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Elizabeth Nambiro

aus

Kenia (Nairobi)

Referent: Prof. Dr. Mathias Becker

Korreferentin: Prof. Dr. Karin Holm-Müller

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Dedication

To mama, Tony and Charles

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AEZ	Agro-Ecological Zone
CBS	Kenya Central Bureau of Statistics
DRSRS	Department of Resource Survey and Remote Sensing
FAO	Food and Agriculture Organization
GCP	Ground Control Points
GDP	Gross Domestic Product
GIS	Geographical Information System
GNS	Global Navigator System
GPS	Global Positioning System
KARI	Kenya Agriculture Research Institute
KESREF	Kenya Sugar Research Foundation
L	Allans' Land Factor
LGP	Length of Growing Period
LH	Low Highlands
LM	Low Midlands
LR	Long Rainy Season
Max	Maximum
Min	Minimum
OLS	Ordinary Least Squares
R-value	Ruthenberg Index for land use intensity
SR	Short Rainy season
TRFK	Tea Research Foundation of Kenya
UTM	Universal Traverse Mercator

Abstract

The Kakamega District in Western Kenya is characterized by high population densities (600 people per km^2) and shrinking of agricultural resource base. Agriculture is the mainstay of the majority of the population. Farmers in Kakamega adopt land, capital or labor-intensive strategies to meet the growing needs for food, income and employment. A quantitative understanding of land use trends, agricultural intensification and of their driving forces is required to target technology options and intervention measures. This thesis explores the trends in land use changes between 1986 and 2004, the main agricultural intensification strategies, as well as their driving forces and implications. Primary data were collected from some 243 households in the year 2005 by the use of a structured questionnaire. The households were selected out of the representative household clusters of the national census framework (Kenya National Sample Survey and Evaluation Program). Data analysis was based on the combined use of GIS techniques (digitized time series aerial photographs) and the use of standard household models of technology uptake (Tobit and Probit).

Over 50% of the farmers live below the poverty line. The land use system in Kakamega is characterized as permanent cultivation. Yields of the main food crops like maize and beans are declining and the use of external inputs is low and largely limited to industrial crops (sugar cane and tea). Land fragmentation index is 0.6 with the average farm size of 0.9 ha per household. In order to raise the levels of agriculture production four main agricultural intensification strategies were used: 1) the expansion of the cropping area by cultivation of fallow land. The area under food crops increased from 48% to 53% and that under sugarcane from 22% to 42% between the year 1986 and 2004. During the same period, the fallow land decreased from 18% to 7% of the arable area. No further expansion of cultivation into fallow areas is possible today. 2) An increased use of external inputs was the strategy of choice to sustain production levels during the periods when mineral fertilizer was subsidized prior to mid 1980s. However, this strategy is capital-intensive and today it is restricted to the few large farms or to those growing industrial crops. 3) An increased cropping intensity by intercropping and multiple cropping can be observed since the mid 1990s. This strategy has also reached its limits as today most farmers practice maize - bean intercropping and the Ruthenberg value of land use intensity is approaching one. 4) An increased use of labor, mainly for land preparation, weeding operations and harvesting. However, family labor investment already reaches a maximum of 40 man-days per ha during high peak labor requirement and a further intensification in labor use is restricted to farmers that are able to hire labor. The agricultural intensification strategies differ between households and depend on the socio-economic characteristic of the farmer, market factors and the biophysical conditions. The remaining agricultural intensification strategies to improve productivity are linked to efficient use of external inputs. Potential technological options to improve productivity or to counteract the resource base degradation are available but require some modification to fit the prevailing biophysical conditions, as well as to the socio-economic attributes of the household. The targeting of such technical options to specific niches is seen to be the priority of future research and extension efforts in Kakamega.

Zusammenfassung

Die Kakamega Region im westlichen Kenia ist durch eine hohe Populationsdichte (600 Einwohner km^{-2}) bei gleichzeitig abnehmender Verfügbarkeit und Qualität der landwirtschaftlichen Ressourcen gekennzeichnet. Landwirtschaftliche Produktion ist die Haupteinnahmequelle der Mehrheit der lokalen Bevölkerung. Um den kontinuierlich wachsenden Ansprüchen an Nahrung, Feuerholz und Einkommen gerecht zu werden, reagieren die Landwirte mit einer Anbauintensivierung, die die Kultivierung von Bracheflächen, den Zwischenfruchanbau, den zunehmenden Einsatz von Produktionsmitteln wie Kapital (Düngemittel, Mechanisierung) oder Arbeitskraft (organische Düngung, Unkrautkontrolle) beinhalten. Das quantitative Verständnis der Veränderung der Landnutzung und deren Regelgrößen ist zwingend erforderlich, um neue Technologien und Interventionsmaßnahmen etablieren und gezielt einsetzen zu können. In der vorliegenden Arbeit wurde zunächst die zeitliche Veränderung der Landnutzung zwischen 1986 und 2004 untersucht. Dabei standen sowohl die Strategien zur Intensivierung der Landnutzung als auch deren Steuerungsmechanismen und resultierende Konsequenzen im Vordergrund. Ferner wurden sozialökonomische Kenngrößen von 243 Haushalten auf der Basis strukturierter Fragebögen und individueller Interviews erhoben. Die Auswahl der Haushalte erfolgte anhand der Datenbank des nationalen Volkszählungsprogramms (Kenya National Sample Survey and Evaluation Program). Schließlich wurde zur Datenanalyse eine Kombination von GIS-Technologien (Zeitreihen digitalisierter Luftbildaufnahmen) in Verbindung mit standardisierten Haushaltsmodellen zur Adaptation neuer Technologien (Tobit und Probit Analysen) herangezogen.

Über 50% der Landwirte leben unterhalb der Armutsgrenze. Dauerbewirtschaftung mit zwei Ernten pro Jahr (Mais-Bohnen Mischanbau) sowie dem Anbau von Dauerkulturen (Zuckerrohr und Tee) ist die vorherrschende Landnutzungsform. Die Erträge der Hauptanbaukulturen sind in den letzten Jahren stark zurückgegangen. Der Einsatz von externen Produktionsmitteln liegt weit unterhalb der notwendigen Minimalgrenzen und beschränkt sich auf die Dauerkulturen mit industrieller Nutzung (Zuckerrohr und Tee). Der Landfragmentierungsindex beträgt 0.6 bei einer durchschnittlichen Betriebsgröße von 0.9 ha pro Haushalt. Um den landwirtschaftlichen Produktionsausstoß zu erhöhen wurden im Wesentlichen vier Strategien der Intensivierung verfolgt: 1) Ausweitung der Produktionsflächen. Von 1986 bis 2004 erhöhte sich die Produktionsfläche für Grundnahrungsmittel von 48% auf 53% und die von Zuckerrohr von 22% auf 42% der Gesamtanbaufläche. Gleichzeitig reduzierte sich der Anteil der Kulturbrache von 18% auf 7%. Ein weiteres Ausweichen der Produktion auf Extrem- oder Brachestandorte ist heutzutage nicht mehr möglich. 2) Mineraldüngereinsatz. Zur Erhaltung des aktuellen Produktionsniveaus wurde über die Subventionierung mineralischer Dünger in den 80er Jahren eine Steigerung des Einsatz externer Produktionsfaktoren erreicht. Die Strategie ist jedoch Kapitalintensiv und beschränkt sich heute auf einige wenige Großarmen und auf marktorientierte Betriebseinheiten mit Industriekulturen. 3) Anbauintensivierung. Seit Mitte der 90er Jahre ist eine Intensivierung der landwirtschaftlichen Produktion über Mehrfachanbau- und Zwischenfruchtanbauverfahren zu beobachten. Auch diese Strategien haben derzeitig ihre Grenzen erreicht, zumal seit 2005 die Mehrheit der Landwirte bereits

zweimal jährlich Mais-Bohnen anbaut und sich der Ruthenberg Index zur Beschreibung der Landnutzungsintensität dem Wert 1 annähert. 4) Arbeitskräfteeinsatz. Ein erhöhter und ertragswirksamer Einsatz von Arbeitskräften erfolgt hauptsächlich für die Bodenbearbeitung und die Unkrautkontrolle. Jedoch erreicht der Einsatz von Familienarbeitskräften zu den Spitzenbedarfszeiten schon jetzt 40 Mann-Tagen pro Hektar und Woche und eine weitere Intensivierung beschränkt sich folglich auf Betriebe mit der Möglichkeit externe Arbeitskräfte zu rekrutieren. Die vorherschenden Strategien zur landwirtschaftlichen Intensivierung variieren zwischen den einzelnen Haushalten in Abhängigkeit von den sozio-ökonomischen Betriebskenngrößen, dem Marktzugang sowie von biophysikalischen Faktoren. Die einzige heute noch verbleibenden Strategie zum Erhalt bzw. der Steigerung der Produktion sind technische Innovationen, welche bei gleichzeitigem Erhalt der Ressourcenqualität auch die Effizienz der eingesetzten Betriebsmittel erhöhen. Solche technischen Einsatzmöglichkeiten stehen zwar prinzipiell zur Verfügung, sie müssen aber an die vorherrschenden biophysikalischen Begebenheiten und sozio-ökonomischen Eigenschaften der Haushalte angepasst sein. Die Identifikation und Bewertung dieser technischen Innovationen und deren Extrapolation in spezifische sozial-ökologische Nischen wird von essentieller Bedeutung für eine nachhaltige Erzeugung und den Erhalt der Lebensgrundlage der ländlichen Haushalte in Kakamega sein.

1 Introduction

Agriculture is the mainstay of the economies of many African countries. In Kenya, agriculture remains the main occupation and the source of income for the majority of the population. It accounts for about one-third of the gross domestic product (GDP), employs more than two-thirds of the labor force, generates 70% of the export earnings (excluding refined petroleum), provides the bulk of the country's food requirements, and supplies a significant proportion of the raw materials for the agriculture-based industrial sector (CBS, 2005). Agriculture is divided into large and smallholder sub-sectors. The smallholder1 sub-sector contributes about 75% of the total value of agricultural output, as well as 55% of the marketed agricultural output, and it provides over 85% of the total employment in agriculture (CBS, 2005). Only some 19% of Kenya's total land area of 57.6 million hectares is classified as high and medium potential area for agriculture. These 9.4 Mio ha support about 80% of the population. The remaining area is made up of protected areas like national reserves or game parks, and arid and semi-arid lands (CBS, 2005).

With an annual population growth rate of 2.4%, this restricted potentially favorable share of the land area is increasingly put under pressure to meet the growing demand for food, feed, fuel and industrial products. Due to demographic growth combined with closed land frontiers (limited potential for expansion into marginal or so far unused land resources), the same land area has to support an ever increasing number of people. The ratio of land under crop cultivation to population (a rough proxy for farm size per capita) has been shrinking consistently and was cut in half over the past 40 years in Kenya (FAO, 2004)2.

The resulting intensification in land use has occurred mostly in the absence of conservation measures and has been identified as the main culprit for land degradation and nutrient depletion (Smaling et al., 1993) and a declining production potential.

The following five intensification strategies can be encountered in smallholder farming systems:

1 Farms less than 12 hectares

2. FAO data since 1960 indicate that the ratio of land under crop cultivation to agricultural population (a rough proxy for farm size per capita) has been shrinking gradually but consistently in Africa Relatively densely populated countries such as Kenya and Ethiopia have seen this ratio cut in half over the past 40 years. And even in countries widely considered to be land abundant, such as Zambia and Mozambique, the data show a clear trend towards declining per capita farm sizes. See Appendix 1

1) an increased proportion of cropped land at the price of a reduced fallow lengths and fallow area (Becker and Johnson, 2001);
2) cropping for longer periods during the year i.e., off-season cropping (FAO, 1997);
3) more crops per unit land area by intercropping and multiple cropping (Andrews and Kassam, 1976);
4) increased input use per unit area (Tiffen *et al*., 1994);
5) increased factor productivity i.e., external inputs (Cassman and Pingali, 2005).

All the mentioned agricultural intensification strategies have happened or are still happening in Kakamega District in an effort to sustain agricultural production levels despite a declining resource base quality. The extend to which the above-mentioned strategies have been applied in Kakamega, and their effect on agriculture production, productivity and livelihood levels is largely unknown.

1.1 Problem Statement and objectives

Despite improvements in land-cover characterization made possible by earth observing satellites (Loveland *et al*., 1999), the agricultural land uses are still poorly characterized. In Kenya, for example, only few studies have quantified land use changes in different parts of the country. The most recent study on agricultural land use changes in Kenya was undertaken in Lambwe valley in South West Kenya (Muriuki *et al*., 2005) while another is on-going in the Laikipia plateau. The only available land use study for Kakamega was limited to the production area of maize during the long rainy (LR) season (Ottichilo, 1986). More detailed studies on land cover changes exist for the Kakamega forest reserve (Akotsi and Gachanja, 2004; Lung and Schaab, 2006) but are largely absent for the surrounding farmland. Such information will be provided by the present study.

Within the context of land use changes, the strategies of agricultural intensification have rarely been studied. While Salasyia *et al*, (1998) studied the adoption of improved maize seed and inorganic fertilizer use in Kakamega in 1996, there is very little information on other agricultural intensification strategies. Also, the recent liberalization of the agriculture input and outputs market due to policy changes has had some impact on adoption. Studies on trends in land use, agricultural intensification and its drivers are seen to help in policy formulation and decision making concerning the sustainability of future agriculture production. This study aims to fill this knowledge gap and provide quantitative information to be used by all the stakeholders involved in policy, land use planning and agricultural intensification. The overall objective of this study was to identify the land use trends and some of the commonly used agricultural intensification strategies practiced in Kakamega District and to determine their driving forces.

The specific objectives are:

- To assess the socio-economic characteristics of households in Kakamega.
- To identify trends in land use changes in the study area.
- To identify the agricultural intensification strategies.
- To determine factors influencing agricultural intensification strategies.

To meet the above objectives the following research questions were formulated to guide the research:

1. What are the trends in land use in Kakamega?
2. What is the existing agricultural intensification strategies practiced in Kakamega?
3. What are the drivers of agricultural intensification in Kakamega?

To achieve the above objectives and answer the research questions, both household surveys and secondary data sources were used.

1.2 Justification of the study

The economic growth in Kenya may be achieved by providing a policy environment that will results in "working markets", improved infrastructure and a healthy population. There is a direct and positive relationship between the growth of the agricultural sector and the entire economy and vice versa (CBS, 2000; Nyoro, 2001). Therefore agricultural growth is seen to play an important role in reducing rural poverty, stimulating economic growth and development in Kakamega. However, agricultural production is determined by resource base quality and availability, and is influenced by land use and agriculture systems intensification.

Land use changes and agricultural intensification occur in rural smallholder farms without documentation. Scientists recognize, however, that the magnitude of change is large. One estimate, for example, holds that the global expansion of croplands since 1850 has converted some 6 million km^2 of forests/woodlands and 4.7 million km^2 of savannas/grasslands/steppes. Within these categories, respectively, 1.5 and 0.6 million km^2 of cropland has been abandoned (Ramankutty and Foley, 1999). Therefore, addressing the challenges of sustainable agricultural development in Kakamega could be aided by a better understanding of land use changes and drivers of agricultural intensification processes. This calls for disentangling the underlying drivers of agricultural intensification and documentation of land use trends.

Increasing per capita food production and raising rural incomes are the key challenges facing farmers in Kakamega, where over fifty percent of the population lives below the poverty line[3] (CBS, 2001b; World Bank, 2000) and are food insecure. One way of solving the problem of food shortage in Kakamega is to increase agricultural productivity using scarce arable land. This can be achieved by the use of modern and advanced technology, such as the application of inorganic fertilizers, organic manure and the use of improved commercial seeds.

Farmers in Kakamega are already applying agricultural intensification strategies that suit their respective household needs and available resource endowments. While current agricultural intensification strategies undertaken in Kakamega are aimed at raising food production, farmers are increasingly faced with problems associated with declining resource base quality which has resulted in very low crop yields (Salasya *et al*., 1998). Agronomic and soil science studies in recent years shows that soil nutrient mining is widespread in Western Kenya, undermining the ability of many agrarian households to produce enough food supplies for household subsistence (FAO, 2004; Smaling *et al*., 1993; Tittonell *et al*., 2005). For example, Smaling *et al*. (1993) report average annual net mining of 42 kg N ha^{-1}, 3 kg P ha^{-1}, and 29 kg K^{-1} ha from the soils of Kakamega. In fact, soil fertility depletion has been identified as a major cause of the chronic food insecurity among the households (Ojiem, 2006).

It is apparent that current agricultural intensification in Kakamega is unsustainable as it leads to soil degradation such as increased soil erosion, declining soil fertility and reduced biodiversity (KARI, 1994). Concerns are raised over the long-term sustainability and the environmental consequences of the current intensification of agriculture systems in Kakamega in addition to the frequent food insecurity situations. Hence, there is need to develop agricultural systems that increases food productivity while maintaining or enhancing the resource base quality and environmental services. Rural livelihoods in the agriculture-based economy of Kakamega depend on the success of implementing sustainable agriculture systems. According to Pingali (2001), key determinants for an agricultural intensification involve:

- The agro-ecological zone (AEZ)

3 According to the World Bank, (2000), definition spending less than one USA dollar per person per day is considered to be below poverty line.

- The quality/vulnerability of the resource base
- The access to input and output markets
- The demographic growth
- Household socio-economic characteristics

Other studies have shown that factors such as the farm size, production risk and uncertainty (i.e. yield variability), availability of social capital, labor and credit, and the tenure security to be main determinants for smallholder agricultural intensification (Doss, 2006; Mercer, 2004).

Non-farm income opportunities and possibilities of infrastructure development are likely to modify the effect of drivers on the agricultural intensification process (McIntire *et al.*, 1992).

The above-mentioned drivers of agricultural intensification could be modeled to determine their applicability in Kakamega. Understanding the land use changes and agricultural intensification has long been a question in geography, agricultural economics, archaeology, and related disciplines (Ramankutty and Foley, 1999). Efforts to stimulate agricultural intensification should be based on a reasonable understanding of the factors that influence it and the current available resource endowment.

1.3 Agricultural intensification in Kakamega

The present study focused on Kakamega District, which is located in Western Kenya. Kakamega is characterized by a mean population density of over 600 people per square kilometer, with a range of 400 to 800 depending on the administrative division. For instance, the municipality has the highest population density. Kakamega has an annual population growth rate of 2.9 % (CBS, 2001a).

The current population exerts a large and growing pressure on land to meet household basic needs requirement like food, employment and income. Kakamega area is considered potentially favorable for agriculture production with high rainfall in a bimodal distribution pattern (700-1800 mm) and moderately weathered soils (Ojiem, 2006). However, the agricultural production is increasingly constrained by scarcity of land amongst other limiting resources. The land scarcity problem is worsened by the decline in average land holding per household, as a result of population growth and the prevailing patrilineal real split-up inheritance system.

Increasing the agricultural production and productivity on smallholder farms is recognized to be the major solution for reversing the current trend of declining per capita food production (Donovan and Casey, 1998; Scoones and Toulmin, 1999). Agriculture productivity improvements require improved factor use (land, capital and labor) efficiency. The agricultural intensification strategies in Kakamega can be classified as being land-, capital- or labor-intensive.

Land is a key resource for farmers in rural Kakamega. Having more land in Kakamega can enhance farm production, consequently increasing the likelihood of acquiring other assets of much higher value and raising household incomes. A typical land-intensive strategy involves the cultivation of maize (*Zea mays*) and beans (*Phaseolus vulgaris*) during the long and short rainy seasons in one year with no or low external input use.

Traditionally, farmers would restore soil fertility by leaving part of their land uncultivated for many years while new and more fertile land was cultivated for food production. The rapid increase in human population has, however, reduced the amount of land available to the farmer and destabilized this traditional system of maintaining soil fertility. Consequently, long-duration natural fallows[4] are no longer possible. They are replaced by short-duration ones, lasting one or two seasons only (Amadalo *et al.*, 2003). Apparent implications of this particular land-intensive strategy are emerging nutrient deficiencies and resource base degradation (Smale *et al.*, 1994).

Another land-intensive strategy involves the partial replacement of the traditional subsistence food crops like maize, beans, groundnuts (*Arachis hypogaea*) and sweet potatoes (*Ipomea batatas*) by commercial crops like tea (*Camellia sinensis*) and sugarcane (*Saccharum officinarum*). Groundnuts and sweet potatoes are grown on sandy patches of the farm. Such commercial crop farming systems use external inputs like inorganic fertilizers and generate cash income to the farmer. Four main policy consideration motivated the Kenya government involvement in the sugar sub-sector after independence: first, there was the need to ensure self-sufficiency, with export of the surplus sugar; second, sugar production was regarded as an essential import substitution strategy to save the country foreign exchange; third, sugarcane growing was a tool for social development i.e. it provided employment opportunities and wealth creation in the rural areas of Kenya; and fourth, sugarcane growing was viewed as an agent for infrastructure and rural development (KSA, 1999; Otieno *et al.*, 2003). Tea was also introduced as a commercial crop in Western, Central and Eastern provinces to improve rural livelihood (KARI, 1994).

Both tea and sugarcane cover the land for longer periods than the annual food crops. Tea is grown on clay Ultisols in the South of Kakamega District with high rainfall, and sugarcane is

4 Natural fallow is land left to rest from cultivation for a long period in order to restore soil fertility lost from cropping. Improved fallow, on the other hand is land resting from cultivation but the vegetation is not natural but managed and planted with species of leguminous trees, shrubs and herbaceous cover crops.

grown on sandy Alfisols in the North with a distinct dry season. Moreover, tea has regular labor demands and provides monthly income, while sugarcane has seasonal labor demands and provides income after 18 months.

Labor-intensive strategies involve manual land preparation, row cultivation and manual weeding and harvesting of crops. Farmers may incorporate labor-intensive soil fertility management practices in food production in order to improve soil fertility and soil-capital. Soil-capital (the amount and quality of land a farmer controls) is one of the major assets smallholder farmers depend on to generate food and cash incomes.

Capital-intensive agriculture strategies involve the substitution of human labor with chemical inputs, machinery and high quality commercial seed to enhance agriculture productivity. The commercial seeds involve mainly hybrid maize and modern cultivars of pulses and vegetable crops. Inorganic fertilizers are also used as a capital-intensive strategy to enhance soil fertility. In some instances chemicals like pesticides could also be applied, especially in the production of high value crops.

The following chapter provides the conceptual framework and the literature review related to agricultural intensification. The farmers' perceived production and consumption decision-making are also discussed. Chapter 3 describes the geographical location of the study area, the survey data and methodology employed in achieving the objectives of the thesis. Chapter 4 presents the key findings of the study. The results include the descriptive statistics of the socio-economic characteristics of the surveyed households, land use trends, agricultural intensification and its drivers. Chapter 5 discusses the study findings. Summary, conclusions and recommendation are found in chapter 6.

2 Conceptual framework and economic theories

This chapter provides the background information on the nature and processes of agricultural intensification considered relevant for the current study. The chapter also outlines the conceptual framework under which smallholder farmers operate to choose their consumption and production decisions.

2.1 Nature and process of agricultural intensification

The process of agricultural intensification can take different forms, with different impacts on livelihoods of the rural people and the environment. These changes include an increased use of labor per unit of land using traditional methods like shortening of fallow cycles, adoption of more labor-intensive methods of production or investment in land, e.g. soil and water conservation structures (Pender *et al*., 2001). The capital-intensive methods of land use intensification involve replacing human labor with machine or the use of external inputs, which include the use of improved hybrid maize or inorganic fertilizer.

Reardon *et al*. (1999) distinguishes sustainable and unsustainable types of agricultural intensification based on the following two criteria mainly environmental and economic. They appraise the sustainability of agricultural intensification by the following two criteria:

- An environmental criterion: whereby the technology protects or enhances the farm resource base and thus maintains or improves land productivity;
- An economic criterion: whereby the technology meets the farmer’s production goals and is profitable.

Reardon *et al*. (1999) further differentiate between the “capital-led intensification” and the “labor-led intensification” strategies. The labor-led intensification is also referred to as “capital-deficient intensification”, which involves excessive dependence on the use of labor as a variable input to production. Capital-led intensification refers to the agricultural intensification based on substantial use of non-labor variable inputs that enhance soil fertility (such as inorganic fertilizers and improved seed) and quasi-fixed capital, particularly land and water conservation infrastructure that increase labor productivity.

Capital-deficient production occurs when farmers depend mainly on labor as a variable input to agriculture production. Labor-led agricultural intensification strategy makes little use of inorganic fertilizer and other chemicals or external inputs but instead emphasizes the use of organic matter and land conservation structures, which is considered less sustainable from the viewpoint of the two sustainability criteria stated above (Reardon *et al*., 1999).

It was earlier revealed that given the increasing cropping intensity and declining number of livestock, sufficient manure is not available to substitute inorganic fertilizer in sub Sahara Africa (Sanders *et al.*, 1996). Observations from West Africa showed that the amount of manure and compost produced in the farm was not sufficient to replace the major nutrients that are mined from the soil during crop production (Reardon *et al.*, 1999). Capital-deficient intensification meets neither the environmental nor economic criteria required for sustainable agriculture but instead causes soil mining and yield decline in the long run (Sanders *et al.*, 1996).

In situations where the factor and credit markets are non-existent or only partially exist, labor can hardly be substituted with capital inputs. High transaction costs in both the labor and input factor markets can lead farmers to follow agricultural intensification methods that involve more use of family labor and less capital. This can be the case where wage rate increases lag behind price increases for variable input prices in which case the farmer opts to follow a path where he merely adds labor, allowing him to crop more densely, and weed and harvest more intensively. Also where land constraints increasingly bind and labor/land ratios are rising, one might expect farmers to choose production methods that are as labor-intensive as possible.

The seasonality of agricultural production in Kakamega limits the use of purchased inputs in times when output is out of season and purchases must be funded from savings and/or loans. This causes a negative impact on sustainable agricultural intensification at farm level. The following section gives an overview of the measurements of agricultural intensification.

2.1.1 Measuring agricultural intensification

Measures of agricultural intensification are described in this section. There are many different approaches in measuring agricultural intensification; as reflected in a statement by Leaf (1987) regarding changes that occurred in Punjab (India) agriculture which he describes that: between 1965 and 1978 farming became more intensive by all measures. The measures included: area under irrigation, number of harvests per year, input and output per hectare and per person, capitalization per hectare and per person, population density per hectare, energy consumption per hectare.

The above-mentioned approaches are based on the production per unit area and per unit time (productivity), the cropping frequency (number of harvests per year), and the external input use (fertilizer, commercial seed, novel technology, etc) among other measures (Leaf, 1987). Productivity as a measure of agricultural intensification uses output to measure system intensification. The cropping intensity and input use are surrogate measures that can be used where output data are weak or missing because of lack of records or mixed cropping. However, the population density per hectare is more appropriately considered to be a factor that generates intensification as per Boserup, (1965), rather than a measure of agricultural intensification.

Another spatial measure of agriculture intensity is Ruthenbergs' index (R-value) of land use (Ruthenberg, 1980). The R-value index is calculated as the proportion of the farm unit under cultivation relative to the total available arable land. R-value is also known as land use intensity. Using the R-value index, the land use production systems may be classified into seven main categories: 1) shifting cultivation, 2) fallow rotations, 3) leys and dairy systems, 4) permanent and crop cultivation, 5) arable irrigated farming, 6) perennial cropping and 7) grazing systems (Ruthenberg, 1980).

This study applied the R-value to quantify land use intensity in combination with the extent of external input use, especially labor intensity (man days per ha), inorganic fertilizer and improved hybrid maize seed use. Adoption of improved hybrid maize seed was chosen since all surveyed households grew maize. Maize is also the staple food of most people and hence grown by all farmers. Annual per capita consumption of maize is approximately 103 kilograms (Pingali, 2001). Use of improved hybrid maize seed is considered an agricultural intensification strategy when used in complementary with inorganic fertilizer to enhance productivity. Inorganic fertilizer and improved hybrid maize seed use were thus considered capital-intensive options for agricultural intensification in addition to labor- and land-intensive strategies.

Output per unit area as a measure of agricultural intensification was not possible because most farmers in Kakamega do not keep proper and accurate records of their output. Most of the values obtained from respondents and filled into the questionnaires were considered unreliable and inaccurate.

From the foregoing discussion there are two distinct types of agricultural production: capital-led intensification and labor-led intensification. Even though agricultural development comprises the use of capital-led intensification and management practices, there is also capital-deficient intensification strategies practiced. There are many competing theories that try to unravel the drivers of the nature and process of agricultural intensification as conceptualized in the section 2.2 below. An econometric model was formulated within a household theoretic framework to analyze the farmer production and consumption behavior.

2.2 Conceptual framework

A typical agricultural household was hypothesized to make decisions between farm and non-farm employment, and engage in a number of production activities, which include production of own subsistence and for the market (Ellis and Freeman, 2004). The decisions could be made under perfect or imperfect market scenario.

The household supply to farm and non-farm sectors is depicted as a function of returns to and risks of farm and non-farm activities, preferences and the household's capacity to undertake the activities. Rural household members enter the non-farm labor market to earn high incomes (pull factors) and due to factors such as risk in farming and missing insurance, consumption and input credit markets (push factors) (Reardon *et al*., 2001). Agricultural intensification and the decision for the farm to be a supply are affected by factors such as existence of nearby towns, information flow, markets and socio-economic factors.

The existence of a nearby town can offer direct employment in the manufacturing and the service sector or induce the development of the non-farm sector by offering market for agricultural products. The income derived from non-farm activities could be invested into agriculture production in form of purchased inputs and hired labor.

Limited access to information causes low use of external inputs and new technologies by a poverty stricken population (Pender *et al*., 2001). In turn, government policies such as those pertaining market liberalization, credit facilities, input supply and infrastructure influence adoption of agriculture technologies (Place and Hazel, 1993). Liberalization strategies in Kenya targeted more on improving prices of agricultural products. However, benefits of market liberalization can be curtailed if reduction in government revenues results in reduced investment in infrastructure.

Liberalization of the market in the agriculture sector in Kenya led to higher variances in input and output prices (Freeman and Omiti, 2003). The high variability in prices can undermine investment in agricultural production. Liberalization eliminated the public input distribution systems in Kenya thereby increasing variable input costs for cash constrained smallholder farmers. Investment, by smallholder farmers, in such costly agriculture inputs could be hindered by imperfections in the factor markets in particular if access to credit is restricted to those having sufficient collateral. High interest rates make investment in agricultural production risky given output prices that are uncertain and production being dependent on weather.

The smallholder farmers are increasingly relying on cash crop and non-farm earnings to finance their production and smooth consumption. Others may choose subsistence production if transaction costs are such that the gap between selling and purchase price is wide and non-profitable.

The impact of socio-economic aspects especially gender-specific priorities also could influence the type of agricultural intensification. Gender segregated agriculture is common in

Africa as households consist of several production units which affects labor allocations (Nyerges, 1997). The male household head controls a ‘communal production unit’ for which he can claim the labor of his dependants, but in addition, the household consists of a number of ‘personal production units’ controlled by wives and junior males. Agricultural intensification and land use decision-making is thus separated into different spheres, and household members do not necessarily share the same production objectives or pursue a single strategy. The sub-units within a household are related in a complex, sometimes gender-specific set of obligations, rights, and responsibilities (Moore, 1992; Reenberg and Paarup-Laursen, 1997). Thus, gender-specific aspects have a considerable bearing on the contemporary pattern of the land use changes in the society. Socio-economic dimensions of the household deserve to be considered in the theoretical modeling on issues of agricultural intensification.

It is conceptualized that producers can operate under perfect or imperfect market conditions as modeled in section 2.2.1 and 2.2.2 due to influences of markets factors, institutions and socio-economic status of the household.

2.2.1 Consumption and production decisions in perfect market conditions

In the presence of perfect markets, as portrayed by a private firm, the farm-households value all the production factors and consumption goods at their respective market prices (Ellis and Freeman, 2004). This allows solving the producer problem (profit maximization) prior to the consumer problem (utility maximization), because household utility depends solely on market prices and income (Benjamin, 1992). The market prices support separate production and consumption decisions among producers; thus the producers make production and consumption decisions independently.

Assuming perfect markets, the household maximizes profit subject to a production function (Yotopoulos and Lau, 1971):

$$q = F(labor, X : fixedcapital, farmsize) \qquad 1$$

Where q is output and X are variable inputs

The reduced models take the form:

Supply function $q_a = q_a(p_a, p_x, w, z^q)$ 2

Factor demand $X = X(p_a, p_x, w, z^q)$ 3

Profit function $\pi = \pi(p_a, p_x, w, z^q)$ 4

Where q_a is the amount produced, p_a is the product price, p_x is the price of variable factor of production, w is the wage rate and z^q are the farm production characteristics (fixed capital and farm size).

The household chooses the levels of labor and other variable inputs that maximize the farm profits given farm current configuration of capital, land and an expenditure constraint.

The optimal input choices depend on the input prices, output prices, and wage rate, as well as the physical characteristics of the farm and the technology level. The household behaves as if production and consumption decisions were decided sequentially, with production decisions made first and consumption and work decisions made later. The farmer behaves as a pure producer basing his decisions on the market price. The income derived from production determines the level of consumption.

On the consumption side, the household maximizes utility: $u = u(c, l_c)$ 5

Subject to:

Budget constraint: $p_m c_m = p_a(q_a - c_a) - w(x_1 - f_1)$ 6

Time constraint: $L_c + L_s = E$ 7

Where p_m is the purchase price, c_m are the purchased commodities, c_a are quantities of commodities produced and consumed at home, x_1 is labor used in farm production, f_1 is family supplied labor, L_c is time spend at home, L_s is time worked and E is total time available to the household.

The reduced model takes the form:

$c_i = c_i(p_a, p_m, w, E, z^{cw})$ 8

Where: $i = a, m, l$, z^{cw} are consumer worker characteristics. Optimal choice depend on prices of the goods consumed, wage rate, total time available and the characteristics of the family members who are the consumers and workers (gender, age etc).

The above profit and utility maximization function of a particular production function occurs under the perfect market. However, developing countries exhibit imperfect markets, which is explained in the following section.

2.2.2 Consumption and production decisions in imperfect market conditions

In many developing country settings, the markets exhibit imperfections, such as high gaps between the buying and the selling prices (.i.e. price bands) for consumable crops or between the wage rates for sold off and hired labor (Bagamba et al., 2004). In these cases, the opportunity costs of goods and family labor are no longer their market values, but endogenous shadow prices that depend on the width of the price band and the household's production factor endowment and consumption requirements.

Agricultural households in developing countries are characterized by high poverty levels, large proportion of their production kept for subsistence needs and sell surplus to the market to meet basic household needs. Production and consumption decisions are integrated. Not all products and factors of production are tradable because of the high transaction costs, shallow markets, risks and uncertainty about weather conditions, which drive purchase prices up and the selling prices low. These transaction costs, which include transport costs and the consequences of imperfect and asymmetric information of market participation influences farmers' production decisions rather than exogenous market prices (De Janvry *et al*., 1991; Sadoulet *et al*., 1998).

Limited access to credit is a frequent cause of market failure, as the household cannot satisfy an annual cash income constraint, with expenditure greater than revenue at certain periods of the year (Bagamba *et al*., 2004). The household faces a price band, where the purchase price is higher than the selling price while production and consumption decisions are no longer taken in response to exogenous prices (Pender *et al*., 2001).

Prices ($P*$) are endogenous, and are determined by the household's demand and supply conditions. When the markets for some inputs and outputs are missing, market prices cannot support separation of production and consumption decisions. Consumption decisions affect production decisions as production depends on the price of consumer goods and the household preferences. The quantity produced for a non-tradable commodity corresponds to an unobservable internal shadow price, the decision price ($\overline{p}_i$), at which supply equals demand.

The household approach is followed, where the problem is to maximize utility subject to available constraints. The following section enumerates some models previously used in technology adoption choice in imperfect market conditions.

2.2.3 Previous models of technological adoption and variety choice

The theoretical formulations and empirical approaches to modeling the partial adoption of agricultural innovations by farmers are plenty (Feder et al., 1985), though the framework within which variety choice is examined has not been uniform. Some models have treated the choice between two types of crops or varieties (modern vs. traditional or subsistence vs. cash) rather than the multi-crop, multi-variety scenarios often observed on farms as enumerated thus: Farmers in this case are assumed to maximize expected utility (EU) according to a von Newman Morgenstern utility function defined over wealth (W) (Newman *et al*., 2001). Whereby (W) is considered only after being spent on the consumption goods that result in utility.

When confronted with a choice between two alternative practices (e.g. use of inorganic fertilizer versus organic manure, or use of improved seed versus local varieties seed) the i^{th} farmer compares the expected utility with the improved modern technology, $EU_{mi}(W)$ to the expected utility with the traditional technology, $EU_{ti}(W)$. While direct measurement of farmers' perceptions and risk attitudes on farming technology are not available, inferences can be made for variables that influence the distribution and expected utility evaluation of the technology. These variables are used as a vector X of attributes of choices made by i^{th} farmer and ε_i is a random disturbance that arises from unobserved variation in preferences, attributes of the alternatives, and errors in optimization.

Using discrete choice analysis and limiting the amount of non-linearity in the likelihood function, $EU_{mi}(W)$ and $EU_{ti}(W)$ may be written as:

$$EU_{mi}(W) = a_m X_i + \varepsilon_i$$

$$EU_{ti}(W) = a_m X_i + \varepsilon_i \qquad 9$$

The difference in expected utility may then be written:

$$EU_{mi}(W) - EU_{ti}(W) = (a_m X_i + \varepsilon_i) - (a_t X_i + \varepsilon_i) = a_m X_i + \varepsilon_i - a_t X_i + \varepsilon_i = aX_i + \varepsilon_i \qquad 10$$

Preference for the modern technology will result if $EU_{mi}(W) - EU_{ti}(W) > 0$ where as, preference for the traditional technology will be revealed if $EU_{mi}(W) - EU_{ti}(W) < 0$.

The modern technology ($_{mi}$) in this case could be the improved hybrid maize seed or use of inorganic fertilizer in the case of capital-intensive technology. Traditional technology ($_{ti}$) could be the indigenous maize seed/ landraces, and the organic fertilizer. “Labor-led agricultural intensification” strategy considered in this study was the proportion of hired labor and annual proportion of land under cultivation.

However, the above detailed preference of modern versus traditional may not be applicable in all adoption studies especially improved seed and variety adoption since within the framework of safety-first behavior, adoption is conditional on the variety fulfilling the food requirements of the household (Herath *et al.*, 1982; Smale *et al.*, 1994). Variety choice has also been addressed from the viewpoint of economies of scope, where adoption is driven by trade-offs between the joint products of a given crop variety rather than by intrinsic input characteristics (Traxler and Byerlee, 1993).

The importance of intrinsic consumption and production variety attributes, as perceived by farmers, has received some attention in the more recent adoption and variety choice literature (Adesina and Zinnah, 1993; Barkley and Porter, 1996; Bellon and Taylor, 1993; Knudsen and Scandizzo, 1982; Smale *et al.*, 2001; Smale *et al.*, 1994).

2.2.4 Conceptual framework of using hired labor

A farmer will use hired labor for the performance of a particular farm operation if the expected benefit from using the hired labor is greater than the expected costs. Failure of many households to use hired labor for the performance of any farm operation is explained by transaction costs (Eswaran and Kotwal, 1986; Sadoulet *et al.*, 1998).

The transaction costs drive a wedge between the household shadow marginal product of hired labor and the market marginal product of hired labor, thus raising the wage effectively paid by households that hire labor, and lower the wage effectively received by laborers. If the transaction costs are $r = 0$, the household equates its shadow marginal product of hired labor with the market value, so that hired labor use is continuous and not subject to a threshold, defined by the price difference (price band) between high effective wages paid and low effective wages received as the market price varies. When $r > 0$, however, the required level of productivity of hired labor that would offset the costs and hence induce its use is higher. As $r \to \infty$ the number of households using hired labor tends to zero.

The share of the farm households using hired labor for the performance of any farm operation has an upper limit of 100% when all the households are using hired labor, and a lower limit of 0% when none of the households are using, thus a proportion of 1 and 0 respectively. Some farmers in the survey did not use hired labor at all. The Tobit model is an appropriate framework for modeling a variable that is so truncated (Adesina and Zinnah, 1993; Polson and Spencer, 1991). Heckman's (1976) model is used for similar analysis and applies when some values of the dependent variable are literally unknown or missing, while the Tobit model applies when some values of the dependent variable are known to be zero (Enete *et al.*, 2004; Heckman, 1976; Lin and Schmidt, 1984). Following Enete *et al.* (2004), the theoretical framework of the Tobit model can be explained by the threshold concept. The estimation of the Tobit model is explained in chapter 3.

2.3 Drivers of agricultural intensification

According to earlier research findings the drivers of agricultural intensification include: location of farm, market access, population and socio-economic characteristics of the household. This section discusses some of the empirical findings on the drivers of agricultural intensification.

In 1817, David Ricardo assumed a heterogeneous landscape where land quality influences land use and farmers cultivating on better land receive a land rent (Ricardo, 2002). Assuming a heterogeneous landscape, Ricardo did not consider the relative location of the production activities. Ricardian models of land use explain the existence of different land rents with differences in land quality that arise from a heterogeneous landscape. Land of better quality or higher soil fertility generates higher land rents. Land with higher quality generates surpluses for farmers compared to farmers with land of lower quality.

The German farmer and economist Johann Heinrich von Thünen was the first to explicitly consider the emergence of a certain spatial arrangement of land use. His pioneering book "Der isolierte Staat" (The Isolated State) was first published in 1826 (von Thünen, 1990). There, he emphasized the importance of transport costs for the development of land-use structures around market locations. Von Thünen found an explanation for the emergence of land use patterns and differing land prices over space as a function of distance from urban centres in his "featureless plain".

These two theories (Ricardian and Von Thünen) are the basis for most economic models of land-use change. Combining the two theories by integrating the inherent features of plots (Ricardo) with distance measures (von Thünen) and relaxing some additional assumptions provides a consistent economic theory to explain land-use changes in a spatially explicit manner. Previous studies on land use made reference to the Ricardian notion of land rent and demonstrate how land use varies across a landscape at a given location and depends on cost-of-access to market, road, and population centers (Deininger and Minten, 2002; Pfaff, 1999).

The market access was considered to be one of the principle driving forces for agricultural intensification in view of maximization of the farm profit (Binswanger and McIntire, 1987; McIntire *et al.*, 1992; Pingali *et al.*, 1987). However, the maximization of farm profits may be constrained by farmers' aversion to risk (Alam, 1993; Wolgin, 1975). In addition to market demand, resource endowments, or lack thereof, may induce technological advance in agricultural development. The poor transport systems due to inaccessible roads are the most prominent causes that constrained investment in agricultural production (Collier and Gunning, 1999). Establishment of the road network and improved market access, e.g. through infrastructure development, often increase the intensity of the agricultural input use and the productivity of agriculture and reduces the risk associated with investments in agricultural production (Lee *et al*., 2001). Better access to the markets can reduce the need for land expansion but enhance agricultural intensification (Reardon *et al*., 2001). Some studies also show that investments by households are hampered due to poor economic service delivery.

Population pressure is another important cause of agricultural intensification and land use intensity change (Binswanger and McIntire, 1987; Ruthenberg, 1980) and has been considered to be the main driver for agricultural intensification by some authors (Boserup, 1965). According to Boserup (1965), high population growth rate and the increasing population density are a stimulus for both reduction in fallow and the introduction of innovations associated with intensified land use. According to this view, provided the rate of population increase is not too rapid, people will adapt their environment and cultivation practices and so increase yields without degrading the resource base. This counters the more pessimistic 'agricultural involution' model (Geertz, 1963). Under the agricultural involution model, agricultural output is maintained under increased population pressure by increasing the input of labor, so that while output per hectare increases, output per capita does not. No new methods are introduced, but existing methods are intensified, thus giving rise to diminishing returns to labor.

Other authors postulated that population growth increased area under crops through forest clearing, encroachment into traditional grazing or pastureland and shortened fallow periods (McIntire *et al*., 1992; Pingali *et al*., 1987). Such strategies require the use of external inputs to maintain soil fertility. Where livestock is produced, farmers paddock the animals on the cropland, use crop residues as feed while manure is collected and used on the farm. As the population pressure increases, more intensive agricultural technologies are adopted and these include a further increase in the application rates of fertilizer and manure to increase crop productivity. With time the duration of and the area under natural fallow reduces significantly, crop residues are harvested and preserved as feed while manure application increases and is targeted to high value rather than subsistence crops. In systems with low external input use, the cultivation of legumes for food and feed purposes is also gaining importance to improve soil fertility, crop yield and livestock productivity.

Socio-economic characteristics of the households modulate the prevalence of agricultural intensification strategies that are used. Some of the socio-economic characteristics that were found empirically to influence agricultural intensification include: family labor availability, household size, household resource endowments, non-farm income and number of livestock. Socio-capital and household nutritional status have also been found to influence agricultural intensification especially the labor-intensive strategies.

The role of labor use, both as a distinguishing characteristic of sustainable agricultural intensification systems and as one of the primary constraints influencing their adoption, has been widely documented. Measures of household size and family labor availability influenced the adoption of agroforestry and intercropping practices in the Brazilian Amazon (Caviglia and Kahn, 2001), and soil conservation investments in the Philippines (Shively, 2001) and Ethiopia (Shiferaw and Holden, 2000).

The household access to other resource endowment like farm and livestock greatly influences the allocation of labor both within the rural household and community. Emerging land shortages and landlessness are also singled out as drivers of off-farm employment. Agriculture being the main source of employment for the poor, loss of land forces people to look for other sources of employment, commonly casual work. This trend is supported by earlier findings, which indicate that land ownerships increases labor supply to crop production, but reduces labor in off-farm activities (Fafchamps and Quisumbing, 1999; Takashi and Humayun, 2006). Similarly, the number of livestock heads increases the amount of hours spent on the farm, but reduces the days on off-farm activities (Fafchamps and Quisumbing, 1999). These results support the hypothesis that, households with more land and livestock are more productive in farming and allocate more land and labor to agricultural production activities.

Other dimensions of socio-economic characteristics influencing agricultural intensification comprises of the availability of social and human capital and the household nutritional. For example, body height, a proxy for child and adolescent nutrition, was shown to raise productivity and labor effort in livestock production while the body mass index (BMI), an indicator of the current nutritional status was found to have a large and significant effect on productivity and labor use in off-farm activities. Thus a rise of one point in BMI for all adults in the household was established to be associated with a 3.7-4.6 % rise in household income (Fafchamps and Quisumbing, 1999).

It may be concluded that that access to input/output markets, population pressure, the socio-economic characteristics of the households, biophysical features and government policy and institutions are the main drivers of agricultural intensification in the small holder farming systems. The relative importance of these drivers in explaining the prevalent agricultural intensification strategies in Kakamega District was assessed in the present thesis.

The next chapter maps out the methodology for exploring trends in land use over a specified period of time in Kakamega District. The chapter also describes data collection process and analysis to determine the driving forces of agricultural intensification in Kakamega.

3 Methodology

This chapter outlines the characteristics of the study area, presents the measures used to quantify land use changes and agricultural intensification and lays out the modeling approach taken in this study. The spatial-temporal pattern of land use changes was analyzed using GIS technique. The econometric background of limited dependent variable (LIMDEP) models was used for an empirical analysis of both secondary and primary data sources.

3.1 Geographical location

Kakamega is located in Western Kenya. Figure 1 shows the map of Kakamega District.

Figure 1: Map of Kakamega District in Western Kenya and the respective administrative Divisions

Source: KARI (1994).

The area is classified as moist mid-altitude zone (MM) (Lynam and Hassan, 1998). The MM zone forms a belt around Lake Victoria, from its shores at an altitude of 1110 meters, up to an altitude of about 1500 meters above sea level. These zones largely follow an altitude gradient, with higher elevation areas receiving more rainfall. Kakamega District is largely comprised of the Lower Highland (LH), Upper Highland (UH), Lower Midland (LM) and Upper Midland (UM) Agro-ecological zones (AEZ). The tea-growing areas are in the Southern part of the district classified as Lower Highland (LH) and the sugarcane growing areas in the North of the district mainly belong to the Lower Midlands (LM) (Jaetzold and Schimdt, 1982).

Jaetzold and Schimdt (1982) divided the temperature belts of this zone in sub-categories (called main zones) ranging from humid 1; to less humid 6; and differentiated by altitude, soil type and fertility, rainfall and the range of crops growing in the respective areas. According to the FAO classification scheme, Kakamega is classified as "humid Forest agro-ecological zone" with a length of growing period (LGP) thus $LGP(days) = P \geq \frac{1}{2}ET + E_{100}$ ranging from 325 – 348 days per year (FAO, 1978-81).

The LGP is defined as the period of the year in which agricultural production is possible from the viewpoint of moisture availability and absence of temperature limitations with continuous period during which precipitation (P) exceeds one and a half of the potential evapo-transpiration (ET) plus the time required to evaporate an assured 100 mm from the soil after the rains have ceased (De Pauw, 1989; Nachtergaele and Bruggeman, 1986).

The soils in the study area are mainly ferralo-orthic Acrisols (north) and ferralo-chromic/orthic Acrisols in the northern and southern part of the district respectively. The other minor soil types found in the area are Nitisols, Cambosols and Planosols etc (Amadalo *et al.*, 2003). In this study the soils in the south are referred to as Ultisols. The soils in the north are undergoing a transition from Alfisols/Luvisols to Ultisols but will be referred to as Alfisols. However, in this study the soils in the north were referred to as Alfisols. Tea is grown in the southern part while sugarcane is grown in the northern part of Kakamega District. For future reference in the thesis the south of the district will be referred to as the tea zone and the northern part of the district will be referred to as the sugarcane zone.

Crop production in Kakamega is constrained by soil N, P and K deficiencies (Lijzenga, 1998). Some studies undertaken in the area showed that measurements of maize response to N, P and K fertilization in smallholder fields indicated that 75% of the 33 study sites had < 4 mg bicarbonate – EDTA extractable P kg^{-1} of soil and responded to P fertilization. Once P deficiency was overcome through inorganic fertilizer application, N limited maize growth in nearly all cases (Hartemink *et al*., 1996; Lijzenga, 1998; Nziguheba *et al*., 1998). K deficiency in soils limited maize growth in about 25% of the study sites (Lijzenga, 1998). The N, P and K deficiency in the soils differ in the North and South of the district (Nziguheba et al., 1998).

The annual average rainfall in Kakamega District ranges between 700 and 1800 mm, and is received in a bimodal pattern as shown in Figure 2. The first rainy season starts in February/March and the second one in August/September. At lower elevation, rainfall is lower and the second rainy season is less reliable for crop production than the first and longer rainfall season.

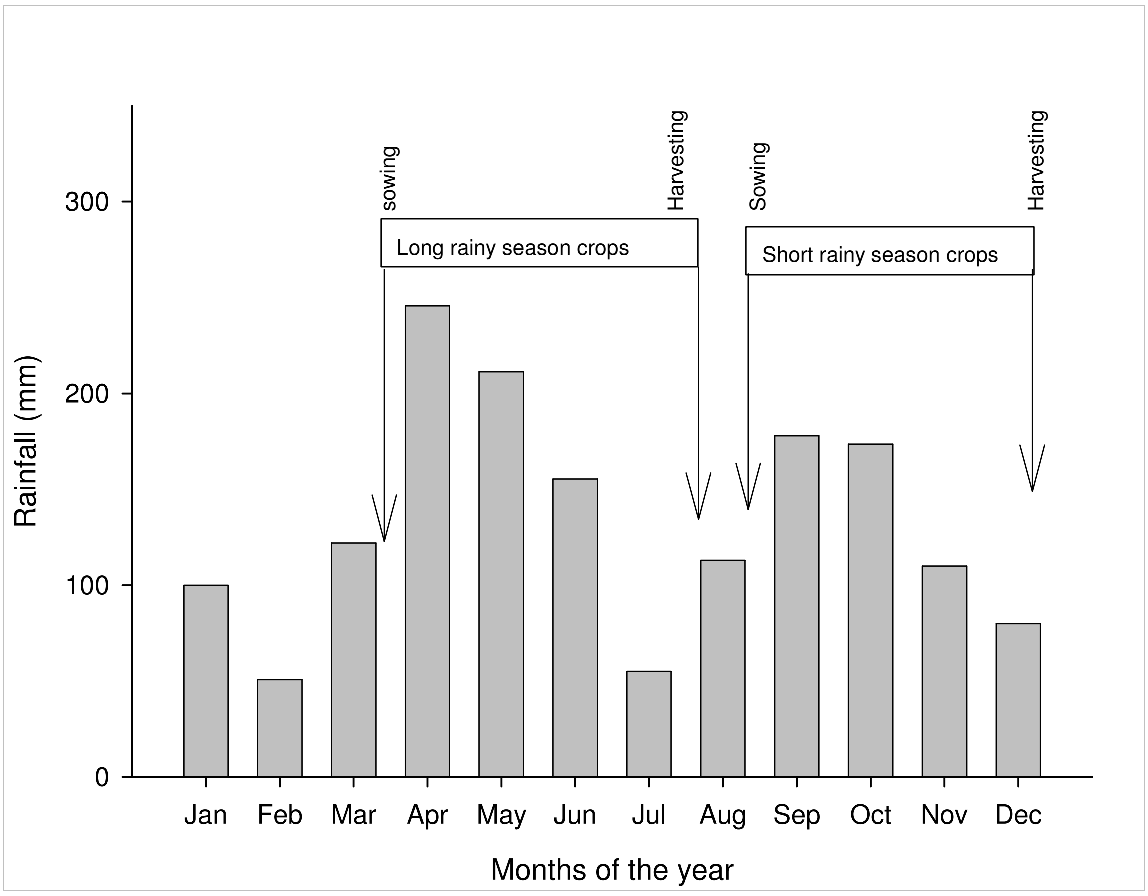


Figure 2: Monthly average rainfall of Kakamega District in 2004 and cropping periods of annual field crop (maize)

Source: Ojiem (2006).

The average annual temperature (calculated over a decade), is 22.1℃, with an average minimum of 13℃ and an average maximum of 30℃ (KARI, 1994). The altitude of Kakamega District ranges between 1250 m in the peneplain to 2000 m above sea level in the hill belt that is made up of rugged granites. The peneplain is slightly undulating in the Northern, Central and its Eastern parts. The Nandi Escarpment forms a prominent feature on the districts' eastern border with its main scarp rising from the general elevation of 1700-2000 m. There are two main rivers: Nzoia, which flows south-west and Yala which flows to the west from the Nandi Escarpment.

Kakamega District is comprised of six administrative divisions namely: Municipality, Shinyalu, Ikolomani, Lurambi, Navakholo and Ileho and covers an area of 1,498 km^2. The Kakamega Forest Reserve is located across the divisions of Ileho (north) and Shinyalu (south) and also extends to neighboring Malava and Nandi Districts.

The district had a population of 749,851 people in the year 2004 with a population growth rate of 2.9 per annum (Kakamega District Development Plan, 2002). Excluding the municipality, which has a population density of 1,577 persons' per km^2, the population density is higher in the southern divisions than the northern ones. The average population density of Kakamega District was 657 persons per km^2 in 2004 (Kakamega District Development Plan, 2002).

This relatively high and rapidly-growing population is putting an increasing strain on the resource base for agricultural production and also on the protected reserve of Kakamega Forest, which is solicited to provide feed, fuel and medicinal plants. This exceptional anthropogenic pressure on both forest biodiversity and resource base quality was the main reason for selecting this particular area for the present study on agricultural intensification strategies. This study is part of the work done by Biodiversity Transect Monitoring Analysis (BIOTA) team under the sub project E14 whose objective was to study the land use pattern around the Kakamega Forest.

3.2 Origin and generation of secondary data

There were two sets of secondary data used in the study. The first data set was obtained and compiled from the Ministry of Agriculture, Kenya. It contained information on area under different land uses in the district and was used to graphically present the trends in land use in the district.

The second data set was obtained from Department of Resource Survey and Remote Sensing (DRSRS), of the Ministry of Planning Kenya. It contained a set of three aerial photographs of three sites for the years 1991, 2000 and 2004 and was used to determine land use changes over time in selected areas of Kakamega. In total nine aerial photographs were used.

Aerial photography surveys have been carried out annually in Kenya since 1986 by DRSRS. The aerial photographs are taken below the cloud cover during the peak crop-growing season during the long rains when the maize crop is knee high. At this height a possible intercrop can be differentiated by different color shades. Use of aerial sample photography involves multistage sampling technique using low altitude aerial vertical photographs. When undertaking photography, Kakamega District is usually divided into 5 x 5 km square sampling units using the Universal Transverse Mercator (UTM) grid system. East-west or north-south sampling flight line is placed at 5km apart. One photograph was taken systematically for each sampling unit. The flight height was approximately 488 meters above ground level. Navigation was performed using the Global Navigation system (GNS) fitted on a twin-engine aircraft. The photographic system consisted of a 35 mm Nikon F3 camera with a 20 mm lens and 35 mm ektachrome 200 slide film. This setting gave positive transparencies covering approximately 560m by 850 m on the ground (50 ha), with a scale of 1: 24,380.

Satellite images like SPOT and Quick Bird could have been the most appropriate in this study. They were not used because they were too expensive to be accessed. However, the use of aerial photographs achieved the objectives of the current study.

3.2.1 Secondary data processing and interpretation

Land use cover changes were evaluated from the aerial photographs. Two villages from the sugarcane-growing area and one village from the tea-growing part were chosen. Each village had a series of three aerial photos for the period 1991, 2000 and 2004. A total of 3 aerial photographs each from the divisions of Shinyalu, (southern part of the Kakamega District), Lurambi, and Navakholo (northern part of Kakamega District) were analyzed. Spatial land cover change detection was done by comparing time series photographs. Figure 3 depicts a set of three aerial photographs for the chosen site of Namirama village in Navakholo Division.

Spatial land use change detection was done using the GIS overlay procedure. Ground control points (GCP) on the aerial photos were identified. Ground truthing was done using the Global Positioning Systems (GPS) and at least ten GCPs in each photograph were established, using road crossings, typical morphological structures like rocks etc. The GCPs were marched to similar locations on the image for geo-referencing. The photographs were digitized, then edited and re-projected. Attributes for different land segments were assigned using ground truth field data. The major steps used in analyzing and detecting the land use changes are shown in Figure 4. Image to image geometric correction was done to georeference photographs 2 and 3 of the same area. Each image was geo-referenced to the UTM Zone 37.

A) Navakholo, 1991

The main feature in the photo is the road, in the middle of the photo. The road junctions were used to locate the GCP.

B) Navakholo, 2000

Due to the drift of the plane flight the road starts at the right corner of the photo. However, the settlement on left side of the road, next to the junction can be clearly viewed.

C) Navakholo, 2004

In this photograph the road is again in the centre. GIS clipping techniques of intersecting areas was employed to determine the overlapping areas in the three photos.

Figure 3: Changes in land use at a similar site (aerial photographs of Navakholo village)

Source: DRSRS (2004).

Attempts to use both supervised and unsupervised classification methods proved inefficient, due largely to the lack of a consistent spectral signature associated with each rain-fed agriculture category. Visual interpretation of contrast stretched-color composites was more reliable. The vector shape files were converted to Raster images and land use mapping was done. The digitized land use maps were classified under different main land use types: The most common land use types were food crops, sugarcane, tea, pastureland, woodlots and bushes.

Using the GIS tool, the aerial photograph shape files were overlaid and the intersecting areas clipped. Clipping was necessary because the areas did not fully overlay during the three years as a result of the drifts by the aircraft during photography (

Figure **3**). Each photograph initially represented 50 hectares on the ground. However due to clipping of the similar areas, the overlapping areas on the photographs were less than 50 ha. The main criterion for choosing the three villages was that at least 60% of the photograph series per site overlapped. The clipped area for the three moments were projected and used in processing the land use cover changes for the three years period.

Analysis was done using ERDAS 8.5, Arc view GIS 3.2 and Arc GIS 9 software.

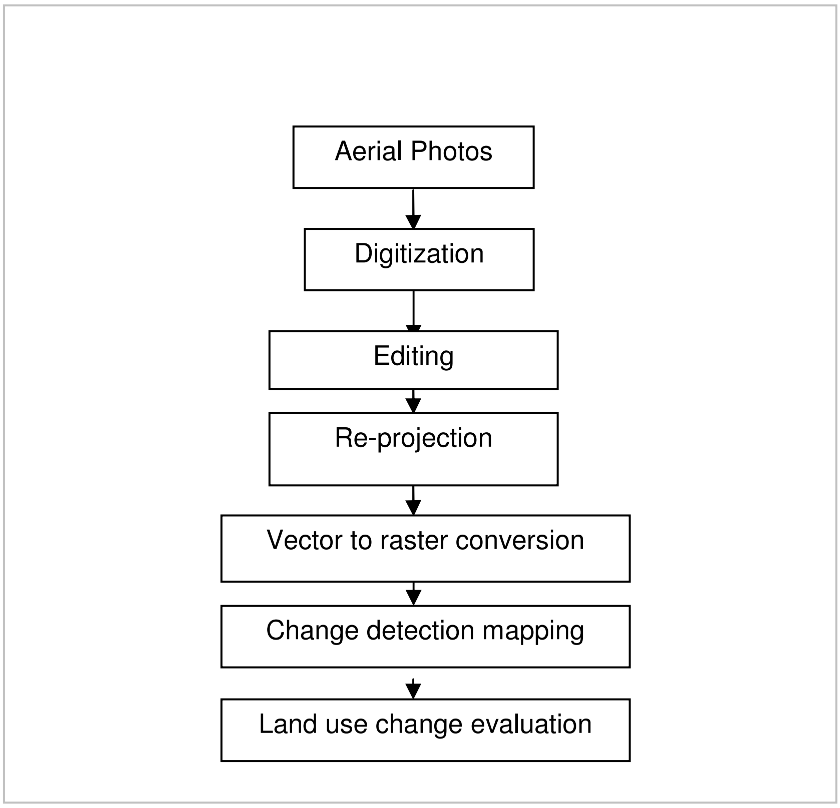


Figure 4: Steps of land use change detection using sample aerial photos

To determine the rate of land use change, two sub periods were compared, mainly the period 1991 to 2000 (referred to as earlier period) and the 2000 to 2004 (referred to as later period). Land use intensity comprehensive indices were calculated thus:

$$I = 100 \times \sum_{i=1}^{n} (G_i \times C_i) \qquad 11$$

where I is the land use intensity comprehensive index; G_i is the gradation value of the i th ranking land use type; C_i is the percentage of the i th ranking land use intensity; and n is the number of land use grade (He *et al.*, 2002; Lai *et al.*, 2002). In the gradation index system, unused land or fallow was assigned the factor 1; forests, pastureland, woodlots and bush land were factor 2; food and industrial cropland was factor 3, while buildings had a factor 4 (Wang and Bao, 1999).

The land use degree change parameter (ΔI_{b-a}) expressed the change in the land use intensity and was:

$$\Delta I_{b-a} = I_b - I_a \qquad 12$$

Where I_b and I_a are land use intensity comprehensive indexes at time point b and a, respectively. If the parameter $\Delta I_{b-a} > 0$, the land use is being used intensively (Wang *et al.*, 2002).

3.3 Generation and processing of primary data

This section mainly describes the primary data (household survey) sampling frame and the methods used in data collection and analysis.

3.3.1 Sampling Frame

Cluster sampling was used. This is a type of multistage design, used when determining minimum sample sizes for a sequential sampling plan. In cluster sampling, elements are individual units from which data are collected or sampled in clusters; each representing a primary unit. Elements are also sometimes called subunits, the primary sampling unit (Hamilton and Hepworth, 2004). Cluster sampling is a technique where the entire population is divided into groups, or clusters and a random sample of these clusters is selected. All observations in the selected clusters are included in the sample. Cluster sampling method can be one stage where by all elements within selected clusters are included in the sample or two stage where a subset of the elements within selected clusters are randomly selected for inclusion in the sample (Brown, 2004).

Sometimes, the cost per sample point is less for cluster sampling than for other sampling methods. Therefore, given a fixed budget, the researcher may be able to use a bigger sample with cluster sampling than with the other methods. This study used cluster sampling due to lack of a complete list of the members of the population in Kakamega. Even though use of simple random sample would have been desired it was impossible due to lack of enough resources to undertake the survey.

The Kenya Central Bureau of Statistics (CBS) provided the Kenya's fourth National Sample Survey and Evaluation Programme (NASSEP IV) document; that is used as a master sampling frame designed to guide household surveys in Kenya and Kakamega District in particular. This sampling frame was developed from the most recent national population and housing census in 1999. The frame is updated after every five years and contains the standard procedure for household surveys in the country.

In the districts covered, the population is stratified into subunits referred to as divisions, locations, sub-locations, clusters and household units. In Kakamega District, NASSEP IV covers 26 clusters of a size between 48 and 168 households containing a total of 2,687 households. With very few (urban) exceptions, the clusters are found in different rural sub-locations. The clusters are chosen to represent the typical livelihood zones of the district. The master sampling frame clearly identifies households by their household heads and the concomitant details, including a map showing their physical location. For the households that fall in a CBS cluster there is always an identification number painted on the door of the household head clearly marking the household's main dwelling structure.

3.3.2 Sampling design

This study used a two-stage sampling design which is also employed by CBS for the national household survey based on NASSEP IV. The study deviated from the national household survey by choosing more households per cluster (20 instead of 10) and covering less number of clusters (20 instead of 26).

The number of sampled households from each stratum was proportional to the population share of that stratum (based on census information). This was used to obtain a self-weighting sample. The main reason for covering more households in less clusters were the high costs of reaching different clusters, but this does not seriously affect the information obtained. After identifying the clusters to be visited, twenty households were randomly pre-selected from each cluster. The household survey was carried out by the BIOTA research team.

The household was assumed to be the lowest decision making unit regarding production and consumption. It was taken to consist of members living together and eating from the same pot, with decisions made by the household head. Thus the characteristics of the household head (age and main occupation) were included in the model as independent variables affecting production and consumption decisions. A total of 400 household units were interviewed[5]. Non-farming households that reside in urban areas were also interviewed due to the different needs of the household survey research team. However, this study only considered 243 farm household units for analysis, after excluding the urban non-farming households. The household survey was conducted from October to December 2005. Interviews were conducted in places convenient to farmers either at home or in the field.

3.3.3 Questionnaire surveys

By virtue of the study's diagnostic nature, interactive questionnaire surveys, and general field observations were used to solicit answers and responses to issues covering the following broad aspects:

- Household socio-economic information, gender dimension, agricultural intensification strategies, food and industrial crop production, use of production factors.
- Land use dynamics e.g. land acquisition, tenure, farm sizes, share of fallow land.
- On-farm agro-biodiversity.

3.4 Statistical analysis of primary data

This section describes the models used in the analysis to determine factors affecting agricultural intensification strategies. The agricultural intensification strategies can be land, capital and labor-intensive strategies. The empirical analysis determines the farmers' decision whether to or not to adopt improved seed or use of inorganic fertilizer (capital-intensive technology) or land- and labor-intensive technologies. Whenever, a farmer deviated from the traditional low-input rotation fallow system to adopt capital, land or labor-intensive strategies, it was assumed in this study that agricultural intensification is occurring.

3.4.1 Land use intensity at household level

It was assumed that high land use intensity deviates from the traditional low-system rotation fallow system, and thus was considered as an agricultural intensification strategy. Land use intensity data were obtained from the household survey. The proportion of area under

5 See Questionnaire in Appendix 1.

cultivation[6] annually in relation to the whole farm area of the household was calculated. An alternative definition of R-value is: [cropped area / (cropped area + fallow area) which can be presented thus:

$$\text{Land use intensity (R-value)} = \frac{\sum_{i=1}^{m} a_i}{\sum_{i}^{m} \sum_{\substack{j \\ i \neq j}}^{n} a_{ij}} \qquad 13$$

Each set of annual area shares (α_{ij}) among m food and commercial crops and n fallow land types sums to one and where $i = 1,2,....m, j = 1,2,.....n$.

The classification of R-value was done as follows: Fallow rotation systems, are an intermediate stage between shifting cultivation or long rotation fallow systems where land is cropped for less than one-third of the area (R < 0.33) and continuous cropping where land is cropped for more than two-thirds of the area (R > 0.67).

Using household survey data, the factors influencing R-value were determined using standard Tobit[7] model. This is a censored normal regression model used in technology adoption modeling. The Tobit model maximizes a two-part log-likelihood function, which is continuous for adopters and discrete for non-adopters (Greene, 1997; Tobin, 1958). That is y^* is observed if $y_i^* > 0$ and is not observed if $y_i^* \leq 0$. The observed y_i was defined as:

$$y_i = \begin{cases} y_i^* = \beta x_i + \varepsilon_i & if \quad y_i^* > 0 \\ 0 & if \quad y_i^* \leq 0 \end{cases} \qquad 14$$

Whereby $y^*{}_i$ denotes land use intensity of the farm households. x_i are the independent variables, which include agro ecological factors, market access and socio-economic characteristics of the household and ε_i is the error term.

3.4.2 Improved maize seed use as capital-intensive strategy

The above Tobit model (equation 14) was also used to determine the most important drivers of improved maize seed use as a capital-intensification strategy thus.

$$y_i = \begin{cases} y_i^* = \beta x_i + \varepsilon_i & \text{if} \quad y_i^* > 0 \\ 0 & \quad\quad y_i^* \leq 0 \end{cases}$$

6 Annual and perennial crops on the farm

7 A full mathematical treatment of the Tobit model is not included as its usage is common in applied economics research. Thorough treatments of the model may be found in Greene (1997), chapter 20, pp. 896-951.

y^*_i is the proportion of land area of household with improved maize seed. The dependent variable is continuous between zero and one. x_i were the independent variables which include institutional factors like market access, extension agent visits; and socio-economics characteristics of the household.

3.4.3 Inorganic fertilizer use as a capital-intensive strategy

In this study, it was not possible to quantify the amount of inorganic fertilizer applied by farmers. Therefore, inorganic fertilizer application was recorded as a dichotomous variable. Response to the use of inorganic fertilizer as an agricultural intensification strategy could be yes or no. However, independent variables that may affect a given agricultural intensification strategy were collected and expressed both qualitatively and quantitatively.

When the dependent variable was continuous, linear models such as ordinary least squares (OLS) were used. However, when the dependent variable was dichotomous i.e. yes or no, the use of linear probability models is not appropriate because the predicted value can fall outside the relevant probability range of 0-1. To overcome this problem, Logit or Probit models have been recommended (Gujarati, 1988).

Logit and Probit models translate the values of the independent variables (X_i), which may range from $-\infty$ to $+\infty$, into a probability for Y_i which ranges from "0" to "1" and compel the disturbance terms to be homoscedastic. The forms of probability functions depend on the distribution of the difference between the error terms associated with a particular choice

The Probit and Logit models assume the existence of an underlying latent variable y^* for which a dichotomous realization is observed (Gujarati, 1988) thus:

$$y^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \qquad 15$$

Where y^* is not observed and commonly called a latent variable and includes desire or ability to use a technology. What is observed is a dummy variable y_i defined by:

$$y_i = \begin{cases} 1 \approx y^* > 0 \\ 0 \approx otherwise \end{cases} \qquad 16$$

Multiplying systems of equation (16) y^* by any positive constant does not change y_i. Hence, if y_i is observed then $\beta's$ in equation (15) can be estimated only up to positive multiple. Hence it is customary to assume variance one which further fixes the scale of y_i^*. According to Maddala (2002), from the relationship of equation (15) and (16) the following equation is obtained:

$$P_i = prob(y_i = 1) = prob\left[u_i > -1\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_i\right)\right] \quad = 1\text{-F} \left[\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_i\right)\right]$$

Where F is the cumulative distribution function of error term (u). If the distribution of u is symmetric, since 1-F ($-z$) =F(z), it can be written:

$$P_i = F\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_{ij}\right) \qquad 17$$

Since the observed y_i are just realizations of a binomial process with probabilities given by equation 17 and varying from trial to trial (depending on x_{ij}) the likelihood function is written as:

$$L = \prod_{y_i=1} P_i \prod_{y=0_i} (1 - p_i) \qquad 18$$

The functional form for F in equation 17 will depend on the assumption made about the error term u. If the cumulative distribution of u_i is logistic we have a Logit model. In this case

$$F(Z_i) = \frac{\exp(Z_i)}{1 + \exp(Z_i)} \qquad 19$$

Hence $\log \frac{F(Z_i)}{1 - F(Z_i)} = Z_i$

Note that for the Logit model

$$\log \frac{p_i}{1 - p_i} = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij}$$

The left side of later equation is called the *log-of-odd ratio.* The logs odd ratio is the linear function of the explanatory variables (Maddala, 2002).

If the error term in equation (18) follows a normal distribution; we have a Probit model (it should more appropriately be called the *normit* model). In this case:

$$F(Z_i) = \int_{-\infty}^{z/\delta_i} \frac{1}{\sqrt{2\Pi}} \exp\left(-\frac{t^2}{2}\right) dt \qquad 20$$

Maximization of the likelihood function (equation 18) for either the Probit or Logit model is accomplished by nonlinear estimation methods. The likelihood function is concave (does not have multiple maxima) and hence any starting values of the parameters is relevant (Pratt, 1981).

Since the cumulative normal and logistic distributions are very close to each other except for the tails, it is likely that the results are similar. Probit was used in this study since the results are similar with Logit and thus it was not necessary to use both methods. Therefore, the use of fertilizer as a capital-intensive strategy was considered as a discrete state with binary variables: a farmer is either a “user” or not.

Probit model was used to determine factors affecting use of fertilizer as a capital-intensive strategy as follows:

$$Y_i = \alpha + \beta_i X_i + \varepsilon_i \qquad 21$$

Where:

Y_i is the observed response of the i[th] farmers’ using chemical fertilizer, while X_i are the factors that affect the probability that a farmer uses chemical fertilizer as an agricultural intensification strategy and include: farm size (a proxy for population density); market access and socio-economic characteristics of the household. The α, and β are the parameters estimated, ε_i comprise the unobserved factors or the errors.

This study used McFadden R^2 to test the goodness of fit, which is useful in limited dependent variable analysis.

3.4.4 Labor-intensive strategies

Hired labor use in man days for maize production during the long rainy season was determined. For each of the farms, the hired labor use was assessed for the five main farm operations (land clearing, planting, weeding, fertilizer application and harvesting) using a questionnaire. Each household gave a detailed inventory of the amount of labor used for the different agricultural production activities. The percentage of farm operations that was partially or entirely executed by hired labor was calculated. This number was summed up across operations within each farm and the proportion of hired relative to total labor constituted the dependent variable for the analysis.

There were some cases or households where family and hired labor were used together to perform a particular farm operation and hence, this could under represent the level of hired labor used. However, the objective of this analysis is not to determine the quantity of hired labor used by each household but to identify the factors that drive its use.

A Tobit model was used once more to determine the most important drivers of hired labor intensity.

$$y_i = \begin{cases} y_i^* = \beta x_i + \varepsilon_i & \text{If } y_i^* > 0 \\ 0 & y_i^* \le 0 \end{cases} \qquad 22$$

For i =1, 2,------ N.

Where Y_i was proportion of hired labor for agriculture production and ranges between zero to one. The Y_i takes on two values; $Y_i = y^*{}_i$ if the decision is to use hired labor for any farm operation and Y_i =0 if decision is to use family labor only. X_i are the factors that affect hired labor use such as: market access, farm size and socio-economic characteristics, while ε comprises the unobserved factors or error term. The parameters to be estimated are β while ε_i is an independently distributed error term assumed at $N(0,\sigma^2)$. To estimate β, a maximum likelihood procedure is applied using the Tobit model.

3.4.5 Definition of variables used in the analysis

As no economic theory dictates the choice of independent variables for adoption studies, the variables were selected based on the adoption literature. The farm households' decision to adopt any intensification strategy or use hired labor may be related to the characteristics and composition of the household, the size of the farm, capital lay out of the household and the level of transaction costs incurred in the process of using the an agricultural intensification strategy. The household composition and characteristics were captured by number of household members, age, and the level of formal education as well as gender of the household head.

The size of the household generally reflects the level of family labor available. It is thus hypothesized that household size is negatively related to hired labor use. The number of household members is, however, hypothesized to be positively related to the adoption of labor-intensive technology options that aim to raise the yield and meet subsistence requirements.

The expected effect of the relationship of age of household head to the adoption of an agricultural intensification strategy is not clearly determined in the adoption literature. Some studies of agricultural technology adoption have shown that older and more experienced household heads have greater and perhaps long-standing contacts with laborers, which allows them greater hiring opportunities at lower costs. However, increased age could also imply lower entrepreneurial motivation and risk-taking behavior and thus lack of adoption (Rizov *et al*., 2001). It is generally believed that when farmers grow older, they are less amenable to change and therefore may be unwilling to change from their old practices to new ones (Adesina and Zinnah, 1993). Younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear the risk due to their longer planning horizons (Polson and Spencer, 1991).

Education has widely been reported to positively influence entrepreneurial and managerial skills (Enete *et al*., 2002; Panin and Brummer, 2000; Rizov *et al*., 2001). Since the use of hired labor suggests production beyond the immediate capabilities of the family labor, it is expected that the level of education of the household head will be positively related with hired labor use. The effect of the gender composition of the household head is difficult to predict a priori or hypothesize its effect on the adoption of agricultural intensification strategies. A positive relationship between farm size and the dependent variable of adoption of an agricultural intensification strategy is expected as households with larger farm holdings will require greater labor input (whether family or hired). They may also adopt the capital-intensive strategies more easily than the households with smaller farm holdings.

Although a farmer may be aware that a given capital-intensive strategy like the use of inorganic fertilizer and improved seeds has high returns, lack of cash may prevent the farmer from adoption. As in most developing countries, farmers are often cash strapped and invariably unable to meet their financial obligations. Whenever deemed appropriate, households convert assets into cash, implying that the assets accumulated may be used to judge a household's wealth status. It is well known that ownership or access to assets that can be put to productive use is the cornerstone of the capacity of poor households to chart a route out of poverty (Janke, 1982; Moser and Barrett, 2003). The livestock of the household using TLU number and non-farm income in this case measured assets. Non-farm income may be necessary for capital- and labor-intensive strategies. Some of the explanatory variables and the hypothesized effect on agricultural intensification strategies of land, capital and labor are in presented in Table 1.

Distance to market is expected to have a negative impact on demand in that the farther away farmers are from markets the less they consider profitability as an objective of farming but rather self-sufficiency and hence less willing to purchase inorganic fertilizer or improved seed. Distance to access road is expected to be negatively related with hired labor use. Poor market access increases a household's cost of suitable labor wages to make transaction decisions, thereby reducing its leisure time (Rizov *et al*., 2001). The higher the transactions costs faced by individual households, the lesser they will be willing to adopt new technologies. This is as a results of lack of access to input and output markets.

Table 1: Explanatory variables and hypothesized effect on agricultural intensification strategies

	Hypothesised effects on agricultural intensification strategies		
Variable	Land	capital	Labor
Age of household head in years	0 or +/-	0 or +/-	0 or +/-
Household size	0 or +/-	0 or +/-	-
Gender of household head (0=female, 1=male)	0 or +/-	0 or +/-	0 or +/-
Non-farm income	+	+	+
Total land size of farm (ha)	+	+	+
Total Livestock Units	0 or +/-	0 or +/-	+
Distance to nearest access road (km)	-	-	-
Distance to nearest market (km)	-	-	-
Number of contact with extension agent	0 or +	0 or +	0 or +
Position of the farm (0=sugarcane, 1=tea)	0 or +/-	0 or +/-	0 or +/-

Contact with extension agent could have a positive effect on agricultural technology strategy adoption based on the innovation-diffusion theory. Such contacts, by exposing the farmers to the availability of information can be expected to stimulate adoption (Polson and Spencer, 1991). Some adoption studies have shown that contact by farmer with agriculture extension agent has had mixed impact in developing countries by either not having any effect at all or positive effect (Moser and Barrett, 2003).

Biophysical factors of the area (soil condition, slope, precipitation, pests and diseases) could affect the agricultural intensification strategies that farmers adopt. In this study, the biophysical factors of the area were implicitly represented by using a dummy for the agro-ecological zone. As earlier discussed the study area lies in two agro-ecological zone represented by the tea and sugarcane zone in the south and northern part of the District respectively.

This entire chapter has presented methods and approaches that were applied to assess the adoption of land-, capital- and labor-intensive strategies, as well as their determinants in Kakamega District. Data source and collection were also presented.

4 Results

This Chapter is divided into four subsections, which represent the four specific objectives of the study. It commences with descriptive statistics of the socio-economic characteristics of the people in the study area, followed by land use trends, existing agricultural intensification strategies and finally establishes factors influencing agricultural intensification strategies applied by farmers.

4.1 Description of the household socio-economic characteristics

This section presents the results on: the socio-economic characteristics of the household unit according to the zones and farm sizes; the income status of the farmers in the study area; the farm labor profiles in Kakamega and the history of agricultural intensification strategies using the case of maize production for the household. As earlier mentioned in section 1.3, maize is the most important crop in Kakamega since it is the staple food. It is grown by over 99% of the farmers. Therefore, any discussion on food security, agriculture production and productivity cannot overlook the important role of maize in the lives of the people of Kakamega.

4.1.1 Socio-economic characteristics of households according to zones and farm size

The tea zone is comprised of Shinyalu, Ikolomani and Ileho divisions of Kakamega District, while the sugarcane zone is comprised of Lurambi and Navakholo divisions as earlier mentioned in section 3.1.

Average farm size did not statistically differ between the tea and sugarcane zones and the empirical analysis pooled the data together as one sample. However, in order to capture any differences, socio-economic characteristics of the households could be differentiated by farm size (less than 1.5 ha) and (over 1.5 ha) in the tea and sugarcane zones (Table 2).

Over 58% of the farmers practiced farming as there main occupation. This varied between the zones with 52% and 69% in the tea and sugarcane zone relying on farming as main occupation respectively. Other main occupation included the informal sector[8] with approximately 30% and 16% of the household heads from the tea and sugarcane zones respectively.

8 Informal sector is also referred to us jua kali whereby individuals set up informal business with low capital base. It includes hand craft making, transportation of goods using bicycles or weaving among others.

Table 2: Socio-economic characteristics of households according to zones, (soil types, predominant industrial crops) and farm size (smaller or larger than 1.5 ha) in Kakamega District in the year 2005

Variables		Ultisols (Tea Zone)			Alfisols (Sugarcane Zone)			Both zones
		Farm size<1.5ha n=142	Farm size>1.5ha n=25	Overall N=167	Farm size<1.5ha n=60	Farm size>1.5ha n=16	Overall N=76	Overall N=243
Household characteristics								
Age of household head (yrs)	Mean	46.5 (1.01)	52.1 (1.17)	47.3 (1.45)	43.1 (1.51)	50.0 (1.8)	45.0 (1.31)	46.6 (1.14)
Household size (number)	Mean	6.2 (0.22)	6.8 (0.05)	6.5 (0.21)	5.9 (0.29)	5.0 (0.31)	5.7 (0.24)	6.1 (0.23)
Gender (%)	Male	44.0	52.0	45.0	90.0	77.0	88.2	58.8
Occupation (%)	Farmer	43.0	56.0	52.6	67.0	79.0	69.7	58.0
	Informal sector	26.0	24.0	30.2	15.0	14.0	15.8	16.3
	Formal sector	31.0	20.0	17.2	18.0	7.0	14.5	25.7
Farm level characteristics								
Total farm size (ha)	Mean	0.6 (0.01)	3.1 (0.34)	0.9 (0.01)	0.7 (0.01)	2.3 (0.15)	1.1 (0.02)	0.9 (0.01)
Per capita farm size (ha)	Mean	0.1 (0.02)	0.5 (0.11)	0.2 (0.00)	0.1 (0.01)	0.5 (0.01)	0.2 (0.01)	0.2 (0.01)
Land share maize crop (ha)	Mean	0.3 (0.00)	1.3 (0.14)	0.5 (0.01)	0.3 (0.00)	0.6 (0.11)	0.3 (0.03)	0.4 (0.02)
Distance to access road (km)	Mean	0.5 (0.01)	0.6 (0.11)	0.5 (0.02)	0.8 (0.11)	1.1 (0.21)	0.8 (0.18)	0.6 (0.10)
Distance to market (km)	Mean	2.5 (0.15)	2.9 (0.21)	2.6 (0.21)	4.6 (0.41)	3.4 (0.51)	4.4 (0.18)	3.2 (0.19)
Tropical Livestock Unit (TLU[9])	Mean	2.4 (0.21)	4.2 (0.25)	2.7 (0.16)	2.3 (0.38)	2.4 (0.21)	2.4 (0.29)	2.6 (0.21)
Cash crop on farm (%)	Yes	10.0	44.0	14.2	46.0	79.0	52.0	33.0
Number of extension visit yearly (%)	None	80.0	62.0	78.0	77.0	70.0	76.0	77.4

Numbers in parenthesis present the Standard Errors of the means

9 A TLU (Tropical Livestock Unit) is an animal unit that represents an animal of 250 kg live weight, and used to aggregate different species and classes of livestock as follows: Bullock :1.25; cattle: 1.0; goat, sheep and pig: 0.1; guinea fowl, chicken and duck: 0.04 and turkey: 0.05 (Janke et al. 1982)

Only 25% of the household heads had regular off-farm employment with occupation as teachers or civil servants being the main career.

Household head in the tea zone were generally older (47 years) than those in the sugarcane zone (45 years). The overall average age of the household head was 46 years but varied between a minimum of 18 and a maximum of 90 years. Larger farms (> 1.5 ha) were generally headed by household heads with an average age of > 50 years.

The average family sizes in the study area ranged from 1 to 12 persons in the sugarcane zone and from 1 to 16 persons per household, in the tea zone. The overall average household size in the study area is 6 persons per household; hence each household head had at least 5 dependents. The households comprised of 34% children of ten years and below while 21% were aged between 11 and 17 years old. The average farm size was 0.9 ha per household, with a minimum of 0.004 and a maximum of 11 ha. Farms were larger in the sugarcane zone (1 ha). All households were classified as smallholder farmers as defined in chapter 1, (farm size less than 12 ha) with an average per capita farm size of 0.2 ha.

All farmers grew maize annually, either as a mono-crop or intercropped with beans. The average area under maize per household was 0.4 ha. However, the share of farmland under maize was significantly ($p < 0.01$) higher in the tea than in the sugarcane zone. Irrespective of the farm size, households in the tea zone allocated over 45% of the total arable land area to maize while in the sugarcane zone only 20% of the land was cultivated with maize.

The distance of the farm house from the nearest access road ranged from 0.1 to 4 km. The average distance from the farm house to nearest input/output market in the tea zone and sugarcane zone were 2.6 and 4.4 km, respectively. The average distance from farm house to the nearest access road was 0.5 and 0.8 km in the tea and sugarcane zones respectively.

Farmers keep livestock as a custom, for investment and as a risk management strategy with an average of 2.6 TLU per household. The number of livestock was larger in the tea than in the sugarcane zone with 2.7 and 2.4 TLU respectively. Large farms in the tea zones had the highest average TLU of 4.2. Among the livestock kept were local breeds of cattle, sheep, goats, chicken, turkeys and ducks. Less than 10% of households had improved dairy or cross breed cattle. Sheep and goats were kept by less than 10% of the farmers. Chicken were raised by over 98% of the households. Less than 5% of the households kept turkeys or ducks in addition to the chickens. The poultry were kept under a free range system roaming freely within the homestead. Only 2% of the farmers kept exotic breeds of poultry for commercial purposes.

The relative importance of the industrial crops for commercial purpose differed between the Northern and the Southern parts of the districts. Thus, 52% of the farmers in Lurambi and Navakholo grew sugarcane as a commercial crop. Only 14% of the farmers had tea as a commercial crop in Shinyalu and Ikolomani. Only 10% of farmers with small farms in the tea zones had tea as commercial crops, while 46% of the small farms grew sugarcane as commercial crop. Forty four percent of large farms had tea while 79% grew sugarcane in the South and North of the district respectively. It was noted during the survey that most tea plantation were over twenty years old. Therefore, farmers were not planting any new tea plantation in the study area.

Generally, the contact between the farms and extension agents is low. Thirty percent of the farmers in large farms had accessed extension services at least ones in the previous year. Only 20% of farmers in small farms had at least one access to extension services in the previous year. Socio-economic characteristics according to selected administrative divisions of Navakholo, Lurambi and Shinyalu divisions of Kakamega District are presented in Appendix 5.

4.1.2 Income status and poverty levels in the study area

Households in the study area got income from different sectors mainly: livestock, crops, agroforestry, off-farm sources, remittances and wages. Total annual household income[10] was converted to per capita income using the household size as the deflator. It was computed to daily rates by dividing by 365 days of the year, and standardized to US $ rates to facilitate ease of comparison with poverty line measures. The daily per capita formula[11] was used to compute daily per capita income for all households. The average annual per capita income of US $257 in Kakamega District was lower than the average national per capita income of US $400[12] in the same year. Average daily per capita is US $0.7, with 64% of the households having daily per capita income of less than US $0.5[13]. Twenty four percent of the households had a daily per capita income of between US $0.5 and 1 and only 22% had daily per capita income of above US $1.

10 Overall income earnings in 2004 from all possible sources e.g. agriculture, remittances, salary and other off farm sources.

11 The formula used was daily per capita income =annual per capita income/365 days and the exchange rate of 1 US $ = Kenya Shillings 73.

12 See CBS (2005)

13 According to CBS (2000); the Government of Kenya defined poverty line of US $ 16.5 per adult equivalent per month for rural areas Kakamega.

This study further explored the average daily per capita incomes of selected administrative divisions of Kakamega, which were Navakholo, Lurambi and Shinyalu and results are presented in Table 3. Shinyalu had the least average daily per capita income of US $0.47 with 68% of the household having less than US $0.5 per adult equivalent daily.

Navakholo and Lurambi had an average daily per capita income of US $0.79 and 0.65 respectively. Lurambi had the most of its households (74%) living below US $0.5 per adult equivalent daily. Navakholo division had the highest average annual per capita income of US $292; Lurambi had US $236 and Shinyalu had US $172.

Table 3: Household per capita income in sugarcane zone (Navakholo and Lurambi Divisions) and the tea zone (Shinyalu Division) of Kakamega District in 2004

Variable		Navakholo (n=26)	Lurambi (n=25)	Shinyalu (n=60)
Daily per capita income (US $)	Mean	0.8 (0.1)	0.7 (0.1)	0.5 (0.1)
Yearly per capita income (US $)	Mean	291.9 (67.8)	236.1 (85.1)	172.2 (41.5)
Living below 0.5 US $ per adult equivalent daily (%)	%	54.3	74.1	68.5
Living below 1 US $ per day (%)	%	60.0	77.1	72.2

Note: Numbers in parenthesis are standard errors.

Farmers in the study area practiced both subsistence and commercial agriculture, but with more orientation towards subsistence agriculture. Apart from agriculture, they were also engaged in off-farm activities. Engagement in various activities was mainly geared towards meeting the diverse subsistence requirements, diversifying income sources and guarding against the risks of crop failure. Engagement in a variety of activities by the rural population of Kakamega was a basic coping strategy.

The study further explored the percentage share contribution of different income sources among farmers in Navakholo, Lurambi and Shinyalu (Table 4). Income sources were classified as formal wage, self employment and agriculture income. Formal wage included mainly permanent source of monthly employment in the civil service or different companies. Self employment source of income included small enterprises and business. Agriculture income was that from both crop and livestock products.

On average, Navakholo division had 33% of its income source from formal employment, 32% from self-employment and 35% from agriculture produce. Shinyalu got the largest share (46%) of its income from formal employment. Lurambi had the least average income share

(12%) from formal employment but instead self-employment contributed most of the household income share (71%).

Table 4: Share (%) of income sources to the total household income among farmers in the sugarcane zone (Navakholo and Lurambi) and the tea zone (Shinyalu) in Kakamega District in the year 2004

Division	Share (%) of income source		
	Formal wage	Self-employment	Agriculture income
Navakholo (n=26)	33	32	35
Lurambi (n=25)	12	71	17
Shinyalu (n=60)	46	37	17

Agriculture income was mainly from sale of crop produce as the local breeds of cattle kept by most farmers in the study area were mainly for subsistence. There are a diverse number of crops that were grown by farmers in an attempt to satisfy household food security. The average area dedicated to various main crops grown in Kakamega is shown in Table 5.

Table 5: Major crops grown by farmers in Kakamega District in 2004

	Common name	Species name	Average area (ha)	% of farmers growing
Food crops	Maize	*Zea mays*	0.42	99.19
	Beans	*Phaseolus vulgaris*	0.22	93.06
	Sweet potatoes	*Ipomea batatas*	0.09	37.11
	Bananas	*Musa spp*	0.06	29.03
	Groundnuts	*Arachis hypogaea*	0.16	8.04
	Cassava	*Manihot esculenta*	0.05	6.04
	Soya beans	*Glycine max*	0.14	2.12
	Sorghum	*Sorghum bicolar*	0.30	2.11
Industrial crops	Sugarcane	*Saccharum officinarum*	0.60	52.01
	Tea	*Camellia sinensis*	0.23	14.21

Maize and common beans were grown by majority of the farmers as annual field crops. Sugarcane was the most grown industrial crop. Sweet potatoes and bananas were also grown by over 25% of the farmers. Groundnuts, cassava, soya beans and sorghum were grown by less that 10% of the farmers.

4.1.3 Farm labor allocation and profile in Kakamega

Labor is required for various farm activities. Land preparation for food crops is mostly done using hoes while some farmers (45%) use ox-ploughs. Twenty percent of the farmers owned oxen. Four percent of the farmers interviewed had hired a tractor for food crop production in the last 12 months before the survey date. Planting, weeding and harvesting crops was done manually in the study area. Labor source was either from immediate family members and/or hired. Crop production in the study area highly depended on rainfall pattern and so did labor profile causing a variation in farm labor needs between different months of the year.

Average monthly labor use according to farm types and size in Kakamega in 2004

The amount of labor allocation varied between and within farms[14] in the tea and sugarcane zone. Average monthly family labor allocation among the farmers had a minimum value of 9 and maximum of 21 man days[15] per farm. The farmers in the sugarcane zone without sugarcane, and with less than 1 ha of land, had the least average monthly family labor allocation of 9 man days per farm.

Family labor was not compensated for but was translated to monetary terms in this study. One man day is equivalent to US $1. Therefore, the farms with 9 man days per month from family labor could have otherwise spent approximately US $9 on the farm in case of hired labor use. The largest amount of monthly family labor (21 man days) is among farms with tea and above 1 ha in size. This translates to monthly expenditure of US $21 per farm in case of hired labor.

Average monthly hired labor allocation among the farmers had a minimum value of 7 and maximum of 28 man days per farm. Farms in the tea zone without commercial crop and less than 1 ha in size had the minimum average monthly hired labor of 7 man days per farm. Thus, they spent on average US $7 on hired labor per month. The largest amount of monthly hired labor (28 man days) was among farms, above 1 ha in size and with tea crop. These farms had an equivalent monthly expenditure of US $28 on hired labor. In some cases farmers used both family and hired labor.

14 Farms: were divided as follows: 1) <1 ha, 2) 1-2 ha, 3) >2 ha and were differentiated according to farms with industrial crops (tea and sugarcane) or farms without industrial crop in the tea and sugarcane zone.

15 Man day is equivalent to a full day job or 8 hours work, normally with some 2 hours meal break.

Farms with tea and over 1 ha had the highest average total monthly labor use of 50 man days per farm. The farms in the sugarcane zone, with less than 1 ha in size and without any commercial crop used the least average monthly total labor of only 18 man days. Farms with tea, but less than 1 ha in size used the same average total monthly labor like farms with sugarcane that were more that 2 ha in size.

The average monthly family, hired and total labor among different farm types and sizes in Kakamega District are presented in Appendix 6.

Monthly labor requirements according to farm types and size

Labor requirement fluctuates monthly between and within the farm types. Peak labor requirement alternates with less labor constraint (slack period). The slack period occurs mostly during the dry season, especially from December to February and in July. Farmers therefore, use different monthly man days of family labor per farm type and size as presented in Figure 5 and 6 (see detailed values in Appendix 7a and b).

The slack period of February had family labor requirement of 4 man days amongst farmers without commercial crops. In February, the highest family labor requirement was 9 man days. August had the highest peak family labor requirement with the minimum of 27 man days per month amongst farms without cash crops and a maximum of 45 man days among small farms with tea.

The peak months of March, April, May, June and August, required over 8 man days of family labor per month in the study area. The highest amount of hired labor (60 man days) was in the month of August among farms above 1 ha in size, and with tea which translates to an expenditure of US $60. During high labor demands in August, the large farms with tea spent up to approximately US $60 on hired labor while the large farms in the same zone without tea spent US $46 during the same month.

The largest farms with tea also spent at least US $13 in a month on hired labor, while large farms without tea in the same zone could sometimes spent as little as US $4 per month on hired labor. During the slack period of December to February, there was reduced hired labor on farms that some farm types had as low as 2 man days of hired labor in a month.

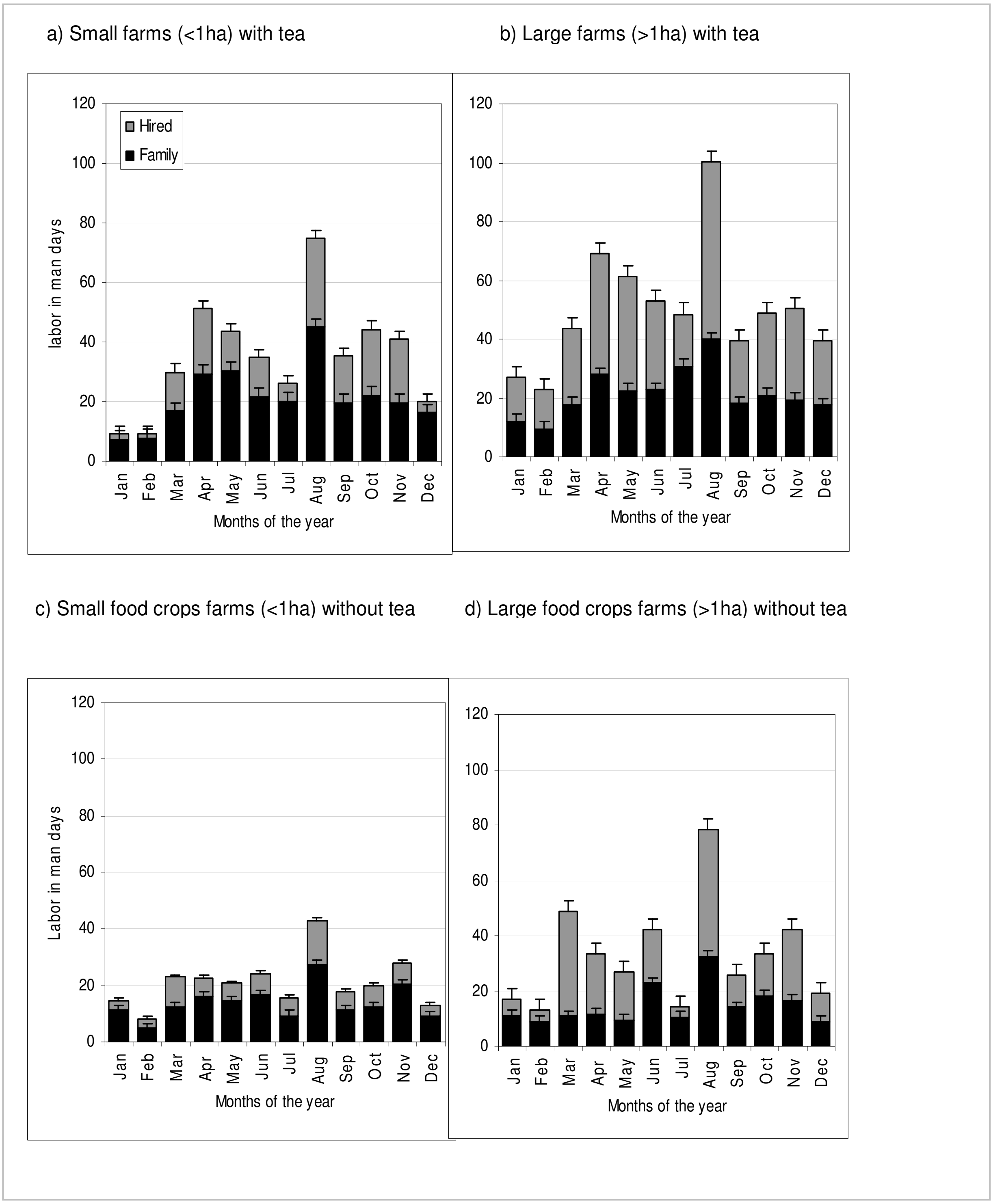


Figure 5: Labor allocation according to farm size in the tea zone of Kakamega in 2004

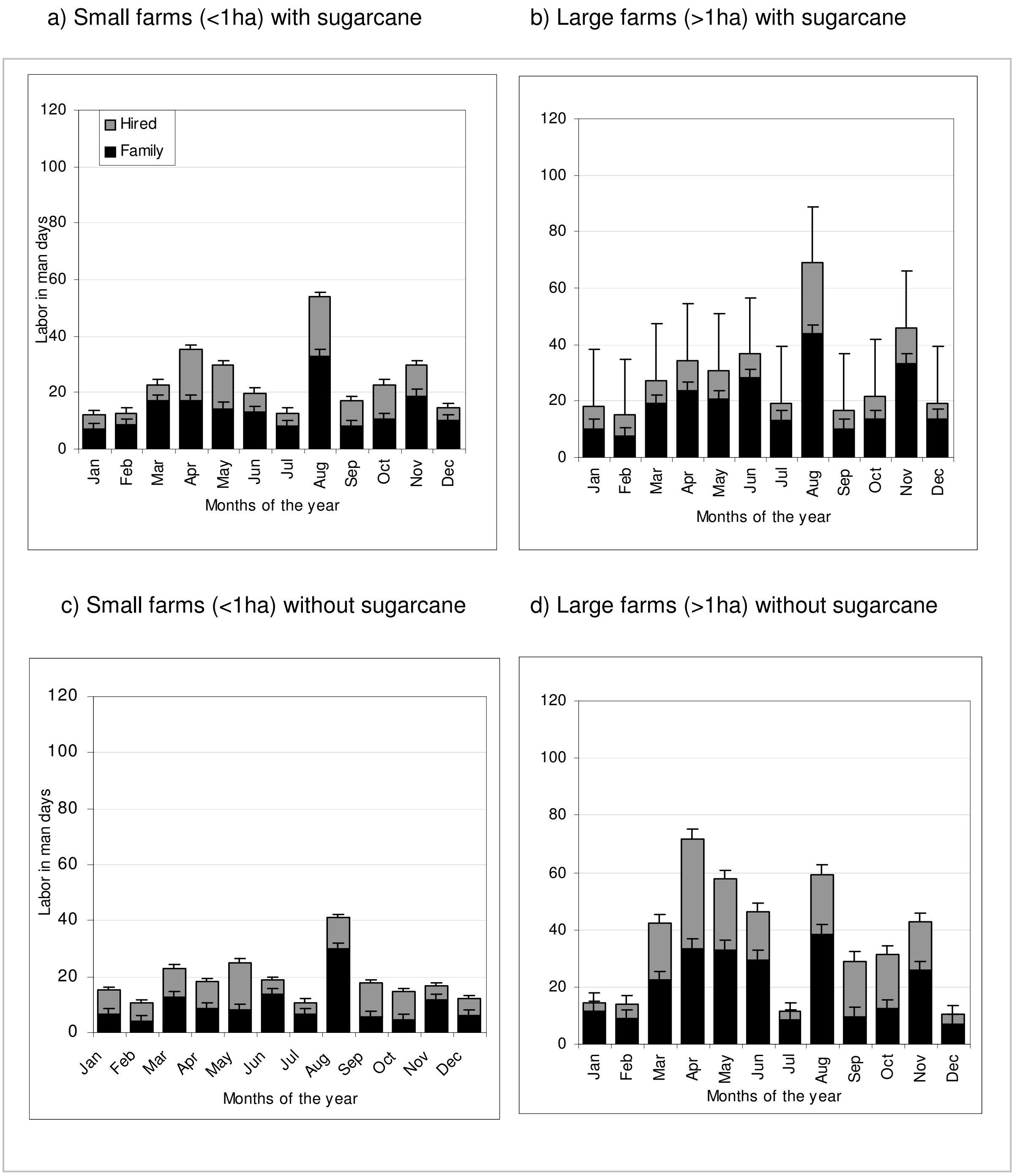


Figure 6: Labor allocation according to farm size in the sugarcane zone of Kakamega in 2004

Family and hired labor use per hectare in the tea and sugar zone

Family labor per ha varied within the tea zone (Ultisols) with farms with tea allocating 50% of the total labor required from the family and the remaining was hired. The farms in the tea zone without tea used 70% family labor and hired the remaining 30%. Family labor provided 60% of the total labor requirement per ha in the sugarcane zone in both the farms with and without sugarcane as shown in Figure 7. Farms with tea hire the most labor per ha in Kakamega District.

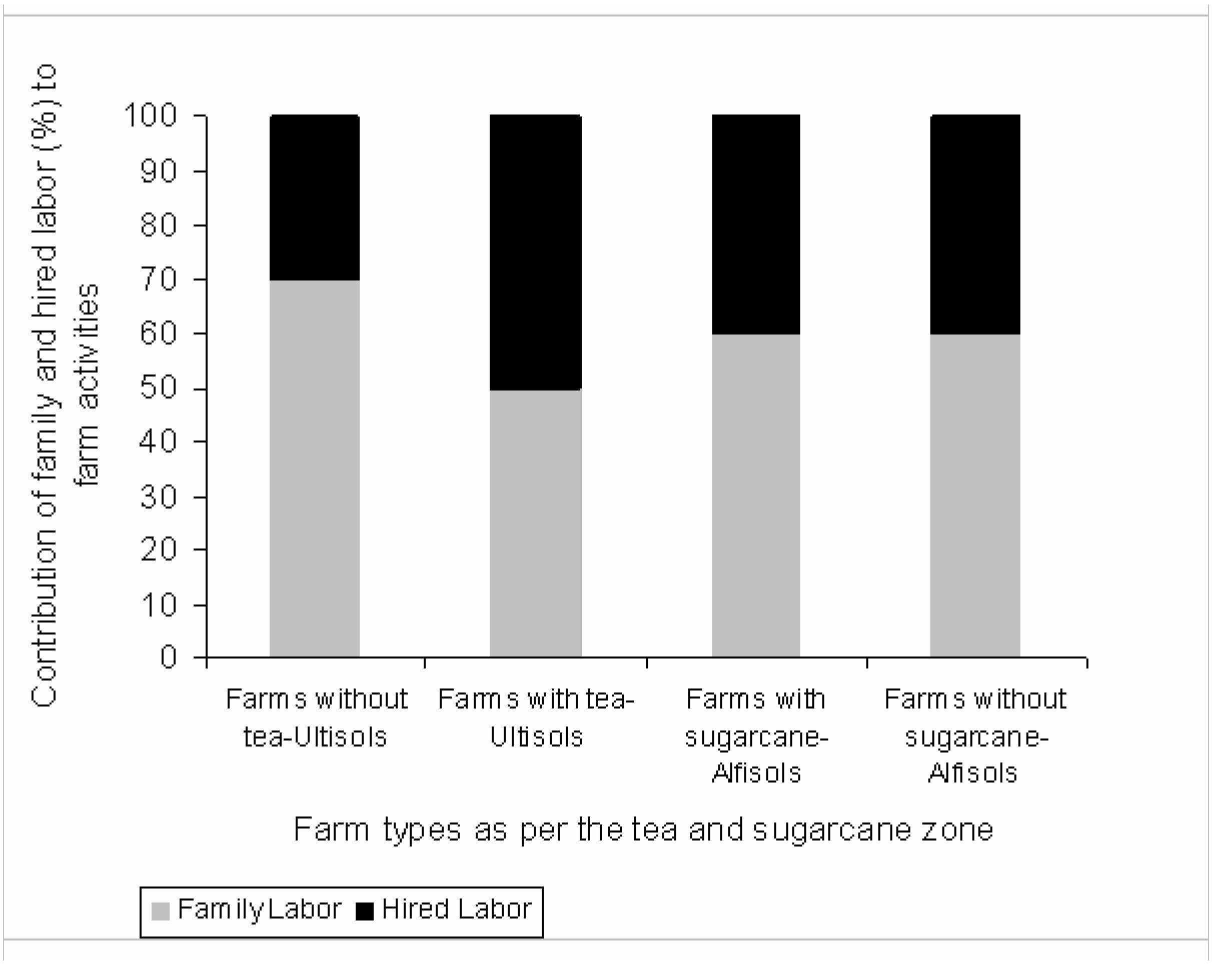


Figure 7: Hired and family labor share (%) in the tea zone and the sugarcane zone according to farming systems in Kakamega District in 2004

Family labor used per ha varied monthly between and within farm types as presented in Figure 8 and 9.

The labor profile in the tea zone is similar between farms with tea and those without tea. The month of August seems to have the highest family labor per ha while the month of February has the least family labor per ha in the study area.

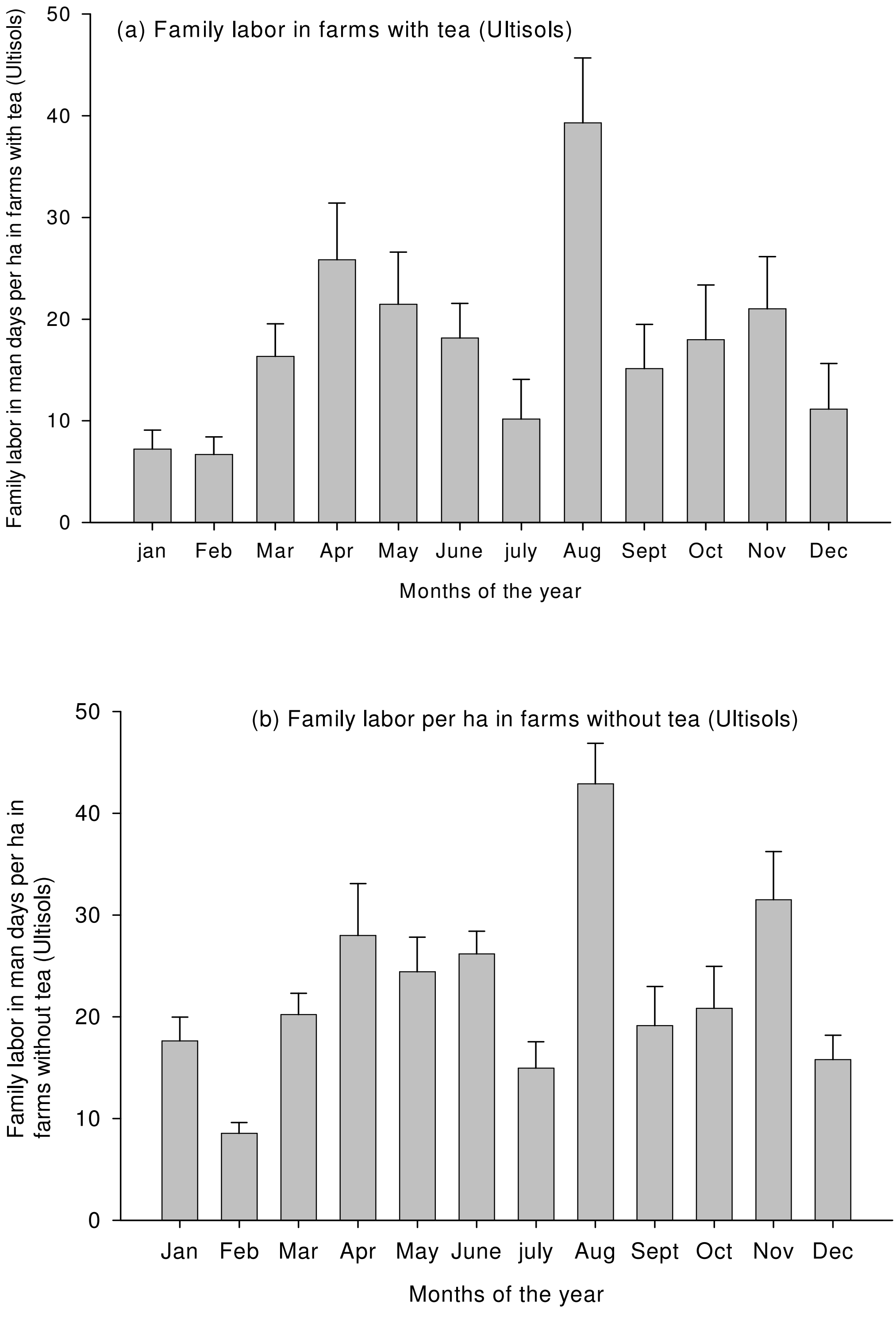


Figure 8: Family labor use per ha according to farm types: (a) farms with tea -Ultisols, (b) farms without tea -Ultisols, in Kakamega farmland in 2004 (Bars indicate Standard error)

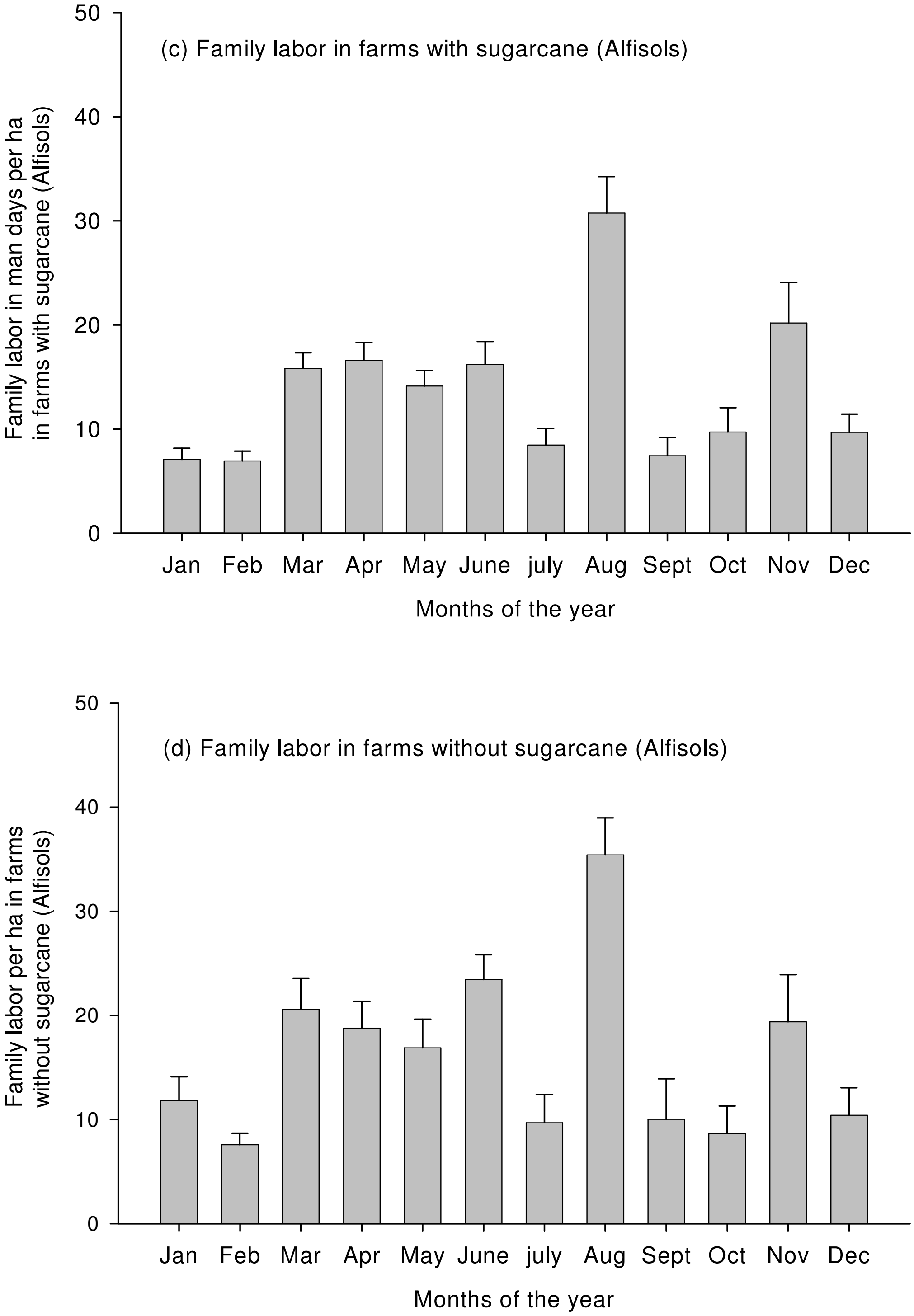


Figure 9: Family labor use per ha according to farm types: ((c) farms with sugarcane – Alfisols and (d) farms without sugarcane – Alfisols in Kakamega farmland in 2004 (Bars indicate Standard error)

Farms within the tea zone used a lot of family labor per ha as compared to farms in the sugarcane zone. Average monthly family labor tended to exceed significantly ($p < 0.05$) the hired labor per ha, among farms without tea. The month of August had the high amount of hired labor per ha in both zones as presented in Figure 10 and 11.

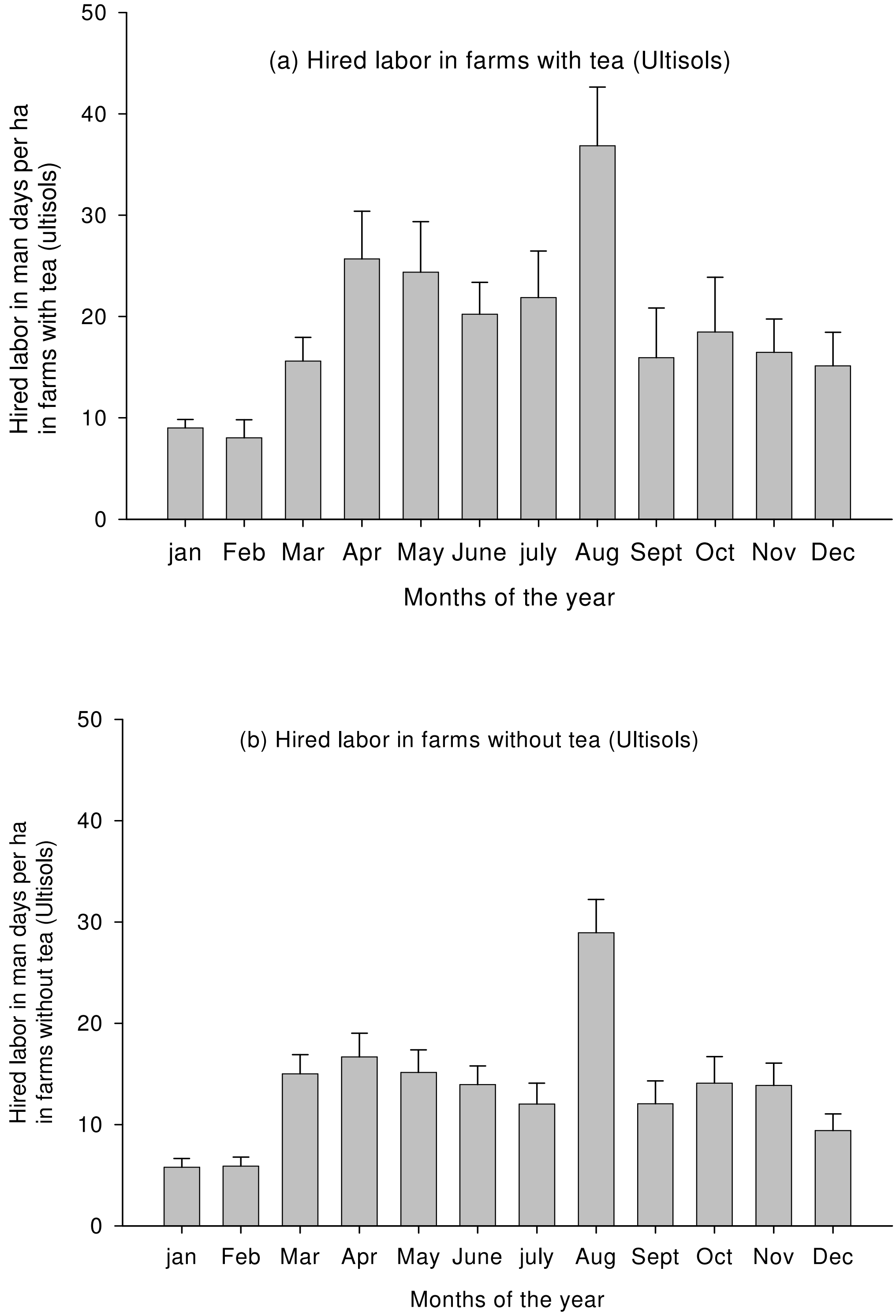
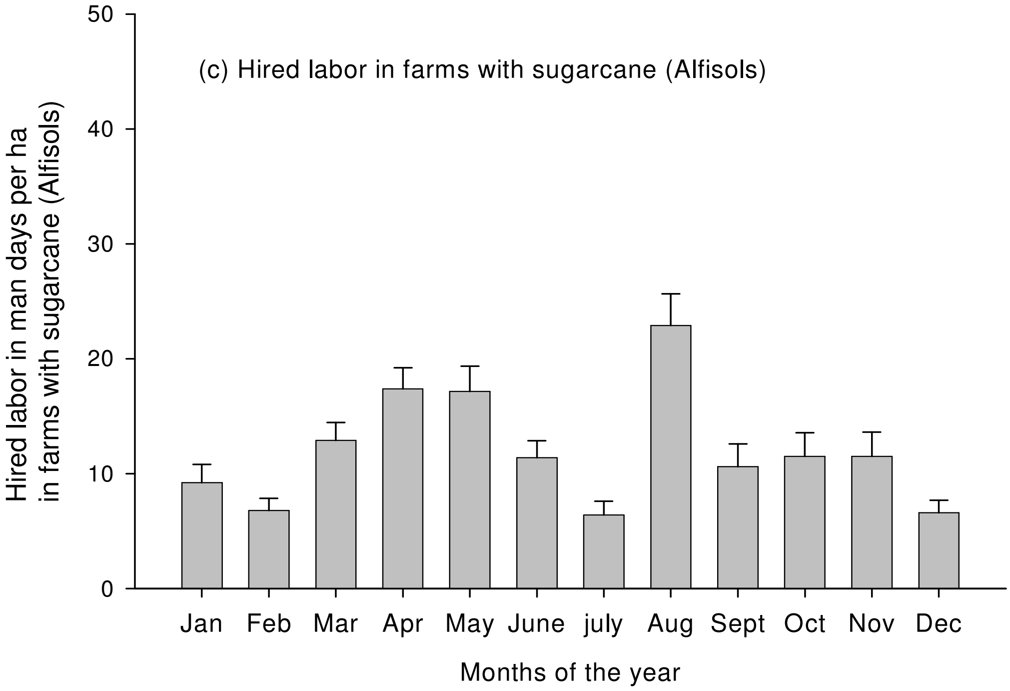


Figure 10: Hired labor use per ha according to farm types: (a) farms with tea - Ultisols, (b) farms without tea -Ultisols, in Kakamega farmland in 2004 (Bars indicate Standard error)



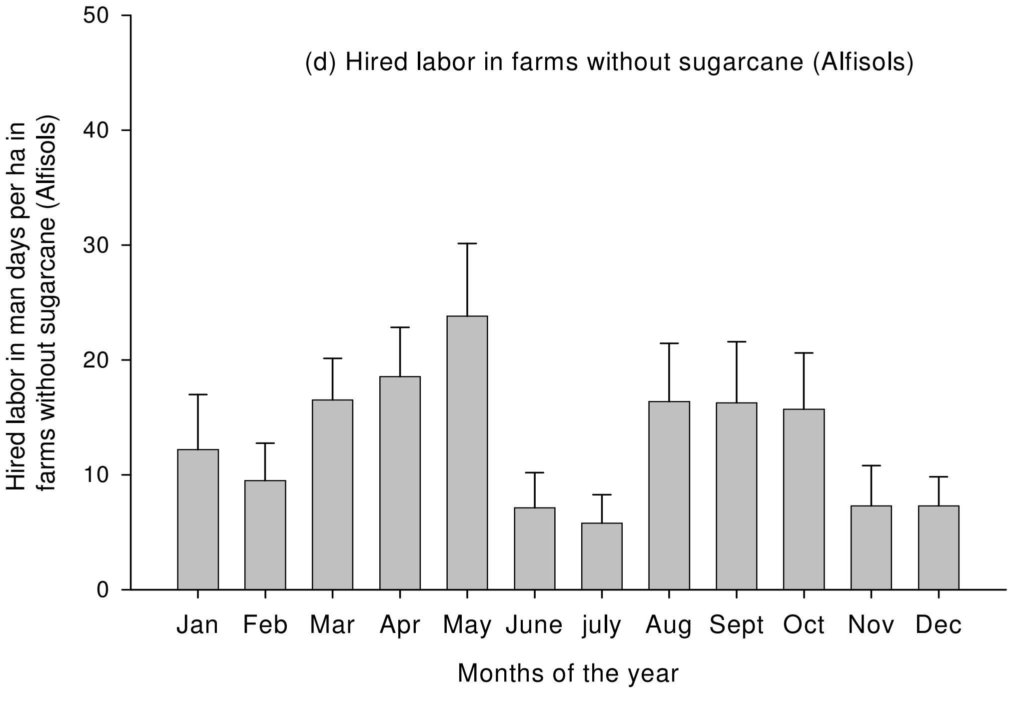


Figure 11: Hired labor use per ha according to farm types: (d) farms without sugarcane – Alfisols in Kakamega farmland in 2004 (Bars indicate Standard error)

Farms with tea also had the highest number of hired man days per ha in a year. The highest man days (40) per ha of hired labor amongst farms with tea was in August at a cost of US

$40. The farms without tea in the Ultisols had the highest man days (20) per ha in August at a cost of approximately US $20. Farms with sugarcane use relatively lower family and hired labor per ha as compared to farms without sugarcane in the Alfisols. The highest amount of hired labor in man days per ha among farms in the Alfisols was in May for farms without sugarcane and August for farms with sugarcane with a cost of US $25 and US $20 respectively.

4.1.4 Intensification strategies in Kakamega and the current status quo – case of maize production

In an effort to maintain maize production levels the farms in Kakamega have undergone three distinct phases as shown in Figure 12 and 13.

The first phase (1977-1986) shows a decline in maize yield as depicted in Figure 12a. During the same period the total area (km^2) planted to maize annually show an upward trend (Figure 13). Expansion was done through reduction of fallow land i.e. land – based intensification. Therefore, despite the declining yields of the maize, the production levels (Figure 12 b) were almost achieved by expanding the area cropped. Declining maize yields are almost fully compensated for by the expansion of cultivated area leading to reduction of fallow and grazing area. Thus, the overall production levels of maize are maintained.

The second phase (1987-1996), depicts an increase in the yield of maize. At the same time there is even reduction of the total area planted to maize but maize production levels are almost maintained until 1993 when there is a gradual downward trend. The use of inorganic fertilizer and improved hybrid maize was practiced and this raised the maize yield during the period 1987-1996. The use of capital-intensive inputs almost maintained the production level of maize. The total area planted to maize decreased since sugarcane was planted instead of maize to earn the rural household income.

The current phase 3 (1997 to 2006) can be referred to as a dilemma period. The maize yield is showing a declining trend. The maize production levels cannot be achieved and also shows a gradual downward trend. In order to maintain maize production levels, farmers started planting maize twice a year. Planting of maize twice a year seem to increase the annual total area of maize but does not maintain the production levels and the yields are lower that in the earlier phase. The strategy of increasing area under maize has reached its limits and farmers are in a dilemma of the next move to improve the yields. At the same time the farmers cannot achieve the previous maize production levels.

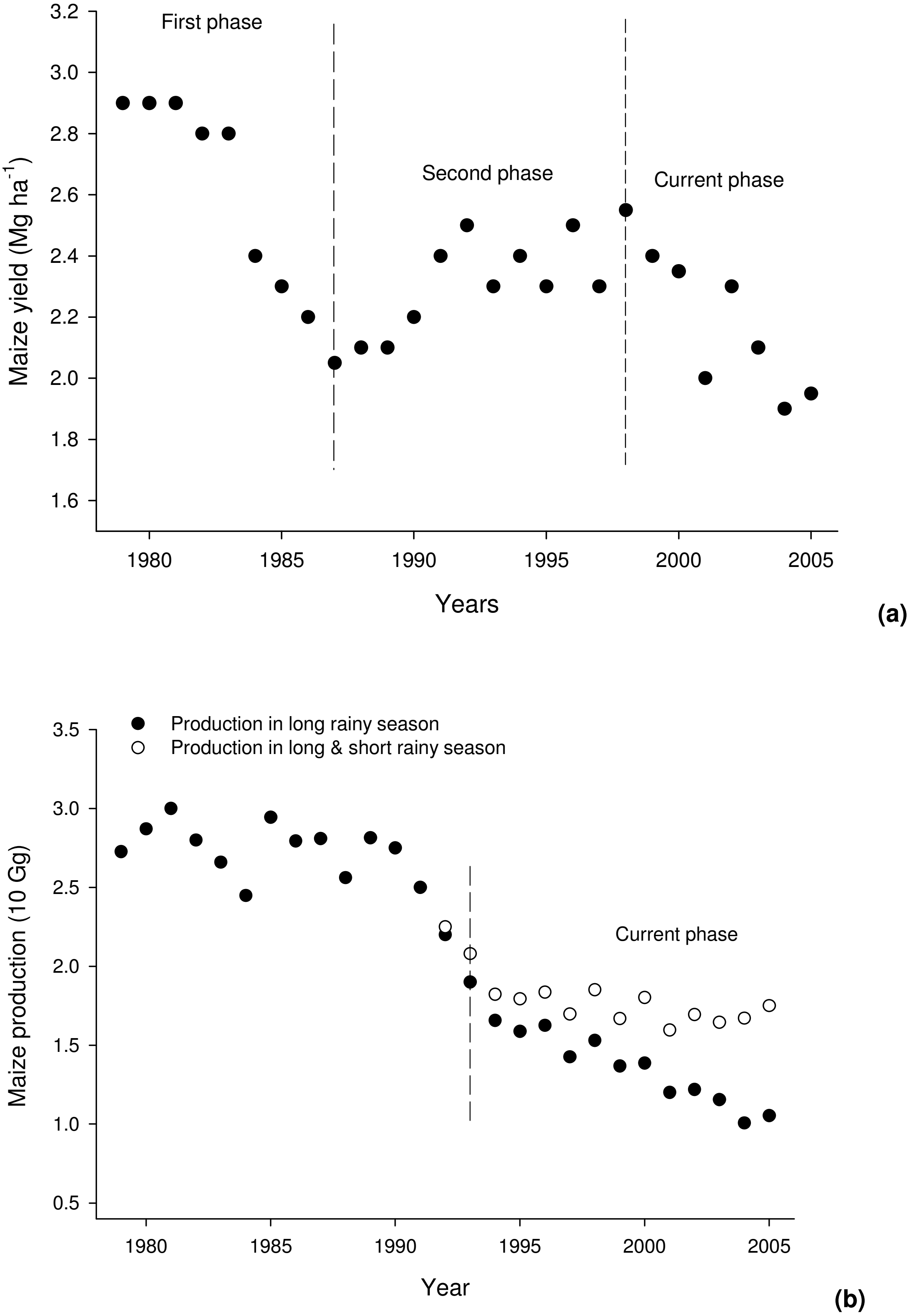


Figure 12: Three distinct phases in a) maize yield and b) maize production levels in Kakamega (1979-2005)

Source: Compilation from the Ministry of Agriculture, Kakamega office.

Before the mid 1990s, most farmers usually planted maize only in the long rainy season with rare cases of short rainy season maize crop (Figure 13). However, this tradition has changed over time. By the year 2005 the area under maize in the short rainy season had tripled compared to the early 1990s period. However, maize production levels are still showing a downward trend. The increase in the area under maize seems not to improve the maize production levels and farmers are in a dilemma.

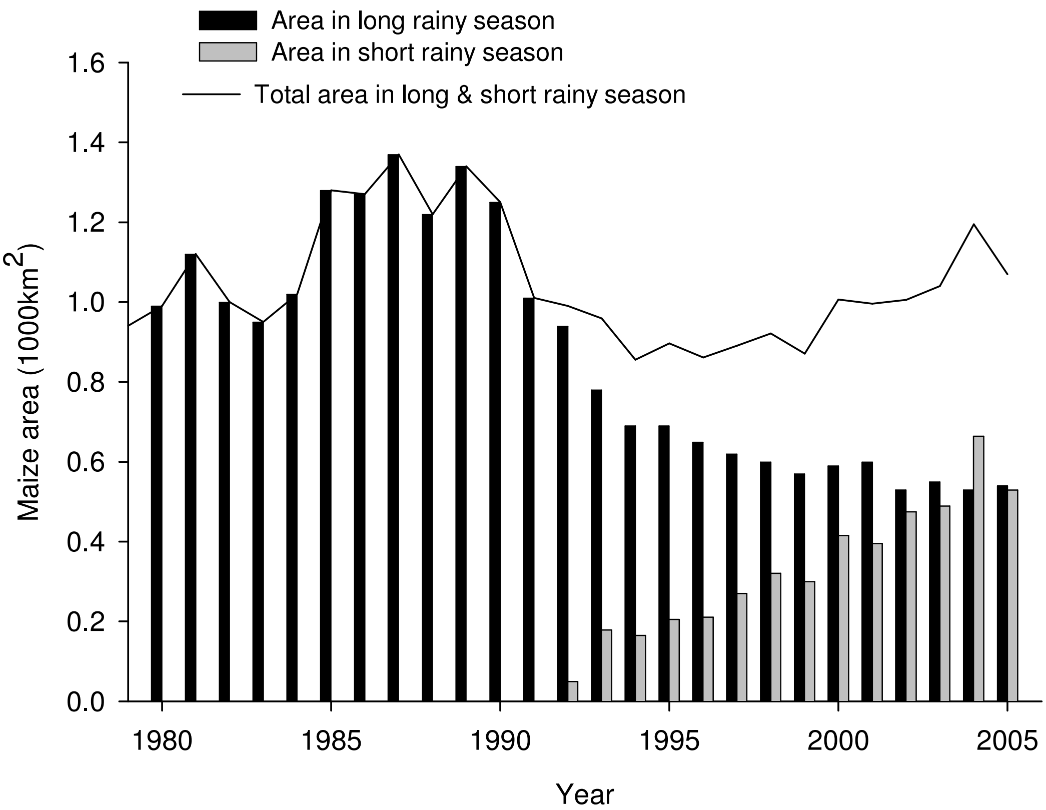


Figure 13: Trends in the area under maize during the short rainy and long rainy season (1992 to 2005) in Kakamega, District, Kenya

Source: Compilation from the Ministry of Agriculture, Kakamega office.

4.2 Trends in land use in the study area

Using secondary data, the trends in land use types are presented in

Figure 14. The data series is sufficient for use in this thesis since it can clearly show the trends and changes in land use types. The land use types were divided into four main classifications: food crops, industrial crops, fallow and forests. Food crops comprised all the

annual crops on the farm, which included maize, beans, vegetables, bananas, and cassava among others. The commercial crops are sugarcane and tea. Fallow [16]was land with grass or play grounds which were used for both grazing alongside occasional sports events.

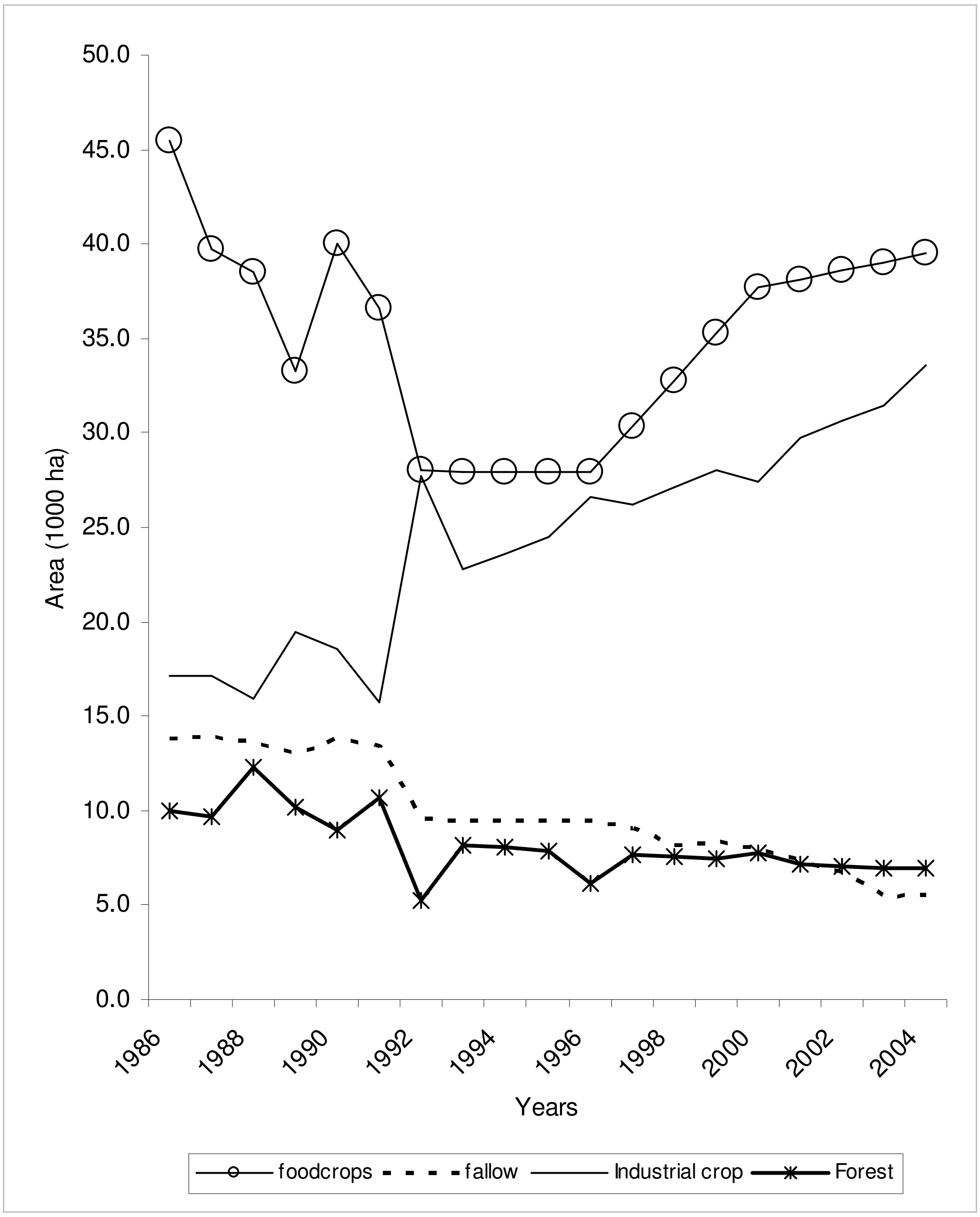


Figure 14: Land use trends (area, type of land use) in Kakamega District (1986-2004)

Source: Compilation from Ministry of Agriculture & Planning, Kenya

16 Fallow land and pasture land is used interchangeable to refer to the same land use type.

The area under the fallow land use type has gradually been on a downward trend over the years under review. The trend also shows that the expansion of the cropped area under food crops and sugarcane seems to have occurred at the expense of the reduction in fallow land. The area under industrial crop steadily increased while forest area showed minimal reduction over the period under review. The area under food crops fluctuates over the years, and occupies the largest share of the total land in Kakamega. The overall land use degree change parameter for Kakamega District was 10.3.

Eliminating the forest component from the data, there was further analysis of current farm land use types in Kakamega using the same data set. Arable land was further classified as food crops, commercial crops, and fallow. Percentage area of food crops fluctuates between 50 -59%. Industrial crop gradually increased in area by 20% from 22% to 42%. Fallow land area decreased by 11% from 18% to 7%.

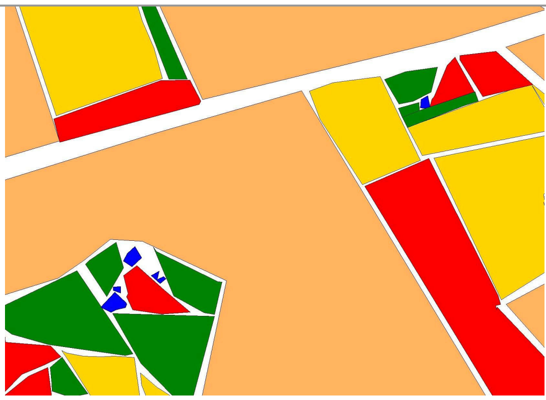
4.2.1 Trends in land use types using aerial photos: Cases of selected administrative divisions of Kakamega District

This section mainly describes different case scenarios in selected villages in Kakamega. Analysis of land use changes in three cases was done using the following gradients:

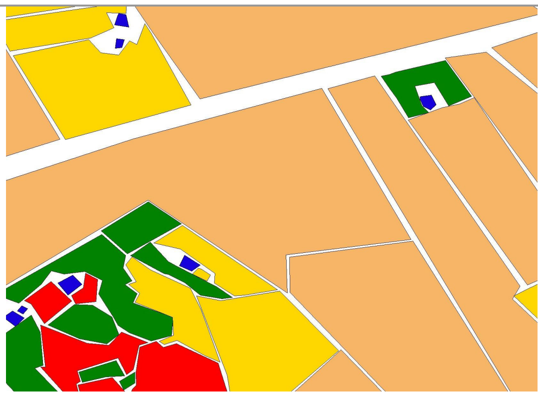
- Farms near to municipal markets and far from Kakamega forest as the case of Eshisiru village of Lurambi division.
- Farms far from both municipal market and forest as the case of Namirama village of Navakholo division
- Farms closer to forest but far from municipal market as the case of Ikoli village of Shinyalu division

Namirama village of Navakholo Division was far from both the municipal market and the Kakamega forest. Sugarcane occupies 64% of the total land in Namirama, while food crop and woodlots occupied 22% and 9% respectively. The fallow land area and settlement occupy 5% and 0.8% of the area respectively. The land use in Namirama village showed a decrease in the fallow land area. In 1991, the fallow land use area covered 10%, while in 2004 it covered only 5 % of the Namirama village. Most of the fallow land in Namirama village was replaced by sugarcane plantations, which increased from 60% in the year 1991 to 64% in 2004. There was an increase in settlement area from 0.6% in 1991 to 0.8% in 2004. In comparing land map 1A (1991) and B (2004) in Figure 15, it can clearly be seen that sugarcane had replaced some of the food crop and the fallow land area by the year

2004 in Namirama village. The Land map 1B also showed a higher land subdivision as compared to the Land map 1A.



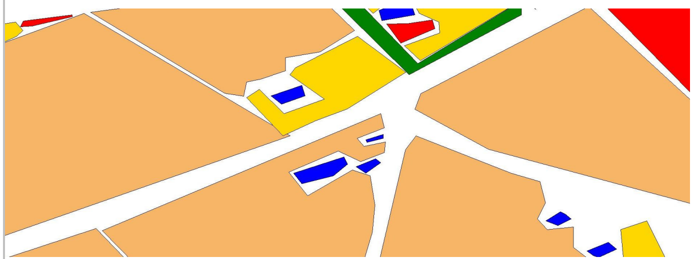
1A) Namirama village in Navakholo, 1991



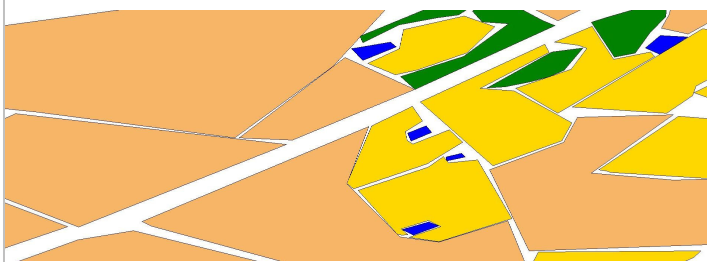
1B) Namirama village in Navakholo,, 2004

2A) Ikoli village in Shinyalu, 1991

2B) Ikoli village in Shinyalu, 2004



3A) Eshisiru village in Lurambi, 1991



3B) Eshisiru village in Lurambi, 2004

There were cases in Lurambi division where farmers had replaced sugarcane with food crops. The farmers attributed this action to delays in payment of their dues by the sugarcane factories and the need for more subsistence food.

However, the farmers noted that there was some improvement in the sugar industry management and in case sugarcane prices improved the farmers would revert their land back to sugarcane growing.

Buildings	Food crops	Fallow land	Sugarcane	Woodlots	Roads

Figure 15: Land maps of 1991 and 2004 in selected sample villages of: 1) Navakholo, 2) Shinyalu and 3) Lurambi in Kakamega District

Ikoli village in Shinyalu Division is closer to Kakamega forest but far from the municipal market. The percentage shares of each land use in Ikoli village in Shinyalu Division show some changes between the year 1991 and 2004. In the year 2004, food crop was the major land use type in Ikoli village and occupied 92% of the total area, followed by woodlots at 5% and fallow area at 2%. Even though the fallow land occupied the least area, it reduced from an initial area share of 16% in 1991 to 2% in 2004. Woodlots increased during the same period to 5% in 2004 from the initial 4.4%. Land map 2A and B shows replacement of fallow area by food crops. Land fragmentation increased in the year 2004 as compared to 1991 with the farm units decreasing in size due to continued subdivision among family members. Details of the land use area share of selected villages of Namirama, Ikoli and Eshisiru as shown in the land use maps in Figure 15 are presented in Table 6.

Table 6: Land use change in Navakholo, Shinyalu and Lurambi Divisions of Kakamega District (1991-2004) using selected sample villages of Namirama, Ikoli and Eshisiru.

	Land use type	1991		2004		Land use change (%)
		Area (ha)	%	Area (ha)	%	1991-2004
	Buildings	0.2	0.6	0.3	0.8	50.0
Navakholo	Food crops	9.0	22.5	8.7	21.8	-2.2
(Namirama)	Fallow/Pastures	4.1	**10.1**	1.8	**4.6**	53.6
	Sugarcane	24.2	60.1	25.5	63.7	5.3
	Woodlots	2.6	6.4	3.7	9.2	42.3
	Total	40.0	100.0	40.0	100.0	
	Buildings	0.11	0.5	0.2	0.7	45.4
Shinyalu	Food crops	18.0	79.3	22.0	92.0	22.2
(Ikoli)	Fallow/Pasture	3.7	**15.8**	0.5	**2.0**	-83.1
	Sugarcane	-	-	-	-	-
	Woodlots	1.02	4.4	1.2	5.0	17.4
	Total	23.0	100.0	23	100.0	
	Buildings	0.2	0.6	0.3	0.8	3.1
Lurambi	Food crops	5.8	15.1	9.8	24.5	66.2
(Eshisiru)	Fallow/Pasture	5.6	**14.5**	0.2	**0.4**	-91.4
	Sugarcane	26.8	68.8	28.9	72.4	8.1
	Woodlots	0.4	1.0	0.8	2.0	100.0
	Total	39.0	100	39.0	100.0	

Eshisiru village in Lurambi division is closer to the municipal market but relatively far from Kakamega forest. Farmers in Eshisiru produce vegetables for sale in the neighboring Kakamega municipal market in addition to sugarcane for the sugar industry. Sugarcane growing is the main land use type in Eshisiru and occupies 72% of the area. The food crops area occupied 25% of the area. The woodlots, pastures and settlement occupied 3% of the total land area. The food crop area had increased over the years from 15% in the year 1991 to 25% of the total area in 2004. Unlike Namirama village in Navakholo area, where sugarcane replaced food crops, the Land use map 3A and B show replacement of sugarcane crop by food crops in Lurambi. However, there was an increase in both the food crop and sugarcane area while the fallow land area decreased.

4.3 Agricultural intensification strategies in Kakamega

Farmers are in a dilemma on how to maintain maize production levels as enumerated in section 4.1.4. Due to the declining maize yield trend, farmers are unable to maintain the production levels of maize even with the increased per annum area. Therefore, they adopt agricultural intensification strategies in order to increase production and improve farm productivity. Since maize was the most important crop in the district, the discussion on capital-intensive strategies was in terms of maize crop production as introduced at the beginning of this chapter. The existing agricultural intensification strategies are enumerated with a focus on land, capital and labor and include:

1. Land-intensive strategies
   - Over 80% of farmers had crops cover the land for over 10 months in a year and cropped over 75% of the farm area
   - Intercropping practiced by 80% of the farmers
   - Multiple cropping on same plot done by 76% of farmers
   - Agroforestry is used by 25% of the farmers
2. Capital-intensive strategies
   - Approximately 56% of farmers use improved maize seed
   - Farmers (70%) applied inorganic fertilizer with low application rates of less than 5 kg per ha by over 50% of the farmers.
3. Labor-intensive strategies
   - Use of livestock manure by 64% of farmers
   - Use of green manure by 25% of farmers

- Zero grazing by less than 5% of the farmers

When land-intensive strategies were used, the majority of the farmers (80%) cropped over 75% of their land. Most of the farmers (76%) practiced continuous, double or multiple cropping on the same plots in a year. The average land use intensity is 0.78 with a minimum of 0.05 and a maximum of 1 among the farms. The average land use intensity for the tea and sugarcane zone is 0.77 and 0.80 respectively.

Sixteen percent of the household had continuous rotation fallow17, and only 8% of farmers practiced rotational fallow. Sixty percent of the farms had increased in the cropping intensity as compared to the previous 10 years. Over 50% of the farms had vegetables on small patches of land all year long. The vegetables were mainly for subsistence but could be sold in case of surplus as reported by 30% of the farmers. There was no significant difference in land use intensity between the tea and the sugarcane zone at 5% level of significance (Appendix 3).

Capital-intensive strategies in the study area included the use of improved hybrid maize seed and inorganic fertilizer. Use of improved hybrid maize seed is considered an agricultural intensification strategy only if the farmers apply the recommended agronomic management associated with it in order to increase the potential yield.

Farmers (56%) used improved hybrid maize seed while the remaining used local maize varieties[18] that were selected and named by the local communities. Among the improved hybrid maize seed users, 33% had increased the quantities used compared to the previous three years, while 17% had decreased quantities of the amount used. The most common reason given by farmers for reducing the use of improved hybrid maize seed was due to high purchasing price of the improved hybrid maize seed.

Inorganic fertilizer was used in food crop production especially maize by approximately 70% of the households, even though it was sub-optimally applied. The main type of mineral fertilizer used in all sub-locations was diammonium phosphate (18:46:0) at planting, followed by calcium-ammonium nitrate and urea (46:0:0) for top dressing. Rock phosphate and triple

17 Fallow land occurs when initially cropped land is left to rest for a cropping season or over one year in order to regain lost nutrients, while continuous cropping system does not allow time for land to rest. Continuous cropping system is an intensive land use method that requires that the soil restoring functions of a fallow have to be obtained in less time, by a so-called improved (more effective) fallow, or that these functions have to be fully integrated into the cropping system by integrated soil management practices such as addition of manure or inorganic fertilizers.

18 e.g. Samaria, Shipindi, Opapari, Maseno double cob, Radier, Nyamula, Isukha, Nyar Maragoli.

super phosphate were less widely used. Tea growers used a compound fertilizer (25:5:15) obtained through the tea processing industry.

There is also variation in the amount of the inorganic fertilizer use per ha across selected administrative divisions as shown in Table 7.

Table 7: Inorganic fertilizer use on food crops in selected administrative divisions of Kakamega District in 2004.

	Inorganic fertilizer application per ha on food crops				
Divisions	0 kg	1-5 kg	5.1-10 kg	>10 kg	Total
		Percent of households			
Navakholo	25	45	10	20	100
Lurambi	29	21	40	10	100
Shinyalu	9	40	21	30	100
Ikolomani	10	50	15	25	100

At least 9% of farmers do not use inorganic fertilizer at all in the selected administrative divisions. Navakholo and Lurambi had 25% and 29% of the respective farmers that do not use inorganic fertilizer, while Shinyalu and Ikolomani had 9% and 10% of farmers not using inorganic fertilizer respectively.

At least 20% of the farmers in the selected divisions of Shinyalu, Ikolomani, Navakholo and Lurambi used between 1-10 kg of inorganic fertilizer per ha in maize production in the year 2004. The farmers cited high purchasing prices of the inorganic fertilizer as the main cause of sub-optimal use. They were fully aware of the advantages associated with the use of inorganic fertilizer in improving soil fertility. Of the total households who use inorganic fertilizers, 24% had decreased the quantity used compared to the previous three years.

Labor-intensive strategies were accomplished with the family or/and hired labor as earlier presented in section 4.1.3 on page 45. Labor-intensive strategies were adopted in the area to enhance crop productivity, mainly focusing on adoption of integrated soil fertility management.

The dynamics in using some selected agricultural inputs at farm level over the years has been described with reference to maize production following its importance in the area as earlier described. The past and current uses of selected agricultural inputs and other agronomic management applied in maize production were listed. Farmers were asked to recall if they used the agronomic management practices or inputs ten years back (1994). The results are presented in Table 8.

Table 8: Farm management practices and selected input use in maize production as reported by the surveyed farmers in Kakamega District in 2005 (% of farmers surveyed).

Input use or management practice	% of farmers use in maize production	
	1994	2004
Inorganic fertilizer use	71	70
Intercropping	77	80
Animal manure	68	64
Trash lines/mulch	62	60
Improved maize seed use	54	56
Ox plough use	52	45
Hand hoe	48	55
Agroforestry	27	25
Fallowing	12	8
Herbicides & pesticides	0	0

Farmers used improved hybrid maize seed varieties in producing maize. The proportion using the hybrid maize variety is higher for the year 2004 at 56% as compared to 54% in 1994. Technologies associated with soil capital, fertility improvement and conservation were the most common for the production of maize both in the recent seasons and last ten years. These included intercropping of maize with nitrogen fixing crops, use of inorganic fertilizer, animal manure, green manure and use of trash lines. Use of ox plough had reduced from 48% in 1994 to 45% in 2004 as indicated by farmers. The proportion of farmers who practice fallow cultivation had also reduced since 1994 from 12% to 8% in the year 2004. Even though pesticides and herbicides are not used in maize production, 25% of farmers reported using them in commercial vegetable production.

4.4 Factors influencing agricultural intensification strategies

The following section describes the drivers of agricultural intensification strategies, which are categorized as land-, capital- and labor-intensive strategies.

4.4.1 Factors influencing land use intensity

Regressions results of the factors influencing land use intensity are presented in Table 9. Six explanatory variables are statistically significant in explaining the high land use intensity by the farmers. The factors influencing the land use intensity in Kakamega included socio-economic characteristics of the household; mainly age, gender and the occupation of the household head.

The male farmers (with farming as the main occupation) positively and significantly influenced land use intensity. This was similar to the household heads with permanent employment off farm/ or with formal employment in neighboring towns. Age of household head significantly negatively influenced the land use intensity. The negative coefficient indicates that as farmers increase in age the land use intensity on their farms reduces. Thus, the older farmers had lower land use intensity than younger farmers.

The market access parameters were measured by the distance (km) from the farm house to the nearest input or output market and showed a significant influence on the land use intensity. The farms closer to input-output markets had higher land use intensity than farms far away from the market.

Table 9: Tobit regression estimates to explain factors influencing land use intensity (R-value) in Kakamega District in 2005

Variable	Marginal effects	P-value
Position of farm (0 = sugarcane zone, 1 = tea zone)	0.073	(0.247)
Age of household head (years)	-0.011	(0.101)*
Gender of household head (1= male, 0 female)	0.171	(0.003)***
Occupation of household head (1= farmer, 0 =otherwise)	0.267	(0.013)***
Occupation of household head (1= employee, 0=otherwise)	0.222	(0.044)**
Occupation of household head (1=informal sector, 0=otherwise)	0.125	(0.280)
Number of people residing in household	0.001	(0.957)
Experience squared (number of years as a farmer)	0.001	(0.190)
Land tenure system (1=title deed, 0 = otherwise)	0.011	(0.842)
Distance (km) from farm house to nearest access road	-0.027	(0.464)
Distance (km) from farm house to input-output market	-0.024	(0.022)**
Use of improved seed (1=yes, 0=no)	0.031	(0.570)
Use of chemical fertilizer (1=yes, 0=no)	-0.004	(0.948)
Number of contact with extension agent in a year	-0.051	(0.020)**
n	245	
Log likelihood	-128	
Pseudo R	0.41	

Dependent variable	Land use intensity

Note: *** Significant at 1% level of error probability, ** Significant at 5% level of error probability and * Significant at 10% level of error probability.

Access to the extension services as determined by the number and frequency of visits by the extension agents to the farmer significantly influenced the land use intensity. Farmers who received more than three time visits from the extension agents had much lower land use intensity value than farmers without frequent visit from the extension agent. Thus, the number of contact with an extension agent in a year influenced the land use intensity.

For instance, using the marginal effects of the analysis, the study shows that if the distance to the market is increased by 1% then this could result in a reduction in the land use intensity by 2%. Similarly if the household age increases by 1 year, then there will be a reduction in land use intensity by 1%. The marginal effect on the extension variable shows a greater impact. The results show that if the number of contacts between the extension officers and the farmer increases by one unit, then there is a probability of reducing land use intensity by 5%.

Although the initial research design hypothesized that the land use intensity is not driven by market factors and socio-economic characteristics of the household, the effects of these parameters are statistically significant and influence the land use intensity. Thus the null hypothesis that the land use intensity is not driven by the market factors and the socio-economic characteristics of the household is rejected.

4.4.2 Factors influencing use of capital-intensive agriculture strategies

In this section the drivers of capital-intensive agricultural strategies are considered. These are mainly factors that influenced use of improved hybrid maize seed and the use of inorganic fertilizers in food crop production.

Factors influencing use of improved maize seed as an intensification strategy

The means of the proportion of the land under maize crop in the two zones were significantly $(p < 0.01)$ different from zero in the study area. Thus tea and sugarcane zone samples were analyzed separately. Zero area indicated non-adoption of the improved hybrid maize seed. The Tobit model was used to predict the factors influencing the use of improved hybrid maize seed as an agricultural intensification strategy and estimates are presented for tea and sugarcane zone respectively, as shown in Table 10. The log likelihood ratio tests are significant at 1% level in the tea and sugarcane zone, which is an indication that the explanatory variables fitted the data well.

The adoption history of using the improved hybrid maize seed for the previous 10 years, (that is since 1994) positively and significantly influenced the current use and proportion of area allocated to improved hybrid maize seed in the tea and the sugarcane zones. Also the adoption of the use of inorganic fertilizer, positively and significantly influenced the proportion of farm allocated to improved hybrid maize seed in both zones.

The distance to the nearest market negatively influenced the share of the farm area allocated to improved hybrid maize seed in the tea zone. This implies that market access has a positive influence in the adoption of the improved hybrid maize seed use even though the influence is only significant in the tea zone. Also the total number of people residing in the household had a positive and significant influence on the proportion of land allocated to improved hybrid maize seed use in the sugarcane zone.

Table 10: Tobit estimates of factors affecting use of improved maize seed in tea and sugarcane zones of Kakamega District in 2005

	Tea Zone		Sugarcane Zone	
Variable	Coefficient	P-value	Coefficient	P-value
Distance (km) from farm house to nearest market	-0.151	(0.072)*	-0.011	(0.809)
Use of chemical fertilizer (1=yes, 0=no)	0.307	(0.051)**	0.252	(0.004)***
Occupation of household head (1=farmer, 0 = otherwise)	0.206	(0.367)	-0.058	(0.615)
Occupation of household head (1=employee, 0= otherwise)	0.221	(0.345)	-0.117	(0.378)
Occupation of household head (1= informal sector, 0= otherwise	0.143	(0.567)	0.111	(0.680)
Used improved seed since 1994	0.468	(0.000)***	0.176	(0.002)***
Number of people residing in household	-0.010	(0.601)	0.026	(0.102)*
Number of contact with extension agent in a year	0.032	(0.574)	0.022	(0.490)
Land tenure system (1=title deed, 0 = otherwise)	0.074	(0.507)	0.162	(0.037)**
Labor intensity (man days per ha)	-0.009	(0.043)**	-0.004	(0.101)*
Household has a cash crop (ha)	-0.074	(0.628)	-0.137	(0.091)*
Gender of household head (1=male, 0 female)	0.249	(0.016)**	-0.210	(0.071)*
Constant	-0.650	(0.032)**	0.026	(0.881)
n	169		74	
Pseudo R	0.38		0.43	
Log likelihood	-100.3		-45.3	
Dependent variable	Proportion of land used for improved maize			

Note: *** Significant at 1% level of error probability, ** Significant at 5% level of error probability and * Significant at 10% level of error probability.

Area allocated to cash crop negatively influenced the proportion of farm size under improved hybrid maize seed in Kakamega, but was only significant in the sugarcane zone. There was an inverse correlation between the area under cash crop and the proportion of area under improved hybrid maize seed. The households with cash crop tend to reduce the area share or proportion of farm allocated to improved hybrid maize seed. Instead they allocate more area to cash crop.

Interestingly, the results on the gender of the household head differed in the tea and sugarcane zones. Positive and significant sign on gender in the tea zone indicates that the likelihood of allocating larger proportion of the farm to improved hybrid maize seed as an intensification strategy is higher for men compared to the women. The negative and significant sign on gender in the sugarcane zone indicates that the likelihood of allocating area under improved maize seed use was lower for men than the women.

The land tenure system positively and significantly influenced the proportion of area under improved hybrid maize seed in the sugarcane zone. Implying the probability of allocating areas to improved hybrid maize seed decreased as land ownership changed from an individual to communal ownership and leased farms. The households on leased farms or with access rights to a farm preferred allocating more area to the planting of the sugarcane instead of maize. The land tenure system did not have an effect on the proportion of the area under improved hybrid maize seed in the tea zone.

The labor intensity (man days per ha) was negative and significantly affected the proportion of the farm area under improved maize hybrid seed in both the tea and the sugarcane zones. The higher the man days per ha, the lower the probability of allocating more proportion of land to improved hybrid maize seed.

From the above estimates, again the null hypothesis of the initial research design that adoption of improved maize seed is not driven by the market factors and the socio-economic characteristics of the household is rejected. Some of the estimates of the market factors and the household socio-economic parameters are found to be statistically significant and influences the proportion of land allocated to improved hybrid maize seed in Kakamega.

Factors affecting use of inorganic fertilizer in maize production

The Probit model was used to predict the probabilities of the factors affecting the use of inorganic fertilizer in food crop production. The estimated coefficients and P-values from the regression analysis are presented in Table 11 for the tea zone and the sugarcane zone respectively.

There is a significant and positive influence of the current use of improved maize seed and the use of inorganic fertilizer in the tea and the sugarcane zone. The farmers that used improved hybrid maize seed had a high probability of using the inorganic fertilizer on their farms, especially for food crop production.

Growing of a commercial crop (tea or sugarcane) also had a positive and significant influence on the use of inorganic fertilizer in both the zones. The cash crop industries supplied inorganic fertilizer for their respective cash crop (tea and sugarcane). The farmers diverted some of the supplied inorganic fertilizer for food crop production.

Table 11: Probit results of factors affecting the adoption of fertilizer by farmers in tea and sugarcane zone of Kakamega District in 2005

	Tea Zone		Sugarcane Zone	
Variable	Coefficient	P-value	Coefficient	P-value
Constant	-0.277	(0.810)	-1.915	(0.251)
Used improved seed since 1994	-0.120	(0.662)	-1.067	(0.005)***
Age of household head (years)	0.033	(0.354)	0.053	(0.358)
Total number of people resident in household	-0.045	(0.405)	0.048	(0.626)
Distance from farm house to nearest market	-0.026	(0.719)	-0.054	(0.310)
Farm size	-0.028	(0.618)	0.505	(0.003)***
Current use of improved maize seed	0.692	(0.056)**	0.902	(0.052)**
Tropical livestock unit	-0.002	(0.506)	0.102	(0.422)
Household has a cash crop	0.224	(0.004)***	0.003	(0.005)***
Number of contact with extension agent in a year	0.267	(0.101)*	0.003	(0.858)
Farmers' experience squared	-0.001	(0.307)	-0.001	(0.101)*
Gender of household head (1=male, 0 female)	0.388	(0.171)	0.611	(0.390)
Non/Off-farm income	0.000	(0.049)**	0.000	(0.605)
n	169		76	
Log likelihood function	-62.00		-30.02	
Pseudo R	24.00		0.41	
Dependent variable	Fertilizer adoption by farmer			

Note: *** Significant at 1% level of error probability, ** Significant at 5% level of error probability and * Significant at 10% level of error probability

In addition, the off-farm income positively influenced use of the inorganic fertilizer in the both the zones but was significant only in the tea zone. The number of contact a farmer had with an extension agent in a year also had a positive and significant influence on the use of inorganic fertilizer in the tea zone. Generally, these factors (off-farm income and number of contact with extension agent in a year) were not significant in the sugarcane zone.

There was a significant and positive relationship between the size of the farm and the use of inorganic fertilizer in the sugarcane zone. In the sugarcane zone, farmers with larger farms had a higher probability of using inorganic fertilizer than farmers with smaller farms. The effect of farm size was not significant in the tea zone.

The farmers' experience in using the inorganic fertilizers and improved hybrid maize seed significantly and negatively influenced the current use of the same in food crop production among farmers in the Northern part of Kakamega This implies that with more experience (in using improved maize seed and inorganic fertilizer), farmers tended to dis-adopt the use of the inorganic fertilizer in the sugarcane zone.

Although the distance to input and output markets had a negative effect (indication that market access is important) in both the tea and the sugarcane zones, it does not significantly influence the use of inorganic fertilizer in food crop production.

4.4.3 Factors influencing use of hired labor

In terms of consistency with *a priori* expectations on the relationships between the dependent variable and the explanatory variables, the model performed well. Given that the data is cross-sectional, the explanatory powers of the factors were good: The pseudo-R^2 value is 30% and the overall goodness of fit as reflected by $\Pr ob > \chi^2$ was less than 0.001. Factors influencing hired labor are presented in Table 12.

Table 12: Tobit estimates of factors influencing hired labor in Kakamega District in 2005

Variable	Coefficient	P-value
Tropical livestock unit	0.379	(0.011)***
Current use of improved maize seed (1=yes, 0=no)	0.689	(0.322)
Position of farm (0 = sugarcane zone, 1 = tea zone)	1.029	(0.101)*
Age of household head (years)	0.008	(0.739)
Distance from farm house to nearest market	-0.724	(0.086)*
Farm size	0.749	(0.000)***
Education level of household head	-0.181	(0.430)
Use of oxen plough in crop production (yes/no)	-1.723	(0.008)***
Number of household members <10 years old	0.346	(0.109)*
Number of household members 11-18 years old	0.070	(0.758)
Use of tractor in crop production (yes/no)	-2.346	(0.014)***
Constant	7.923	(0.005)***
N	245	
Log Likelihood function	-379.76	
Pseudo R squared	0.29	

Dependent variable:	Proportion of hired labor on farm

Note: *** Significant at 1% level of error probability, ** Significant at 5% level of error probability and * Significant at 10% level of error probability

The factors influencing the use of hired labor on the farm are socio-economic characteristics of the household; markets access parameters, the position of farm in the tea or the sugarcane zone and the farm characteristic. The results show that the farms in the tea zone had a higher probability of using hired labor than the farms in the sugarcane zone.

The relationship between the size of the farm and amount of hired labor use was positive and significantly influenced the amount of hired labor. Large farms had a higher probability of using hired labor than smaller farms sizes. This result was also depicted earlier in section 4.1 that showed the tea zone hired and used more labor than the sugarcane zone.

The dependency ratio as depicted by the number of the residents in the household that are less than 10 years old was also positive and significantly affected the amount of hired labor used on the farm. At the tender age of 10 years and below, the children are mostly in school and cannot help much on the farm activities or in some cases they require more care. Thus, farmers have to hire labor to do the farm work.

There was a positive and significant correlation between the market access and the amount of hired labor used for the farm activities. Farmers closer to the markets seemed to hire more labor compared to those far away from the markets. There was also a positive and significant correlation between the TLU value and amount of hired labor. Farmers with higher TLU value (more livestock) had a higher probability of using hired labor than those with none. The hired labor was necessary since the livestock needed to be taken out for grazing among other activities.

Use of a tractor and/or oxen plough was inversely correlated and significantly influenced the amount of hired labor. Since the tractor or oxen replaces hired labor, the farmers that used it for ploughing the farm needed less hired labor to finish the remaining farm activities associated with crop production.

5 Discussion

This chapter provides discussion of the research findings of this study whose objective was to establish trends in land use and agricultural intensification in Kakamega. The discussion is presented in four sections as per the four specific objectives of the study.

5.1 Socio-economic characteristics of households in the study area

In observing the ingenuity and hard work of farmers in coping with land scarcity in Kakamega, it is tempting to see their agricultural system as highly ‘‘adaptive’’ and assume that it is successful. Tiffen *et al.* (1994) assert that a similar (though somewhat less intense) agricultural system in Machakos District in Eastern Kenya is an example of a successful response to population pressure. They argue that increasing population density has had positive effects in Machakos since increasing scarcity of land promoted investment, both in conservation and in yield enhancing improvements and ultimately improved living standards. On the contrary, the current study findings do not fully agree with the above case of Machakos.

Another earlier study in Kakamega and Vihiga Districts showed that the complex and highly diversified farming system, combined with the low household income have allowed the continued survival of the population under conditions of extreme resource scarcity. The study further showed that despite intense pressure on the land, farmers have avoided the threat of severe environmental deterioration that could result from high population growth by construction of simple terraces and the use of intercropping and manure (Conelly and Chaiken, 2000). The study further indicates that the incorporation of trees into the farming system has preserved a supply of fuel wood and building material for the community’s needs while the use of livestock manure has helped maintain crop yields that would otherwise have collapsed under the system of permanent cultivation (Conelly and Chaiken, 2000).

The construction of simple terraces and the use of intercropping and cover crops have prevented serious soil erosion in other environments in Rwanda (Clay and Lewis, 1996). It could be assumed the impact of simple terraces applies for Kakamega. The current findings are in line with the previous study in Kakamega and Vihiga but show that the maize yields and production levels have not been maintained and instead are on a downward trend. Figure 12a shows a continued decline in maize yield since the mid 1990s. Despite an increase in the area during the short rainy season the annual production levels of maize are showing a gradual downward trend. Therefore, the findings by Connelly and Chaiken (2000), that the yields were maintained are contradictory to the current findings. Perhaps, the agriculture systems in Kakamega could have been much worse without the integrated soil management practices. In contrast, to the above-mentioned Machakos study, population increase in Kakamega has not resulted into positive aspects of agricultural intensification.

The average daily per capita income of US $0.7 indicates that majority of these households is trapped in poverty[19]. The households also only possess a small farm with an average of less than 1 ha. Therefore, there is need for an exit strategy from poverty through appropriate use of agricultural intensification strategies. Before introducing any alternatives that could lead to improved yields, some issues about land, capital and labor from the study should be considered. These are:

- Since land is scarce and no longer available any option targeting the improvement and sustainability in agricultural production should be land-saving.
- Majority of the farmers live below the poverty line and is capital constraint thus any alternative or agricultural intensification should be capital-saving or provision of alternative capital source is required.
- Any labor-intensive options should target the months of December to February when there is no labor constraints. However, this time corresponds with the dry season.

The first initiatives to achieve sustainable agriculture, while considering the above-mentioned conditions, include improvement of the current agricultural systems in the study area. Even though the current agricultural intensification strategies can no longer improve yields in the study area, they could be further improved upon by adoption of land, capital and labor-saving strategies. Available on the shelves are some agricultural techniques, which have the desired characteristics of improving yields and at the same time seem to be resource-saving. These include:

1. On-farm seed priming.
2. Use of cover crops like *Desmodium uncinatum* commonly known as Silver leaf desmodium and *Stylosanthes guianensis* commonly known as stylo, which is a cover crop and also livestock feed.
3. Introduce fencing species that are multipurpose i.e. provide fruits, herbal medicine and firewood in addition to fencing.

Seed priming is a simple low-input, low-risk intervention method of improving crop establishment which could be carried out on-farm after farmers are sensitized on the

19Poverty line is the minimum level of income deemed necessary to achieve an adequate living standard. A person living on less than one US $ per day is classified as poor according to the World Bank, 1999.

technique. Seed priming has been successfully done and resulted in better crop stand and yield (Musa *et al*., 2001).

In addition to the current grain legumes, fodder legumes like silver leaf desmodium and stylo should be encouraged to grow as they will not only provide fodder to livestock but also cover the soil thus, reducing labor requirement for weeding and soil erosion. Ojiem (2007) found that farmers in Kakamega are willing to adopt multipurpose grain and fodder legumes with benefits of producing grains and fodder due to the prevailing socio-economic constraints, e.g. scarcity of land and labor.

Introducing fencing species that are multipurpose will not have much effect on land, capital and labor resources, but the benefits will accrue from the fences. Fruit trees like the passion fruit (*Passiflora spp*.) could be planted in the hedges without any further costs. Passion fruits may be consumed and sold with household benefiting through diet improvement or increased income.

The above-mentioned alternatives could be incorporated in the current agriculture systems to improve production levels. The majority of the population in Kakamega do farming as there main occupation. Therefore, improving agricultural productivity would have a larger positive impact to many households in the study area.

5.2 Trends in land use

The Kakamega forest area had changes of less than 1% during the period 1986 to 2004. In the periods before 1986, the forest had experienced increased pressure and degradation by the surrounding human population and also the saw mill factories from outside the district. There was a lot of logging and deforestation (Lung and Schaab, 2006). The image of the forests and the degraded sections is presented in Appendix 8. For the local people the forests has an important role in satisfying their daily needs (e.g. fire wood, house building grass and grazing). Reduction in the forest degradation resulted from increased advocacy to conserve the forest from the stakeholders, especially the government of Kenya, international organizations and the local people around the forest.

Agriculture practice is the mainstay of the people in Kakamega and land use is an important parameter of their agrarian system. Each farming household possess land mainly through inheritance, while a few purchased the farms or some just have access rights to use the farm. The land use trends are captured in this study using land use data, aerial photographs and the surveyed data to some extent. Sub-prefecture level data exists for most important crops cultivated in Kakamega.

The food crop and the sugarcane area increased during the period 1986-2004. The fallow land reduced as a result of an increased food crop and sugarcane demand by households and sugarcane industry. Also the demand for housing and settlement, firewood and charcoal burning had increased, thus the reduction in the woodlots area.

The land maps showed some cases of replacement of the food crops area with sugarcane for the case of Namirama village in Navakholo division. Even though some of the contracted sugarcane farmers in the Lurambi division replaced some of the sugarcane crop area with food crops for the nearby municipal market, there was no overall reduction in the sugarcane area. This is because at the same time some farmers in Lurambi also replaced the fallow land area with sugarcane. The replacement of the sugarcane in Lurambi division was due to the financial problems in the sugar industries that resulted in late payments to the contracted farmers. Navakholo being far from municipal market did not abandon sugarcane farming during the financial crisis in the mid 1990s and in fact when the industry financial status improved more sugarcane was planted. When Mumias sugar factory increased its sugarcane demand due to increased production efficiency in late 1990s, Navakholo farmers opted instead to replace the fallow and the food crops area with sugarcane crops since they are unable to sell other agriculture produce profitable in Kakamega municipal markets due to the high transaction costs. When farmers incur high transactions costs in marketing, the total production costs are increased and the product profit margins are reduced.

The land maps also showed increased human settlement and land fragmentation. People around Kakamega practice patrineal type of inheritance and this has led to subdivision of land into smaller sizes over the generations. This has increased land fragmentation among the households. Land fragmentation in the study area affected agricultural productivity in a number of ways. First, the fragmented land holding increases the transport costs if the plots are located far from the home, and far from each other. There is a waste of time for the workers spent on traveling in-between the plots and the home. The small and scattered plots waste land area and require more land for fencing, border constructions, and paths as well as roads.

Small fragmented land holdings might also cause difficulties to grow certain crops, and prevent farmers from changing to high profit crops e.g. tea and sugarcane. More profitable crops, require larger plot areas, so if the farmers only own small and fragmented plots they may be forced to grow only less profitable crops. Other costs associated with land fragmentation include the hindering of economies of scale and farm mechanization. Small and scattered plots hamper the use of machinery and other large scale agricultural practices. In small fields operating machines and moving them from one field to another can cause problems.

5.3 Agricultural intensification strategies in Kakamega

The land-intensive strategies are commonly practiced on increasingly small land sizes in the study area. Land-intensive strategy comprised of cropping same plot for over ten months in a year, thus raising the land use intensity, increased intercropping and multiple cropping and in some instance the use of agroforestry.

Intercropping of pulses with maize is a land-intensive practice that is highly promoted in the area by the agriculture extension officers. This is due to the fact that legume species have the potential of increasing farm productivity. Biological N_2 (Nitrogen) fixation is viewed as an important option for improving the soil N balance of the smallholder farming systems in addition to increased yields of maize among other benefits (Fujita *et al.*, 1992; Ojiem, 2006; Peoples and Craswell, 1992).

The increase in the area under maize in the short rainy season was due to the increased demand in food for subsistence by the households. The increase in food demand may have been triggered by the declining per capita land ratio and food production in the study area. Even though the annual maize area increased the annual overall maize production levels and yield trend declined over the years in the study area.

As earlier presented very few farmers practiced fallow cultivation. This may be attributed to the increase in population, which exerts pressure on the land resources. Population growth increases area under crops through forest clearing, encroachment into traditional grazing or pastureland and shortened fallow periods (Boserup, 1965). Population pressure also could induce agricultural intensification and this would in turn result in smaller farm holdings and increased land use intensities, e.g. shorter fallow periods and more frequent annual cropping (Boserup, 1981). Since there were no more areas to expand agriculture production due to the closure of Kakamega forest frontier, the only possible way was to reduce the former fallow areas and shorten the fallow duration or periods. With the reduction and elimination of the fallow land and periods farmers could cultivate two crops per year to meet their household subsistence. Farmers in the study area rarely produce for sale in the market and their first objective is to produce for consumption. This may be attributed to non-working markets, high transaction costs among other barriers.

Out-migration from the rural areas in Kakamega to the municipal town is not an option for many households in Kakamega due to the current unemployment levels in the country in general. The situation in Kakamega District is such that up to 62% of the population is engaged in agriculture, 8% in rural self-employment, 20% in wage employment, 2% in urban self-employment and 8% in other sectors (Kakamega District Development Plan, 2002). There is high unemployment rates in other urban areas in Kenya (CBS, 2005), therefore migrating from Kakamega to other urban areas does not guarantee someone a well paid job elsewhere and improved livelihood. Therefore, increased agricultural productivity could play a major role in improved household livelihood.

The main capital-intensive strategy commonly used in the study area was the application of inorganic fertilizer; even though the application levels per unit area was low as compared to the recommended rates[20]. At least 20% of the farmers in the selected divisions of Lurambi, Shinyalu, Navakholo and Ikolomani applied low rates (1-5 kg) of inorganic fertilizer per ha. The current study findings support previous research in Kenya which showed that even though a large proportion of farmers are using fertilizer following market liberalization, rates of application remain extremely low (Freeman and Omiti, 2003; Mose, 1998). Given the low inorganic fertilizer application rates, the farmers are unable to maintain or improve the maize production levels and yield.

The farmers also used improved hybrid maize seed as a capital-intensive strategy. The improved hybrid seed is an agricultural intensification strategy used to improve the yields only when all agronomic aspects of planting, weeding and fertilizer application is strictly followed. The improved hybrid maize seed was not accompanied with the appropriate agronomic management practices that raise the yields by farmers in the study area. Furthermore, the percentage farms allocated to improved maize seed were only 56%. This is low given that maize productivity in Kakamega can only be increased through increased productivity and not by land expansion. Use of capital-intensive strategies is hampered by the seasonality of agricultural production in Kakamega which constrained the use of purchased inputs because output is out of season and purchases must be funded from the farmers' savings and/or loans.

The labor-intensive strategies are most common since farmers in the study area were cash constrained as shown in section 4.1.2 on page 42. The farmer merely adds labor in crop production, allowing him to crop more densely, weed and harvest more intensively. Also due to land constraints, labor/land ratios are rising, and therefore farmers choose production methods that are as labor-intensive as possible to raise productivity.

Labor-intensive strategies were mainly integrated soil management practices. These included uses of agroforestry, trash lines, and animal manure application. The farmers used two or more of the integrated soil management practices on their respective fields. However, the proportion of farmers using these farm management practices in the study area had reduced by the year 2004 compared to 1994. The proportion of use of agroforestry as a farm management practices had reduced. This shows that if all other factors remain constant,

20 75 kg N/ha/year and 25 kg P/ha/year (KARI, 1994)

past adoption history of agroforestry as an integrated soil management practices appears to be on a downward trend. This may be attributed to intergenerational transfer of knowledge and skills. However, in the current study, data was not sufficient to explore if agroforestry as an integrated soil fertility management practice suffer from considerable breaks arising from poor intergenerational transfer of knowledge and skills. These highlights a problem in rural development technology adoption, which is vital in improving farmer productivity and household income, but the complexity of the adoption process, makes targeting technologies difficult. Even when all the essential elements seem to be present (a low external input, high-yielding technology, significant training and extension efforts, etc.), like in the case of agroforestry as an integrated soil fertility management practice, the end result can disappoint those responsible for developing and promoting the method. The labor-intensive nature of agroforestry as a low external input technologies have long been viewed as a positive characteristic in areas where labor is the main resource of the household (Lee and Ruben, 2001). Yet the labor requirement is precisely the obstacle to adoption for many poor households with highly seasonal labor and income patterns21 (Barrett and Clay, 2003). Seasonal family labor and liquidity constraints prevent poorer farmers in Kakamega from taking advantage of agroforestry as an integrated soil fertility management practice. In fact those who had earlier adopted the integrated soil fertility management practices are abandoning its use.

5.4 Factors influencing agricultural intensification strategies

In this section, the factors influencing use of agricultural intensification strategies of land, capital and labor are discussed.

5.4.1 Land use intensity

Land use intensity is influenced by socio-economic factors, which included gender, the occupation and age of the person in charge of the household in addition to market access factors. According to earlier findings land use intensity strategies are based on risk minimizing practices, and also influenced by other factors such as ethnic traditions (Reenberg and Paarup-Laursen, 1997) as well as social status and preferences (Snyder, 1996).

21 This underscores the inaccuracy of the prevailing wisdom that opportunity costs of labor time are inevitably lower among the poor than among the wealthy. In the presence of multiple factor market failures—in this case, for inter-seasonal finance and land—the poor often face greater shadow wage rates greater than the wealthy.

Male headed household were positively and statistically significant in influencing land use intensity than the women headed households. Thus, male household heads are more likely to practice high land use intensity than female household heads. This finding could be explained by previous research in Africa that documented women's lesser access to critical land resources (De Groote and Coulibaly, 1998). Despite their contribution, women in Kakamega face major constraints of access to and control over land, as well as agricultural technologies necessary to increase the efficiency of the agricultural operations. Gender *per se* does not heavily affect the high land use intensity but rather the inherent resource inequality between men and women plays a big role. This inequity was possibly caused by cultural conditions in Kakamega, which traditionally do not grant women secure entitlements to land and other properties.

The age of household head was statistically significant in influencing the land use intensity. The negative coefficient indicates that older farmers are less likely to have high land use intensity. As decision makers' age increase in years, they are unable to work on the farm and require assistance from other family members or have to hire labor. Since farm work requires physical effort, the relatively healthier and stronger younger farmers are more likely to have high land use intensity than their older counterparts. This raises an important extension policy issue. Extension systems should differentiate their clientele based on critical demographic characteristics such as age. If younger farmers are more likely to have high land use intensity, perhaps extension messages on sustainable agricultural intensification and land use should be focused on certain (younger) age cohorts.

Non-farm income from formal non-agricultural employment is important in increasing the land use intensity. Cash is essential in the hiring of labor for the farm activities, e.g. construction and maintenance of terraces, planting agroforestry trees, as well as for the purchase of chemical fertilizer and improved hybrid maize seed. At existing productivity levels and production scales, farms in Kakamega might not be generating sufficient income to invest in capital-intensive inputs or enhance sustainable agricultural intensification. To adopt agricultural intensification strategies non-farm income is required to purchase the external inputs.

Increased distance to the municipal market reduced the intensity of land use among farmers in Kakamega. Access to market is an important variable as it influenced the prices farmers received when they sell their farm produce. Some farmers closer to Kakamega municipal markets kept their plots (increased land use intensity) under food crops or vegetable in response to subsistence and commercial demands, yielding at least two crops per year. But the farmers' further from the markets had lower land use intensity.

Extension presence and access is important in sustainable land use at farm level. High land use intensity that results in soil mining and degradation is discouraged. High land use intensity is only recommended when the soil fertility is restored accordingly. All farmers with extension visits had received advice on land use practices. Soil conservation has been emphasized for some time, and specific extension agents have been attached to the soil conservation project. Despite severe reductions in government support for extension services since the 1990s, this results shows that the extension agents under the National Agricultural and Livestock Extension Program (NALEP) are reaching farmers, especially under the soil and water management program to encourage them to use their land in a sustainable manner.

It is notable that advice on land use practices, particularly soil conservation, was the most common message from the extension agents to the farmers. According to early studies, NALEP supports a pluralistic approach involving all stakeholders and thus facilitates a gradual transition from predominantly publicly supported extension to private provision of demand driven extension services (Nambiro and Omiti, 2007).

5.4.2 Capital-intensive strategies

Use of improved maize seed

Sometimes households persist with agricultural technology adoption over extended periods of time, manifesting “lock-in” effects. This was explored by testing explicitly for persistence in the use and adoption of improved hybrid maize seed by including a dummy variable reflecting past experiences of the farmer for the last ten years. The results showed that adoption history had a positive effect on current adoption and proportion of farm under improved maize seed use. This explanatory power of the adoption history may signal that the use of improved hybrid maize seed involves intergenerational transfer of knowledge and skills *ceteris paribus*. This results show a manifestation of “lock-in effects” in the adoption of improved hybrid maize seed.

Male headed households in the tea zone were most likely to allocate more land to improved hybrid maize seed use while in the sugarcane zone households with a male head preferred a sugarcane crop to maize. The negative and significant effect of gender in the sugarcane zone indicates that the likelihood of allocating area under improved hybrid maize seed use was lower for men than for the women. The men were more interested in sugarcane farming, which was seen as the main crop than maize while in the tea zone maize was the main crop even though some household grew tea. The tea area had not increased since most households had tea bushes that were over 25 years old. The most common factor in the two zones is the reflection that the main crop in an area belongs to the men. The main crop is mostly associated with higher profits or most important in terms of food source. Therefore, the women are left to manage what is considered as less profitable crops.

The family size had a significant positive effect on the proportion of farm allocated to cultivation of improved hybrid maize seed in the sugarcane zone. Households with larger family size were more likely to allocate more area to improved hybrid maize seed use in order to improve the yield and satisfy their subsistence needs and hence achieve food self-sufficiency. Food security could be achieved by purchasing but since the farmers were cash strapped they resorted to food self-sufficiency instead.

The labor intensity in man days per ha had a significant negative effect on proportion of land allocated to improved hybrid maize seed use in the study area. The farmers allocate their family labor to non-farm income generating activities (including wage employment) or use indigenous maize seed whose production characteristics enable farmers to relax the liquidity constraint. Further, due to rampant food insecurity scenarios, compounded by very small land holdings, labor is the only way of financing the current consumption needs of that particular household, precluding them from investing limited cash in capital-intensive technologies like improved hybrid maize seed and inorganic fertilizer on their own farms. The farmers are aware that the improved maize seed performs better when used in association with the prescribed agronomic management like inorganic fertilizer application, timely weeding and top dressing. Sometimes when farmers are sure that they are unable to afford fertilizers, then they also avoid using improved maize seed and instead use the traditional varieties.

Farmers who grew sugarcane are more likely to allocate less share of their total land area to maize crop and improved hybrid maize seed in particular. Sugarcane and maize competed for the land resource. The households with a large acreage under sugarcane tend to concentrate on it more and pay less attention to the food crops. They end up allocating very small proportion of their farms to food crop. The rest of the farm is allocated to sugarcane with the sole aim of increasing the cash income from sale of sugarcane.

The use of inorganic fertilizer had a positive correlation with the proportion of farm under improved hybrid maize seed. This is expected since purchased seed is often of a high-yielding variety that responds better to fertilizer than do traditional maize varieties. The promotion of improved hybrid maize seed and inorganic fertilizer is usually done concurrently by the agriculture extension agents from the Ministry of Agriculture, Kenya. This study further support the correlation between adoption of improved maize seed and inorganic fertilizer use as identified in Tanzania (Nyonka *et al.*, 1997).

The land tenure system influenced the use of improved hybrid maize seed in the sugarcane zone. The probability of allocating land area to improved hybrid maize seed use was reduced as one moved from title deed land ownership to customary access rights and rented farms. Sugarcane crop was preferred to other crops in the northern part of the district. Therefore, it was given first priority and any farmer with access rights to land preferred planting sugarcane to food crop. However, the land tenure system did not have an effect on the proportion of area under improved maize seed in the tea zone.

Although the distance to markets was inversely related to the proportion of farm area allocated to use of improved hybrid maize seed, it was only in the tea zone that it negatively and significantly affected the adoption. Thus, access to the market influenced the use of improved hybrid maize seed in the tea zone. The tea industry does not supply improved maize seed to farmers, as is the case with the sugarcane companies among the sugarcane contracted farmers. Farmers in the tea zone purchase the improved hybrid maize seed from the market and thus, with increased distance the transaction cost of the seed was too high for the farmers. On the contrary, the sugarcane industry supply and had increased availability and accessibility of agricultural inputs like improved hybrid maize seed to the sugarcane contracted farmers.

Use of inorganic fertilizers

“Inorganic fertilizer use” was defined as the application of any amount of basal or top-dressed fertilizer to the field in 2004 by the respective farmers. The current use of improved hybrid maize seed positively affected the use of the inorganic fertilizer. Because of the responsiveness of the improved hybrid maize seed to inputs, they become an important catalyst for the adoption of the inorganic fertilizer (Morris and Byerlee, 1998).

The off-farm income positively influenced the use of the inorganic fertilizer in the tea zone. This finding was expected since farmers require capital to purchase the inorganic fertilizer. Considering that most farmers were subsistence, off-farm income was an important source of capital for purchasing the agriculture input. The sources of off-farm income mainly included salaries, remittances and proceeds from small enterprises.

Farmers who had diversified into commercial cropping activities were found to be more likely to be using inorganic fertilizer. They integrate food and cash crop production, although there have been various views on their interaction. One view is that income generated from cash crops is used to purchase inputs necessary for food crop production (Salasya *et al.*, 2007) or that cash crop producers have access to key inputs such as credit and training through cash crop schemes that are not available to non-participating households (Govereh and Jayne, 2003). The above views were true for the surveyed farmers in the study area. This result was consistent with the finding that increased production of commercial crops not only raises returns to land and labor but also have significant benefits for soil fertility, as well as for other food crops productions (Poulton *et al.*, 2001).

A surprising finding is that even though the coefficient on the variable measuring frequency of extension was positive in both zones, it was only significant in the tea zone to influence the farmer to use inorganic fertilizer. There are two explanations for this scenario. The first reason was attributed to the fact that sugarcane crowded out maize in the sugarcane zone. Thus, extension agents did not promote maize farming since land for maize growing was limited in the sugarcane zone. The second reason supports available findings on the mixed performance of the formal extension systems in disseminating technical information and stimulating the adoption of inorganic fertilizer in Africa (Barrett *et al.*, 2002).

The farm size was positively correlated to the use of the inorganic fertilizer in the sugarcane zone. Farm size is an indication of the level of economic resources available to the farmer and thus a proxy for wealth. Farmers in the sugarcane zone with big farms were most likely growing sugarcane and thus accessed inorganic fertilizer from the sugarcane industry or used the proceeds from the sugarcane to purchase farm inputs.

The negative correlation of the use of inorganic fertilizer and the experience of the farmer in sugarcane zone indicate that farmers will not use what has not been profitable in the previous years. Some earlier studies have shown that farmers had difficulty assessing returns to the use of inorganic fertilizer (Rao and Mathuva, 2000; Sanders *et al.*, 1996). The application of sub-optimal levels of inorganic fertilizer does not improve yield as expected by the farmers thus leading to dis-adoption. This situation is worsened by the weather uncertainty and the cash constraints among the farmers causing the dis-adoption or reduced application rate of the input.

The sugarcane and tea industries supply inorganic fertilizer to commercial crop growers who later sell some of it to their neighbors. This explains why the distance to the market had the expected negative sign, but did not significantly influence the adoption of fertilizer. It also indicates that the distribution of inorganic fertilizer had improved. The growth in the inorganic fertilizer input outlets, and distribution by the cash crop companies had increased availability and access of the input in rural Kakamega.

5.4.3 Labor-intensive strategies

Family labor was often not available in the right amount and at the right time in the study area, which had obvious adverse implications for agricultural production during peak labor requirement periods. The peak requirements for labor using maize[22] production cycle are as follows: 1) March to May during the long rainy season land preparation, planting and weeding, 2) August to November during the long rainy season crop harvesting, the short rainy season land preparation, planting, weeding and harvesting.

The overlapping period of land preparation and planting of the short rainy season crop and at the same time the harvesting of the long rainy season crop in August to September has the highest labor peak requirement. Also the labor peaks are as a result of overlapping activities of planting and weeding of maize in March to May. Work peaks occurred because critical tasks such as planting, weeding and harvesting are closely related to the rainy seasons and should be completed within a limited period of time. Delays will generally cause loss of the yield, so the man-hours needed to finish the task are compressed into a period peak.

Farmers with cash or commercial crop mainly tea and sugarcane had also some part of their farms planted to the food crops. Therefore, during the peak labor requirement those particular farms needed labor for both the commercial and the food crops production. In cases of labor shortages hiring of the labor was the only possible option for the household. Sixty percent of the respondents reported labor shortages at peak food crop planting and harvesting seasons as one of the problems affecting agriculture production. The farms with sugarcane had the lowest labor requirement per ha because: 1) it was also noted that sugarcane farmers allocated less than 20% of there total land to food crops, 2) the agronomic management of sugarcane crop was less demanding in terms of land preparation, planting and weeding, and 3) land preparation was mechanized and happened after four to five years on harvesting the fourth ratoon crop of the sugarcane. The land preparation using tractors greatly reduced the amount of labor required amongst the sugarcane farmers.

The integrated soil management practices in Kakamega are mainly labor-intensive. Twenty and five percent of the households used agroforestry[23] in the tea and the sugarcane zone respectively, to manage soil fertility management. The farmers used leguminous species such as Calliandra (*Calliandra calothyrsus*) and Sesbania (*Sesbania sesban*) and non-leguminous species such as Mexican sunflower (*Tithonia diversiflora*) and Lantana (*Lantana camara*). The shrubs were temporary or permanent part of the plot with the aim of providing

22 Maize is the most grown crop among all farmers and is the staple food. The maize cycle gives an overview of the food crop cultivation in the study area. The maize cropping calendar in the study area is as depicted in Appendix 4.

23 Agroforestry for soil nutrient management refers to inter-planting of the woody species amongst or in close proximity to the main crop.

green manure, fix atmospheric nitrogen and control soil erosion. The shrubs were periodically pruned during the cropping periods to prevent shading of the main or companion crop and the pruning was applied to soil as green manure. The Mexican sunflower and the Lantana were also used as live fences separating the different plots and the homestead.

Traditionally grown food legumes, for example cowpea (*Vigna unguiculata*) and common bean were usually intercropped in maize. The local varieties of bean[24] were grown by almost 80% of the farmers. The Lima bean *(Phaseolus lunatus)* and the groundnuts were mostly intercropped when planting sugarcane for the purpose of fixing nitrogen, providing food and also feed for the livestock.

Livestock manure application was practiced amongst 64 percent of the farmers in the study area. Livestock manure refers to the use of composited livestock cow dung by way of scattering these on the surface of the area for cultivation. Sometimes the manure could also be placed in the seed holes at the time of planting food crops. The livestock manure has the capacity to supply nutrients, and improve the structure and the texture of the soil by increasing cation exchange capacity, improving the water holding capacity and its infiltration rate. Livestock manure was restricted to farmers who kept domestic animals. There was hardly any market or sale of the same in the study area.

Factors influencing labor-intensive strategies

The use of hired labor for the farm activities was employed to alleviate the labor scarcity by some households in Kakamega. The factors influencing use of hired labor included socio-economic characteristics of the household, agro-ecological zone location of the farm and access to the nearest market.

The TLU number positively influenced the amount of hired labor. The farms in the study area are small and it was necessary that the animals are taken out to the forest or in the nearby fields and along the roads for grazing. Grazing of livestock in the Kakamega forest is allowed after payment to the Forest department (FD) which was located in the sugarcane zone. The payment amount is predetermined by the number of livestock. Therefore most farmers with livestock hired someone to herd the livestock daily for grazing purposes.

The farmers with tea on the farms in the tea zones are likely to hire more labor compared to the sugarcane farmers. The tea zone required more labor due to agronomic management in the production of tea, which required manual tea harvesting of at least three times per week per farm. The number of tea harvesting per week could increase with the increased amount

24 Local varieties of beans e.g. Wairimu, Alulu,Punda, Rosecoco, Rusibella

of rainfall. The earlier results of the labor profile needs per cropping system; showed that the tea farmers hired the most amount of labor in addition to family labor.

The results also showed that the number of dependents in the household is positive and significantly influence the amount of on farm hired labor. This suggests that there are also labor constraints imposed on the households with more dependants, which affect the labor availability. The effect is coupled with the need for more subsistence food within the household.

The use of oxen and tractor are inversely related to the amount of hired labor. The use of tractor and the animal traction portrays both input intensification and crop–livestock interaction and signifies an important stage in the process of agricultural intensification (McIntire *et al.*, 1992; Pingali *et al.*, 1987). Farmers in the study area used animal traction from either own or purchased sources for land clearing purposes. Since traction is supposed to replace human labor, more traction use led to less amounts of hired labor.

The amount of hired labor was positively related to the farm size. The large farms use more labor than small farms. When family labor is inadequate farmers with larger farms hire more labor than those with smaller fields because of the amount of labor required in larger fields (Enete *et al.*, 2002).

There is positive correlation between the amount of hired labor and the market access. The positive relationship is consistent with the hypothesis that households with easy access to market will have lower transaction costs of hired labor use than those with poor access. Good market access conditions often imply better farm income and thus input affordability (Enete *et al.*, 2005). Better farm income would invariably also imply better pay for the farm laborers, which in turn would attract more laborers into areas with good market access.

Discussions with farmers on the labor scarcity problems revealed a number of factors responsible for the situation. One of the reasons for the labor scarcity was that children attend school much earlier and return home very late in the evening than they used to do few years ago and thus are unable to supplement the household labor. The second reason was that the labor groups no longer exist and individuals can only offer labor on commercial basis, which were deemed expensive. Third, it was alleged that there is high dependency rate that had been compounded with diseases like Malaria and HIV/AIDS. Finally, a majority of smallholder farmers sold their labor to earn cash for household needs and did not have time to work on their own farms nor had enough resources to hire farm labor.

6 General discussion and conclusions

The hypothesis of this study was that an improved understanding on trends in land use, and on agriculture intensification and its drivers will improve the decision-making concerning the sustainability of the agricultural production in Kakamega. In this context, it was further hypothesized that market factors and socio-economic characteristics of the household are the main drivers of the diverse agricultural land use and intensification strategies encountered in the area. This study has revealed that factors such as market access, off-farm income and age of the household head influence to a large extent the observed evolution of farming systems, the adoption of agricultural intensification strategies and the performance parameters of agricultural production in the study area. These results partially corroborate the earlier works on agricultural intensification by Boserup's (1965), and the induced innovation theory (Binswanger and McIntire, 1987), which stipulates that agricultural intensification is driven by socio-economic and market factors. The present study however indicates that these factors must also be regarded in conjunction with biophysical factors such as climate, soil and resource base quality.

Land use changes in the area started in pre-colonial time with the conversion of natural and secondary forest into agricultural land (Sheriff, 1974). This land expansion strategy ended in the early 1970s with the protection of the remaining forest fragments and their partial conversion into a national reserve. In the more recent past, land use changes comprised mainly high land use intensity by shortening of fallow periods, multiple cropping, and the additional use of off-seasons for crop production. This current land use change has resulted in an unprecedented degradation of the resource base (Tittonell *et al.*, 2005). Today, a majority of the agriculturally-used soils in the Kakamega area are classified as moderately to highly degraded (Solomon *et al.*, 2007) resulting in declining food crop yields and rural livelihood (Salasya *et al.*, 2007). This resource base degradation and associated declines in livelihood levels, however, are not uniform across the area but are modulated in space by soil type and various socio-economic characteristics. Especially household socio-economic and market factors appear to determine the adoption of soil and land conserving technologies that can at least partially counteract the reported degradation trends. An improved understanding of the trends in land use change, their driving factors and implications and the diverse socio-ecological conditions that modulate these implications is seen to better evaluate future land use scenarios and the targeting of technology options to counteract negative effects of land use changes or to improve rural livelihood.

The recent trends in land use showed that there is a gradual decrease in the area under fallow and woodlots. Household level data confirmed that settlement and fragmentation of agriculture farms had increased over the period 1991 to 2004 resulting in highly fragmented fields and an average farm size of 0.9 ha per household. Therefore, the tendency of leaving a farm fallow to restore fertility had almost disappeared. Only few farmers (less than 8%) have fallow land today in the study area. The analysis of the cropping pattern revealed that most of the land is under food crops (53%), and also a significant share of the farmland is cropped with industrial crops (37%). This latter option, however is restricted to farmers with access to input and output markets. When fallow is shortened or even eliminated, land productivity either declines and may result in the collapse of the socio-ecological system (e.g. poverty, hunger, and out-migration) or is being maintained or restored by introducing technological changes or adopting new production strategies. Such strategies may be geared towards a restoration of soil fertility or an increase in the output per unit area being introduced. The prevailing trend in land use or the type and level of technology adoption depend largely on the resource endowment of the farmers. In the current study a high population growth rate has led to permanent cultivation systems and the subsequent requirement for technological changes to sustain the agricultural intensification strategies. Such transitions from extensive to more intensive systems of land use are usually driven by the demographic development within a given area (Boserup, 1965).

The strategies to counteract negative effects of land use intensification, particularly in situations with a fragile resource base, are diverse and depend on the production objectives, the availability and accessibility of production factors and the biophysical framework conditions.

Thus, agricultural intensification strategies in the study area included land-intensive strategies (e.g. agroforestry), capital-intensive strategies (e.g. use of improved hybrid maize seed and inorganic fertilizer), labor-intensive strategies (e.g. organic manure amendments, manual weed control), or combinations of those. These strategies were found to differ between biophysical units (climate, soil type), the resource endowment of the individual farm, socio-economic characteristics of the household and the market access factors. While about 70% of all farmers applied inorganic fertilizer to counteract declining soil fertility or to enhance food crop production, this strategy was limited to households with cash income, be it by off-farm employment, remittances or to farms growing industrial crops. In addition, the application rates varied widely and were in most cases far below the recommended rate. The application of livestock manure was restricted to about 64% of the households. Within those farms, the availability of labor largely decided if the organic matter was only dumped into the home garden or was also applied to field crops. An estimated 25% of the farmers grew nitrogen-fixing green manure plants. Due to both land and labor requirements for such measures, green manure was largely restricted to larger farms with the possibility to employ hired labor. In addition, green manure was essentially associated with farms on more sandy textured soils. Improved hybrid maize seeds were used by only 56% of all maize-growers. The requirement to purchase every year afresh hybrid maize seeds from the market linked the adoption of hybrid maize seed to market access and cash availability within the household. Cash availability is often not accessible within the subsistence orientation of the very small farms.

Specific household socio-economic characteristics further modulated the technology adoption patterns described above. Most prominent are the age of the household head, off-farm income generation, the contacts to extension agents, and the access to the market.

The land use intensity was influenced negatively by age, e.g., elderly farmers have lower land use intensity. Since the agriculture in the study area is mainly manual, they can neither do the manual work nor afford to hire labor. This results corroborate with earlier findings that age is an important factor in adoption of agriculture technologies (Gockowski and Ndoumbe, 2004; Hassan *et al*., 1998).

It has also been found that access to alternative non-farm income leads to higher use of capital-intensive agricultural strategies. In particular the use of inorganic fertilizer is restricted to those households with alternative non-farm income sources. Since most households in the study area did subsistence-based agriculture, non-farm income is necessary to purchase the external inputs. Some studies have also shown the importance of non-farm income as a catalyst in the adoption of agriculture technology (Adesina, 1996; Pender *et al*., 2004).

The results show that the adoptions of agricultural intensification strategies are influenced by the frequency of the farmers' contact with extension services. Farmers with more contact to the extension agents had higher probability to use inorganic fertilizers. This finding show that information flow to farmers is vital for the uptake of sustainable agricultural intensification strategies. The study by Salasyia *et al*. 2007 agrees that information flow is vital in adoption of agriculture technologies but proposes that informal channels of information by neighbors could be encouraged. Since information flow is vital in adoption of agricultural intensification strategies, this study emphasize the need for farmers to be well informed. Both formal (agriculture extension agents) and informal (neighbors) channels of information flow could be used for dissemination of agriculture technology.

Market access was found to be the major driving factor of agricultural intensification strategies. The further the distance of farmhouse to the market, the lower the probability of using the hybrid maize seed in the tea zone. Farmers closer to the markets had a high probability of using improved hybrid maize seed. This study result is similar to earlier findings that considered market access to be a major driving force of agricultural intensification

(Binswanger and McIntire, 1987). Reardon *et al*. (2001) indicated that better access to market could enhance agricultural intensification.

Sustainable agricultural intensification could occur with concomitant development of markets for the agricultural inputs and products. Improving farmers' access to markets has a potential of improving the household income, increasing agriculture produce demand and triggering sustainable agricultural intensification. When farmers sell their agricultural produce competitively they are able to reduce the income constraint hence are able to purchase the external inputs that are required to increase agriculture productivity. For instance the case of access to improved maize seed, could be achieved through institutionalization of the cereal banking (CB) concept known to work effectively in Siaya and Vihiga district of Western Kenya (Kelly *et al*., 2003). Siaya and Vihiga districts are immediate neighbors of Kakamega District. The CB concept is a project that allows farmers to bulk, store and market grains of maize and pulses collectively at the community level. The improved maize seed used in CB are open pollinated varieties, which yield higher than the traditional maize varieties. The collective action at community level gives the farmers the power to bargain for better grain prices. Once farmers have access to competitive markets, they have the ability to increase farm productivity and improve their household income and livelihood.

Market development will require increased investments in infrastructure, including roads and transport systems, warehouse and storage facilities, communications systems, and electricity. This were generally lacking in the study area. Unless the markets develop, farmers will have no incentives to raise their agricultural productivity through investing in external inputs like hybrid maize seed, inorganic fertilizer and hired labor. Why should farmers incur the extra costs in agriculture production if there are no market outlets for the products? Market towns within easy reach, farm-to-village-to-market roads, and transportation and warehouse facilities are the first prerequisites to lift agriculture to the modern green revolution age. If agricultural products remain locked within the village precincts, agriculture will remain condemned to a predominantly subsistence-rather than a market orientation and farmers will also remain without working capital.

The two zones in Kakamega District differ in soil types and quality, rainfall distribution and reliability, slope and crops that are grown. Some study findings have shown that N fertilizer use on sandy soils is low, and is aggravated by high N losses in the study area (Tittonell *et al*., 2005).

It is hence obvious from the presented discussion that the drivers of land use intensification strategies and technology adoption patterns reflect the diversity of the prevailing socio-ecological conditions. Neither blanket recommendations nor larger scale extension of specific technologies will improve adoption rates or production levels. Only a stratified consideration of the biophysical and the socio-economic conditions at farm level and the targeting of site- and system-specific socio-ecological niches are seen to contribute to an improved livelihood in Kakamega.

6.1 Conclusions and recommendation

What do these findings and results teach us for future development of public policies? The land use system in Kakamega is characterized by permanent cultivation since about 20 years. The resource base quality is low and has been declining recently. Demographic pressure is high, land shortages are severe, and alternative income opportunities are rare. Production and livelihood increases must be generated from agricultural production on an ever-declining resource base. Therefore, technology changes that not only enhance agricultural production but also consider the diverse biophysical and socio-economic situations need to be promoted and implemented. In the low-input small-scale farms, the current agricultural intensification strategies must be improved on to raise the productivity at low capital investment and with minimal risk of failure. Examples for such options include nutrient priming of food crop seeds, the use of permanent ground cover by leguminous cover crops or the introduction of multi-purpose crops, both in green manures and the fencing species. In capital-intense larger farms, production increases may be achieved by improving the input use efficiency. This may involve site-specific nutrient management, improved modern cultivars or modified tillage systems, which all require an intense contact with extension services. Such technologies are available and have been proven to enhance agriculture productivity in other environments of sub Sahara Africa. Their dissemination and site- as well as system-specific extrapolation by the national research and their implementation by the agriculture extension agents together with the target farmers are required.

Specifically the following conclusions can be derived from the work presented:

1. That agriculture is currently the main source of livelihood for the majority of the population in the study area.
2. That Kakamega is characterized by permanent cultivation agriculture systems with low resource base.
3. Appropriate site-and system-specific agricultural technologies to increase productivity and restore the declining resource base should be promoted and implemented without fail.

4. The adoption of the agricultural technologies in the study area is influenced by the socio-economic characteristics of the household, market access factors as well as the biophysical conditions of the farm

The econometric models applied to study the drivers of agricultural intensification strategies show that the agro-ecological zones have a significant impact on the adoption of productivity-enhancing technologies. The term agro-ecological zone combines soil and climatic factors that differ between the major zones of Kakamega district. At this stage it is unclear which soil or climatic factors affect the performance and the adoption of the different technologies. This information is required for the desired definition of socio-ecological niches.

7 References

Adesina AA. 1996. Factors affecting the adoption of fertilizers by rice farmers in Cote d'Ivoire. Nutrient Cycling in Agroecosystems 46:29-39.

Adesina AA, Zinnah MM. 1993. Technology characteristics, Farmer perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agricultural Economics 9:297-311.

Akotsi E, Gachanja M. 2004. Changes in forest cover in Kenya's five "water towers" 2000-2003. Nairobi, Kenya: Department of Resource Survey and Remote Sensing. 80 p.

Alam S. 1993. Diversification of specialization in agricultural production activities. Economic Affairs 38:84-88.

Amadalo B, Jama B, Noordin Q, Nyasimi M, Place F, Franzel S, Beniest J. 2003. Improved fallows for western Kenya: An extension guideline. Nairobi, Kenya: World Agroforestry Centre (ICRAF). 5 p.

Andrews DJ, Kassam AH. 1976. The importance of multiple cropping in increasing world food supplies. In: Papendick A, Sanchez GB, Triplett, editors. Multiple Cropping. Madison, WI. USA: ASA Special Publication 27. p. 1-11.

Bagamba F, Ruben R, Kuyvenhoven A, Kalyebara R, Rufino M, Kikulwe E, Tushemereirwe WK. Determinants of resource allocation in low input agriculture: The case of banana production in Uganda; 2004 August 1-4, 2004; Denver, Colorado, USA. p 12.

Barkley AP, Porter LL. 1996. The Determinants of Wheat Variety Selection in Kansas, 1974-1993. Journal of Agriculture Economics 78(1):202-211.

Barrett CB, Clay DC. 2003. Self-targeting accuracy in the presence of imperfect factor markets: evidence from food-for-work in Ethiopia. Journal of Development Studies 39:152-180.

Barrett CB, Place F, Aboud A, Brown DR. 2002. The challenge of stimulating adoption of improved natural resource management in Africa Agriculture. In: Barret CB, Place F, Aboud A, editors. Natural management in African Agriculture: Understanding and improving current practices. CAB International, Wallingford, UK. p. 1-21.

Becker M, Johnson DE. 2001. Cropping intensity effects on upland rice yield and sustainability in West Africa. Nutrient Cycling in Agroecosystems 59:119-127.

Bellon MR, Taylor JE. 1993. Folk soil taxonomy and the partial adoption of new seed varieties. Economic Development and Cultural Change 41:763-786.

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

Binswanger H, McIntire J. 1987. Behavioral and material determinants of production relations in land-abundant tropical agriculture. Economic Development and Cultural Change 35:73-99.

Boserup E. 1965. The Conditions of Agricultural Growth: the econommics of agrarian change under population pressure. London, UK: George Allen and Unwin. 1-108 p.

Boserup E. 1981. Population and technological change: A study of long-term trends. Chicago, USA: Chicago University Press. 39-40 p.

Brown JA. 2004. Designing an efficient adaptive cluster sample. Environmental and Ecological statistics 10(1):95-101.

Cassman KG, Pingali PL. 2005. Intensification of irrigated rice systems: Learning from the past to meet future challenges. GeoJournal 35(3):299-305.

Caviglia JL, Kahn JR. 2001. Diffusion of Sustainable Agriculture in the Brazilian Rain Forest: A Discrete Choice Analysis. Economic Development and Cultural Change 49:311-333.

CBS. 2000. Poverty in Kenya. Volume I-incidence and depth of poverty. Nairobi, Kenya: Central Bureau of Statistics Ministry of Finance and Planning. 11-20 p.

CBS. 2001a. Kenya Population Census, 1999. Nairobi, Kenya: Government Printers. 20-35 p.

CBS. 2001b. Poverty reduction strategy paper, 2001-2004. Nairobi, Kenya: Government printers. 10-19 p.

CBS. 2005. Economic survey. Nairobi, Kenya: Government Press. 200 p.

Clay DC, Lewis LA. 1996. Land use, soil loss, and sustainable agriculture in Rwanda. In: Bates DG, Lees SH, editors. Case Studies in Human Ecology. New York, USA: Plenum Press p. 11.

Collier P, Gunning JW. 1999. Explaining Afican economic performance. Journal of Economic Literature 37(1):64-111.

Conelly TW, Chaiken MS. 2000. Intensive farming, agro-diversity, and food security under conditions of extreme population pressure in western Kenya. Human Ecology 28(1):20-51.

De Groote H, Coulibaly N. 1998. Gender and generation: an intra-household analysis on access to resources in Southern Mali. African Crop Science Journal 6:79-96.

De Janvry A, Fafchamps M, Sadoulet E. 1991. The peasant household behaviour with missing markets: Some paradoxes explained. The Economic Journal 101:1400-1417.

De Pauw E. 1989. Models of the climatic growing period, An inquiry into concepts, analysis and applications in regional agriculture planning [Ph.D Thesis]. Ghent, Belgium: University of Ghent. 30-50 p.

Deininger KW, Minten B. 2002. Poverty, Policies and Deforestation: The Case of Mexico. Economic Development and Cultural Change 47(2):313-344.

Donovan G, Casey F. 1998. Soil fertility management in sub Sahara Africa. Washington D.C, USA: World Bank. Report nr 408. 1-63 p.

Doss CR. 2006. Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. Agricultural Economics 34:207-219.

Ellis F, Freeman HA. 2004. Rural livelihoods and poverty reduction in four African countries. The Journal of Development Studies 40:1-30.

Enete AA, Nweke FI, Tollens E. 2002. Determinants of cassava cash income in female headed households of Africa. Quarterly Journal of International Agriculture 41(3):241-254.

Enete AA, Nweke FI, Tollens E. 2004. Gender and cassava processing in Africa. Quarterly Journal of International Agriculture 43(1):57-69.

Enete AA, Nweke FI, Tollens E. 2005. Hired labor use decisions in cassava-producing households of sub-Saharan Africa. Quarterly Journal of International Agriculture 33:269-275.

Eswaran M, Kotwal A. 1986. Access to capital and agrarian production organization. Economic Journal 96:482-498.

Fafchamps M, Quisumbing AR. 1999. Human Capital, Productivity, and Labor Allocation in Rural Pakistan. Journal of Human Resources 34:369-406.

FAO. 1978-81. Reports of the agro-ecological zones project: World Soil Resources Rome, Italy: Food and Agriculture Organization of United Nations. Report nr 48 Vols.1-4. 5-20 p.

FAO. 1997. Food Outlook: Global information and early warning system. Rome, Italy: FAO, GIEWS. 10-20 p.

FAO. 2004. Scaling Soil Nutrient Balances: Enabling meso-level applications for African realities. Rome, Italy: FAO. 1-50 p.

Feder G, Just RE, Zilberman D. 1985. Adoption of Agricultural innovations in developing countries: a survey. Economic Development and Cultural Change 33:255-297.

Freeman HA, Omiti JM. 2003. Fertilizer use in semi-arid areas of Kenya: analysis of smallholder farmers' adoption behaviour under liberalized markets. Nutrient Cycling in Agroecosystems 66:23-31.

Fujita K, Otsu KG, Ogta S. 1992. Biological Nitrogen fixation in mixed legume cereal cropping systems. Plant and Soil 141:155-175.

Geertz C. 1963. Agriculture involution: The process of ecological change in Indonesia. California, USA: University of California, Press, Berkeley. 65 p.

Gockowski J, Ndoumbe M. 2004. The adoption of intensive monocrop horticulture in southern Cameroon. Agricultural Economics 30:195-202.

Govereh J, Jayne TS. 2003. Cash cropping and food crop productivity:synergies or trade-offs? Agricultural Economics 28:39-50.

Greene WH. 1997. Econometric analysis. Prentice-Hall, USA: Englewood Cliffs. 896-951 p.

Gujarati DN. 1988. Basic Econometrics. New York, USA: Mcraw-Hill. 245-246 p.

Hamilton AJ, Hepworth G. 2004. Accounting for Cluster Sampling in Constructing Enumerative Sequential Sampling Plans. Journal of Economic Entomology 97(3):1132-1136.

Hartemink AE, Buresh RJ, Jama B, Janssen BH. 1996. Soil nitrate and water dynamics in sesbania fallows, weed fallows, and maize. Soil Science Society of America Journal 60:568-574.

Hassan RM, Njoroge K, Njore M, Otsyula R, Laboso A. 1998. Adoption Patterns and Performance of Improved Maize in Kenya In: Hassan RM, editor. Maize technology development and transfer: A GIS application for research planning in Kenya. Wallingford, U.K: CABI. p. 256.

He CY, Zhou HL, Yu ZT, Zhang QT. 2002. Regional land use/cover information processing. Resources Science 24(2):64-70.

Heckman J. 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals of economic and social measurement 5:475-492.

Herath HMG, Hardaker JB, Anderson JR. 1982. Choice of varieties by Sri Lankan rice farmers: Comparing alternative decision models. American Journal of Agricultural Economics 56:764-768.

Jaetzold R, Schimdt H. 1982. Farm Management Handbook of Kenya: natural conditions and farm management information. Nairobi, Kenya Ministry of Agriculture, Kenya, and German Agency for Technical Cooperation (GTZ). 10-40 p.

Janke HF. 1982. Livestock production systems and livestock development in tropical Africa. Kiel, Germany. 33 p.

Kakamega District Development Plan. 2002. Kakamega District Development Plan 2002-2008. Nairobi, Kenya: Ministry of Planning and National Development. 11-25 p.

KARI. 1994. Strategic Plan for Cereals (1993-2013). Nairobi, Kenya: Kenya Agriculture Research Institute. 8 p.

Kelly V, Adesina AA, Gordon A. 2003. Expanding access to agricultural inputs in Africa: a review of recent market development experience. Food Policy 28:379-404.

Knudsen O, Scandizzo P. 1982. The demand for calories in developing countries. American Journal of Agricultural Economics 64(1):80-86.

KSA. 1999. Kenya Sugar Authority yearbook statistics. Nairobi, Kenya: Government press. 10-25 p.

Lai YB, Xu X, Wang JA, Wang L, Yu YY, Yang C. 2002. Analysis of LUCC pattern of physical region in NSTEC. Progress in Earth Science 17(2):215-220.

Leaf MJ. 1987. Intensification in peasant farming: Punjab in green revolution. In: Turner B, and Brush SB, editor. Comparative farming systems. London, UK: The Guilford Press. p. 248-275.

Lee D, Ruben R. Putting the 'farmer first': Returns to labor and sustainability in agroecological analysis; 2001; Berlin, Germany. p 250.

Lee DR, Barrett CB, Hazell P, Southgate D. 2001. Assessing Tradoffs and Synergies among Agricultural Intensification, Economic Development and Environmental Goals: Conclusions and Implications for Policy. Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. Wallingford, UK: CAB International. p. 451-464.

Lijzenga M. 1998. Maize response to NPK in relation to soil fertility indices in western Kenya. [MSc]. Wageningen, The Netherlands: Wageningen Agricultural University. 150 p.

Lin T, Schmidt P. 1984. A test of Tobit specification against an alternative suggested by Cragg. Review of economics and statistics 66:174-177.

Loveland TR, Zhu Z, Ohlen DO, Brown JF, Reed BC, Yang LM. 1999. An analysis of the IGBP global land-cover characterization process. Photogrammetric Engineering and Remote Sensing 65(9):1021-1032.

Lung T, Schaab G. 2006. Change-detection in Western Kenya: The documentation of fragmentation and disturbance for Kakamega forest and associated forest areas by means of remotely sensed imagery. Department of Geoinformation, Karlsruhe University of Applied Sciences, Germany. p. 1-6.

Lynam J, Hassan RM. 1998. A new approach to securing sustained growth in Kenya's maize sector. In: R.M H, editor. Maize technology development and transfer: A GIS pplication for research planning in Kenya. Wallingford, UK: CAB International. p. 256.

Maddala GS. 2002. Introduction to econometrics. West Sussex, UK: John Wiley & Sons Ltd. 322-332 p.

McIntire J, Bourzat D, Pingali P. 1992. Crop-livestock interactions in sub Sahara Africa. The World Bank, Washington D.C, USA. 246 p.

Mercer DE. 2004. Adoption of agroforestry innovations in the tropics: a review. Agroforestry Systems 11:311-328.

Moore HL. 1992. Households and gender relations: the modelling of the economy. In: Ortiz S, Lees S, editors. Understanding economic process. Lanharn, USA: University Press of America. p. 131-148.

Morris ML, Byerlee D. 1998. Maintaining productivity gains in post-green revolution Asian agriculture. In: Eicher CK, Staatz J, editors. Agricultural development in the third world third ed. Baltimore, USA: Johns Hopkins University Press. p. 150.

Mose LO. Factor affecting the distribution and use of fertilizers in Kenya: A preliminary assesment; 1998; Egerton University, Kenya. Tegemeo institute of Agricultural Policy and Development. p 200.

Moser CM, Barrett CB. 2003. The Disappointing Adoption Dynamics of a Yield-Increasing, Low-External Input Technology: The Case of SRI in Madagascar. Agricultural Systems 76:1085-1000.

Muriuki GW, Njoka TJ, Reid RS, Nyariki DM. 2005. Tsetse control and land-use change in Lambwe valley, south-western Kenya. Agriculture Ecosystems and Environment 105:99-107.

Musa AM, Harris D, Johansen C, Kumar J. 2001. Short duration chickpea to replace fallow after aman rice: the role of on-farm seed priming in the high barind tract of bangladesh. Experimental Agriculture 37:509-521.

Nachtergaele FO, Bruggeman HY. 1986. Methodology for regional analysis of physical potential for crop production. Bangkok, Thailand: Food and Agriculture Organization of the united Nations. Report nr 5. ftp://ftp.fao.org/agl/agll/docs/nasrec.doc p.

Nambiro E, Omiti JM. 2007. Access to, and willingness to pay for, agricultural extension in Western Kenya. In: Barret CB, Mude AG, Omiti JM, editors. Decentralization and social economics of development Lessons from Kenya. Wallingford, UK: CAB International. p. 84-91.

Newman C, Henchion M, Matthews A. 2001. Infrequency of purchase and double-hurdle models of Irish households' meat expenditure. European Review of Agricultural Economics 28(4):393-419.

Nyerges EA. 1997. The social life of swiddens: juniors, elders and the ecology of Susu upland rice farms. The Ecology of Practice. Amsterdam, The Netherlands: Gordon and Breach Publishers. p. 169–200.

Nyonka E, Schroeder T, Norman D. 1997. Factors affecting adoption of improved maize seed and fertilizer in Northern Tanzania. Agricultural Economics 48(1):1-12.

Nyoro J. 2001. Institutional and Performance Differences in Coffee Cooperatives of Kenya. Nairobi, Kenya: Tegemeo Institute. 10-22 p.

Nziguheba G, Palm CA, Buresh RJ, Smithson PC. 1998. Soil phosphorus fractions and absorption as affected by organic and inorganic sources. Plant and Soil 198:159-168.

Ojiem JO. 2006. Exploring socio-ecological niches for legumes in western Kenya smallholder farming systems [Ph.D thesis]. Wageningen, The Netherlands: Wageningen University. 35-116 p.

Otieno O, Kegode P, Ochola S. 2003. The challenges and way forward for the sugar sub-sector in Kenya. Nairobi, Kenya: Friedrich Ebert Stiftung 10-23 p.

Ottichilo WK. 1986. Long rains maize and wheat production in Kenya. Nairobi, Kenya: Ministry of Planning and National Development, Departament of Resource Surueys and Remote Sensing. Report nr 172. 50 p.

Panin A, Brummer B. 2000. Gender differentials in resources ownership and crop productivity of smallholder farmers in Africa: a case study. Quarterly Journal of International Agriculture 39(1):65-78.

Pender J, Nkonya E, Jagger P, Sserunkuumab D, Ssali H. 2004. Strategies to increase agricultural productivity and reduce land degradation: evidence from Uganda. Agricultural Economics 31:185-195.

Pender J, Scherr S, Durón G. 2001. Pathways of development in the hillsides of Honduras: Causes and implications for agricultural production, poverty and sustainable resource use. In: Lee DR, Barret CB, editors. Tradeoffs or Synergies. Wallingford, UK: CAB International. p. 171-195.

Peoples MB, Craswell ET. 1992. Biological nitrogen fixation investments, expectations and actual contribution to agriculture. Plant and Soil 141:13-39.

Pfaff ASP. 1999. What drives deforestation in the Brazilian Amazon? Evidence from satellite and socioeconomic data. Journal of Environmental Economics and Management 37:26-43.

Pingali P, Bigot Y, Binswanger H. 1987. Agriculture mechanization and evolution of farming systems in Africa. Washington D.C, USA: The World Bank. 216 p.

Pingali PL. 2001. 1999-2000 World maize facts and trends. Meeting world maize needs: Technological opportunities and priorities for the public sector. Mexico D.F, Mexico: CIMMYT. 35-53 p.

Place F, Hazel P. 1993. Productivity effects of indigenous land tenure systems in Sub Saharan Africa. American Journal of Agricultural Economics 75:10-19.

Polson RA, Spencer DSC. 1991. The technology adoption process in subsistence agriculture: the case of cassava in Southwestern Nigeria. Agriculture systems 36(1):65-78.

Poulton C, Al-Hassan R, Cadisch G, Smith L. 2001. The cash crop versus food crop debate, crop post harvest program. London, UK: Department for International Development (DFID). Report nr 3. 30 p.

Pratt JW. 1981. Concavity of the log likelihood. Journal of the American Statistical Association 76(373):103-106.

Ramankutty N, Foley JA. 1999. Estimating historical changes in global land cover: Croplands from 1700 to 1992. Global Biogeochemical Cycles 13:997-1027.

Rao MR, Mathuva MN. 2000. Legumes for improving maize yield and income in semi arid Kenya. Agriculture Ecosystems and Environment 78:123-137.

Reardon T, Barrett C, Kelly V, Savadogo K. 1999. Policy reforms and sustainable agricultural intensification in Africa. Development Policy Review 17(4):375-386.

Reardon T, Barrett CB, Kelly V, Savadogo K. 2001. Sustainable versus unsustainable agricultural intensification in Africa: Focus on policy reforms and market conditions. In: Lee DR, Barrett CB, editors. Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. Wallingford, UK.: CAB International. p. 365-383.

Reenberg A, Paarup-Laursen B. 1997. Determinants for land use strategies in a Sahelian agro-ecosystem, anthropological and ecological geographical aspects of natural resource management. Agriculture Systems 53:209-229.

Ricardo D. 2002. The principles of political economy and taxation. London, UK: Janus Publishing. 56 p.

Rizov M, Gavrilescu D, Gow H, Mathijs E, Swinnen JFM. 2001. Transition and enterprise restructuring: the development of individual farming in Romania. World Development 29(7):1257-1274.

Ruthenberg A. 1980. Farming systems in the Tropics. Oxford, UK: Clarendon Press. 298 p.

Sadoulet E, de Janvry A, Benjamin C. 1998. Household behavior with imperfect labor market. Industrial Relations Journal 37:85-108.

Salasya BD, Mwangi W, Mwabu D, Diallo A. 2007. Factors influencing adoption of stress-tolerant maize hybrid (WH 502) in western Kenya. African Journal of Agricultural Research 2(10):544-551.

Salasya BD, Mwangi W, Verjurjl H, Odendo MA, Odenya JA. 1998. An Assessment of the Adoption of Seed and Fertilizer Packages and the Role of Credit in Smallholder Maize Production in Kakamega and Vihiga Districts. Mexico D.F, Mexico: CIMMYT Publication. 50 p.

Sanders JH, Shapiro BI, Ramaswamy S. 1996. Agriculture technology in semi arid sub saharan Africa. Baltimore, USA: John Hopkins University Press. 312 p.

Scoones I, Toulmin C. 1999. Policies for soil fertility management in Africa. London, UK: DFID (Department for International Development). 25 p.

Sheriff AH. 1974. The dynamics of change in pre-colonial East African societies. African Economic History Review 1(2):7-14.

Shiferaw B, Holden ST. 2000. Policy Instruments for Sustainable Land Management: The Case of Highland Smallholders in Ethiopia. Agricultural Economics 22:217-232.

Shively GE. 2001. Poverty, Consumption Risk, and Soil Conservation. Journal of Development Economics 65:267-290.

Smale M, Bellon M, Aguirre Gomez J. 2001. Maize diversity, variety attributes, and farmers' choices in southeastern Guanajuato. Economic Development and Cultural Change 50(1):201-225.

Smale M, Just RE, Leathers HD. 1994. Land Allocation in HYW Adoption Models: An Investigation of Alternative Explanations. American Journal of Agriculture Economics 76:535-546.

Smaling EMA, Stoorvogel JJ, Windmeijer PN. 1993. Calculating soil nutrient balances in Africa at different scales. II: District scale. Fertilizer Research 35:237-250.

Snyder KA. 1996. Agrarian change and land use strategies among Iraqw farmers in Northern Tanzania. Human Ecology 24(3):315-340.

Solomon D, Lehmann J, Kinyangi J, Amelung W, Lobe I, Ngoze S, Riha S, Pell A, Verchot L, Mbugua LD, Skjemstad J, Schäfer T. 2007. Long-term impacts of anthropogenic perturbations on the dynamics and macromolecular speciation of organic carbon in tropical forest and subtropical grassland ecosystems. Global Change Biology 13(2):511-530.

Takashi K, Humayun K. 2006. Human capital, productivity, and stratification of rural Pakistan. Review of Development Economics 101(1):116-134.

Tiffen M, Mortimore M, Gichuki F. 1994. More People, Less Erosion. Chichister, UK: John Wiley & sons. 300 p.

Tittonell P, Vanlauwe B, Leffelaar PA, Shepherd KE, Giller KE. 2005. Exploring diversity in soil fertility management of smallholder farms in western Kenya II. Within-farm variability in resource allocation, nutrient flows and soil fertility status. Agriculture Ecosystems and Environment 110(2005):166-184.

Tobin J. 1958. Estimation of relationships for limited dependency variables. Econometrica 26:24-36.

Traxler G, Byerlee D. 1993. A joint-product analysis of the adoption of modern cereal varieties in developing countries. American Journal of Agricultural Economics 75:981-989.

von Thünen JH. Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalokonomie; 1990; Aalen, Germany. Date of original publication: 1826. p 85.

Wang SY, Zhang ZX, Zhou QB, Wang CY. 2002. Study on spatial-temporal features of land use/land cover change based on technologies of RS and GIS. Journal of Remote Sensing 6(3):223-228.

Wang XL, Bao YH. 1999. Study on the methods of land use dynamics change research. Progress in Geography 18(1):81-87.

Wolgin JM. 1975. Resource allocation and risk: A case study of agriculture in Kenya. American Journal of Agricultural Economics 54:35-39.

World Bank. 2000. World Development Report: Attacking poverty. New York, USA: Oxford University Press. 150 p.

Yotopoulos PA, Lau LJ. 1971. A test for relative efficiency and application to Indian Agriculture. American Economic Review 61(1):94-109

8 Appendices

Appendix 1: Land-to-person ratio[25] (10 year average) in selected countries in Africa

Sub Sahara Africa	1960-69	1970-79	1980-89	1990-99
Ethiopia	0.508	0.450	0.363	0.252
Kenya	0.459	0.350	0.280	0.229
Mozambique	0.389	0.367	0.298	0.249
Rwanda	0.215	0.211	0.197	0.161
Zambia	1.367	1.073	0.896	0.779
Zimbabwe	0.726	0.583	0.583	0.525

Sources: FAO, 2004.

25 Land-to-person ratio = (land cultivated to annual and permanent crops) / (population in agriculture

Appendix 2: Questionnaire

Section 1: Basic information, dwelling and location
a) Household coordinates, respondent and interviewer information

Question code	Question	Response	Codes
s1aq1	CBS cluster number		See below
s1aq2	Household number		
s1aq3	GPS coordinates (Latitude)		
s1aq4	GPS coordinates (Longitude)		
s1aq5	Name of the respondent		
s1aq6	Sex of the respondent		1 Female
			2 Male
s1aq7	Respondent's position in the household		1 Household head
			2 Spouse of household head
			3 Child
			4 Other relation
s1aq8	Interviewer's name		
s1aq9	Interview date		

Codes for s1aq2

Bukhonyi	1186	Lutaso	1178	Mutoto A	1181	Shikondi	1185	Sichilayi	1771		
Bukhulunya	1774	Mahiakalo	1773	Muyundi	1180	Shingodo	1187				
Ewamakhumbi	1192	Matere	1194	Ngaywa	1183	Shingoto	1191				
Industrial	1772	Mavusi A	1179	Savane	1190	Shipalo	1188				
Lukala	1776	Musakhwe	1177	Shianda	1182	Shirere	1775				
Lukwilo	1170	Mushifumbi	1193	Shikhambi	1769	Shitsiulio	1189				

b) Dwelling characteristics

Question code	Question	Response	Codes
s1bq1	What is the chief source of cooking power in this household?		1 Firewood
			2 Charcoal
			3 Kerosine
			4 Other
s1bq2	What is the main source of lighting for the household?		1 Kerosine
			2 Electricity
			3 Candles
			4 Other
s1bq3	What is the main source of domestic water for the household?		1 Pipe in the house
			2 Public pipe / Piped water from somewhere else
			3 Stream/River
			4 Other
s1bq4	Main material of the walls of household head's house		1 Mud
			2 Bricks
			3 Stone
			4 Timber
			5 Other
s1bq5	Main material of the roof of household head's house		1 Iron sheets
			2 Tiles
			3 Thatch
			4 Other
s1bq6	Main material of the floor of household head's house		1 Cement
			2 Mud
			3 Other
			2 Toilet
			3 Other
s1bq8	Distance to nearest access road (not foot path) in metres		
s1bq9	Type of access road		1 Tarmac

Section 2: Basic individual characteristics (all individuals, including ALL children, househelp – start with household head)

	s2q1	s2q2	s2q3	s2q4	s2q5	s2q6	s2q7	s2q8	s2q9
ID	Relationship to household head	Age	Sex	Marital status	Religion	Literacy status	Education (highest level)	Years of education	Occupational status
	1 Household head	0 if younger than 1	1 female	1 Single	1 Protestant	1 Neither read nor write	1 No formal schooling		1 Too young (up to 12)/ too old to work
	2 Spouse of household head		2 male	2 Married (mono.)	2 Roman Catholic	2 Read only	2 Primary incomplete		2 Student
	3 Child			3 Married (poly.)	3 7th day adventist	3 Write only	3 Primary complete		3 Unemployed
	4 Grandparent			4 Widowed (mono.)	4 Muslim	4 Read and write	4 Secondary incomplete		4 Occupied
	5 Other relatives			5 Widowed (poly.)	5 Other		5 Secondary complete		
	6 Worker/ Househelp			6 Separated/divorced			6 Vocational training		5 Housework
	7 Other			7 Cohabiting			7 Tertiary college (no university)		
							8 University		If 4: Fill section 3 for this member now
							9 University +		
1									
2									
3									
4									
5									

s2q10	Household size (should be consistent with the above table, repeat this number to the respondent in order to make sure you did not forget anybody)	

Section 3: Job characteristics **(DON'T FORGET TO PUT THE NUMBER OF THE INDIVIDUAL FROM SECTION 2 FIRST)**

	s3q1	s3q2	s3q3	s3q4			s3q5	s3q6	s3q7	s3q8		
ID s2	Main occupation	Sector/Main crop on farm	How many days per week in this occupation?	How much do you earn in this occupation (in KSh) (ONLY IF EMPLOYEE/WORKER)?			Secondary occupation	Sector/Main crop on farm	How many days per week in this occupation?	How much do you earn in this occupation (in KSh) (ONLY IF EMPLOYEE/WORKER)?		
	1 Farmer 2 Employee/Worker 3 Non-agricultural self-employment / employer 4 Non-paid household member	See codes below		Only one entry per individual!			1 Farmer 2 Employee/Worker 3 Non-agricultural self-employment / employer 4 Non-remunerated household member	See codes below		Only one entry per individual!		
				Daily	Weekly	Monthly				Daily	Weekly	Monthly

Codes for s3q2 and s3q6

1	Food crops	9	Food production (including bakeries, butchers, etc.)	17	Transport (other)	25	Formal services (banking, insurance, real estate)
2	Tea	10	Furniture, wood-related carpentry, timber materials	18	Repair of motor vehicles	26	Church, NGOs, international organizations etc.
3	Sugar cane	11	Metal works	19	Other repair shops (bicycles etc)	27	Hotels and restaurants
4	Vegetables	12	Charcoal production	20	Retail - street vendor	28	Government and government agencies, public service
5	Other crops (trees etc.)	13	Other manufacturing (clothing, textiles etc.)	21	Retail - fixed stall, shop	29	Househelp
6	Livestock	14	Construction	22	Wholesale	30	Other informal services (Shoe shining, washing etc.)
7	Fishing and hunting	15	Transport (own motor vehicle)	23	Medical service, hospital, pharmacies	31	Other formal services (Security etc.)
8	Mining and quarrying	16	Transport (boda-boda)	24	Hair dressing and beauty	32	Other (Specify)

Section 4: Non-agricultural enterprise, i.e. self-employment (possibly with households members helping) or employer (if there is no non-agricultural enterprise go to section 5)

	s4q1	s4q2	s4q3	s4q4	s4q5			s4q6			s4q7
No.	Sector of the enterprise	When was this enterprise started?	How many household members participate in this enterprise?	How many hired workers work in this enterprise?	What is the amount of sales of your enterprise?			How much do you earn from this enterprise once you deduct all expenses e.g. for hired labor, for machines and raw materials?			The earning from this enterprise have increased/decreased/stayed constant during the last three years?
	See codes below	Year			Only one entry per row!			Only one entry per row!			1 Increased 2 Decreased 3 Stayed constant
					Daily	Weekly	Monthly	Daily	Weekly	Monthly	
1											
2											
3											
4											

Codes for s4q1

		9	Food production (including bakeries, butchers, etc.)	17	Transport (other)	25	Formal services (banking, insurance, real estate)
		10	Furniture, wood-related carpentry, timber materials	18	Repair of motor vehicles	26	Church, NGOs, international organizations etc.
		11	Metal works	19	Other repair shops (bicycles etc)	27	Hotels and restaurants
		12	Charcoal production	20	Retail - street vendor	28	Government and government agencies, public service
		13	Other manufacturing (clothing, textiles etc.)	21	Retail - fixed stall, shop	29	Househelp
		14	Construction	22	Wholesale	30	Other informal services (Shoe shining, washing etc.)
		15	Transport (own motor vehicle)	23	Medical service, hospital, pharmacies	31	Other formal services (Security etc.)
8	Mining and quarrying	16	Transport (boda-boda)	24	Hair dressing and beauty	32	Other (Specify)

Section 5: Land ownership and use (Go to section 8 if household does not have land)

Question code	Question	Response	Codes
s5q1	Do you own your farm or is it rented?		1 Owned 2 Rented (Go to s4q3)
s5q2	Which type of land rights do you hold?		1 Title deed 2 Customary rights 3 Other
s5q3	Total land size of your farm (in acres)		
s5q4	Do you have separate parcels of land, if yes, how many?		1 No (Go to s4q6) 2 One 3 Two 4 Three or more
s5q5	How far from here is the largest of these parcels? (in km)		
s5q6	When did you start farming independently? (year)		
s5q7	When you started farming how did you acquire your land?		1 Inherited 2 Bought 3 Rented 4 Government allocation 5 Other
s5q8	What was the size of your parents' farm? (in acres)		
s5q9	Since you started your farm, how has the size of the farm changed?		1 Increased 2 Decreased 3 Stayed constant (Go to S4q11)
s5q10	How have these changes occurred?		1 Sold out land 2 Bought land 3 Rented land 4 Divided land 5 Inherited land 6 Loss of land due to erosion 7 Other
s5q11	Total size of land under cultivation during the long rains 2005 (in acres)		
s5q12	Total size of land under cultivation during the short rains 2005 (in acres)		
s5q13	Do you leave some plots on your land fallow?		1 Yes 2 No (Go to s4q17)
s5q14	What is the size of the fallow plot in acres?		
s5q15	When was this fallow plot last under fallow?		1 More than 10 years ago 2 5-10 years ago 3 Less than 5 years ago 4 I do not remember(Go to s4q17)
s5q16	What was the duration of this former fallow? (in months)		
s5q17	In the past 10 years, have you changed fallow duration?		1 Increased

Section 6: Agricultural production except livestock (go to section 8 if no agricultural activities)

a) Maize, beans, other staple food crops (4 main crops)

s6aq1	s6aq2	s6aq3		s6aq4		s6aq5		s6aq6	s6aq7	s6aq8
Crop code	Area in acres	Quantity harvested (last harvest after long rains)		Quantity sold of last harvest after long rains		Price per unit of quantity in KSh at time of sale (not current price!)		Today you plant more/less/the same of this crop compared to three years ago?	Today are yields of this crop higher or lower compared to three years ago?	Which seeds do you use?
See below		Quantity codes see below		Quantity codes see below		Quantity codes see below		1 More	1 Higher	1 Local
								2 Less	2 Lower	2 Improved
								3 The same	3 The same	3 Mixed
		Unit of quantity	Quantity	Unit of quantity	Quantity	Unit of quantity	Price			4 Other

Codes for s6aq1

1	Maize	9	Groundnuts
2	Beans	10	Irish potatoes
3	Sweet potatoes	11	Soy beans
4	Cooking Banana		
5	Cassava		
6	Sorghum		
7	Arrow roots		
8	Millet		

Unit of quantity codes

1	Piece/Number
2	Kg
3	90 kg bag
4	Gorogoro
5	Bunch

b) Tea (if no tea go to section s6c)

s6bq1	s6bq2	s6bq3		s6bq4
Crop	Area in acres	Monthly harvest		Today you plant more/less/the same of this crop compared to three years ago?
		Quantity codes see above		1 More
				2 Less
				3 The same
		Unit of quantity	Quantity	
Tea				

c) Sugar cane (if no sugar cane go to s6d)

s6cq1	s6cq2	s6cq3			s6dq3		s6cq6		s6cq7
Crop	Area in acres	Date of last harvest		How long had the sugar cane been on the field before it was harvested (in months)?	Quantity harvested (last harvest)		Price per unit of quantity in KSh at time of sale (not current price!)		Today you plant more/less/the same of this crop compared to three years ago?
					1 Tons 2 Big tractor 3 Small tractor		1 Tons 2 Big tractor 3 Small tractor		1 More 2 Less 3 Same
		month	year		Unit of quantity	Quantity	Unit of quantity	Price	
Sugar cane									

d) Other crops and vegetables, max. 3, ranked by importance (if no other crops etc. go to section s6e)

s6dq1	s6dq2	s6dq3	s6dq4		s6dq5		S5dq6		s6dq7
Code	Area in acres	How many harvests per year?	Quantity harvested (last harvest)		Quantity sold of last harvest		Price per unit of quantity in KSh at time of sale (not current price!)		Today you plant more/less/the same of this crop compared to three years ago?
See below			Quantity codes see below		Quantity codes see below		Quantity codes see above		1 More 2 Less 3 Same
			Unit of quantity	Quantity	Unit of quantity	Quantity	Unit of quantity	Price	

Codes for s6dq1

1	Napier	7	Mrere/mrenda/Corchorus Olitoris/Lihoo	13	Terere	19	Egg Plant/Aubergine
2	Local sugarcane	8	Tsisagaa/Spider Weed/Gynandropsis Gynandra	14	Nderema/Basela Alba		
3	Kunde	9	Malenge/Tseveve/Pumpkin Leaves/Sebebe	15	Onions		
4	Sukuma	10	Dodo/Toto/Amaranthus Hybridus/Mchicha/Terere/Libokoi	16	Chili/Pili-Pili		
5	Cabbage	11	Lisutsa/Sucha	17	Kanzera		
6	Miro/mito/Crotolaria	12	Tomato	18	Black night shade/ Isutsa		

Unit of quantity codes

1	Piece/Number
2	Kg
3	90 kg bag

e) Fruit crops, max. 3, ranked by importance (if no fruit crops etc. go to section 7)

s6eq1	s6eq2	s6eq3		s6eq4		s6eq5		S6eq6		s6eq7
Code	How many trees	How many harvests per year?		Quantity harvested (last harvest)		Quantity sold of last harvest		Price per unit of quantity in KSh at time of sale (not current price!)		Today you had more/less/the same of this tree compared to three years ago?
See below				Quantity codes see below		Quantity codes see below		Quantity codes see above		1 More 2 Less 3 Same
				Unit of quantity	Quantity	Unit of quantity	Quantity	Unit of quantity	Price	

Codes for s6eq1

1	Ripening bananas	7	Loquarts
2	Sweet bananas	8	Musioma/Zambarau
3	Avocado	9	Passion Fruit
4	Mango	10	White support
5	Guava	11	Mukhombero
6	Paw Paw	12	Mufudu

Codes for units of quantity

1	Piece/Number
2	Kg
3	90 kg bag
4	Gorogoro
5	Bunch

Section 7: Input use, extension, fencing and pollination

a) Non-labor input use

s7aq1		s7aq2
Non-labor inputs: Do you use the following inputs?		Today you use more/less/the same of this input compared to three years ago
	1 Yes 2 No	1 More 2 Less 3 The same
Improved seed		
Manure		
Inorganic fertilizer		
Pesticides and/or herbicides		

b) Labor input, extension, and technology

Question code	Question	Response	Codes
s7bq1	How many household members (without payment) work on the farm?		
s7bq2	How many hired workers work permanently on your farm who are not members of the household?		
s7bq3	In very busy times (harvesting or weeding), how many hired workers work on your farm (including permanent workers)?		
s7bq4	Today you hire more/less/same number of workers compared to three years ago?		1 More 2 Less 3 Same
s7bq5	What is the main source of agricultural information?		1 Agricultural extension 2 Community based organizations 3 NGOs 4 Church 5 Farmer groups/farmer associations 6 Other 7 None
s7bq6	How often are you visited by an agricultural extension officer?		0 Not at all 1 1 or 2 times in the past 5 years 2 Once every year 3 Once every month 4 Weekly
s7bq7	Have you hired a tractor in the past 12 months?		1 Yes 2 No
s7bq8	Have you hired oxen power in the past 12 months?		1 Yes 2 No

Section 8: Household expenditure

a) Items with high share of home or free consumption

	s8aq1	s8aq2			s8aq3			s8aq4	
		Home produced (last month)			Purchased (last month)			Free – Presents, gifts (last month)	
		Quantity codes below			Quantity codes below			Quantity codes below	
		Unit of quantity	Quantity	Price per Unit of Quantity	Unit of Quantity	Quantity	Price per Unit of Quantity	Unit of Quantity	Quantity
1	Maize								
2	Beans								
3	Cooking Bananas								
4	Sweet potatoes								
5	Cassava								
6	Arrow roots								
7	Fire Wood								

Codes for units of quantity

1	Piece/Number
2	Kg
3	90 kg bag
4	Gorogoro
5	Bunch

b) Other food items

	s8bq1	s8bq2	s8bq3
		Value of home production (last month)	Value of purchases (last month)
8	Other staple foods or derived products (rice, sorghum, millet, all types of flour)		
9	Vegetables e.g. tomatoes, traditional, cabbages etc.		
10	Fruits e.g. sweet bananas, paw-paw, mango, etc		
11	Eggs		
12	Dairy products e.g. milk, yoghurt		
13	Oil and fats		
14	Meat e.g. beef, fish, pork etc.		
15	Tobacco products e.g. cigarettes etc		
16	Alcoholic drinks e.g. traditional brew etc.		
17	Tinned food e.g. fish, baby food		
18	Spices e.g. salt, chilly, baking powder etc.		
19	Beverages e.g. soda, coffee, tea, soy, chocolate etc.		
20	Sugar e.g. nguru, etc		
21	Jam, honey, sweets etc.		
22	Expenditure in food kiosks /restaurants		

c) Regular non-food items

	s8cq1	s8cq2	s8cq3
		Value of home production (last month)	Value of purchases (last month)
23	Clothing including blankets, pillows, mosquito nets, etc (all)		
24	Footwear (all)		
25	Household utensils		
26	Furniture		
27	Personal goods e.g. jewellery; wallets, etc.		
28	Household operation e.g. soap, match box, detergents, candles etc.		
29	Personal care e.g. salon, sanitary pads, hair oil		
30	Charcoal		
31	Kerosene /paraffin		
32	Electricity		
33	Communication costs e.g. phone/stamps		
34	Individual transport costs e.g. boda-boda, buses, taxis etc		
35	Farm products transport costs		
36	Electricity, water etc. (bills).		
37	Rent of rented house		
38	Rent of rented farm		
39	Recreation and entertainment e.g. news paper, video show , magazines		
40	Domestic worker /s		
41	Maintenance of housing unit e.g. repairs		
42	School fees and items		
43	Taxes		
44	Market fees		
45	Contributions to the church / mosques		
46	Contributions to other organizations		
47	Interest paid on loans		
48	Savings		

Section 9: Other income sources (and migration)

Question code	Question	Response	Codes	
s9q1	Renting out land or property per month (in KSh)			
s9q2	Pension payments per month (in KSh)			
s9q3	Other income (interest earnings, dividends etc. per month , other public transfers e.g. unemployment benefits) per month (in KSh)			
s9q4	How many former household members have migrated during the last 10 years?			
s9q5	What is the amount the household receives from family members living outside this household (in KSh)?		Per week	Only one entry!
			Per month	
			Per year	
s9q6	Today you rely more or less on remittances than three years ago?		1 More	
			2 Less	
			3 Same	

Section 10: Assets and livestock

	s10q1 Type of asset	s10q2 Quantity	s10q3 Value as of today (per unit)	s10q4 Today you own more/less/same of this asset compared to three years ago?
				1 More 2 Less 3 Same
1	Cows			
2	Pigs			
3	Chicken (or other poultry)			
4	Goats or sheep			
5	Radio			
6	Television			
7	Bicycle			
8	Mobile phone			
9	Fixed telephone			
10	Rental houses	Put total value!		
11	Sewing machine			
12	Kerosene stove			
13	Plates, sufurias, i.e. crockery	Put total value!		
14	Energy saving jiko	Put total value!		
15	Sofa set			

Section 11: Institutional Embedding

Question code	Question	Response	Codes
s12q1	Is anybody of this household member of a credit scheme or group?	nnn	1 Yes 2 No
s12q2	Does the household have an outstanding loan or have you borrowed money during the last 12 months?		1 Yes 2 No (Go to s12q4)
s12q3	This loan is given by		1 Neighbours or friends 2 Savings group 3 Other microfinance institutions 4 Cooperatives 5 Banks 6 Other
s12q4	Is anybody of this household member of a farmers' organisation?		1 Yes 2 No
s12q5	Is anybody of this household member of a trade union?		1 Yes 2 No
s12q6	Is anybody of this household member of a self-help group?		1 Yes 2 No

Appendix 3: ANOVA analysis of the dependent variable and the agro-ecological zone

Dependent variable	Agroecological Zone	Sum of squares	DF	Mean square	F	Sig
Land use intensity	Between Groups	3.88E-02	1	3.88E-02	0.61	0.4
	Within Groups	15.3	242	6.34E-02		
	Total	15.3	243			
Proportion of area under improved maize seed	Between Groups	2.6	1	2.6	19.3	0
	Within Groups	32.8	240	1.37		
	Total	35.4	241			
Labor intensity in maize	Between Groups	43.1	1	43.1	0.29	0.6
	Within Groups	35491.1	242	146.6		
	Total	35534.2	243			
Use of inorganic fertilizer in food crop	Between Groups	1.5	1	1.5	9.89	0
	Within Groups	37.6	242	0.2		
	Total	39.1	243			

Appendix 4: Cropping calendar of staple foods in the study area

ACTIVITY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land preparation												
Planting												
Weeding												
Harvesting												
Tea picking												

Appendix 5: Household and farm level characteristics by administrative Divisions of Navakholo, Lurambi and Shinyalu of Kakamega in 2005

		Administrative Divisions in Kakamega District		
		Navakholo n=26	Lurambi n=25	Shinyalu n=60
Household characteristics				
Age of household head in years	Mean	38.6 (3.61)	50.4 (3.27)	45.2 (1.85)
Household size	Mean	5.8 (0.42)	6.6 (0.81)	6.5 (0.35)
Gender (%)	Male	87.5	92.9	70.5
Occupation (%)	Farmer	50.0	80.0	75.0
	Informal sector	37.5	10.0	13.3
	Formal sector	12.2	10.0	11.7
Farm level characteristics				
Total farm size (hectares)	Mean	0.9 (0.21)	1.3 (0.21)	0.8 (0.11)
Farm under maize crop (ha)	Mean	0.2 (0.00)	0.5 (0.00)	0.4 (0.00)
Distance (km) to access road	Mean	0.6 (0.11)	0.9 (0.25)	0.5 (0.00)
Distance to market(km)	Mean	2.7 (0.33)	2.7 (0.36)	3.2 (0.32)
Tropical livestock Unit	Mean	1.6 (0.06)	3.4 (0.72)	2.2 (0.32)
Cash crop on farm (%)	Yes	62.5	29.1	20.0
Number of extension visit yearly (%)	Yes	43.7	60.0	17.7

Note: Numbers in parenthesis are standard errors.

Appendix 6: The average monthly family, hired and total labor according to farm types (tea and sugarcane zone) and sizes in Kakamega District in the year 2004.

Farm type	Farm size (ha)	Number of labor allocation in man days					
		Family labor		Hired labor		Total labor	
		Average monthly	Total yearly	Average monthly	Total yearly	Average monthly	Total yearly
Tea zone							
Farms with tea							
	<1 (n=10)	21.3	256.0	13.7	163.0	**35.0**	**419.8**
	1-2 (n=10)	**21.6**	259.0	**28.6**	343.7	**50.2**	**602.7**
	>2 (n=0)	-	-	-	-	-	-
Farms without tea							
	<1 (n=34)	13.7	164.3	**7.1**	85.5	20.8	249.6
	1-2(n=10)	14.6	174.7	18.4	220.3	32.9	394.9
	>2	-	-	-	-	-	-
Sugarcane zone							
Farms with sugarcane							
	<1 (n=16)	13.8	165.8	9.8	117.9	23.6	283.6
	1-2 (n=14)	19.8	237.8	9.8	117.9	29.5	354.0
	>2 (n=17)	15.1	181.5	20.3	243.7	**35.4**	425.2
Farms without sugarcane							
	<1 (n=15)	**9.5**	114.9	8.8	105.6	18.6	223.5
	1-2 (n=10)	20.0	239.7	16.0	191.5	35.9	431.1
	>2	-	-	-	-	-	-

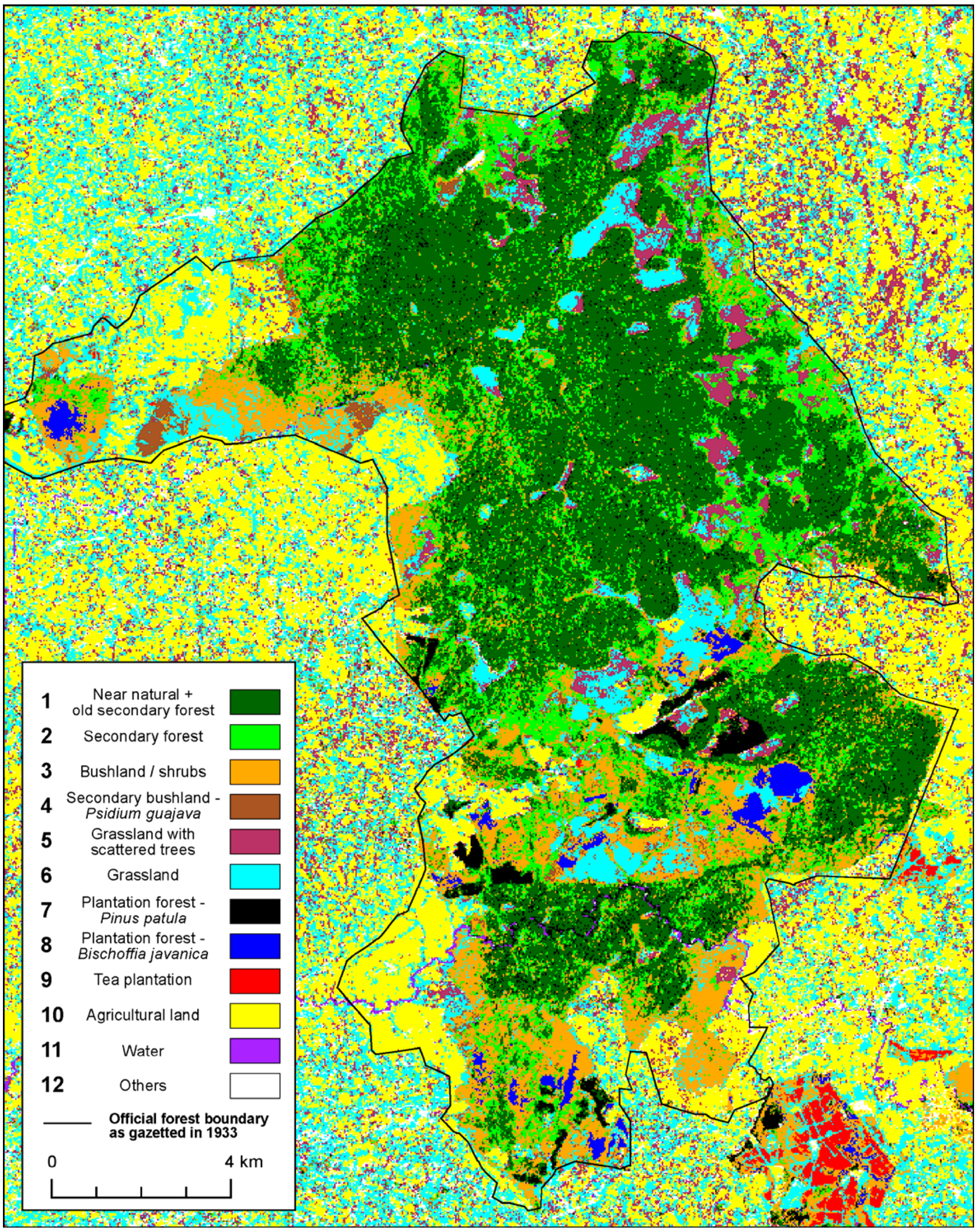
Appendix 7a: The average family labor according to farm types (tea and sugarcane zone) and sizes in Kakamega District according to months in 2004

Farm types	Farm size (ha)	Average monthly family labor											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tea zone *Farms with tea*													
	<1 (n=10)	7.4	7.9	16.7	29.3	30.5	21.5	20.1	**45.0**	19.4	22.3	19.7	16.2
	1-2 (n=10)	12.2	**9.6**	17.8	27.9	22.4	22.8	30.4	39.8	18.0	21.0	19.3	17.6
	>2 (n=0)	-	-	-	-	-	-	-	-	-	-	-	-
Farms without tea													
	<1 (n=34)	11.2	**4.8**	12.2	16	14.5	16.7	9.3	**27.2**	11.0	12.2	20.2	9.1
	1-2(n=10)	11.0	8.7	10.8	11.6	9.5	22.8	10.6	32.3	14.0	18.0	16.4	9.0
	>2	-	-	-	-	-	-	-	-	-	-	-	-
Sugarcane zone *Farms with sugarcane*													
	<1 (n=16)	7.0	8.4	17.0	16.9	14.3	13.2	8.0	33.0	8.2	10.6	18.9	10.1
	1-2 (n=14)	10.3	7.5	19.1	23.8	20.6	28.1	13.3	43.7	10.3	13.7	33.5	13.8
	>2 (n=17)	11.5	6.7	21.5	21.9	18.2	25.2	7.2	31.4	6.3	8.1	16	7.5
Farms without sugarcane													
	<1 (n=15)	6.7	**4.3**	12.6	**8.6**	**7.9**	13.6	6.7	**26.5**	5.4	4.6	11.7	6.0
	1-2 (n=10)	11.5	8.8	22.2	33.4	33	29.5	8.5	38.5	9.5	12.2	25.7	6.9
	>2	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 7b: The average monthly hired labor according to farm types (tea and sugarcane zone) and sizes in Kakamega District in the year 2004

Farm types	Farm size (ha)	Average monthly hired labor											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tea zone													
Farms with tea													
	<1 (n=10)	**1.7**	**1.5**	13.3	21.9	13.1	13.2	5.8	30.0	16.0	22.1	21.4	3.8
	1-2 (n=10)	14.7	**13.2**	25.6	41.1	38.8	30.1	17.7	**60.4**	21.4	27.8	31.1	21.9
	>2 (n=0)	-	-	-	-	-	-	-	-	-	-	-	-
Farms without tea													
	<1 (n=34)	3.3	3.4	10.6	6.4	6.2	7.5	6.1	15.6	6.7	7.8	7.5	4.0
	1-2(n=10)	5.8	**4.3**	37.8	22	17.6	19.6	**3.8**	46.2	11.9	15.3	25.7	10.4
	>2												
Sugarcane zone													
Farms with sugarcane													
	<1 (n=16)	5.1	4.3	5.9	18.2	15.5	6.6	4.8	21.0	9	12.3	10.9	4.3
	1-2 (n=14)	8.0	7.4	8.1	10.5	10.3	8.5	5.9	25.2	6.4	8.2	12.3	5.4
	>2 (n=17)	18.4	11.9	19.6	**48.3**	32.9	23.6	12.6	33.6	12.0	15.5	6.8	8.6
Farms without sugarcane													
	<1 (n=15)	8.4	6.5	10.5	9.8	17.2	5.1	4.2	11.3	12.3	10.2	5.1	6.0
	1-2 (n=10)	3.1	5.0	20.0	38.5	24.9	16.8	2.9	20.9	19.2	19.2	17.0	3.6
	>2												

Appendix 8: Landsat ETM+ land cover classification result of 2001 for the subset of Kakamega Forest, displayed together with the official forest boundary as gazetted in 1933.



Source: Lung and Schaab, 2006

Curriculum Vitae

Name : **Elizabeth Lutomia Nambiro**.
Date of birth and place : 13-05-1973, Nairobi Kenya
Email : enambiro@yahoo.com

EDUCATION

Institution	**Period**	**Qualifications**
University of Bonn, **Germany**	Apr 2005 – to date	Ph.D. Agricultural Sciences
The University of Manchester, **UK**	Jan - Apr 2007	Certificate in Science, Technology and Innovation, Policy and Management
Ben Gurion University of the Negev, **Israel**	Nov - Dec 1999	Agriculture under Arid and Semiarid Conditions Advanced Agrotechnologies
University of Nairobi, **Kenya**	Dec 1998 – Dec 2001	M.Sc. Agricultural Economics
Ben Gurion University of the Negev, **Israel**	Jun - Nov 1998	Diploma in Stress Resistance Breeding
University of Nairobi, **Kenya**	May 1993 – Dec 1997	B.Sc. Agriculture

WORK EXPERIENCE:
Date of employment: January 2002 to current
Name of employer: Kenya Agricultural Research Institute (KARI)

8.1.1.1 Position held: Program Coordinator

Station of Work: Nairobi, Kenya