THE EFFECT OF USING ANIMAL TRACTION ON FARM EFFICIENCY AND HOUSEHOLD LABOUR ALLOCATION ON SMALLHOLDER FARMS IN KENYA: A CASE OF KIRINYAGA DISTRICT.

BY

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DECLARATION

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

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ABBREVIATIONS AND CONVERSIONS

Abbreviations

IFPRI=International Food Policy Research Institute

GDP=Gross Domestic Product

GNP=Gross National Product

CBS=Central Bureau of Statistics

KENDAT=Kenya Network for Draft Animal Technology

ATNESA=Animal Traction Network for Eastern and Southern Africa

DAREP = Dryland Agricultural Research and Extension

OLS=Ordinary Least Squares

MLE=Maximum Likelihood Estimate

C-D =Cobb-Douglas

Kshs =Kenya Shillings

Kg =Kilogram

Yr =Year

LR =Log-Likelihood Ratio

LRI =Likelihood Ratio Index

ASL = Above the Sea Level

Conversions

1 Hectare = 2.47 acres

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ABSTRACT

The continued sub-division of land due to population pressure coupled with traditional inheritance patterns has led to an accelerated decrease in individual land holdings. The small-scale farm will therefore remain the model farm in Kenya in the foreseeable future. To meet the food demand of the increasing population, increasing productivity of small-scale farms is paramount. Appropriate mechanization of the small farm is one of the ways of increasing farm production. In addition to allowing for expansion of cultivable land, the use of animal traction has the advantages of deeper ploughing and greater timeliness in carrying out field operations. However, when introduced into a household, animal traction can affect the labour allocation patterns of the whole household. Furthermore, with the existing patterns of labour allocation by gender, the increase in labour demands may imply shifts in workloads between gender categories and also between agricultural operations. The current study analysed the effect of using animal traction on maize production efficiency and on inter-gender labour allocation.

A multi-stage sampling approach was used to select 80 farmers in Kirinyaga district from whom data were collected using a structured questionnaire. A profit function was estimated to test the hypothesis of equal economic efficiency between “traction” and “hoe” farms. Farm labour-time allocation models were estimated and used to test hypotheses regarding intergender labour allocation patterns.

The results indicated that farmers who used animal traction obtained maize profits that were 86% (CONFIRM THE FIGURE) higher than those who used the hoe. ‘Traction’ farmers obtained an average profit of Kshs 6,423.00/acre from the maize enterprise while their ‘hoe’ counterparts achieved an average of Kshs 1,342.53 from maize enterprise. This was so in spite of the ‘traction’ farmers having used lesser amounts of fertilizers in maize production. Farmers who used animal traction had more land under maize and hired more labour than those that used the hoe.

However, use of animal traction was accompanied by increased labour requirements that were in this case met through hiring. The factors that were found to influence the female farm labour- time allocation were the education level of the female farmers, the number of dependants in the household and the amount of hired labour. . On the other hand, hired farm labour and farm income were significant in the male farm labour-time allocation model. The significance of these coefficients implies that, labour time allocation of the different gender groups can be altered if any interventions affecting the corresponding variables are undertaken.

The study underscores the viability of animal traction in increasing efficiency of small-scale farms. The results showed that with the use of animal traction, there was an increase in farm labour requirements but there was no overburdening of any particular gender group in the household. The extra labour requirements were largely met through hiring. Animal traction was largely used by men at the land preparation stage with little application during weeding.

The government and other agencies should continue with their efforts in advocating the use of animal traction in the smallholder farms. But there is need to consider intensifying mechanization beyond the land preparation stage. Financial assistance and training should be considered for helping farmers acquire and learn to use weeding implements. This would ease the problem of extra labour needs that arise with the use of animal traction. However, given the ability of households to hire more labour, use of animal traction can be viewed a good source of rural employment.

CHAPTER I

1.0 INTRODUCTION

1.1 Background Information

Agriculture is the mainstay of the economies of many developing countries. In Kenya, agriculture remains the main occupation and source of income for the majority of the population. Apart from sustaining most of the rural population through subsistence, agriculture also makes a major contribution to GDP, export earnings and government revenue. Between the year 1996 and 2000, agriculture contributed about 24.5% of the GDP and employed 51% of the work force directly (Kenya, 2002).

Kenya's agricultural sector is commonly subdivided into the small-scale, large-scale and pastoral sub-sectors. The pastoralists mainly occupy arid and semi-arid areas, which cover about 70% of Kenya's land surface. Most of the small and large-scale farmers are located in the highland areas that cover about 30% of the country (Kilungo, 1999).

Statistics indicate that small farms continue to account for the bulk of agricultural production. As indicated by Table 1-1, the smallholders' share of employment is currently 57.5% and is projected to drop slightly to 54.4% by the year 2008.

Table 1-1: Employment forecasts for the years 2002-2008

Sector	Sector share in '00	Forecast Av. Growth rate (%) 2000-2008	Sector share in 2008	Jobs created (Millions)
Formal Agriculture	2.3	0.52	1.9	0.01
Small-scale Agriculture	57.5	2.8	54.4	1.68
Informal rural Sector	10.8	4.2	11.3	0.49
Informal urban Sector	19.5	5.7	22.4	0.86
Formal Non-Agriculture	9.9	3.6	9.9	0.38
Total	100	3.6	100	3.42

Source: National Development Plan 2002-2008, CBS, Ministry of Economic Planning and National Development.

There are about 3 million small-scale farms[1] in Kenya of which 80% are less than 5 acres[2]. The smallholder sub-sector mainly consists of farmers using hand tools for carrying out agricultural operations. They produce a substantial value of agricultural production (Kaumbutho, 1996). According to Kenya (2002), small-scale farmers are responsible of producing 75% of the 2.3-2.7 million tonnes of maize produced in Kenya during the long rains. Major crops grown by small-scale farmers are maize, potatoes, coffee, tea, vegetables and pyrethrum. A large proportion of smallholder farmers also keep dairy animals. The dominance of the small farm is bound to continue as sub-division of large farms continues due to prevailing land inheritance patterns.

[1] According to the ministry of agriculture, farms less than 10 acres are classified as small-scale. In the study area, over 95% of the farms fall under this category.

[2] One acre is equivalent to 0.47 hectares

Therefore, given its relative importance, any strategy for stimulating agricultural growth must inevitably target the smallholder sub-sector. For many of the rural poor people, increasing agricultural production represents their best (or only) opportunity for meeting their food requirements and for earning income to meet other needs (Gerhart, 1986). In the past three decades, Kenya's agricultural sector has been experiencing stagnation in production especially of the food crops (Mutahi, 1996). The average annual growth rate of GDP of the agricultural sector has been declining over the years as shown in Table 1-2. The growth rate fell from 4.6% p.a. in 1964-73 period to 1.1% p.a. in 1996-2000. Between 1990 and1995 the growth rate was a mere 0.4%p.a.

The stagnation in agricultural production has been attributed to several factors such as unfavourable policies, weather variability, liberalisation, poor marketing infrastructure, high costs of inputs, limited access to credit and static technologies (Kenya, 2002). Therefore, given the diversity of causative factors of the stagnation in agricultural production, broad-based measures are needed to address the problem. The stagnation in agricultural production has occurred in a situation of an increasing population (averaging 3% per year) leading to a widening gap between production and consumption demand for food.

Table 1-2: Average Annual Growth of Real GDP (%) by Sector

Sector	1964-73	1974-79	1980-89	1990-95	1996-2000
Agriculture	4.6	3.9	3.3	0.4	1.1
Manufacturing	9.1	10.0	4.8	3.0	1.3
Finance, Real Estate	9.8	12.4	6.7	6.6	3.6
Government Services	16.9	6.5	4.9	2.6	1.0
Private Households	3.5	14.5	10.0	10.3	5.6
Others	-	8.8	7.7	3.6	2.3
GDP	6.6	5.2	4.1	2.5	2.0

Source: National Development Plan 2002-2008, CBS, Ministry of Economic Planning and Development.

The major inputs in smallholder agriculture are land and labor (Kosura, 1983; Rahji, 1999). Use of manual labor is associated with low productivity and drudgery (Kosura, 1983; Panin and Ellis-Jones, 1995). Poor timeliness in carrying out operations, poor seedbed preparation, inability to break the hard pan, stress of temperature and sometimes poor nutrition are some of the reasons that explain low productivity of manual labor. One way of arresting stagnation in the agricultural production and raising incomes of a large section of the rural population is through use of technologies that raise labor productivity (Eicher and Baker, 1982; Kosura, 1983; Panin and Ellis-Jones, 1995).

In this light, mechanisation[3] has been identified as having a big potential to increase agricultural productivity (Sial, 1984). The main reason why mechanisation may achieve an increase in productivity is because farm labor, when used in combination with any form of mechanisation enables completion of a greater amount of work per unit time (Eicher and Baker, 1982).

1.2 Small Farm Mechanisation in Kenya

In the first two decades after independence, governments of Sub-Saharan African countries (Kenya included) tried to promote tractor mechanisation of smallholder farms through government managed tractor hire services and tractor credit schemes. The thrust of these initiatives was to enable small-scale farmers to access tractors either through hire or ownership. However, these efforts had limited success and were not sustainable (Oudman, 1993; Starkey, 1994). In some cases, those who accessed the credit to buy tractors ended up using the money for other reasons (Kosura, 1983). Further, the government managed tractor schemes were bureaucratic and were bogged down by tractor breakdowns that took too long to be repaired. In the small farms, use of tractors has proved not to be economically viable. Most small-scale farmers cannot afford the initial cost of purchase, maintenance and operation (fuel) cost due to financial constraints. Furthermore, the farm sizes are small, scattered and have irregular shapes which make tractor operations difficult and in turn increase the operation cost.

[3] Eicher and Baker (1982), define mechanisation as any form of power used to assist or replace hand labor in agriculture; including donkey power, oxen power, tractors, combines and mechanical threshers.

Due to the limited success of the government sponsored tractor hire services and tractor credit schemes, the use of animal traction for small farm mechanisation has received more attention in the last two decades. The revived interest led to the formation of the Kenya Network for Draft Animal Technology (KENDAT) in the early 1990's to co-ordinate research efforts and information generation on the use of animal traction. At the regional level a similar body has been formed; Animal Traction Network for Eastern and Southern Africa (ATNESA). There has been an increase in efforts to promote the use of animal traction by various stakeholders. The Kenyan government's concern for more research on the use of animal traction was registered over one decade ago (Kenya, 1986).

Research has linked the benefits of using animal traction to several factors. First, use of animal traction enhances timeliness of farm operations and increases the cultivated area compared to manual labor. Secondly the animal traction package comes with the possibility of income generation through off-farm transportation and hiring. Thirdly, use of animal traction has the potential to increase yields through improved seedbed preparation and deeper plowing. Fourthly, ownership of draft animals leads to soil fertility improvements through application of manure from animals and reduced drudgery. Lastly use of animal traction has the potential to bring about labor savings for agricultural operations for which it is applied.

In Kenya, the relevance of animal traction is expected to increase in the future for various reasons. First, the traditional land inheritance patterns combined with a high population growth rate will keep farm sizes relatively small compared to the area considered viable for tractors. Although it anticipated that possibility of land consolidation exists with economic development as people move to urban areas, animal traction will remain viable the foreseeable future in most of the developing countries. Secondly, the foreign exchange required for the importation of tractors is likely to remain a constraint. Thirdly, tractor hire schemes and tractor credit schemes so far have not been successful for small farm mechanisation. Finally, the government has shown growing interest in the promotion of animal traction to increase food production.

Inspite of the perceived relevance and growing interest on animal traction some of its farm level application aspects have not received sufficient research attention. Kang'ara (1996), drawing from his experience with the Dryland Agricultural Research and Extension Project (DAREP) in Embu (Kenya), noted that not enough time and resources have been spent on investigating the challenges that are encountered by farmers when using animal traction. Since its introduction by colonialists (some communities in Sub-Saharan Africa used animals for transport) in the 1920's animal traction has largely been viewed as a male technology (Eicher and Baker, 1982; Ellis-Jones Panin, 1995; Sylwander, 1994). Animals are owned and controlled by men, women cannot make independent decisions on the use of draft animals despite being actively involved in farming (Okalebo, 1996). Further, use of animal traction requires access to resources such land, cash, credit and implements of which women have less access compared to men. Slywander (1994) noted that in an ideal situation it would not be necessary to specifically address gender aspects of animal traction. But unfortunately, gender aspect of animal traction has become a problem that needs special attention. Women play an important role in agricultural production apart from being actively involved in carrying out household chores (Lynn *et al*, 1995). Women in eastern and southern Africa constitute 60-70% of farmers and produce about 80% of the food as noted by Rwelamira and Sylwander (1999). However, inspite of their significant contribution to the welfare of rural households, women are largely neglected by researchers (Lynn *et al* 1995; Rwelamira and Sylwander, 1999).

Further, some researchers have expressed doubts whether animal traction increases farm profitability. Mettrick (1978) in a study done in Gambia found that 'traction' farmers increased acreage but there was no change in yields. Barret *et al* (1982), in study done in Upper Volta, found that use of animal traction only led to modest effects in acreage and yields but labor inputs per acre were reduced by as much as 20 to 25 percent. Kosura (1983) in a study done in Western Kenya found the use of owned oxen for land preparation most profitable for maize production among the three options available to the farmers. The other options were hired tractors and hired oxen.

1.3 Problem Statement

Low productivity in smallholder agriculture has translated into the problem of food insecurity and low incomes in Kenya. In fact, the per capita food production has been declining over the past three decades (World Bank, 1990). There is need for concerted efforts to address these problems. Such efforts should be directed towards increasing agricultural productivity as well as increasing off-farm income earning opportunities in the rural areas.

The use of animal traction has been advocated as one of the possible ways of increasing farm productivity. Enhanced timeliness of carrying out agricultural operations, improved seedbed preparation, deeper plowing and soil fertility improvement through application of manure from the animals all contribute towards increasing productivity. According to researchers and other stakeholders use of animal traction is seen as appropriate, viable and affordable for the small-scale farmers.

The technical aspects of animal traction are well documented (Sylwander, 1994). In Kenya several appropriate animal drawn implements and accessories have been developed. For instance, Bukura Mark II plow, cultivators, a variety of animal drawn carts and harnesses have been developed and released to farmers. However, the user aspects of animal traction have received less attention (Kabutha and Kooijman, 1996; Marshall and Sizya, 1994; Sylwander, 1994). As noted by Starkey (1994) the overall low level of use of animal traction in sub-Saharan Africa raises doubts about its profitability and sustainability. In Kenya for example, 80 years after introduction of animal traction only 12% of small-scale farmers are using it (Mutahi, 1993). Furthermore, the assumption that all members of a household will benefit from the use of animal traction is not always correct (Marshall and Sizya, 1994).

In many areas where animal traction is used, it is predominantly applied for tillage with little or no application in subsequent operations. When it is applied for primary tillage, animal traction has the potential of bringing more land under cultivation compared to the use of the hand tools (Okalebo, 1996). Kosura (1983) in a study done in Western Kenya found that those farmers who on average cultivated 1 acre of maize used oxen for land preparation while those who cultivated less than an acre (0.54 acres on average) of maize used the hoe. Increased acreage implies that more labor would be needed in subsequent operations such as planting, weeding and harvesting. As noted by Stevens (1994), animal traction is rarely applied for weeding in Africa, even where plowing has been practised for generations. Lack of well-adapted equipment has been cited as one of the main reason for low application of animal traction for weeding operation (Eicher and Baker, 1982; Mwanda, 2000). Lack of readily available weeding implements has been cited as another reason for the low use of animal traction for weeding (Mwanda, 2000; Shimba, 2000). The third frequently cited reason for low use of draft animals for weeding is inadequate training of both the draft animals as well as the users (Mbalule, 2000; Shimba 2000). The commonly used implement is the single mouldboard plow with relatively few numbers of harrows, cultivators and ridgers (Dibbits, 1993). Most farmers weed by hand, using a variety of well-developed traditional hoes. If applied for weeding animal traction can significantly reduce the labor inputs required. Kwiligwa *et al* (1994), in a study done in Tanzania reported that the labor input in weeding operation reduced by about 80% when animal traction was applied.

The increase in acreage as a result of using animal traction for land preparation implies an increase in labor requirements that can be met either from household's stock of labor or through hiring. Therefore, when introduced into a household, animal traction can affect the labor allocation patterns of the whole household as noted by Marshall and Sizya (1994) and Sosovole (1994). Furthermore, with the existing patterns of labor allocation by gender, the increase in labor demands may imply shifts in workloads between gender categories and also between agricultural operations. Women who disproportionately do more work in weeding and harvesting may have a higher workload. In this respect the effect of using animal traction on inter-gender labor allocation within a household need to be investigated.

Weeding is recognised as a critical factor in determining crop yields. From an agronomic point of view weeds compete for soil nutrients and moisture with the crops hence hinder crop growth. Mwanda (2002) estimated that uncontrolled weed growth could reduce crop yields by up to 60%. Even inadequate weeding can considerably reduce yields. As noted earlier use of animal traction results in larger acreage being cultivated hence more weeding is required. Weeding operation is cost intensive especially in terms of labor requirements. In many cases, farm labor available for weeding determines the final area that can be harvested. Mwanda (2000) estimated that in some areas of Machakos district in Kenya weeding labor input takes up as much as 50% of the total labor inputs into crop production. This raises the question of whether or not it is profitable to use animal traction in crop production. Given the extra acreage that come with using animal traction and additional weeding that must be carried out and the likely yield losses, is the use of animal traction increase efficiency at the farm level? This study attempts to answer this question.

1.4 Objectives of the Study

The overall objective of this study was to assess and compare farm efficiency and inter-gender labor allocation patterns of small-scale farmers using animal traction to carry out farm operations with those using hand tools in Kirinyaga District, Kenya.

The specific objectives were to:

1. Determine whether use of animal traction increases farm efficiency.
2. Analyse the effect of using animal traction on inter-gender household labor allocation.

1.5 Hypothesis Tested

The following hypotheses were tested in the study:

1. There was no significant difference in farm efficiency between farmers who use animal traction and those who use hand tools.
2. The use of animal traction did not significantly increase the farm labor-time of women.

1.6 Justification of the Study

With the prevailing traditional patterns of land inheritance and increased population pressure, the smallholder farms will be the future model farms for the Kenyan agriculture (Mutahi, 1996). In order to ensure that food requirements of an increasing population is met, technologies that raise agricultural productivity must be employed more intensively. Attempts at increasing productivity in agriculture have focussed on interventions involving use of improved seeds, improved crop husbandry and application of agrochemicals. In addition to these, there is need to apply appropriate source(s) of farm power to boost productivity in agriculture. The use of animal traction appears to be a viable mechanization strategy for smallholder farms (Simalenga, 1993).

The current study will shed light on whether or not use of animal traction significantly increases farm efficiency or not. Further, the study will also provide gender-disaggregated information on how the use of animal traction affects workload distribution among gender groups in the household. The results of this study will be useful for all the stakeholders involved in strategizing for the smallholder mechanisation. The information provided by the result will be useful in putting in place strategies of the best way of mechanising small farms putting into consideration the various gender groups involved.

1.7 The study area

Kirinyaga District was selected as the study area. Kirinyaga district is the smallest of the six districts of the central province. It has an area of 1,437 square kilometres, forming 11% of central province and 0.3% of Kenya's total area. It has four administrative divisions, that is, Ndia, Gichugu, Mwea and the Municipality (Kerugoya-Kutus). To the North of the district, Mt Kenya occupies about 21% of the district's total area. The general landscape of the district rises from an elevation of 1480 ASL in the south to over 6,800m ASL at the mountain peak. The effect of the latitude is to increase precipitation and decrease temperatures as one proceeds from lower to higher altitudes. In general, the whole landscape can be divided into three distinct relief features: The low area, rising from 1,480 m to about 2,000m. This comprises the udulating land of the Mwea Division in the south. The midland area, rising from 2,000m to about 4,800m which forms the midland part of Gichugu and Ndia Divisions and the highland, rising from 4,800m to over 6,800m. This area lies in upper Gichugu and Ndia Division, including the Mt. Kenya forest region. Kirinyaga has a tropical type of climate with an equatorial pattern of rainfall. The district has two seasons of rainfall i.e. long rains (March to May) and the short rains (October to December). Usually planting of food crops is done during these two rainfall seasons because there is adequate rainfall that makes the district self reliant in production of various types of food crops.

From literature the area has a relatively high intensity of use of animal traction especially for tillage operations. However, the use of animal traction in Kirinyaga district closely follows a regional pattern. Most of farmers that were found using animal traction to carry out farm operations were concentrated in the lower parts of the district. The traditional zebu cattle (particularly the oxen) were applied for animal traction. A pair or in some few cases two pairs of oxen were used to pull a mouldboard plough. There are many farmers in Kirinyaga district who do not use animal traction to carry out agricultural operations. Some use tractors while majority use hand tools.

The farmers in the upper regions of the district put their large portions of their farms under cash crops such as coffee and tea. They also keep dairy animals for milk production. Farmers in the lower region do not produce tea or coffee due to unfavourable climate. They keep herds of zebu cattle and produce maize and rice as major crops. Maize-bean intercrop is common.

1.8 Organisation of the Thesis

This thesis is divided into five chapters. Chapter I presents an introduction to the study, statement of the research problem, research objectives and the hypothesis tested. In Chapter II, a review of literature relevant to this study is undertaken. Chapter III presents the methodology that was employed to accomplish the set of research objectives. It includes an explanation of data requirements for the study and data collection and analysis procedures. Chapter IV is a presentation of the results of both descriptive and econometric analysis and their discussion. Chapter V contains the summary, conclusions and the recommendations of the study.

CHAPTER II

2.0 LITERATURE REVIEW

2.1 The use of animal traction: A world-view

Use of draft animals is an old practice that has persisted to the present times. Remains of animal harnesses and chariots in ceremonial graves, tomb paintings, temple decorations, statuettes, coins and seals attest to this fact. Archaeological records indicate that land sledges drawn by oxen were used in Mesopotamia before 3500BC (Encyclopaedia Britannica, 1982). Before the Romans developed the waterwheel, man's only supplement to, or replacements for, his own muscle power were animals he trained to work for him. It is estimated that 52% of the cultivated area in developing countries, excluding China, is farmed exclusively with draft animals (FAO, . Although they have virtually disappeared from the western world, the numbers of draft animals in the rest of the world are declining only slowly and will long retain the place they have held in agriculture for the last 5000 years.

In Asia, draft animals have been used for thousands of years. To this day, animal traction technology remains a widely used, highly persistent and economically essential component of many Asian smallholder-farming systems (Starkey, 1994). Cattle are the main work animals, and they are generally worked in pairs with withers yokes. In Asia it is rare for more than one person to work with a pair of animals. Draft animals are used for plowing and levelling swamps and upland soils. Most of the implements are pulled by long wooden beams. The implements are made in villages largely from wood but with steel shares.

In the south Americas animal traction was introduced by early colonialists hundreds of years ago. In the tropical zone, cattle are the main draft animals. They are usually worked in pairs, using horn/head yokes. The traditional long-beamed, wooden plows are widely used. Small-scale farmers in Mexico, Chile and Argentina employ horses, donkeys and mules for cultivation. In the USA, tractors have gradually replaced draft animals. However, several thousand Amish farmers profitably make use of horses for most farm operations.

Europe has had centuries of tradition of using draft animals. Oxen were the original work animals, and these were worked with withers yokes in northern Europe and head/horn yokes in southern and Western Europe. During the last century, tractors have virtually replaced horses and oxen in performing agricultural operations in European countries.

In North Africa animal traction has been used since the time of the Egyptian pharaohs. Along the North Africa coast, cows, donkeys, mules, horses and camels are widely used for cultivation, pack transport and pulling carts. Ethiopia has had generations of experience of use of draft animals. Work oxen and pack donkeys have been part of Ethiopian farming for centuries. Farmers cultivate with pairs of oxen, using a withers yoke and a long-beamed *maresha* plow.

Compared to the other parts of the world, sub-Saharan Africa (excluding Ethiopia) has had a shorter history of using draft animals (Starkey, 1994). In much of Africa, crop farming and cattle herding tended to be separate activities carried out by different tribal groups. However, there has been a longer history of the use of cattle and donkey as pack animals among certain pastoralists in Western and Eastern Africa. The colonial settlers introduced the use of draft animals to small-scale farmers of sub-Saharan Africa around the 1920's (Dibbits, 1993; Eicher and Baker, 1982; Starkey, 1994; Sylwander, 1994). The use of draft animals for carrying out farm operations has been spreading rapidly in some areas and slowly in others in Africa (Starkey, 1994). The extent to which animal traction is used in Kenya is relatively low. Mutahi (1993) estimated that only about 12% of small-scale farmers were using it compared to 3% who were using tractors while over 80% were using hand tools. Since its introduction by European settler farmers and missionaries about 80 years ago, little attention was given to introducing it to small-scale farmers (Dibbits, 1993). In the early decades after independence, little support and promotion was given to animal traction by the government. On the contrary the government tried to promote tractor mechanisation through tractor hire schemes and tractor credit schemes. In fact this favouring of motorised mechanisation could have lead to degrading of animal traction to a "backward technology" (Oudman, 1993). Further, the acquisition and maintenance of the animal traction package may require credit, veterinary and extension services and after sale services of the implements which may not be readily available to the farmers. In general farmers who adopt the use of animal traction become more dependent on the outside world. Other constraints to the use of animal traction were lack of know-how of the farmers, keeping and foddering draft animals and maintenance and repair of the implements.

2.2 Yield, profitability and efficiency effects of using animal traction

As noted by Kosura (1983), there is no common agreement among researchers about how mechanisation affects crop yields. This stem partly from the methodologies used in the studies, and partly due to the differences between the various study areas with regard to technical and socio-economic factors. The effects of mechanisation on yields can be viewed as; direct effects (higher yields *ceteris paribus*) and indirect effects (increased timeliness of carrying farm operations, application of manure from draft animals). Direct effects of mechanisation have not shown consistent results. Some studies indicate that use of higher levels of mechanisation increase yield due to the subsequent high quality land preparation and timeliness of farm operations (Inukai, 1970; Kosura, 1983; Olomola, 1998; Rao 1972). Others show no significant difference in yield between those who mechanise farm operations and those who do not (Barret *et al*, 1982; Binswanger, 1978; Mutebwa, 1979; Sargent *et al*, 1981). The indirect effects of mechanisation are less disputed for instance, timeliness of carrying out farm operations. Mechanisation is seen as facilitating a more effective use of high yielding inputs.

The overall low levels of use of animal traction technologies in sub-Saharan Africa have raised doubts about its profitability and sustainability in small farms (Starkey, 1994). However, its persistence and spread in Africa suggest that it can be profitable. Kosura (1983) did a study in Western Kenya to evaluate three alternative methods (human, oxen and tractors) of land preparation for maize production. The study sample was divided into four groups consisting of; the hoe group, owned oxen group, hired oxen and hired government or private tractor group. Apart from differences in farm power sources, the farms also differ in fundamental aspects of production such as differences in input application levels. This causes a difficulty in interpreting results. All other factors are not held constant. To overcome this problem two approaches could be applied; covariance analysis or before and after mechanisation yields comparison. The latter method is inappropriate most of the time due to lack of data for comparison. Kosura (1983) applied covariance analysis to isolate direct effects of mechanisation. Covariance analysis is a way of testing whether there are significant differences in the behavioural relationships between sets of observations. In Kosura's study, the three groups (hoe, owned oxen and hired oxen) were found to be statistically different (at 5% level) from each other in the way the included variables explained variation in the maize yield. The study employed both the Cobb-Douglas (log-linear form) and linear production functions to analyse yield of the different groups identified. The results of the study showed that those who used owned oxen achieved higher yields than those who hired oxen or tractors. Those using the hoe achieved the lowest yields and the lowest labor productivity. The use of the production function approach, however, is thought by some researchers as less appropriate for studying efficiency of individual farms due to its inherent assumption that firms have identical ratios of inputs and outputs (Adesina and Djato, 1997; Ali and Flinn, 1989). Instead, the profit function approach is thought to be more appropriate because it takes into account that individual firms face different prices and they have different factor endowments (Adesina and Djato, 1997; Ali and Flinn, 1989; Khan and Maki, 1979; Knox *et al*, 1999; Kilungo, 1999; Llewelyn and Williams 1996; Yotopoulos and Lau 1971; Yotopoulos and Lau 1973). In his study Kosura (1983) employed partial budget analysis to evaluate profitability of alternative forms of mechanisation. A maize production budget for each of the different categories of farms was developed for a representative farm in the region. The results of partial budget analysis showed that use of owned oxen (for land preparation) for growing of maize was more profitable than use of hired tractor, hired oxen or the hoe. Olukosi and Ogunbile (1994) did a study in nothern Nigeria, to determine the requirements and distribution of labor under different modes of weeding technologies in production of maize and sorghum. The results showed that labor requirements were reduced by 40% in maize and 59% in sorghum as a results of oxen use and 36% in maize and 27% in sorghum due to herbicide use. Through the use of a partial budget approach, ox cultivation was found to be a better alternative in improving profitability of weeding technology. A study done by Barret *et al* (1982) in Eastern Upper Volta (West Africa) showed that yields per hectare for 'traction' farmers were not significantly higher than those of hoe farmers except for some minor crops. However, the yield effects may have been understated because data was averaged from both plowed and unplowed fields. Olomola (1998) did a study on choice and productivity effects of animal traction in the semi-arid zone of nothern Nigeria and found that use of animal traction generated positive productivity effects in the study area. He found that land productivity was higher for farmers who used animal traction for all crops he considered except sorghum and cowpeas.

The study by Kosura was done about 20 years ago in the Western region of the country. Since then the economic environment has significantly changed especially with liberalisation of the input and output markets. Further, research indicate that on average farmers in the current study area (central Kenya) are better off economically than their counterparts in western Kenya. It therefore follows that their production patterns (for example levels of input use) are likely to be different. The current study is expected to show how using animal traction affects the efficiency of maize production in Kirinyaga district in central Kenya.

2.3 The Concept of Efficiency and its Measurement

Efficiency is an elusive concept, defined and therefore measured differently by different disciplines. The economist, the engineer and the policy maker for example all define efficiency differently. Policy implications arising from economic efficiency are important to both micro-and macro-level decision-making. Efficiency, as defined by Farrell (1957) in his pioneering work on the subject is the ability to produce a given level of output at the lowest cost. Farrell (1957) clearly distinguished between technical efficiency and price or allocative efficiency. Technical efficiency according to him refers to the proper choice of production function among all actually in use by firms in the industry. Price efficiency on the other hand refers to the proper choice of input combinations. Economic efficiency combines both. Technical efficiency is purely an engineering concept while price efficiency is purely a behavioural concept. It is possible for a firm to have either technical or allocative efficiency without having economic efficiency (Adesina and Djato, 1997). Technical and allocative efficiency are necessary, and when they occur together are sufficient for achieving economic efficiency (Yotopoulos and Nugent, 1976). Doll and Orazem (1978) define economic efficiency as the combination of inputs that maximise individual or social objective. Economic efficiency has to meet both the necessary and sufficient conditions. The necessary condition is met if in the production process there is no possibility of producing the same amount of product with fewer inputs and when there is no possibility of producing more output with the same amount of inputs. The sufficient condition encompasses both individual and social goals and values for example, profit maximisation.

Many researchers have used the production function as a tool to study economic efficiency. Some researchers have used the production function to separately estimate technical efficiency and allocative efficiency. The production function approach assumes that all firms have identical ratios of inputs and outputs hence only one point on the production surface would be observable. However, as noted by Ali and Flinn (1989), a production function approach may not be appropriate when estimating the economic efficiency of individual firms because they face different prices and have different factor endowments. Due to these differences the firms will have different best practice production functions and thus, different optimal operating points. Adesina and Djato (1996) in a study on relative efficiency of women as farm managers, have pointed out that reliance on production function methods to test for allocative and economic efficiency have been criticised as suffering simultaneity bias because input levels are endogenously determined. Quisumbing (1994) has noted that problems of endogeneity can be avoided by estimating profit or cost function instead of production functions. A firm's profit is a function of prices of inputs, price of output and the level of fixed inputs, which are all exogenous from the firms' point of view.

Yotopoulos and Lau (1971) argue that the minimum requirements for assessing economic efficiency in an industry are that the criteria should:

1. Account for firms that produce different quantities of output from given set of measured inputs of production. This is the component of differences in “technical efficiency”
2. Take into account that different firms vary in their ability to maximize profit, that is, in equating the value of the marginal product of each variable factor of production to its price. This is the component of price (allocative) efficiency and
3. Account for the fact that a firm farm may operate with different sets of market prices for both inputs and outputs.

It is clear that two firms of equal technical efficiency which have successfully maximised profits would still have different values of profits so long as they face different prices. The profit function becomes the operationally ideal tool that allows for encompassing these requirements into a single framework for evaluating economic efficiency. Yotopoulos and Lau (1971) used the profit function to compare efficiency of small and large farms in India. They further suggested that the same reasoning could be applied to compare different groupings such as owners versus share tenants or adopters of a new technology versus non-adopters. As noted by Khan and Maki (1979) differences in economic efficiency among groups of farms (say users of a given technology and non-users) may result from variations in technical efficiency (larger output with equal amounts of inputs) and price efficiency (higher profits). Profit maximisation is implied if the value of marginal product of each variable input is equal to its price. Thus we test the relative economic efficiency of the two groups of firms by comparing their actual profit functions. The current study will adopt the profit function approach to analyse the effect of using animal traction on economic efficiency of the sample farms in the study area.

2.4 The Concept of Household Labor-time Allocation

Work on economic theory of the household has led to greater recognition of household members' time, as both a consumption good and a productive resource (Allan, 1986; Evenson, 1978; Leone, 1991; Rahji, 1999). In fact, for the rural household, it is the dominant household resource (Evenson, 1978). An important application of this theory as noted by Allan (1986), is that time and cash are substitutable. Time can be “sold” to generate cash or non-market goods and it can be “purchased” by spending cash on time saving inputs. A household may allocate its time for production purposes, hire it out to earn wages or use it for leisure. Therefore, a technology that reduces the time spent on the farm is desirable because the saved time can be used to earn income elsewhere or to increase leisure. However, as noted by Rahji (1999), the use of time allocation to model economic behaviour has only received the attention of researchers recently.

Rahji (1999), observed that although there are intercultural and internal differences in the relative importance of time allocation to household activities, a detailed family time use shows that there are three principle sectors within the rural households. These are farming activity sector, non-farming commercial activity sector and the non-monetised home production activity sector. These activities which are closely related compete for time and decision-making from the same household unit. Farm work includes food and livestock production activities such as land preparation, planting, weeding, fertiliser application, herding, milking and other related activities. Market work includes various types of income generating activities such as wage employment, practice of profession and marketing/trading. Under home work are childcare, food processing, cooking, washing, fetching water, fuel wood collection, cleaning/sweeping and maintenance work at home. In a rural household setting, these activities are distributed among the members of the household based on the existing pattern of gender division of labor. The analysis of intra-household economics has been receiving increasing attention over time as planners and policy makers have become increasingly aware that neither poverty nor development interventions affect all individuals uniformly.

In most of the developing countries gender division of labor leaves women relatively short of time than men given their role in agricultural production, domestic production and other market activities (Lynn *et al,* 1995). This situation ultimately hurts the family because women have less time to provide “care” to their families. “Care” activities have been identified by Lynn *et al* (1995) as “paying adequate time and attention to meeting the physical, mental and social needs of growing children and other household members”. “Care” affects even the food security of the family through feeding practices such as breast-feeding and preparation of nutritious food for weaned infants and others in the family. It also affects the family through health and hygiene practices such as the bathing of children and washing of hands before food preparation. The situation is further compounded by the low farm incomes which force farm households to have non-farm income to supplement the farm incomes (Rahji, 1999). As noted by Lynn *et al*, 1995), there is need to develop technological innovations that relieve women’s’ time. The current study will investigate how use of animal traction impacts on the inter-gender labor time allocation within the household.

2.5 Animal Traction and Labor Use

As noted by Kosura (1983) there is no agreement among researchers about the effects of farm mechanisation on labor use. Some researchers argue that mechanisation is not good in developing countries due to its labor displacing effects. On the other hand some researchers argue that use of mechanisation leads to increased acreage, which consequently leads to increased labor requirements which may eventually lead to an increase in hired labor. The latter argument means that higher levels of mechanisation would lead to increased rural employment, which is desirable in developing countries.

Research has shown that mechanisation of whatever form if applied for land preparation leads to increased acreage, hence increased labor requirements in the subsequent operations. A study by Kosura (1983) in Western Kenya showed that mechanisation whether by tractor or by oxen reduced the time required to prepare land, but it increased the labor demands in the subsequent operations. The study however did not analyse how the households met the increase in labor requirements. There are two possible ways of meeting the increased labor requirements; the household may have to increase its labor input or may hire labor from outside the household. In the case where the increases in labor requirements are met from household's own stock of labor, sharing between genders within the household is important. With the prevailing labor division by gender in the rural households, women have a dual role both as producers as well as caretakers. Therefore, increasing their farm time may negatively impact on their role as caretakers in their homes. The increase in farm labor time may also decrease the chances of the household members participating in non-farm activities that provide supplemental income for the household.

In the past most research on labor utilization has focused on organization of work on farms, including number of hours worked by household members, seasonal patterns of labor use and amounts of hired labor. The results have been useful in comparing the level of utilization or under-utilization of labor by region, ecological zone and farming system. However, as noted by Eicher and Baker (1982), and Deere (1982) few studies have provided insights into adjustments in labor use resulting from introduction of new technologies. This information is important because the assumption that a technology will impact on all household members the same way does not always hold. Time allocation research should be built into the technology design to avoid over-burdening some household members.

Barret e*t al* (1982) carried out a study in Upper Volta (West Africa) to determine the impact of animal traction on household labor allocation. The study used descriptive statistics to compare labor allocation between ‘hoe’ households and ‘traction' households. The study evaluated the differences in labor allocation between the two groups in the relative amount of time spent on farm and off-farm activities. The study reported that even though savings in farm labor associated with using animal traction were somewhat offset by additional labor used to maintain the draft animals, total labor savings were not eliminated. Use of animal traction reduced the average labor input per hectare by 25% with 68% of the reduction in labor input being in the land preparation. The study found that women in traction households spent more time in the farm than their counterparts in the hoe households. Women in ‘traction’ households spent proportionately less time on household chores compared to women in the hoe households. In this respect however, there was effect of demographic structure because the ‘traction’ households were larger and had more women to share in household chores.

It would be interesting to find out whether similar labor allocation patterns emerge when households in Kenya move from the use of the hoe to the application of animal traction in Kenya. This study will shed light on whether or not use of animal traction has same or different effects on inter-gender labor allocation here in Kenya as in Upper Volta. Further, the current study unlike the one carried out by Barret (1982) will consider other factors that are thought to influence farm labor-time allocation. In addition to the form of farm mechanisation, personal, socio-demographic, market and farm characteristics are considered to influence labor-time allocation (Rahji, 1999).

CHAPTER III

3.0 METHODOLOGY

3.1 Conceptual Framework

The study conceptualised that farmers who use hand tools in carrying out farm operations are constrained in the process of crop production through poor timeliness, inability to break the hard pan, limited land areas cultivable and drudgery. Mechanising farm operations is one of the ways to break these constraints. Farmers who mechanise farm operations are more likely to achieve the benefits of: -

(i) Timeliness of carrying out operations such as land preparation, planting and weeding.

(ii) Breaking of the hard pan

(iii) Increased acreage

For the majority of small-scale farmers, use of tractor is hypothesised not to be economically viable due the high initial cost of purchase as well as high maintenance cost. For the small-scale farmers, use of animal traction is viewed as an appropriate, viable and sustainable method of farm mechanisation. Use of animal traction is conceptualised to facilitate use of other inputs in the production process in order to intensify and increase agricultural production (Rwelamira and Sylwander, 1999). It is therefore hypothesised that use of animal traction enhances the efficiency of agricultural production.

It is further conceptualised that animal traction is not a gender neutral technology as observed by some researchers such as Barret *et al*, 1982; Marshall and Sizya, 1994; Okalebo, 1996; Rwelamira and Sylwander, 1999; Sosovole, 1994; Stevens, 1994 and Sylwander, 1994. Therefore, there is need to consider the gender aspects of the technology. It is hypothesised that use of animal traction leads to increases in acreage under cultivation compared to when hand tools are used. An increase in land acreage has an implication on how the extra workloads are shared by the household members given the existing patterns of labor allocation. In this regard use of animal traction is conceptualised to affect inter-gender labor allocation patterns within the household.

Observations reveal that with the prevailing patterns of gender division of labor women do more work in all agricultural operations such as land preparation, planting, weeding and harvesting (Lynn *et al*, 1995; Rwelamira and Sylwander, 1999). Apart from the agricultural work women are also involved in "care" activities within the household and therefore a technology that relieves their time is desirable (Lynn *et al,* 1995). This study therefore will seek to establish how use of animal traction affects inter-gender labor allocation within a household.

3.2 Analytical Procedures

Three analytical procedures were used to assess the efficiency of maize production and differences in labor allocation between 'hoe' households and 'traction' households in the area of study. These procedures included descriptive statistics, profit function analysis and farm labor-time allocation function analysis. These procedures are described in detail in the following sections.

3.2.1 Descriptive Analysis

This method involved calculating means and percentages of the various variables considered in the study. This procedure was useful in analysing the socio-economic characteristics of the 'hoe' and 'traction' households.

3.2.2 Profit Function Analysis

The profit function developed below closely follows the one formulated and used by Yotopoulos and Lau (1971).

To formulate the profit function model, a firm with a production function shown below was assumed.

$Y = F(X_{1,} \ldots, X_m; Z_1 \ldots, Z_n)$ (3-1)

Where Y is output, X_i represents variable inputs, and Z_i represents fixed inputs of production. The formula for profit can be written as follows:

$$P' = p.F(X_1, \ldots, X_m; Z_1, \ldots Z_n) - \sum_{i=1}^{m} q_i' X_i \quad (3\text{-}2)$$

Where P' is profit, p is the unit price of output, and q_I' is the unit price of the i^{th} variable input. The fixed costs are ignored because: (1) they do not affect the optimal combination of the variable inputs and (2) majority of Kenyan small scale farmers own most of their fixed inputs (Kilungo, 1983) and can therefore make decisions based on Gross Margins.

It is assumed that a firm maximises profits given the levels of its technical efficiency and fixed inputs. Therefore, the marginal productivity conditions for such firms are;

$p \ \partial F(X;Z)/ \partial X_i = q_I'$ i = 1,…m   (3-3)

By using the price of the output as numeraire we may define $q_i \cong q_I' /p$ as

normalised price of the i^{th} input. Hence, equation (3-3) can be written as:

$\partial F / \partial X_i = q_i$ I = 1,…,m.   (3-4)

Normalising input prices by the price of the output we can rewrite (3-2) as (3-5)

where P is defined as the " Unit-Output-Price" Profit (or UOP profit).

$$P = P'/p = F\,(X_1, \ldots, X_m; Z_1, \ldots Z_n) - \sum_{i=1}^{m} q_i x_i \quad (3\text{-}5)$$

Using equation (3-4) we may solve for the optimal quantities of variable inputs

denoted X^*_i's, as functions of the normalised prices of the variable inputs and of

the quantities of fixed inputs,

$X^*_i = f_i\,(\mathbf{q}, \mathbf{z})$, i= 1,…,m (3-6)

Where **q** and **z** are the vectors of normalised input prices and quantities of fixed inputs, respectively.

By substituting (3-6) into (3-2) we obtain the “profit function”

$$\prod = p\,[F(X^*_1, \ldots, X^*_m; Z_1, \ldots Z_n)] - \sum_{i=1}^{m} q_i X^*_i \quad (3\text{-}7)$$

$$\prod = G\,(p, q_1 \ldots, q_m; Z_1, \ldots Z_n) \quad (3\text{-}8)$$

It should be noted that the profit function gives the maximised value of the profit for each set of values $\{p, q_1 \ldots, q_m; Z_1, \ldots Z_n\}$. Since the term within square bracket on the right-hand side of (3-7) is a function only of **q** and **z**, we can write

$$\prod = p\,G^*\,(q_1, \ldots, q_m; Z_1, \ldots Z_n) \quad (3\text{-}9)$$

Therefore, the UOP profit function is given by

$$\prod^* = \prod/p = G^*\,(q_1, \ldots, q_m; Z_1, \ldots Z_n) \quad (3\text{-}10)$$

It can be observed that maximisation of profit in (3-2) is equivalent to maximisation of UOP profit in (3-5) in that they yield identical values for the optimal X^*_i's. Therefore, π^* in (3-10) indeed gives the maximised value of UOP profit in (3-5). We use the UOP profit function $\prod^*$ (profit normalised by output price) because it is easier to work with than $\prod$ as noted by Yotopoulos and Lau (1971) because variations in $\prod^*$ are explained directly by normalised prices of variable inputs and levels of fixed inputs. It is clear that given $\prod^*$ one can always find $\prod$, and vice versa.

3.2.3Testing Relative Economic Efficiency

Economic efficiency encompasses both technical and price efficiency. We can talk about relative efficiency only by comparing two or more firms (Yotopoulos and Lau, 1971). As noted by Knox *et al* (1999), if two classes of firms have different degrees of technical and price efficiency and face similar prices in both input and output markets, the firm class with higher profits is considered to be more economically efficient. The approach is that, given comparable endowments, identical technology, and normalised input prices, the UOP profit of two firms should be identical if they both maximised profits. If one firm is more price efficient, or more technically efficient, than the other, the UOP profits will differ even for the same normalised input prices and endowments of fixed inputs.

Following Khan and Maki (1979), Kilungo (1999), Knox *et al* (1999), Yotopoulos and Lau (1971) and Yotopoulos and Lau (1973) we specify at this stage the appropriate profit function to be used in testing the relative economic efficiency. For this purpose we can begin from a Cobb-Douglas or any other forms of a production function. Tests done by Yotopoulos and Nugent (1976) have shown Cobb-Douglas function to be superior.

A Cobb-Douglas production function with decreasing returns in the “m” variable inputs and with “n” fixed inputs is given by

$$V = A \left(\prod_{i=1}^{m} X_i^{\alpha i}\right) \left(\prod_{j=1}^{n} Z_j^{\beta j}\right) \quad (3\text{-}11)$$

The UOP profit function, through a series of computations gives the actual UOP profit functions as shown by Yotopoulos and Lau (1971):

$$\Pi_\alpha^i = (A^i_*) \{\prod_{j=1}^{m} (q_i)^{1 - \alpha j (1 - \mu) - 1}\}. \{\prod_{j=1}^{n} (Z_j^i)^{1 - \beta j (1 - \mu) - 1}\} \quad i = 1,2 \quad (3\text{-}12)$$

Where Π_α^i is actual UOP profit (total revenue less total variable cost[4], divided by the price of output). The model is specified in terms of normalised input prices (Kilungo, 1999; Yotopoulos and Nugent, 1976). Assuming that farmers maximise expected profits, this normalised profit function, with the conditional factors included as fixed inputs, is used to analyse the farmers' behaviour. By reorganising the terms, and taking natural logarithms of the equation of the two types of firms, the final estimation equation (a Cobb-Douglas case of the profit function) becomes:

$$\text{Ln}\ \pi = ß_o + ß_1\ \text{ANTRAC} + ß_2 \ln \text{WAGE} + ß_3 \ln \text{LPFERT} + ß_4 \ln \text{LMACR} + ß_5 \ln \text{LSEED} + \mu \quad (3\text{-}13)$$

Where π is normalised profit in Kshs, defined as total revenue less total costs (all inputs except land) normalised by the price of maize. ANTRAC is a dummy variable with value 1 for 'traction' farms and 0 for 'hoe' farms. WAGE = Wage rate in Kshs per Manday normalised by the price of maize. LPFERT is the price of fertilisers in Kshs normalised by the price of maize. MACR is the Acreage under maize in acres. LSEED is the price of seeds in Kshs normalised by the price of maize. While μ is the error term and $ß_i$'s are the regression coefficients.

[4] Gross margin is used as proxy for profit

This expression of p (profit) in logarithmic form makes it possible for the analyst to use the least squares estimation method using the assumption that the error term is independently distributed from one farm to another with a mean zero and a finite variance. Hence, the estimation is done using the ordinary least squares (OLS). In the Cobb-Douglas formulation, examining the coefficient of the group dummy variable makes the comparison of relative efficiency of the two groups of firms possible. The test is that the coefficient of the dummy variable is not significantly different from zero.

3.2.4 Hypothesis Testing under Profit Function Analysis

Hypothesis tested was that there was no significant difference in farm efficiency between farmers who use animal traction and those who use hand tools. This was done by testing the statistical significance of $ß_1$ coefficient. The hypothesis of relative economic efficiency can be evaluated in terms of the constant by which the two profit functions of 'Traction' group and 'Hoe' group differ as shown by (Adesina and Djato, 1997; Khan and Maki, 1979; Knox *et al*, 1999; Yotopoulos and Lau, 1971; Yotopoulos and Lau, 1973; Yotopoulos and Nugent, 1976). If H_0 was not rejected it meant that there was no difference between the economic efficiency of ' traction' group and 'hoe' group.

3.2.5 Covariance Analysis

Covariance analysis was carried out to isolate the direct effects of mechanisation on farm profits. Apart from the power source, "traction" and "hoe" farms may differ in other fundamental aspects of production. This may lead to difficulty in interpreting results because the increase in profit may not all be attributed to the power source. Covariance analysis involves estimation of separate profit functions for “traction” and “hoe” farms and comparing whether the included independent variables are significantly different in the way they explain variation in the profit. Covariance analysis is carried out through the Chow F-test. The Chow F-test, more commonly known as the “Chow test” is a simple way to test if the underlying parameter values for data sets change across specified subsets of that data, for example, between two different farm groups. The chow test compares the regression sum of squares (RSS) from a restricted (RSS_R) model (that assumes that the parameters are constant across data subsets) with the RSS from an unrestricted model (that allows the parameters to vary across data subsets). The unrestricted RSS is obtained by running two separate regressions for the two data subsets and summing the resulting RSSs ($RSS_U = RSS_{'hoe'} + RSS_{'traction'}$). The test statistic (estimated F) was given as:

$F = [(RSS_U - RSS_R)/ df_n]/ [RSS_U/ df_d$ (3-14)

3.3 Variables used in the profit function

In this section, the dependent and independent variables included in the profit model are defined.

3.3.1 The dependent Variable

Profit from maize production (Π)

Profit obtained from maize production in the short rain season of 2001/2002 normalised by the price of maize was the dependent variable. This variable was defined as the gross revenue less the total variable costs. Since it was not possible to exhaustively quantify all the major costs, 'gross margin' was used as a proxy for profit. The gross margin was calculated as the difference between the gross revenue and variable costs. The gross revenue was obtained from multiplying the total maize production produced in the short rain season of 2001/2002 by the price received by the farmer from private sales (to neighbours or other buyers). The variable costs included the cost of labor, fertilisers, pesticides and seeds.

3.3.2 The Independent Variables

The following independent variables were included in the profit function:

Wage rate (WAGE)

This variable was defined as the amount of money in Kshs/Manday that was paid out to hired labourers to work in the maize plots normalised by the price of maize.

Price of Fertiliser (LPFERT)

This variable was the price of fertiliser in Kshs normalised by the price of maize.

Area Planted Under Maize (LMACR)

This variable included the area under maize in (Acres).

Dummy for farm mechanisation (ANTRAC)

This variable included the form of mechanisation that was employed for major agricultural operations such as land preparation and weeding for maize enterprise. For farmers that applied animal traction to carry out the agricultural operations they were assigned a value **1** while those that used hand tools were assigned a value **0.**

Price of seeds (LSEED)

This variable was defined as the price of seeds in Kshs normalised by the price of maize.

3.4 Farm Time-Labor Allocation Functions

In order to estimate the relationship between the time allocated to farmwork and the various personal, socio-demographic, market and farm characteristics, labor allocation functions need to be estimated (Rahji, 1999; Thapa, 1992). The labour allocation functions are obtained by regressing the independent variable (number of hours spent on a given activity) and the proposed explanatory variables. The choice of the regression model depends on whether or not the dependent variable is censored or not. When the dependent variable has a number of values clustered at a limiting value, usually zero the Tobit analysis is preferred (McDonald and Moffit, 1980). The Tobit technique uses all observations, both those at the limiting value and those above it, to estimate a regression line, and it is preferred in general to those techniques that estimate a line only with the observation above the limit. On the other hand if the dependent variable is not censored other regression techniques such as ordinary least squares (OLS) can be applied. Rahji (1999), in a study carried out in southwestern Nigeria observed that time allocated by males and females to farm work is likely not a censored variable in the farming set-up. This assumption is plausible because in a rural farming set-up it is more likely than not that both males and females will be involved in some form of farm work. In contrast to the study by Rahji (1999) in the current study farm time by both male and female was considered a censored variable, because of many cases of males and females farmers who did not allocate any of their time to farm work.

The household time allocation function is expressed as follows;

$T_j^k = f(X_1, X_2, \ldots, X_n)$ (3-15)

Where:

T= Time allocated to farm work

j= Activity (farm work)

k= Gender of the participant (either Male or female)

X_i = represent various personal, socio-demographic, market and farm characteristics

In this study, farm-time labor use functions by gender for farm work were estimated. Following Rahji (1999) and Thapa *et al* (1992) the study assumed a linear relationship between the time allocated to farm work and the set of explanatory variables.

Tobit analysis was applied to analyse the farm labor use function. A Tobit model analyses the potential participant's decision of whether or not to participate and the hours allocated to the activity after the participation decision has been made. The parameters of the Tobit model were estimated as follows:

$$T^k = \beta_o + \beta_l AGE + \beta_2 EDUC + \beta_4 FSIZE + \beta_5 FINC + \beta_6 HLAB + \beta_7 DEPEND + \beta_8 ANTRAC \qquad (3\text{-}17)$$

3.4.1 Variables used in Farm labor-Time Allocation Function

In this section, the dependent and independent variables included in the farm labor-time allocation model are defined.

3.4.2 The dependent variables

Female Farm Labor Time (FFLAB)

This variable was defined as the man-days of female labor input in the maize enterprise. The variable considered the female labor input in land preparation, planting, weeding and harvesting of maize. The value was measured in man-days in the 2001/2002 short rain season. One man-day was equated to an adult working 6 hours in the field. Women and men were considered to be participating equally in the field. There was found no need to give them a weighting of half as some authors have done in the past.

Male Farm Labor Time (FMLAB)

This variable was defined as the man-days of male labor input in the maize enterprise. The variable considered the male labor input in land preparation, planting, weeding and harvesting of maize. The value was measured in man-days in the 2001/2002 short rain season.

3.4.3 The independent variables

Age (of female or male)- (M/FAGE)

It was hypothesised that the older the farmer the less the time he/she will devote to farm work. Older farmers are assumed to be physically weak hence have less energy to spend on the rigorous operations on the farm. This variable was defined as the age in years (Yrs).

Years of formal education (of female or male)- (M/FEDUC)

An educated farmer was expected to be able to use his time to attain the greatest income. Therefore, the educated farmers were expected to allocate their time between home, farm and market work so as to obtain maximum income. This variable was defined as the number of years spent in formal schooling (Yrs). Educated farmers are most likely to expend less time in the farm because they are likely to earn more outside the farm either in employment or in business.

Farm income (FINC)

It was conceptualised that adequate and commensurate farm income may translate to incentive for more farm time. On the other hand spending more time in the farm may not necessarily translate into higher because the farmer has little if any control over the prices he/she gets for his/her produce. This variable was defined as the amount in Kshs that was earned from sale of maize in the 2001/2002 short rain season.

Farm size (FSIZE)

It was assumed to be the proxy for wealth. A large farm may mean higher income *ceteris paribus.* Farmers with large pieces of land may or may not spend more time in the farm than those with smaller pieces because it is assumed they are capable of hiring labor from outside. This variable was defined as farm size in acres that a farmer owned.

Hired labor (HLAB)

The higher the level of hired labor the less the time spent on the farm work. This variable is defined as the amount of hired labor in man-days used in the maize enterprise during the 2001/2002 short rain seasons.

Number of dependants (DEPEND)

Dependants are defined as the members of the household (both children and the aged) who are not actively involved in farm work or market work. They largely depend on other family members for the provision of their necessities. Children of less than 14 years of age and adults over 60 years of age were classified as dependents. However, this general rule was complemented by actual interview to determine the actual number of family members who were dependants. The number of children was hypothesised to affect farm time of women as child rearing and care is almost an exclusive preserve for women. Further, the children if many, will compete for women's farm time. With more dependants, men are expected to work more to meet their needs.

Dummy for farm mechanisation (ANTRAC)

It was hypothesised that use of animal traction results in labor time reallocation between genders in the households. Households that use animal traction were assumed to have different time allocation patterns from those that use the hoe. Use of animal traction was hypothesised to increase farm time due to the increased acreage. Further, it was hypothesised that use of animal traction was likely to increase the farm labor-time of women in the household due to the existing gender division of labor.

3.4.4 Hypothesis Testing under Farm labor-Time Allocation Function

The main hypothesis tested was that the use of animal traction does not significantly affect requirements for women’s farm labor-time. This was done by testing for statistical significance of the coefficient β_8 in the equation 3-17.

The hypothesis testing took the following form:

$H_0 : ß_8 = 0$

$H_A : ß_8 \neq 0$

3.5 Data Sources and Method of Data Collection

Farm level data for this study were collected using a structured questionnaire. Two trained enumerators administered the questionnaires. Information gathered included both quantitative and qualitative forms of data from the farms. These included the acreage under maize in the previous season, amounts of fertilisers and other agro-chemicals used in maize production, family and hired labor input into maize production and inter-gender labor time allocation for farm work, home work and market work. Initially, a sample of 80 farmers were interviewed but 5 questionnaires were found unsuitable due to gross internal inconsistencies and therefore, only 75 were included in the final sample for analysis.

3.5.1 Sampling procedure

A combination of multi-stage random and purposive sampling procedures were applied to obtain a sample of 80 farmers that were interviewed in this study. First, three divisions out of the four divisions of Kirinyaga district were randomly selected namely; Gichugu, Mwea and Ndia. In the next stage, two locations were randomly selected in each division. The selected locations were Baragwi and Karumandi in Gichugu division, Mutithi and Murinduko in Mwea division and Mutira and Inoi locations in Ndia division. At the location level, purposive sampling was applied to obtain a sample containing both 'traction' and 'hoe' group. A total of 80 farmers were sampled for interview. Out of the final 75 questionnaires included in the final analysis 43% (32 farmers) were from the 'hoe' group and 57% (43 farmers) were from the 'traction' group.

3.5.2 Difficulties and limitations of Data Collection

The major limitation of the study was that data was collected from farmers' through the recall method because small-scale farmers rarely keep records of their farming activities. This procedure introduces inaccuracies in the data collected. The problem of inaccuracies in the data was addressed through careful cross-checking within the questionnaire. Further, the information provided by farmers though not very accurate provides the researcher with the general pattern of the farmers' behaviour. Based on this information it was still possible to make useful inferences about farmers behaviour.

Labor-time allocation data was collected in this study using subjects' self-report which is one of the two major approaches commonly used in collecting time allocation data. The other approach is direct observation of the subject. An ideal approach to collect time allocation data should be technically possible and ethically tenable. This means that it should neither overburden the researcher in terms of time and resources, nor over encroach the respondents freedom on what to report or what not to report. Many researchers prefer to use the informant as an observer of his or her own behaviour. This solves most ethical issues because the informants decide which information to report and which not to report. It also saves a great proportion of the researchers time. However, the method results in low correspondence between the informants' report of their own behaviour and that same behaviour as measured by outside observers (Johnson, 1990). Direct observation is the most straightforward approach to study how people spend time. The focus in direct observation is on specific individual or a close knit group, for example a household. However, this method is limited to a small number of individuals and to a short period of time. Furthermore, such data may not be representative of the community and of the varying seasons of the year.

Due to limitations of time and finances, the current study used the subjects' self-report method where the informants were asked to describe the overall pattern of time allocation. The major problem with this method is the accuracy of the data.

To minimise error in the recall, a shorter and more recent period (the latest agricultural season preceding data collection) was considered in this study.

CHAPTER IV

4.0 RESULTS AND DISCUSSION

4.1 Problems experienced in Estimation

As noted by Greene (1993), it is rare that the data that a researcher has in hand for estimating a regression model conform exactly to the theory underlying the model. Any number of problems will arise, even in the most carefully designed survey. In this section the most commonly experienced data problems and their implications for estimation are discussed. The section also highlights measures that were taken to alleviate the consequences of data problems that were experienced.

Multicollinearity

Multicollinearity refers to the presence of linear relationships (or near linear relationships) among the explanatory variables (Koutsoyiannis, 1973). Since economic data is unexperimental many econometric variables tend to move together in a systematic way and hence are termed collinear. As a result, hypothesis testing becomes weak so that diverse hypotheses about parameter values cannot be rejected (Kennedy, 1985). Multicollinearity is a sample problem and as such it cannot be tested. Rather, what is testable is the degree of multicollinearity in the exogenous variables. The seriousness of its effect depends on the degree of intercorrelation as well as the overall regression coefficient. As such, standard errors and the overall coefficient of determination (R^2) may be used for testing for multicollinearity.

Multicollinearity was examined through inspection of signs and magnitudes of the parameter estimates and use of partial correlation coefficient. Kennedy (1985) states that a value of 0.8 or higher in one of the correlation coefficients indicates a high correlation between the two independent variables to which it refers. Based on this criterion, the partial correlation coefficients indicated that FAGE and FEDUC in the Female Farm Labor Time Allocation were highly correlated (see appendix 2). As noted by Mukras (1993), the presence of high multicollinearity implies that the estimates of coefficients will be imprecise owing to large variances of the estimators.

It was observed that older female farmers had lower levels of education compared to younger ones. This has a historical perspective because in pre-independence times most women did not attend formal schooling. Therefore, it is plausible that female farmers' education level is closely related to her age in the area of study.

The problem of multicollinearity implies that it is not possible to hold other things equal when we vary one regressor and therefore the interpretation of regression becomes invalid. As noted by Mukras (1993), there is no easy solution to the problem of multicollinearity, on one hand including the collinear variables will increase the variance of the estimator while exclusion of the variable will introduce bias in the estimator. For the case at hand, the individual effects of the variables have policy implication and are not just for forecasting in which case the current relationship would be assumed to hold in future. Therefore, it is a lesser evil to drop one of the variables from the model in this case FAGE was dropped.

Heteroscedasticity

One of the major problems with cross-sectional data is the tendency of the disturbances to vary with some or all of the explanatory variables (Kennedy, 1985). This violates the constant variance assumption of the disturbance term, resulting in heteroscedasticity. Heteroscedasticity renders the estimated ß's inefficient and thus invalid for use in making predictions about the dependent variables (Greene, 1993).

This study tested for heteroscedasticity in the three estimated models using the likelihood ratio (LR) statistic. The null hypothesis was that the model in question is homeoscedastic against the alternative that it is heteroscedastic. The LR statistic is similar to the F test in OLS. It is asymptotically distributed chi-square with k degrees of freedom, where k is the number of independent variables in the model. The LR statistic was calculated from;

$$LR = -2(Ln_{het} – Ln_{hom})$$

Where Ln_{het} and Ln_{hom} are the heteroscedastic and homoscedastic log-likelihood functions respectively. The computed LR value for the female farm labor-time allocation model was -7.9666 while the tabulated X^2 value, at α=0.01 and k = 8 was 20.08 on the other hand the computed LR value for male farm labor-time allocation was –0.367. The computed LR value for the profit function model was –1.3161 while the tabulated X^2 value, at α=0.01 and k = 5 was – 13.32. Since the calculated LR values in the three cases were less than the tabulated X^2 value, the null hypothesis of homoscedasticity could not be rejected for the three models. These results are reported in appendix (3).

Goodness of Fit

A goodness-of-fit measure is a summary statistic indicating the accuracy with which a model approximates the observed data. For the case of the profit function the goodness of fit was measured using R^2 .The values of R^2 lie between 0 and 1, where 1 indicates a perfect fit. The value of R^2 was found to be 0.88 as shown in Table 4-5. To measure the goodness-of-fit in qualitative response models, Greene (1993) suggested use of likelihood ratio index (LRI). The LRI (also called McFadden R^2 or pseudo R^2) is analogous to the R^2 in a conventional regression. It was computed from the following formula:

$$LRI= 1-Ln_i/Ln_o$$

Where Ln_I is the log-likelihood function for the model having all the independent variables and Ln_o is the log-likelihood function for the model computed only with the constant term. A zero LRI value indicates lack of fit while a LRI value of one indicates perfect fit. Empirical evidence suggests that LRI usually lies between 0.2 and 0.4 (Mbata, 1997). The LRI values for the model estimated in this study were 0.07 for the male farm time allocation function and 0.01 for the female farm time allocation function (Table 4-8 and 4-9 respectively).

Measurement Errors

As is the case with many smallholder farms, reliable farm production data was lacking, as most farmers did not keep farm records. The author had to rely on the farmers' memory and approximation for information. This introduces measurement error and decreases the quality of data in general. Obtaining more reliable data from the small-scale farmers would involve spending longer periods in the field to collect data or mobilising farmers to keep records. This would necessitate mobilisation of huge financial budget, which cannot justify the value added to the data collected. However, the data obtained for this study was found to be good enough to make policy recommendations.

4.2 Results of Descriptive Analysis

Presented in this section are the results of the descriptive analysis of the survey data together with their interpretations. The results indicate that the two groups of farms had significant differences in their farm characteristics but were very similar as regards family characteristics.

4.2.1 Socio-economic characteristics of the sample farmers

This section describes the socio-economic characteristics of the maize farmers in the study area. These socio-economic characteristics are summarised in Table 4-1 below. There were significant differences in some of the socio-economic variables considered for the two groups of farms. Land is one of the four major factors of production. Major enquiries under land included, farm size and land ownership. The main focus was on the land where the homestead was situated and secondly, on any piece of land either owned elsewhere or rented. The mean farm size was 3.48 acres for the whole sample. On average, ‘traction’ households had larger pieces of land averaging 4.1 acres, compared to the ‘hoe’ group who owned 2.6 acres on average. Very few farmers owned land elsewhere (less than 5%), apart from the land on which they resided.

The land sizes in the area of study are generally small regardless of whether one is in 'traction' or the 'hoe' group. Therefore, there is need to intensify land use through land augmenting technologies (such as fertilizers and high yielding crop varieties). There is also need to increase off-farm income generating opportunities for the farm families to supplement their farm incomes.

Table 4-1 Mean Values Socio-economic Variables of the sample farmers

Variable	**'Hoe' Group**	**'Traction' Group**
Land Size (Acres)***	2.61	4.13
Farm Income (Kshs)***	7510.00	29825.56
Hired Labor (Mandays)***	5.84	10.97
Acreage under Maize (Acres)***	1.41	3.53
Maize Yield (Kgs/Acre)***	601.25	827.11
Fertilisers (Value in Kshs)***	2061.38	1103.02
Age of Household Head (Years)	50.38	51.33
Years of Formal Schooling (HH Head)	6.00	6.53
Farming Experience (Years)	26.03	29.81
No. of Dependants	2.00	2.00
Family Size	6.30	6.10

*** Significant at 1% level

Source: Authors' Survey, 2002

The 'hoe' group on average had a lower farm income averaging Kshs 7510.00. The 'traction' households on average had a farm income of Kshs 29825.60. The income considered refers to the income generated from the sale of maize. The 'traction' farmers were able to obtain a significantly higher income than the 'hoe' farmers. This observation coupled with the results of profit function indicates that 'traction' farmers achieve higher efficiency in maize production than 'hoe' farmers. This strengthens the case for the use of animal traction for smallholders as advocated by Mutebwa, (1979).

On average 'traction' households hired more labor than 'hoe' households did. 'Traction' households hired an average of 10.97 man-days of labor for the maize enterprise compared to an average of 5.84 man-days hired by 'hoe' households. From these results, one can infer that the use of animal traction in land preparation increased labor demands that were met through hiring. Since the family labor stock is almost the same in both sets of farmers (an average of six people per household as shown in Table 4-1), then hiring of labor is necessary for use of animal traction. Therefore, labor requirement component of animal traction must be considered when dissemination strategies are being considered.

The mean acreage under maize was 2.62 acres for the whole sample. This means that farmers in the study area on average put about 74% of their land holdings under maize. It can be inferred from this observation that farmers in the study area regard maize as an important crop. The acreage varied from 0.25 to 8 acres with a median of 2.00. The 'traction' farmers managed more acreage of maize with an average of 3.53 acres compared to the ‘hoe’ group who managed 1.41 acres of maize on average. These observations concur with those of Kosura (1983) in Western Kenya, where larger pieces of land were put under maize by ‘traction’ farmers while smaller pieces of land were put under maize by “hoe” farmers. One possible reason for this observation is the higher working rate of the oxen, which enables more land to be plowed before planting time compared to using the hoe.

The average maize yield for the whole sample was 730.75 Kgs/acre. There was a significant difference in the maize yield between the two groups of farmers. ‘Traction’ group on average obtained 827.11 Kgs of maize/acre while the ‘hoe’ group obtained 601.25 Kgs of maize/acre. For the ‘hoe’ group yield varied between 300 Kgs/acre and 900Kgs /acre while for ‘traction’ group the maize yield varied between 490 Kgs/acre and 1260 Kgs/acre. The above results seem to concur with the proposition of those who advocate for the use of animal traction. They argue that use of animal traction facilitates timeliness in land preparation and planting, as well as ensuring deeper plowing at the onset of rains which later translates to higher crop yields *ceteris paribus*.

The average value of fertilisers and pesticides used in the sample farms was Kshs 811.92. The value ranged from Kshs 0.00 to Kshs 6250 with a median of Kshs 655. ‘Hoe’ group used more fertilisers and pesticides for maize production than ‘traction’ group did on average. The mean value of fertilisers and pesticides was Kshs 1418.99 and Kshs 360.15 for ‘hoe’ and ‘traction’ group respectively.

‘Traction’ group on average used less fertiliser than ‘hoe’ group but they still obtained higher yields on average compared to ‘hoe’ group. There is no simple explanation for this observation but there is a possibility that the yield increasing effects of using animal traction overshadowed those of using fertilisers. Most of the farmers in the sample (including those in the ‘traction’ group) indicated that they applied manure.

The mean age of the farmers (the household heads) for the whole sample was 51.34 years, with the youngest farmer being 24 years old while the oldest was 90 years old. The median age was 50 years. The ‘hoe’ group had an average of 50.38 years while ‘traction’ group had an average age of 51.33 years. There was no significant difference between the ‘hoe’ and the ‘traction’ farmers in terms of their ages. The farmers are relatively old with relatively low levels of education hence they are unlikely to engage in formal employment. The average years of formal schooling were 6.31 years for the whole group with a range of 0 - 14 years. There was no significant difference between the two groups in terms of the average years of formal schooling. The mean formal schooling years was 6.00 years and 6.53 years for the ‘hoe’ and ‘traction’ group respectively. This has a bearing on the extent to which the farmers can be involved in other non-farm activities. The low level of education practically isolates them from well paying jobs in the formal employment sector since they need good education to secure employment. It also limits their involvement in the business sector, which requires some technical skills. For these farmers, increasing farm productivity offers their best option to increase their incomes and improve their livelihoods as noted by Gehart (1986).

Most farmers had a relatively long farming experience stretching up to three decades. The average years of farming experience were 28.95 years for the whole sample with a minimum of 2 years of farming experience and a maximum of 49 years. The ‘hoe’ group had a farming experience averaging 26.03 years while ‘traction’ group had an average of 31.12 years of farming experience. With such a long experience in farming the farmers are expected to make well-informed decisions with regard to farming. As regards the family sizes for the sample farmers, there was no significant difference between the two groups of farmers. The average family size was 6.3 and 6.1 individuals per household in ‘hoe’ and ‘traction’ households respectively. The average family size for the whole sample was 6.24 individuals. The average number of dependants for the whole sample was 2 individuals in a household.

The two sets of households seem to have almost the same patterns of household composition. The family labor stock and the number of dependants were almost the same for the two groups of farmers. These results contrast the results of a study done by Barret *et al* (1982) in Western Africa where ‘traction’ households were found to have larger families with more wives compared to the ‘hoe’ households. Given similar household composition (same level of labor stock), an increase in labor requirement that necessitates hiring of labor, the household income base will determine how much labor they can hire. Households with higher incomes will easily hire labor but those with lower incomes will not be able to hire labor.

4.2.2 The Household Labor Allocation Patterns

The labor allocation patterns of the sampled farmers in the two groups are summarised in the Table 4-2 below:

Table 4-2 Household Labor Allocation Patterns (Average Values)

Variable	'Hoe' Group	'Traction' Group
Male Farm Labor (Mandays/acre)**	10.2	5.91
Female Farm Labor (Mandays/acre)***	14.65	6.35
Hired Labor (Mandays/acre)***	0.00	2.0
Male Home work (Hours/week)*	1.21	0.00
Female Home work (Hours/week)**	36.65	45.89
Children Home work (Hours/week)***	6.09	0.88
Male Market work (Hours/week)	7.31	11.86
Female Market work (Hours/week)	1.13	2.93

*** Significant at 1% level

** Significant at 5% level

* Significant at 10% level

Source: Authors' Survey, 2002

Agriculture is the main source of income in the area of study. Both men and women are actively involved in agricultural activities. Generally farm work is varied and diversified into many crop and livestock enterprises that farmers are involved in. For this study farm work considered labor input into the maize enterprise. This was based on the relative importance of the maize enterprise to the farmers both as a food crop as well as a source of income whenever there is surplus production. There was no significant difference in the amount of Mandays spent by males and females in the maize enterprise for the sample of farmers considered. Males expended 9.89 Mandays/acre while females expended an average of 7.66 Mandays/acre in maize production (Table 4-3). As far as weeding is concerned, there was a significant difference between men and women in the whole sample. Women expended 5.76 Mandays while men spent 4.88 Mandays on weeding (Table 4-3). This observation concur with the prevailing pattern in most of Sub-Saharan Africa farming areas where weeding is predominantly women's work. There were also significant differences between the two groups as far as weeding is concerned. Both males and females in the 'hoe' households spent significantly more Mandays in weeding than their counterparts in 'traction' households as shown in Table 4-4 below. The figures in the Table 4-4 only include the figures of labor input from the family excluding the values of hired labor for weeding.

Table 4-3 Inter-gender Labor Allocation in Maize production (Average Values In Mandays/acre)

Variable	Males	Females
Total Labor input	9.89	7.66
Weeding Labor input	4.88	5.76

Source: Authors' survey, 2002

Table 4-4 Mean Values for Inter-gender Weeding Labor Input

Variable	'Hoe' Group	'Traction' Group
Female weeding labor (Mandays/acre)***	6.32	2.25
Male weeding labor (Mandays/acre)***	4.76	2.00

*** Significant at 1% Level

Source: Authors' Survey, 2002

Male farmers in the selected sample spent an average of 0.51hours per week on homework. On the other hand, females spent an average of 42.67hours per week on homework with a minimum of 0.00hours per week and a maximum of 75.5 hours per week. Children (less than 15 years of age), on average spent 2.75hours per week on homework. There are marked differences between the two groups of farmers based on how they allocate their time to homework. There is a significant difference (at 10% level) on how males allocate their time to homework. Male in the “hoe” households spent a meagre 1.24 hours per week on homework while their counterparts in “traction” households on average were not involved in homework at all. There is also a significant difference between females in “hoe” households and those in “traction” households with regard to the time they spent on homework. Females in “traction” household spent 45.89 hours per week on homework while those in “hoe” households spent 36.65 hours per week. Therefore, female farmers in “traction” households spent significantly more time in homework than their counterparts in “hoe” households. Further, the results imply that homework is generally a preserve of women with relatively low input from men and children. The results further indicate that women in “traction” households spend less time in the farm hence are able to spend more time carrying out homework compared to women in the hoe households. Although it is not included in the national accounts, homework is very important in improving the welfare of the family. In this regard, technologies that save women’s farm time would be very desirable. Such technologies would relive women’s labor from the farm, which would now be available to carry out homework as well as market work where opportunities exist.

There is relatively low involvement of the farm families in the area of study to market activities. There are no significant differences in the time allocated to market work by the two groups of farmers. Market work is important in supplementing the income earned from farming especially where farm incomes are low. Farmers are likely to spend more time in market activities if opportunities are available and if they are likely to earn more than what they would have gained if they spent their time on farming. Males devoted relatively more time in market activities than the female farmers. Male farmers devoted an average of 10.77hours per week to market work compared to 2.27hours per week devoted to market work by women. Males in “traction” households spent approximately six more hours per week on market work compared to their counterparts in the “hoe” households. Similarly, women in “traction” households spent more time in market work than their counterparts in “hoe” households. On average, a female farmer in a “hoe” household spent 1.13 hours per week on market work while a counterpart in the “traction” household spent 2.93 hours per week.

4.3 Results of Profit Function Analysis

The following section gives the results of the profit function analysis. The profit function was estimated using OLS procedure using the LIMDEP software program. The profit function was estimated in the following form:

$$\text{Ln } \pi = ß_o + ß_1 \text{ ANTRAC} + ß_2 \ln \text{WAGE} + ß_3 \ln \text{LPFERT} + ß_4 \ln \text{LMACR} + ß_5 \ln \text{LSEED} + \mu \quad (4\text{-}1)$$

Where:

π is normalised profit in Kshs, defined as total revenue less total costs (all inputs except land) normalised by the price of Maize. ANTRAC is a dummy variable with value 1 for ‘traction’ farms and 0 for ‘hoe’ farms. WAGE = Wage rate in Kshs per Manday normalised by the price of maize. PFERT is the price of fertilisers in Kshs normalised by the price of maize. MACR = Acreage under maize in acres; LSEED is the price of seeds in Kshs normalised by the price of maize; μ = the error term and $ß_i$’s = the regression coefficients.

The above equation is a formulation of the Cobb-Douglas case, giving a mathematical form of the profit function used to test relative economic efficiency. It has been linearised into natural logarithms with the coefficients ($ß_I$) interpreted as the elasticities of the maize profit with respect to the independent variables. The included variables in the model explained 89%of the variation in profit among the sample farms (Table 4-5).

Table 4-5 Profit Function Regression Results

Variable	Beta	SE Beta	t-statistic
CONSTANT***	6.82	0.73	9.34
ANTRAC (DUMMY)***	0.98	0.14	7.00
WAGE**	-0.34	0.18	-1.89
LPFERTZ***	-0.40	0.12	-3.33
LMACR***	0.93	0.18	5.17
LSEED**	-0.42	0.24	-1.75

R^2 = .89

R^2 (Adjusted) = .88

F= 111.09

*** Significant at 1% level

**Significant at 5% level

*Significant at 10% level

Source; Authors Survey, 2002

This is the coefficient of multiple determination (R^2). Similarly, the corresponding measure for adjusted R^2 was 88%. These results indicate that the profit model had a good fit of the data. Further interpretation of the profit function revealed that the F-value, which tests the hypothesis that all coefficients are equal to zero, should be rejected since F-value was highly significant.

As expected, the prices of variable inputs (wage rate, seeds and fertilisers) had a negative coefficient in the profit function. It is expected that the higher the price of variable inputs of production the less the profit that a farmer can attain. All the prices of variable inputs are significant in the model. This result concurs with those of Adesina and Djato (1997), Ali and Flinn (1989), Khan and Maki (1979) and Yotopoulos and Lau (1971). The coefficient of land is positive and significant and concurs with the results of studies by Adesina and Djato (1997) and Khan and Maki (1979) and Yotopoulos and Lau (1971). The coefficient of mechanisation was found to be positive and significant. This result indicates that use of animal traction had a significant effect on increasing maize enterprise profits.

4.3.1 Testing for Hypothesis of Equal Economic Efficiency

The hypothesis tested in this chapter is that 'traction' group and 'Hoe' group had equal economic efficiency. As indicated earlier, taking the natural logarithms of the profit function and testing whether the coefficient of a dummy variable that differentiates the two groups of farms, is significantly different from zero we can test the hypothesis of relative economic efficiency. The results indicated that the coefficient of the dummy variable was significantly different from zero. At 5% level of significance we reject the null hypothesis that 'traction farmers' and 'hoe farmers’ have equal efficiency and conclude that indeed ‘traction farmers’ are more efficient than their ‘hoe’ counterparts in maize production.

The test was formulated as follows:

$H_0 : ß_l = 0$

$H_A : ß_1 \neq 0$

and the test statistic was calculated using the formula:

$t = ß_1/S.E\ (ß_1) = 0.98/0.14 = 7.00$

After calculating "t" value, it was compared with the tabulated "t" value at 5 % level of significance and 70 degrees of freedom. The results showed that the calculated value of “t” was more extreme than the tabulated “t” value (1.671), we reject H_0 that ‘traction’ group and ‘hoe’ group have equal economic efficiency and conclude that indeed the ‘traction’ group is more efficient than their ‘hoe’ counterparts in Maize production.

4.3.2 Covariance Analysis Results

Covariance analysis was carried out to isolate the direct effects of using animal traction i.e. to test whether there are significant differences in the behavioural relationships between ‘hoe’ group and ‘traction’ group. The results of the two unrestricted regressions used for the Covariance analysis (Chow test) were summarised in Table 4-6 and 4-7 below. The analysis showed that at 5% level of significance, the two groups are statistically different from each other in the way the included independent variables explain variation in the profits from maize production.

The chow test compares the regression sum of squares (RSS) from a restricted (RSS_R) model (that assumes that the parameters are constant across data subsets) with the RSS from an unrestricted model (that allows the parameters to vary across data subsets). The unrestricted RSS is obtained by running two separate regressions for the two data subsets and summing the resulting RSSs ($RSS_U = RSS_{'hoe'} + RSS_{'traction'}$)

The test statistic (estimated F) was given as:

$F = [(RSS_U - RSS_R)/ df_n]/ [RSS_U/ df_d$

The number of degrees of freedom was equal to the number of restrictions (The number of slope coefficients that are forced to be equal across the two models equals 5 in the sample). The denominators' degrees of freedom are equal to the degrees of freedom associated with the unrestricted model (sample size minus the total number of coefficients estimated in the unrestricted models).

Therefore, $RSS_1 + RSS_2 = RSS_u = (12.25 + 4.53) = 16.78$ and $RSS_R = 44.81$
The test statistic (estimated F) becomes:

$F= [(16.78-44.81)/5] /(16.78/69)$

$= - 5.61/0.24= - 23.36$

The F-critical (5,69) at 5% was obtained as – 2.35. Since the calculated ‘F’ is more extreme than the tabulated “F’ we reject the hypothesis that the two groups are similar in the way the included variable explain variation in the Maize profit. We therefore conclude that the two groups are different in the way the included variables explain variation in the maize profits.

Table 4-6 Covariance Analysis: Regression Results for Traction Farmers

Variable	Beta	SE Beta	t-statistic
CONSTANT***	6.26	1.28	4.89
WAGE*	-1.32	0.91	-1.45
LPFERTZ**	-0.29	0.17	-1.71
LMACR***	0.90	0.15	6.00
LSEED	-0.74	0.88	-0.84

R^2 = .85

R^2 (Adjusted) = .79

F= 13.26

*** Significant at 1% level

**Significant at 5% level

* Significant at 10%

NB: N= 43 Farms

Source; Authors Survey, 2002

Table 4-7 Covariance Analysis: Regression Results for Hoe Farmers

Variable	Beta	SE Beta	t-statistic
CONSTANT***	8.83	1.78	4.96
WAGE*	-2.21	1.41	-1.57
LPFERTZ*	-0.36	0.22	-1.64
LMACR***	0.98	0.21	4.67
LSEED	-0.51	1.25	-0.41

R^2 = .58

R^2 (Adjusted) = .51

F= 10.67

*** Significant at 1% level

** Significant at 5% level

*Significant at 10% level

NB: N= 32 Farms

Source; Authors Survey, 2002

The results of covariance analysis as shown in tables 4-6 and 4-7, indicate that all the variables included in the model except the price of seeds were significant. Wage and price of fertilizers had negative coefficient, while land had a positive effect on profits resulting from maize production. The variables included in the profit function for the 'traction' farmers explain 79% of the variation while in the corresponding function for 'hoe' farmers the included variables explain 51% of the variation.

4.4 Results of Farm Time Labor Allocation Analysis

The two basic estimating equations included 7 independent variables including a dummy variable for farm mechanisation:

.

FFLAB = $\beta_o + \beta_l$ FAGE + β_2 FEDUC + β_3 NFINC+ β_4 FSIZE + β_5 FINC

+ β_6 FHLAB + β_7 DEPEND+ β_8 ANTRAC + μ (4-2) and

FMLAB = $\beta_{o} + \beta_l$ MAGE + β_2 MEDUC + β_3 NFINC+ β_4 FSIZE + β_5 FINC +

β_6 FHLAB + β_7 DEPEND+ β_8 ANTRAC + μ (4-3)

Where:

FFLAB = Female farm labour i.e. the amount of female labor in Mandays devoted to farm work (Maize enterprise in particular) in the 2001/2002 short rain season.

FMLAB= Male farm labour i.e. the amount of male labor in Mandays devoted to farm work (Maize enterprise in particular) in the 2001/2002 short rain season.

FAGE = the age of female in years; MAGE = the age of male in years; NFINC = monthly income in Kshs earned from non-farm activities; FSIZE = farm size (under maize) in acres; FINC = income in Kshs earned from sale of farm products in 2001/2002 short rain season; FHLAB = amount of Farm hired labor (devoted to maize enterprise) in Mandays; DEPEND = the number of dependants in the family i.e. people who are not available to offer farm labor; ANTRAC = a dummy variable with a value of 1 for 'Traction' group and 0 for 'Hoe' group; β_0 = the constant term; β_I = the regression coefficients estimated for respective variable I; μ= Stochastic (error term).

The above equation is in the form of censored regression in which it is assumed that the dependent variable has a number of its values clustered around zero. In this case the data on labor allocated to farm work has such a clustering around the value zero i.e. cases where individuals may allocate zero Mandays to farm work. It therefore calls for the use of the Tobit estimation technique. The Tobit technique uses all observations, both those at the limit and those above it, to estimate a regression line, and it is preferred, in general, over alternatives that estimate a line only with observations above the limit.

The interpretation of the male farm time allocation function revealed that the F-value, which tests the hypothesis that all coefficients are equal to zero should be rejected since F-value was highly significant. In the same way, the interpretation of the female farm time allocation function revealed that the F-value was highly significant. This means that all the independent variables taken together were important in explaining the variation in the time allocated to farm work by both males and females. The results of the farm time allocation analysis for both men and women are presented in tables 4-8 and 4-9 below.

Table 4-8 Male Farm Time Allocation Regression Results (MLE estimates)

Variable	Beta	SE Beta	t
Constant	0.41	6.89	0.06
ANTRAC (DUMMY)	-2.83	3.42	-0.83
FSIZE	1.04	3.42	1.20
MAGE	0.47	0.31	1.52
DEPEND	0.57	0.91	0.62
FHLAB***	0.81	0.13	6.23
FINC**	3.25	1.65	1.97
NFINC	0.64	1.41	0.45
MEDUC	-0.35	0.31	1.13

** Significant at 5% level

***Significant at 1% level

Log likelihood function (Ln_l) = -263.1705

Log likelihood function (Ln_o) = -283.1501

Likelihood ratio index = 0.07

Source: Authors' Survey, 2002

Table 4-9 Female Farm Time Allocation Regression Results

Variable	Beta	SE Beta	t
Constant**	13.38	5.78	2.32
ANTRAC (DUMMY)	-2.97	2.77	1.07
FSIZE	0.29	0.66	0.44
DEPEND*	-1.28	0.88	-1.46
FHLAB***	-0.89	0.13	6.85
FINC	1.27	1.57	0.81
NFINC	-0.11	1.36	0.08
FEDUC**	-0.54	0.30	1.80

*Significant at 10% level

** Significant at 5% level

***Significant at 1% level

Log likelihood function (Ln_l) = -273.4544

Log likelihood function (Ln_o) = -275.2717

Likelihood ratio index = 0.01

Source: Authors' Survey, 2002

4.4.1 Hypothesis Testing under the Female Farm-Time Allocation Function

As indicated earlier, the hypothesis of whether use of animal traction significantly increases women's farm time can be analysed by testing whether the coefficient of the dummy variable is significantly positive. The results indicated that at the 5 % level coefficient of the dummy variable was not significant as shown below:

The hypothesis took the following form.

$H_0 : ß_8 = 0$

$H_A : ß_8 \neq 0$

and the t-statistic was calculated using the formula:

$t = ß_8/S.E(ß_8) = -2.97/2.77 = -1.07$

Since the calculated t-value (T_{cal}) was smaller than the tabulated t-value (T_{tab}) at 5% we reject the null hypothesis that use of animal traction significantly affects women's' farm labor time. Therefore, the use of animal does not affect the labor allocation of females in the study area. This could be explained by the high level of hired labor and higher level of involvement of male farmers in maize farming.

4.4.2 Farm Labor Time Allocation between Genders

The results of the study as shown in Table 4-8 and Table 4-9 indicate that use of animal traction (ANTRAC) is not significant in influencing farm time allocation of both males and females. In both the male and female farm time labor allocation models, ANTRAC has a negative coefficient. This observation though not expected is not surprising because of three main reasons. First, the study only considered farm labor time in maize enterprise only. If labor use in all the other enterprises were considered the pattern may have been different. Second, unlike in many areas, men in the area of study are actively involved in carrying out farm work hence women are not overburdened. Thirdly, ‘traction’ households met the extra labor requirement through hiring labor.

Evidence from the analysis indicate that some factors had the similar effects for both genders, others had different effects with respect to farm-time allocation. As regards to the performance of the individual explanatory variables in the estimated models, the results of male farm labor time are shown in table 4-8. The results indicate that the intercept (CONSTANT), use of animal traction (ANTRAC), number of dependants (DEPEND), farm size (FSIZE), education level of male farmer (MEDUC), male age (MAGE), and non-farm income (NFINC) were not significant in influencing male time allocated to farm work. On the other hand, the level of hired farm labor (FHLAB) and farm income (FINC) were found to be significant in the model.

The number of dependants (especially the children) traditionally does not affect males as it affects females, as child rearing and/or care is the exclusive preserve of females. It is not surprising therefore that this variable is not significant in influencing male farm time. On the other hand, the number of dependants has a significant negative effect on women's farm labor time. This falls within expectation because in the traditional African set-up women almost exclusively carry out the work of children care. The result of the effect of dependants on male/female farm time allocation concurs with results of a study by Rahji (1999) in Southwestern Nigeria.

There is a significant positive association between earning from the maize enterprise and the hours of male farm time. An increase in farm income will most likely translate to an incentive for more farm time. This is especially so because, farming is often the primary occupation and the main source of income in the area of study. On the other hand, there is no significant association between farm income and the female farm time. This is plausible because the male head controls farm income. In fact some studies indicate that male farmers take over from their wives, farm enterprises that become profitable over time (Deere, 1982).

Female level of education is significant in determining the farm time allocation of the female farmer. Education is an important factor in decision-making. An educated person is expected to be able to use his resources to attain the greatest benefit (Rahji, 1999). The results of the analysis revealed that the higher the female education (FEDUC), the lesser the time they spent on the farm. This implies that the more educated female farmers spent less time in the farm and were most likely involved in market work or even in homework.

Hired farm labor has a positive significant effect in influencing farm labor time of the male farmers. The hiring of more farm labor is expected to reduce the farm time of males but the results show that it in fact increased the farm time of males. This may imply that even after hiring labor, the male farmer has to work in the farm, carrying out the supervisory role. On the other hand hired labor significantly reduced female farmers labor time.

Hired farm labor is also significant in female farm time allocation. There is an inverse relationship between female farm time and the hired farm labor. The results seem to suggest that hired farm labor (FHLAB) and female farm labor time, are substitutes. The more the hired labor employed, given the ability of the household to pay for it, the less time that the average female farmer is expected to put into farm work. This may be due to comparative advantage of females in other household tasks (Roberts, 1982).

Female education is significant in determining time allocation in the farm, the higher the level of education a female has the less the time she spends on the farm. This implies that the time of an educated woman has more value outside the farm either in doing business or in formal employment.

CHAPTER V

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The study analysed two main issues, namely; differences in efficiency of maize production as well as inter-gender labor-time allocation between ‘traction” and “hoe” farmers in Kirinyaga district of Central Kenya. The study covered three out of the four divisions of Kirinyaga district, namely Gichugu, Ndia and Mwea. A sample of 80 farmers was included in this study. Data was collected through questionnaire interviews between April and May 2002. The study assessed whether using animal traction increases efficiency in maize production by comparing the maize production efficiency between 'traction' and 'hoe' farmers. The study also analysed the effect of using animal traction on farm labor-time for both women and male farmers. The high cost of purchase and maintenance of tractors make it out of reach of most smallholders. As the farm sizes get smaller and smaller through sub-division an appropriate mechanisation strategy need to be developed for the small farms. The technical aspects of animal traction are well understood but its socio-economics aspects have not received research attention.

Profit function as well as labor use functions were estimated from the data. Descriptive statistics were used to give socio-economic description of the sample farmers. The results of descriptive statistics indicated that, “traction” farmers achieved significantly higher profits from the Maize enterprise than the “hoe” farmers. “Traction” farmers on average obtained a profit of Kshs 26,527 from the maize enterprise while their “hoe” counterparts achieved on Kshs 3,504 on average. In the same way “traction” farmers obtained higher yields (38% higher) of maize than their “hoe” counterparts. Profit function analysis indicated that ‘traction’ farmers were significantly more efficient in maize production than their ‘hoe’ counterparts.

Farm labor-time allocation analysis indicated that use of animal traction was not significant in influencing farm time allocation by both males and females. However, use of animal traction for land preparation increased labor demands in the subsequent operations. The increased labor demands were met through hiring as evidenced by higher labor hiring done by traction farmers. Using animal traction did not significantly increase labor input of women into maize farming in the area of study. This is because of two main reasons; first, both men and women are equally involved in maize farming hence the burdens of increased labor requirements are equally distributed. Secondly, the extra labor requirements are met through hiring of labor from outside the family.

5.2 Conclusions

The current study has examined some socio-economic aspects of using animal traction as a strategy for small farm mechanisation in Kirinyaga district. The results indicated that use of animal traction (both owned or hired) *ceteris paribus* increased the efficiency of maize production. The 'traction' farmers achieved maize yields averaging 827kg/acre compared to an average of 601kg/acre achieved by 'hoe' farmers. This observation seems to concur with the proponents of use of animal production who say that if applied in farm operations animal traction can facilitate a more efficient use of other production inputs. The results of the study further indicated that using animal traction did not necessarily increase the workload of women but of the whole family in general. The 'traction' households hired an average of 2.00 Mandays per acre compared to negligible amounts hired by 'hoe' farmers. More labor had to be hired from outside the family to cater for the extra labor requirement. This implies that without cash to hire labor, use of animal traction could overburden the family members due to higher labor requirements.

However, there is need for further studies to evaluate how farmers make decision on which method of mechanisation to use to carry out farm operations and what constraints they face as they make those decisions. This would shed more light on how a farmer's resource base (for example land, labor, and cash) influences his/her choice on the method of farm mechanisation to use. At the time of this study there was a parallel study (Agwara, forthcoming) that was dealing with adoption aspects of animal traction.

5.3 Recommendations

- The study has established that use of animal traction has a significant positive effect on increasing efficiency of maize production in the area of study. Therefore, use of animal traction should be promoted as a way of increasing efficiency at the farm level. The government and other stakeholders in small farm mechanisation should continue with their efforts to promote the use of animal traction. The government could establish a short-term credit facility to help farmers acquire the animal traction package, that is, the animals and the implements.

- Although use of animal traction has a significant effect in increasing yields, it also increases labor requirements that can either be met from the family labor stock or from hired labor. The extra labor requirements could be eased if animal traction is applied in other farm operations such as weeding. Therefore, the government (through the extension system) and other stakeholders should promote the application of animal traction in the weeding operations. The government could promote the manufacture of appropriate weeding implements by the local blacksmiths, by offering them short-term credit facility to increase manufacture of weeding implements.

- Higher levels of hiring labor accompanied the use of animal traction. Therefore, animal traction can be promoted as a way of increasing rural employment. The government should promote its use for example through short-term credit facilities to farmers willing to adopt it. Once adopted it can provide some rural employment, which can ease the burden of unemployment.

- The results of the study indicated that there were low levels of involvement in market activities by farmers in the area of study. The new approach to rural livelihood development stresses the need for integrating both farm and no-farm income activities. There is need for further research on factors that determine the involvement of rural households in non-farm activities. This would shed light on the possible interventions that would increase participation of rural households in no-farm activities.

- Due to limitations of time and finances, the study could not address all pertinent issues as far as small farm mechanisation is concerned. Therefore, I recommend that further studies be done to shed more light on the dynamics (both technology attributes and farmer/farm characteristics) that influence farmers' decision-making process in relation to resource constraint as regards the different mechanisation strategies available to them.

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APPENDICES

Appendix 1: Hypothesis Testing in the Female Farm-Time Allocation Function

Appendix 2: Testing for Multicollinearity

Partial Correlation Coefficients

a) Profit Model

	ANTRAC	LMACR	LSEED	WAGE	LPFERTZ
ANTRAC	1.0000				
LMACR	-0.1968	1.0000			
LSEED	-0.0958	0.0292	1.0000		
WAGE	-0.1029	0.3732	0.2846	1.0000	
LPFERTZ	0.2135	0.3216	0.3400	0.3754	1.0000

Source: Authors' Survey, 2002.

b) **Female Farm Time Allocation Model**

	FAGE	FEDUC	FINC	NFINC	FSIZE	FHLAB	DEPEND	ANTRAC
FAGE	1.00							
FEDUC	-0.80	1.00						
FINC	0.30	-0.14	1.00					
NFINC	0.09	-0.15	0.16	1.00				
FSIZE	0.51	-0.50	0.31	0.15	1.00			
FHLAB	0.16	0.05	0.14	0.18	0.30	1.00		
DEPEND	0.18	-0.17	0.08	0.10	0.15	-0.22	1.00	
ANTRAC	0.22	-0.05	0.48	0.18	0.31	0.26	-0.07	1.00

Source: Authors' Survey, 2002

c) Male Farm Time Allocation Model

	MAGE	MEDUC	FINC	NFINC	FSIZE	FHLAB	DEPEND	ANTRAC
MAGE	1.00							
MEDUC	0.74	1.00						
FINC	0.23	-0.11	1.00					
NFINC	0.03	-0.05	0.12	1.00				
FSIZE	0.39	-0.25	0.21	0.13	1.00			
FHLAB	0.06	0.14	0.07	0.13	0.23	1.00		
DEPEND	0.20	-0.23	-0.08	0.16	0.16	-0.20	1.00	
ANTRAC	0.11	0.03	0.49	0.11	0.37	0.24	-0.05	1.00

Source: Authors' Survey, 2002

Appendix 3: Log-likelihood ratio (LR)

$LR = -2(Ln_{het} – Ln_{hom})$

Where LR = Log-likelihood ratio

Ln_{het} = Log-likelihood of the model with heteroskedasticity

Ln_{hom} = Homoskedastic log-likelihood of the model

a) Female Farm Time Allocation Function (FFLAB)

Ln_{he} = -273.4544

Ln_{hom}= -276.5723

LR = -2(-273.4544- -276.5723)

= -7.553

X^2 at 7 d.f. and 0.01 significance level = 18.48 LR< X^2 and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

b) Male Farm Time Allocation Function (FMLAB)

Ln_{he} = -263.1705

Ln_{hom}= -263.3496

LR = -2(-263.1705--263.3496)

= -0.3578

X^2 at 8 d.f. and 0.01 significance level = 20.08 LR< X^2 and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

c) The profit function (MPROF)

Ln_{he} = -499.3121

Ln_{hom}= -499.9704

LR = -2(-499.3121- -499.9704)

= -1.3161

X^2 at 4 d.f. and 0.01 significance level = 13.32 LR< X^2 and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

Appendix 4: Farm Level Questionnaire

FARM LEVEL QUESTIONNAIRE

UNIVERSITY OF NAIROBI

DEPARTMENT OF AGRICULTURAL ECONOMICS

THE EFFECT OF USING ANIMAL TRACTION ON FARM PROFITABILITY AND HOUSEHOLD LABOR ALLOCATION ON SMALLHOLDER FARMS IN KENYA: A CASE OF KIRINYAGA DISTRICT.

The interviewer greets farmer, introduces himself and informs the farmer that he is seeking information on how use of draft animal power affects farm profitability and labor allocation. The interviewer stresses the point that the information collected will used for completing a masters degree of the university of Nairobi. The farmer is assured that the information he gives will be strictly confidential.

FARM IDENTIFICATION

1.1 Questionnaire Serial Number……………………… Start Time……………

1.2 Name of enumerator ……………………………….

1.3 Name of the respondent…………………………………

1.4 Division……………………………………………….

1.5Location……………………………………………

1.6 Village………………………………………………..

1.7 Date of Interview………………………………….

BACKGROUND INFORMATION

Farmer's Name(optional)………………………………………………………..

Age (years)……………………….Gender : M/F...

Education level:

Education level	Stage reached/No. of years spent
Primary	
Secondary	
College certificate	
College diploma	
Degree	

Family Background

How many individuals live in the farm?..

Of these living in the farm,how many are available for farm work?...................................

How many are dependants (elderly or young)?…………..

How many members of the family live elsewhere?..

What is the size of your farm………………………acres

What year did you start operating this farm 19………..

Do you own the title to this land YES/NO if NO go to 2.7

On what terms do you operate the farm?

Rented

Temporary

Other specify

Do you operate any land elsewhere YES/NO if YES acres…………….

3.0 LABOR USE

3.1 Farm work for maize production (for the last season)

Operation	Kind of labor used Family(F), Hired(H) or a Combination (C) Tick the appropriate			Amounts of each kind of labor used (in Mandays)		Family Labor inputs by gender		Cost of hired labor (Kshs)
	F	H	C	F	H	male	female	
Land preparation								
Planting								
Weeding								
Fertilizer application								
Spraying chemicals								
Harvesting								
Irrigation								

3.2 HOME WORK

Activity	Who does it	Education level	Age	Sex	No. Of hours/day/week
Kitchen work and House keeping					
Washing clothes					
Fetching water					
Caring for the young ones ,the aged and Sick					
Fetching firewood					

3.3 MARKET WORK

3.3 (a) Is any member of the family involved in other income earning activities apart from farming? Yes/No If yes go to 3.3 (b)

3.3 (b)

Activity	Family member involved	Age	Sex	No. of hours worked/weeks

3.3 (c) How much income does the family earn from market work per month?

Kshs...

3.4 The effects of mechanization of land use

3.4 (a) What changes in land use have you made since you started using animal traction ?

Area cultivated :

More..........

Less..............

About the same..................

Number of harrowings:

More.....................

Less........................

About the same.......................

Crop mixtures:

Only maize......................

more maize and beans.....................

more cash crop (specify)..........................

less fallow ....

Same mixtures...................................

others (specify).................................

(b) Have you made any changes in weeding practices?

Time of weeding

Earlier……………..

Later………………..

About the same time………….

Number of weedings

More……………

Less……………..

About the same…………

3.4 (c) Maize production

How much of your land did you plant with maize?.................................Acres

How much labor inputs did you use in maize production for the following operations:

Operation	Labor Inputs (Mandays)	
	Hired	Family
Land preparing		
Planting		
Weeding		
Harvesting		

How much fertilizer did you use and at what cost?

Amount of fertilizer used(kg) – Specify	Cost (Kshs)

iv. How much pesticide did you use and at what cost?

Quantity of pesticide (Specify)	Costs (Kshs)

V. How much seed did you use and for how much did you buy them?

Amount (kg)	Cost (kshs)

vi. How much maize did you harvest ?...................................bags/kg

vii. Approximately how much maize was destroyed in the field?................................bags/kg

viii. How much maize did you sell ....bags/kg

ix. How much income did you get from the sale of maize kshs.............................

How much maize are you able to store in your farm ?......................bags

End Time:...

At the end of the interview the farmer is thanked for taking his/her time in answering the questions.