & J.K. Anderson. (1994). "A Review of the Socio-Economic Analysis of Soil Degradation Problems for Developed and Developing Countries. " *Review of Marketing and Agricultural Economics,* Vol. 62: 291-315.

Thomas D.B. (1997). *Soil and Water Conservation Manual for Kenya.* Ministry of Agriculture, Nairobi.

Uphoff, N., M.J. Esman, and A. Krishna. (1998). *Reasons for success: Learning from instructive experiences in rural development.* West Hartford, Conn.: Kumarian Press.

Uphoff, N., and C.M. Wijayaratna. (2000). "Demonstrated benefits from social capital: The productivity of farmer organizations". *World Development,* Vol. 28(11): 1975-1890.

Van den Berg, M. (2002). "Do public works decrease farmers' soil degradation? Labour income and the use of fertilizers in India's Semi-arid tropic". *Environment and Development Economics* 7:487-506.

Van De Ven, G.W.J.(1996). *A mathematical approach to comparing environmental and economic goals in dairy farming on sandy soils in the Netherlands.* Ph.D. thesis, Wageningen Agricultural University.

Van Keulen, H. (1992). Options for agricultural development: a new quantitative approach. In : *Systems approaches for agricultural development.* Vol 2., Proc. of the Int. Symp. for Agric. Development, Bangkok, Thailand (Penning de Vries, F.W.T., P. Teng and K. Metselaar eds.), pp. 355-365.

Veeneklaas, F.R., S. Cissé, P.A. Gosseye , N. Van Duivenbooden & H. Van Keulen (1991). *Competing for limited resources: the case of the fifth Region of Mali. Development scenarios.* Wageningen: CABO-DLO/Mopti: ESPR Mali.

Veeneklaas, F.R., H. Van Keulen, S. Cissé, P. Gosseye & N. Van Duivenbooden (1994). Competing for limited resources: options for land use in the Fifth Region of Mali. in: Fresco, L.O, J. Stroosnijder, J. Bouma & H. van Keulen *The future of the land: mobilizing and integrating knowledge for land use options.* Chichester: John Wiley & Sons. pp. 227-247.

Von Oppen, M., R.P. Parthasarathy, and R.K.V. Subba. (1985). Impact of market access on agricultural productivity in India. In: von Oppen, M., Parthasarathy, R.P. and Subba, R.K.V. (eds), Agricultural markets in semi-arid tropics: proceedings of an international workshop. Patancheru, India, October 24 – 28, 1983.

Wachter, Daniel. (1992)."Land Titling for Land Conservation in Developing Countries." Environment Department Divisional Working Paper 1992-28. World Bank, Washington, D.C.

Walker, David J. (1982). " A Damage Function to Evaluate Erosion Control Economics. " *American Journal of Agricultural Economics*, 64 (4, November): pp. 145-55.

Walker, T and J. Ryan. (1990). *Village and Household Economies in India's Semi-Arid Tropics*. Baltimore: The John Hopkins University Press.

Walker, D.J., and D.L. Young. (1986)."The effect of technical progress on erosion damage and economic incentives for soil conservation." *Land Economics* 62 (1), pp.83-93.

Welch, F. (1978). "The role of investments in human capital in agriculture." in *Distortions of Agricultural Incentives*. T.W. Shultz (Ed.), pp.259-280, Indiana University Press.

Williamson, O.E. (1995). "The Institutions and Governance of Economic Development and Reform." in Bruno M. & Pleskovic B. (Eds.) *Proceedings of the World Bank Annual Conference on Development Economics 1994*, Washington, D.C.: pp171-194.

Williamson, O.E. (1986). "The economics of governance: frame work and implications." in *Economics as a Process: Essays in New Institutional Economics*, (ed.) Langlois, pp171-200, Cambridge University Press.

Winter-Nelson, A.; F. Karin; and M. Nyambu.(1990). *Agriculture in Nakuru district: strategies for growth.Policy Analysis for Rural Development Working Paper No. 4*. Njoro: Egerton University.

Woomer, P.L., M.A. Bekunda, N.K. Karanja, T. Moorehouse, and J.R. Okalebo. (1998). "Agricultural resource management by smallholder farmers in East Africa". *Nature and Resources*, 34(4): 22-33.

World Bank. (1994). *The World Bank and Participation*. Report of the learning Group on Participatory Development. April 1994. Washington, DC: The World Bank

World Bank (1992). World Development report 1992: Development and the Environment. World Bank, Washington D.C.

Wossink, A. (1993). *Analysis of future agricultural change: a farm economics approach* *applied to Dutch arable farming*. PhD thesis, Agricultural University. The Netherlands.

WRR (1992), *Ground for choices: four perspectives for rural areas in the European Community*. The Hague: Netherlands Scientific Council for Government Policy.

Zaal F. (1999). *Investments in the quality of land for sustainable land use. Report on a Farmer Survey in Machakos and Kitui Districts, Kenya* (draft, 28 October 1999; Amsterdam: University of Amsterdam)

Appendix A

Table A1: Consumption Parameters for Machakos and Kitui Districts, Kenya, 2000

	Machakos			Kitui		
Good	Average Expenditure (Ksh/hh)	Price (Ksh)	Share	Average Expenditure (Ksh/hh)	Price (Ksh)	Share
Maize	13,503.15	22.10	.1502	21,459.70	19.10	0.1808
Beans	11,490.40	37.55	.1271	11,855.50	30.90	0.09735
Fuel	4,279.60	25.50	.04625	5,922.85	19.25	0.05209
Ofoods	22,587.45	78.20	.2460	29,871.45	83.45	0.2442
Nfoods	31,965.45	368.35	.2772	39,001.90	391.40	0.3049
Leisure	13961.10	94.30	.1694	14,322.50	107.85	0.1273

Source: Computed from Field survey, 2000

Table A2: OLS parameter estimates for a system of AIDS Engel functions for Machakos and Kitui districts, Kenya, 2000

	Maize	Beans	Fuel	Ofoods	Nfoods	Leisure
P_{maize}	.020477	-.0087014	-.023684	.0030492	.0059882	.002871
	(.653)	(-.47)	(-1.708)**	(.084)	(.084)	
P_{beans}	.036534	.043133	.016251	.048799	-.077436	-.067281
	(.887)	(1.78)**	(0.893)	(1.02)	(-1.14)	
P_{fuel}	-.0043515	.0032667	-.022581	.0069999	.020224	-.003581
	(-.42)	(.54)	(-4.92)***	(.582)	(1.177)	
P_{ofoods}	-.01699	-.017522	.0057912	-.048826	.067646	.0099008
	(-.94)	(-1.65)*	(.72)	(-2.3)***	(2.26)**	
P_{nfoods}	.0021302	.0070071	-.0003367	.0085528	-.0027145	-.0146489
	(.147)	(.822)	(-.0525)	(.5088)	(-.1131)	
$P_{leisure}$	-.025730	-.019391	.0075652	.023732	-.13311	.1469338
	(-.672)	(-.86)	(.447)	(.535)	(-2.3)**	
AGE	-.038734	-.020868	.0096868	-.022784	.081524	-.0088248
	(-1.35)**	(-1.24)	(.764)	(-.686)	(1.72)**	
EDUC	-.0050066	-.013762	-.0014047	-.009354	.03146	-.0019327
	(-.6133)	(-2.9)***	(-.39)	(-.9898)	(2.33)**	
SEX	-.026117	-.019905	-.011206	.04613	.0077076	.0033904
	(-1.1)	(-1.43)**	(-1.07)	(1.68)**	(.196)	
SHH	.0083014	-.0011796	-.0043836	-.042992	.021261	.0189928
	(.493)	(-.12)	(-.589)	(-2.21)**	(.764)	
LOC	.01415	-.047521	.0073909	.018381	.061933	-.0543339
	(.8743)	(-5.0)***	(1.033)	(.981)	(2.313)**	
INC	.0031517	.0035624	.0053532	.0067631	.0050057	-.0238361
	(1.38)**	(2.66)***	(5.3)***	(2.56)***	(1.324)*	
(constant)	.33585	.2705	.031876	.21054	.30626	-.155026
	(1.06)	(1.456)*	(.228)	(.575)	(.585)	
R-square	0.0639	0.3463	0.2985	0.1450	0.1914	-
D.W.	2.0168	1.9498	2.0108	1.8979	1.94	-

The figures in the parentheses are the t-statistics for the null hypothesis that the respective coefficient is zero. * significant at 10% ** significant at 5% *** significant at 1 %.
Source: Estimates from Field Survey, 2000

The Breusch-Pagan lm test for diagonal covariance chi-square = 130.27 with 10 d.f. ; log of determinant of sigma = -27.586, log of likelihood function = 1091.82. The system R-square is 0.8080, chi-square 269 with 60 D.F. Likelihood ratio test of diagonal covariance matrix = 205.54 with 10 D.F.

Table A3: Computed demand elasticities from an AIDS model for Machakos and Kitui districts, 2000

	Maize	Beans	Fuel	Ofoods	Nfoods	Leisure	Income
Maize	-0.91	-0.051	-0.484	0.015	0.015	0.044	1.02
Beans	0.215	-0.70	0.387	0.138	-0.182	0.001	1.02
Fuel	-0.012	0.038	-1.46	0.039	0.046	-0.017	1.09
Ofoods	-0.104	-0.155	0.111	-1.22	0.231	0.105	1.03
Nfoods	-0.014	0.038	0.013	0.007	-0.98	-0.073	1.01
Leisure	-0.144	-0.121	0.132	0.090	-0.506	-0.84	0.84

Source: Estimates from Field survey 2000

Table A4: Calibrated demand elasticities for Machakos and Kitui district, 2000

	Maize	Beans	Fuel	Ofoods	Nfoods	Leisure	Income
Maize	-.910	.084	-.043	-.038	.005	-.053	.954
Beans	.124	-.700	.077	.056	-.146	-.059	.647
Fuel	-.143	.175	-1.460	.059	.047	.027	1.295
Ofoods	-.026	.025	.012	-1.220	.139	.063	1.007
Nfoods	.003	-.056	.008	.117	-.980	-.207	1.116
Leisure	-.064	.048	.010	.113	-.443	-.840	1.272

Source: Author's computation

Table A5: Gross Margins, Transaction costs and typical cropping patterns by farm size in Machakos and Kitui district, Kenya

Crop	Gross Margin (Ksh/ha)	Market Price (Ksh/kg)	Transaction cost Ksh/km	Farm categories (hectares) Small 1.5	medium 3.75	Large 9.9
Maize		20.45	6.154	0.3	1.05	1.7
Beans		37.55	6.154	0.2	0.45	1.15
Coffee		34.00	6.154	-	-	0.1

Source: Jaetzold & Schmidt, 1983; Field survey, 1998, 2000

Table A6: Production parameters for Machakos and Kitui district, Kenya

Crop	Land (hectares)	Labour (Man-days/ha)	Manure (Kgs/ha)	Fertilizer (Kgs/ha)	Yield (Kgs/ha)
Maize	1	132.1	341.6	12.7	1080.3
Beans	1	157.6	535.0	9.6	1241.2
Coffee	1	483.4	4192.6	382.6	3804.5

Source: Field survey, 1998, 2000

Appendix B

Table B1: Terracing status of fields in Machakos and Kitui Districts, Kenya, 2000

Status of plot	Number	Percentage (%)
Not terraced	115	31.1
Terraced	255	68.9
Total	370	100

Source: Field survey 2000

Table B2: Tenure status of fields in Machakos and Kitui Districts, Kenya, 2000

Tenure type	Number	Percentage (%)
Rented in	4	0.9
Rented out	1	0.2
Communal rights	5	1.1
Traditional private rights/demarcated	41	9.1
Still obtaining title deed	224	49.9
Private title deed	174	38.8
Total	449	100

Source: Field survey 2000

Table B3: Slopes of fields in Machakos and Kitui Districts, Kenya, 2000

Slope type	Number	Percentage (%)
Low flat	77	19.3
Lower slope	225	56.5
Mid slope	96	24.1
Total	398	100

Source: Field survey 2000

Table B4: Mode of acquisition of fields in Machakos and Kitui districts, Kenya, 2000

	Number	Percentage (%)
Inherited	327	70
Purchased	124	26.6
Rented	9	1.9
Gift	1	0.2
Newly occupied	3	0.6
Squatted	1	0.2
Temporary, free use	2	0.4
Total	467	100

Source: Field survey 2000

Table B5: Use of fields at time of acquisition in Machakos and Kitui districts, Kenya, 2000

Use of fields	Number	Percentage (%)
Private grazing	34	7.3
Private fallow (used for private grazing)	55	11.8
Private fallow (no grazing)	10	2.2
Private food crop	242	52
Private cash crop	12	2.6
Private food and cash crop	9	1.9
Communal grazing	22	4.7
Bush land or forested	81	17.4
Total	465	100

Source: Field survey 2000

Table B6: Use of fields now in Machakos and Kitui districts, Kenya, 2000

Use of fields now	Number (N)	Percentage (%)
Private grazing	10	2.2
Private fallow (used for private grazing)	20	4.5
Private fallow (no grazing)	10	2.2
Private food crop	330	74.2
Private cash crop	30	6.7
Private food and cash crop	35	7.9
Private feed production	1	0.2
Communal grazing	1	0.2
Bush land or forested	8	1.8
Total	445	100

Source: Field survey 2000

Table B7: Fertility enhancements of parcels in Machakos and Kitui districts, Kenya, 2000

	Number of fields	Percentage (%)
None	2	0.7
Manure	222	77.4
Fertilizer	31	10.8
Green manure	2	0.7
Compost	28	9.8
Other (specify)	2	0.7
Total	287	100

Source: Field survey 2000

Appendix C

Table C1: 3SLS regression results for determinants of soil conservation investment (m/ha) on maize in Machakos and Kitui districts, Kenya, 2000

Equations	1	2	3	4	5
	(TERACE)	(MAN)	(FERT)	(LAB)	(CROPAC)
ln *SLOPE*	-0.232	0.682	0.233E-01	0.612E-01	
	(-1.163)	(3.958)***	(0.185)	(0.514)	
ln *TENURE*	-0.247	-0.509	0.682E-01	0.111	
	(-0.906)	(-2.156)**	(0.396)	(0.677)	
LOC	-0.962	0.220	-0.902	0.392E-01	-0.651E-01
	(-3.840)***	(1.015)	(-5.696)***	(0.246)	(-0.302)
ln *DISTH*	-0.573E-01	-0.569E-01	-0.353E-01	0.698E-02	
	(-1.202)	(-1.384)*	(-1.175)	(0.245)	
ln *LCROPAC*	-0.114	-0.135	0.510E-01	-0.537E-01	
	(-1.118)	(-1.539)*	(0.803)	(-0.887)	
ln *SEACOS*	0.150	-0.323	0.477E-01	0.126E-01	
	(1.716)**	(-4.264)***	(0.865)	(0.241)	
ln *EDUC*	0.578	-0.449	0.876	-0.454	
	(1.837)**	(-1.651)*	(4.423)***	(-2.396)***	
ln *WEALTH*	0.992	0.952	0.429	0.426	
	(3.847)***	(4.267)***	(2.641)***	(2.727)***	
SEX	0.193E-01	0.244	-0.790	-0.408	
	(0.474E-01)	(0.695)	(-3.089)***	(-1.675)**	
ln *FAROR*	0.276	0.760	-0.243	0.424	
	(1.557)*	(4.942)***	(-2.166)**	(3.945)***	
SELFHG	0.193	-0.620E-01	0.501E-01	-0.240	
	(0.831)	(-0.308)	(0.342)	(-1.722)**	
ln *SHH*	-0.879	0.298	0.140	-0.330	
	(-2.710)***	(1.065)	(0.687)	(-1.702)**	
ln *FARMCA*	-0.929	-0.138	0.342	-0.751	
	(-5.348)***	(-0.922)	(3.139)***	(-6.938)***	
ln *INC*	0.485	0.829	-0.164	0.333	
	(3.444)***	(6.802)***	(-1.847)**	(3.924)***	
ln *AGE*	1.851	-0.500	0.735	-0.392	
	(3.567)***	(-1.116)	(2.250)**	(-1.265)	
ln *ACESCOS*	-0.933	-1.711	0.420	0.249	
	(-2.549)***	(-5.421)***	(1.824)**	(1.134)	
ERODE	-0.376	-1.142	-0.141	-0.574E-01	
	(-1.682)**	(-5.891)***	(-1.001)	(-0.428)	
ln *TERACE*					-0.354E-01
					(-0.895)
ln *LAB*					0.813
					(5.489)***
ln *FERT*					0.139E-01
					(0.192)
ln *MAN*					0.349E-01
					(1.119)
IMR	3.451	3.289	1.868		
	(20.60)***	(26.53)***	(16.56)***		
(*CONSTANT*)	-3.235	2.739	-2.122	0.904	2.943
	(-1.063)	(1.039)	(-1.110)	(0.498)	(3.985)***
N	112	112	112	112	112

* significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01

Figures in parentheses are the t-statistics for the probability that respective coefficients are zero

Source: Field survey 2000

Table C2: 3SLS regression results for determinants of soil conservation investment (m/ha) on beans in Machakos and Kitui districts, Kenya, 2000

Equations	1	2	3	4	5
	(TERACE)	(MAN)	(FERT)	(LAB)	(CROPAC)
ln *SLOPE*	0.462	-2.277	-1.005	0.448	
	(0.639)	(-3.362)***	(-1.548)*	(0.966)	
ln *TENURE*	0.917E-01	-0.284	-0.530	-0.874	
	(0.114)	(-0.376)	(-0.733)	(-1.691)**	
LOC	-1.463	1.426	-1.343	0.177	0.151
	(-2.593)***	(2.711)***	(-2.650)***	(0.490)	(0.257)
ln *DISTH*	-0.436	-0.356	0.712E-01	-0.644E-02	
	(-3.917)***	(-3.403)***	(0.711)	(-0.900E-01)	
ln *LCROPAC*	0.112	0.286	-0.658E-01	-0.131	
	(0.499)	(1.358)*	(-0.327)	(-0.914)	
ln *SEACOS*	0.161	-0.300	-0.331E-01	0.140E-01	
	(0.816)	(-1.607)*	(-0.186)	(0.110)	
ln *EDUC*	1.069	-1.279	1.266	0.335	
	(1.797)**	(-2.338)**	(2.411)**	(0.893)	
ln *WEALTH*	0.413	0.618	0.272	0.357	
	(0.903)*	(1.436)*	(0.660)	(1.213)	
ln *FAROR*	-1.092	-0.156	0.233	0.905	
	(-2.094)**	(-0.321)	(0.498)	(2.715)***	
SELFHG	-0.133	-0.914	0.172	0.230	
	(-0.282)	(-2.058)**	(0.405)	(0.756)	
ln *SHH*	0.886E-01	-0.664	-0.755	-0.612	
	(0.160)	(-1.283)	(-1.516)*	(-1.721)**	
ln *FARMCA*	-1.360	-0.314	-0.249	-0.496	
	(-3.956)***	(-0.978)	(-0.808)	(-2.254)**	
ln *INC*	0.819	-0.361	-0.181	0.568	
	(2.860)***	(-1.351)*	(-0.704)	(3.095)***	
ln *AGE*	-0.277	-2.094	2.362	-0.416	
	(-0.244)	(-1.996)**	(2.342)**	(-0.578)	
ln *ACESCOS*	-4.805	1.715	0.973	0.451	
	(-5.996)***	(2.282)**	(1.347)*	(0.875)	
ERODE	2.536	-0.423	-0.504	-0.488E-01	
	(5.497)***	(-0.976)	(-1.213)	(-0.165)	
ln *TERACE*					-0.492E-01
					(-0.670)
ln *LAB*					0.163E-01
					(0.467E-01)
ln *FERT*					-0.711E-02
					(-0.266E-01)
ln *MAN*					-0.211E-01
					(-0.284)
IMR	3.324	3.687			
	(10.05)***	(15.63)***			
(*CONSTANT*)	19.691	13.236	-9.975	-5.026	6.538
	(2.886)***	(2.109)**	(-1.653)**	(-1.167)	(3.777)***
N	47	47	47	47	47

* significant at P<0.10, ** significant at P<0.05, *** significant at P<0.01

Figures in parentheses are the t-statistics for the probability that respective coefficients are zero

Source: Field survey 2000

Appendix D

Table D1: Descriptive statistics for selected variables associated with farmers having negative and positive soil conservation benefits on maize in Kitui and Machakos district, Kenya, 2000

	Groups	N	Mean	Standard Dev.
BENEFITS (2%)	0	43	-336530.40	414340.88
BENEFITS (2%)	1	82	328420.88	248574.07
SLOPE	0	43	2.25	1.03
SLOPE	1	82	2.27	0.93
TENURE	0	43	1.92	1.10
TENURE	1	82	1.87	1.11
DISTH	0	43	947.79	1984.38
DISTH	1	82	1658.56	5610.20
SEACOS	0	43	246.06	261.38
SEACOS	1	82	388.83	488.05
WEALTH	0	43	3.26	1.53
WEALTH	1	82	2.94	1.57
SHH	0	43	7.07	2.94
SHH	1	82	6.83	2.66
FARMCA	0	43	1.17	1.59
FARMCA	1	82	1.08	0.86
INC	0	43	37497.74	47558.95
INC	1	82	58433.35	80500.59
AGE	0	43	48.70	14.77
AGE	1	82	47.18	13.44
ACESCOS	0	43	101.14	37.09
ACESCOS	1	82	110.08	35.31
AREA	0	43	1.29	1.75
AREA	1	82	1.21	0.96
LABOUR	0	43	197.43	246.55
LABOUR	1	82	97.88	70.93
MANURE	0	43	664.10	1200.47
MANURE	1	82	172.45	394.13
FERTILIZER	0	43	19.89	57.43
FERTILIZER	1	82	8.87	37.72
TERRACE	0	43	932.34	1114.36
TERRACE	1	82	350.96	597.68

1 = households with positive net soil conservation benefits, 0, otherwise

Source: Authors own computation from survey data

Table D2: Descriptive statistics for some variables associated with farmers having negative and positive soil conservation benefits on beans in Kitui and Machakos district, Kenya, 2000

	Groups	N	Mean	Standard Dev.
BENEFITS (2%)	0	16	-486395.60	523835.70
BENEFITS (2%)	1	31	820330.63	682374.67
SLOPE	0	16	2.08	1.02
SLOPE	1	31	2.21	1.06
TENURE	0	16	1.54	0.59
TENURE	1	31	1.99	1.17
DISTH	0	16	207.82	279.41
DISTH	1	31	601.00	1065.57
SEACOS	0	16	329.76	305.28
SEACOS	1	31	273.71	308.15
WEALTH	0	16	2.94	1.69
WEALTH	1	31	3.45	1.89
SHH	0	16	6.31	2.55
SHH	1	31	7.03	2.50
FAMCA	0	16	0.22	0.15
FAMCA	1	31	0.37	0.39
INC	0	16	65220.08	119186.50
INC	1	31	49611.72	77221.07
AGE	0	16	41.69	10.90
AGE	1	31	49.03	12.27
ACESCOS	0	16	118.65	36.09
ACESCOS	1	31	106.05	36.53
AREA	0	16	0:88	0.67
AREA	1	31	0.79	0.85
LABOUR	0	16	218.64	207.95
LABOUR	1	31	126.13	113.16
MANURE	0	16	1100.61	2633.09
MANURE	1	31	243.20	387.98
FERTILIZER	0	16	14.67	47.13
FERTILIZER	1	31	6.96	19.20
TERRACES	0	16	1372.74	2475.81
TERRACES	1	31	361.57	801.57

1 = households with positive net soil conservation benefits, 0, otherwise

Source: Authors own computation from survey data

Table D3: Independent Samples Test for maize

	Levene's Test		T-test	
Variables	F	Sig.	t	Sig.
SLOPE	1.293	.258	-.056	.955
TENURE	.020	.889	.255	.799
DISTH	2.351	.128	-.804	.423
LCROPAC	.126	.723	-.282	.778
SEARCO	7.674	.006	-1.786	.077
EDUC	.624	.431	.457	.649
WEALTH	.109	.742	1.083	.281
FAROR	.843	.360	.865	.388
SHH	1.515	.221	.463	.644
FARMCA	1.623	.205	.427	.670
INC	2.503	.116	-1.566	.120
AGE	.572	.451	.578	.564
ACESCOS	.151	.699	-1.320	.189
TERACE	16.162	.000	3.803	.000
LAB	25.544	.000	3.408	.001
FERT	4.746	.031	1.288	.200
MAN	31.286	.000	3.387	.001
CROPAC	.753	.387	-.238	.813
AREA	1.420	.236	.346	.730
BENEFITS	8.593	.004	-11.207	.000

Source: Field Survey 2000

Table D4: Independent Samples Test for Beans

	Levene's Test		T-test	
Variables	F	Sig.	t	Sig.
SLOPE	.256	.615	-.421	.676
TENURE	.778	.382	-1.469	.149
DISTH	3.736	.060	-1.443	.156
LCROPAC	3.423	.071	-1.243	.220
SEARCO	.204	.654	.593	.556
EDUC	.003	.957	.242	.810
WEALTH	2.265	.139	-.913	.366
FAROR	.441	.510	-.522	.604
SHH	.025	.874	-.940	.352
FARMCA	3.391	.072	-1.518	.136
INC	1.224	.275	.543	.590
AGE	.430	.515	-2.015	.050
ACESCOS	.030	.864	1.125	.267
TERACE	8.393	.006	2.089	.042
LAB	6.348	.015	1.984	.053
FERT	3.091	.086	.797	.429
MAN	11.860	.001	1.794	.080
CROPAC	8.452	.006	-2.428	.019
AREA	.139	.711	.390	.699
BENEFITS	3.542	.066	-6.696	.000

Source: Field Survey 2000

Table D5: Descriptive statistics of some selected variables used in the analysis for maize soil conservation benefits in Machakos and Kitui districts, Kenya, 2000

Variable	Minimum	Maximum	Mean	STD. DEV.
SLOPE	0.21	5.00	2.26	0.96
TENURE	0.60	9.60	1.89	1.11
DISTH	1.00	44020.00	1414.06	4691.33
SEACOS	0.25	3000	339.72	428.22
EDUC	1	5	3.08	1.05
WEALTH	1	8	3.05	1.55
SHH	2.00	18.00	6.91	2.75
ACESCOS	31.25	200	107.00	36.04

N=125

Source: Authors own computation from survey data

Table D6: Descriptive statistics of some selected variables used in the analysis for beans soil conservation benefits in Kitui and Machakos district, Kenya, 2000

Variable	Minimum	Maximum	Mean	STD. Dev.
SLOPE	0.60	5.00	2.17	1.04
TENURE	1.00	6.30	1.84	1.02
DISTH	0.30	5000	467.15	895.23
SEACOS	2.00	1100.39	292.79	305.02
EDUC	1	5	3.26	1.15
WEALTH	1	8	3.24	1.83
SHH	2.00	12.00	6.79	2.48
ACESCOS	50.00	200.00	110.34	36.49

N=47

Source: Authors own computation from survey data