Socio-Economic Factors Influencing Environmental Degradation in Kakamega Forest Complex, Kenya: The Case of Fuelwood Exploitation

Albert Luvanda Makee

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Department of Agricultural Marketing and Co-Operatives

Faculty of Agriculture,

Moi University.

DECLARATION

DECLARATION BY THE CANDIDATE

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.... 19/10/05 ....

Albert Luvanda Makee (AGR/PGR/11/2000) Date

DECLARATION BY SUPERVISORS

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

.... 21/11/05 ....

Prof. H. K. Maritim Date
School of Economics and Business Management,
Moi University,
P.O. Box 3900,
Eldoret – Kenya.

.... 19-10-05 ....

Mr. Paul O. Ongugo Date
Natural Forests Programme,
Kenya Forests Research Institute,
P.O. Box 20412,
Nairobi – Kenya

Thesis Submitted to Graduate School,
Moi University,
Eldoret – Kenya

ABSTRACT

For decades forest adjacent communities have depended on natural forests for their livelihoods. This practice was sustainable when the population was still low. However, with an increase in population accompanied by the ever-changing socio-economic environment in which these households operate, the exploitation of natural forests can no longer be considered sustainable. Fuelwood is the most exploited forest product by the forest adjacent communities. The goal of this study was to identify key socio-economic factors that significantly influence the annual quantity of fuelwood collected from Kakamega forest complex by the forest adjacent communities with a view to making policy recommendations for the long-term sustainable conservation of the forest.

A structured schedule/questionnaire was used to solicit information from a random sample of 235 households residing in five sub-locations. Secondary information from existing sources was used to supplement the primary data. Data obtained was analyzed using descriptive statistics and regression analysis using Statistical Package for Social Scientists. The results of a linear regression model show that the quantity of fuelwood harvested from the farm, price of the fuelwood from the farm, land size, time spent on firewood collection per week and gender in marketing significantly affect quantity of fuelwood harvested from the forest. The annual per capita off-take from the Kakamega forest was estimated at 4.32 m^3 with 72% of it being marketed either as either firewood or charcoal. It is recommended that a combination of strategies be used to correct the unsustainable harvesting practices. These strategies focused on management, on-farm tree planting programmes, licensing, and provision of credit facilities, research, awareness programmes and promotion of improved conversion technologies among the forest adjacent communities.

DEDICATION

To my beloved wife Mary and children: Manu, Ruth, Vivian, Annett and Joyce. Much thanks for your moral and material support. God bless you all.

ACRONYMS AND ABBREVIATIONS

ACTS	African Centre for Technology Studies
AFC	Agricultural Finance Co-operation
CBD	Convention on Biological Diversity
EMENA	Europe, Middle East and North Africa
FAO	Food and Agricultural Organisation
FD	Forest Department
GDP	Gross Domestic Product
ICDC	Industrial and Commercial Development Co-operation
ICIPE	International Centre for Insect Physiology and Ecology
ICRAF	International Centre for Research in Agroforestry
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature and Natural Resources
KEEP	Kakamega Forest Education and Environment Programme
KEFRI	Kenya Forestry Research Institute
KFR	Kakamega Forest Reserve
KIE	Kenya Industrial Estate
KIFCON	Kenya Indigenous Forest Conservation Project
KWS	Kenya Wildlife Services
LAC	Latin America and Caribbean
LPG	Liquefied Petroleum Gas
MENR	Ministry of Environment and Natural Resources
NGO	Non Governmental Organisation
OECD	Organization for Economic Cooperation and Development
RoK	Republic of Kenya
SPSS	Statistical Package for Social Scientists
UNEP	United Nations Environmental Programme
WB	World Bank
WMES	Welfare Monitoring and Evaluation Survey
WTP	Wood and Tree Products

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CHAPTER 1: INTRODUCTION

1.1 Background information

According to the World Bank (WB) and International Monetary Fund (IMF), 1986, tropical forests[1] cover about 7% of the planet's land surface that provide habitat to over 80% of the plant and animal species on earth. The WB puts the annual rate of deforestation at 1% to 2%. The area that is destroyed can be compared to the size of Great Britain. Millions of plant, animal and insect species, which have evolved over hundreds of millions of years, face extinction as their habitats are destroyed. Riswan and Hartanti, 1995, reported that at least one species is being condemned to extinction every day worldwide. Some 60% of tropical forest loss is attributed to agricultural settlement, while a further 20% is attributed to logging. The impact of logging is larger: it establishes access to the cleared areas and later encourages farmers and grazers to follow (Colchester, 1995a).

Rasheed (1996) in a study conducted for the Food and Agriculture Organisation (FAO) estimated that Africa's 6.5 million Km^2 of forest area in 1980 shrunk to 6.0 million Km^2 in 1990, a loss of about 51,0000 Km^2 annually. In 2000, it was estimated that about 2.5 billion people were not able to satisfy their needs for energy, wood consumption exceeded the rate of wood production and the industrial wood deficit was close to 960 million m^3 (Türker and Türker, 1997).

There are 1.24 million ha of closed canopy indigenous forests in Kenya which account for 2% of the country's total land area where large percentage of the nation's biodiversity is found. The species, which occur, include 40% of mammals (over 500g), 30% of the birds and about 35% of the butterflies. An estimated 50% of woody plants are also found in closed canopy forests (Wass, 1995; MENR, 1994). Gazetted forests in Kenya are being lost at an average rate of 5,000 ha per year as forestland is converted to settlement and agriculture without following the full process of consultation and legal excision from the forest estate (KIFCON, 1994). Kenya has lost more than 40% of its local forest cover during the past 20 years (MENR, 1994; Wass, 1995; Lwayo, 2000). This is accompanied by a general decline in the quality of the remaining forest.

Widespread natural forest degradation[2] and depletion is the main environmental and economic problem (hiring of forest guards to protect forest, loss of revenue, etc) facing Kenya's forest sector. One very important impact of forest destruction is the growing alienation of people from the natural resource base on which their lives depend (Svarstad, 1994). The other factors are weak policy and institutional framework: poor enforcement of the forestry regulations and protection, inadequate private rights to use and manage forests, poor stakeholder–manager linkages and improper pricing and valuing of forest goods and services.

The Conservation of biological diversity requires people's participation: giving back control over natural resources to local communities, reviving relevant traditional systems, channeling benefits of biodiversity conservation to local people, formally involving local people at all levels of decision making, encouraging partnerships between formal sector scientists and local communities and encouraging mass public awareness and education.

Developing countries with 76% of the total world population use 23% of the total world energy consumption, while developed countries with 24% of the total world population use 77% of the total world consumption of conventional energy (Türker and Kaygusuz, 1996). In 1980, the total demand for wood in Kenya was about 20.8 million tonnes with 94% (19.6 million tonnes) being used as woodfuel (Hankins, 1989). Firewood is either obtained from woodlot that farmers plant on their compounds and farms or illegally collected from natural forest within the country. Nationally, woodfuel supplies over 70% of Kenya's energy demand whereas the contribution is over 93% of rural household energy requirement (RoK 1997b; MENR, 1994; Wasike, 1992; Wass, 1995). The current policy on woodfuel emphasizes the provision of adequate supplies of wood to satisfy demand through a sustained yield while at the same time, conserving the environment. At least 80% of urban households woodfuel demand is met by charcoal (RoK, 2001b).

The main users of the forest resources are people living within 5 km of the forest. It has been estimated that 2.9 million people, representing 530,000 households live within 5 km of forest area in Kenya (Wass, 1995). The indigenous forest provide not only wood products, but a wide range of goods and services including medicinal plants, honey, thatching grass and fodder to those local users (MENR, 1994; Wass, 1995).

In Kakamega forest, 84% of the forest-adjacent households use the forest to provide at least one of the following basic forest commodity i.e. firewood, poles and posts, medicines, grazing, thatching grass, fruits, etc. (Emerton, 1991; Emerton, 1994). Firewood being the major source of energy at the household level is used for the following functions: cooking, heating, lighting and processing. These use patterns form the basic core of demand for firewood in both rural and urban households.

The oil crisis in the 1970s awoke the global interest in new and renewable sources of energy and led the Organization for Economic Cooperation and Development (OECD) to adopt measures to ensure continued energy supply for their member countries. Estimates of traditional fuels consumption, such as fuelwood and charcoal, crop residues and animal waste, indicate that they constitute 60% of the total energy consumption in Africa, 40% in Asia, 10% in Europe, Middle East and North Africa (EMENA) and 30% in Latin America and Caribbean (LAC) (Türker and Kaygusuz, 1996).

The demand for wood in the high and medium potential districts of Kenya was estimated to increase from 15.1 million m^3 in 1995 to 30.7 million m^3 in 2020 (Table 1). Fuelwood (firewood and wood for charcoal making) accounted for about 86% of the wood demand in 1995 and was projected to increase to 89% by the year 2020 (MENR, 1994 and Lwayo, 2000).

Table 1: Projected demand for wood in the high and medium potential areas of Kenya ('000 m^3)

Purpose	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Firewood	7,993	9,251	10,686	12,251	13,889	15,593
Wood for charcoal	5,085	6,298	7,351	8,511	9,726	10,972
Poles	948	1,111	1,308	1,544	1,823	2,153
Industrial wood	1,058	1,209	1,378	1,543	1,709	1,961
Total wood demand	**15,084**	**17,869**	**20,723**	**23,849**	**27,147**	**30,679**

Source: MENR, 1994

Firewood collection is the most widespread activity among forest-adjacent communities and is permitted under license – usually for deadwood in gazetted[3] forests. A license costs Ksh. 39 per month for one headload per day or Ksh. 77 per m^3 at the time of study. The collection of dead wood for fuelwood has some negative effects on the recycling of nutrients within the forest ecosystem and it leads to loss of biodiversity when the rate of off-take reaches a high level that little deadwood can be found on the forest floor. It was common for fuelwood collectors to ring bark trees so that there are future supplies of dead wood, thereby accelerating off-take to meet demand from the surrounding urban centres of Shinyalu and Kakamega among others. Studies conducted in some parts of Kakamega forest showed that hole-nesting birds had declined and there were no signs of wood-eating termites because most of the dead branches on the ground had been collected for firewood. (MENR, 1994; Mungatana, 1999).

The performance of the economy may to some extent explain the rampant incidences of forest degradation as many local people usually resort to illegal means of survival. During the period 1964 to 1973, Kenya's Gross Domestic Product (GDP) grew on average by 6.6% per year. Since mid 1970s, based on the current prices the performance of the economy has remained very poor. For example, between 1974 and 1979 the growth rate had declined to an average of 5.2% per year, 4.1% for the period 1989 to 1990 with the year 1995 registering the lowest average growth rate of 2.5%. For the period 1998 to 2002 the GDP showed slight improvement by registering an annual growth rate of 6.8% with the year 2000 registering the lowest growth of 4.4% (RoK, 1997b and RoK, 2003).

The Kenyan government needs to create more accurate national accounting systems that reflect the relationship between the environment and socio-economic systems. The

Gross National Product (GDP) measures the aggregate value of the output of a country's economy in a given year but does not record deterioration of the environment, which may negatively affect economic welfare. Ecological systems are complex to place a value on them or to design an accurate indicator of their state of well being. The stock of natural capital would decrease when resources such as oil reserves or standing forests are depleted.

The contribution of forestry sector to Kenya's GDP has remained relatively constant over the last decade with an annual growth rate of 2.7 % of the non-monetary economy within the period 1996-2000 (RoK, 2001b). It was estimated that the forestry sector contributed about US$ 88 million to Kenya's GDP and stimulated capital formation worth US$ 33 million in 1995. Although the sector's contribution to GDP has remained relatively small and constant over the years, its contribution to the informal economy is substantial. It is estimated that the forestry sector and the associated formal and informal industries/enterprises support approximately 10,000 households through employment and generates direct financial revenue to the Forest Department of about US$ 3 million annually (Emerton, 1992c; Mogaka, 2000).

1.2 Study area

Kakamega forest is hereby described by location, size, access, settlement, land ownership and user rights, flora, demographic factors, rainfall, temperature and basis for selection for this study.

1.2.1 Location, size and access

Kakamega forest[4] is located in the eastern side of Kakamega town in Western Province at the foot of Nandi escarpment between 0^0 10′ and 0^0 21′ N and longitudes 34 ° 47′ and 34° 58′ E. The forest is about 40 km north of Lake Victoria. Its altitude varies between 1520m and 1680m above sea level. Until early 1992, the forest was wholly located in Kakamega District. Kibiri forest block, which covers an area of 3,691.3 ha, is administered from Vihiga District (RoK, 1997c). The original gazetted area of Kakamega forest in 1933 was 23,795 ha, in the main forest block, plus Kisere Forest an isolated forest remnant of 471 ha. The other forest blocks are Malava (718 ha), which is 25 km from either Webuye or Kakamega and Bunyala (825 sq. km). The area under Kakamega Forest Reserve (KFR) has been reduced to 19,649 ha through excisions.

The major change in the forest status since gazettement there has been the creation of two national reserves, one covering part of the main Kakamega forest and the second comprising the whole of Kisere Forest. The Kakamega National Reserve (4,455ha) is managed by the Kenya Wildlife Services (KWS)[5]. It occurs in two discontinuous parts: the Buyangu area (3,984 ha), gazetted in 1986, previously part of the forest reserve to the south and west and the isolated Kisere Forest (471 ha) to the North. In addition there have been two excision for settlement, Virhembe and Eshuru excisions (KIFCON, 1992a; Muriuki, 1994; Wachira, 1995; RoK, 1997b).

Kakamega forest, the surviving equatorial rainforest in Kenya, is home to many plants and animal species found nowhere else in the world. It is part of the Guineo-Congolean equatorial rainforest remnants stretching in a belt across the Democratic Republic of Congo, Uganda and Western Kenya. Endowed with high agricultural potential, the district supports one of Kenya's highest population densities (500 per sq. km) and population growth rates (2.98 per cent per year). The high population has created pressure on land and other resources as the average farm size per household gets smaller over time (ICIPE, 2000 and Mogaka, 2000). Appendix 1 gives location of Kakamega forest.

The Kakamega Forest Reserve (KFR) is accessible from three main roads: the first one being to the southeast, Kaimosi to Chepsenoi; the second one running from Kakamega to Kitale along the Northeast border and then through the forest to the third road which connect Kakamega to Kapsabet through the KFR. In addition, there are numerous access and old logging tracks running into the forest from the main roads. The good road network contributes to the accelerated rate of deforestation, as forest produce finds easy access into the market. The numerous roads contribute to the forest resource finds its way into the market un-noticed.

The mean maximum temperature for Kakamega forest station for the period 1978 to 1992 was 26° C while the mean minimum was 12.9 ° C. Mean monthly maximum temperature varies between 18.3 ° C and 29.4 ° C while the mean monthly minimum temperature for the same period was 10.5 ° C and 21.1 ° C (Muriuki, 1994). The forest is situated in a fairly wet area of Kenya with annual rainfall of between 1200 and 2100 mm per annum, with the Kakamega forest station recording an annual mean rainfall of about 2025 mm. The rainfall is bimodal, with the main rainy season falling in March to June and mid August to November (Mungatana, 1999). Between 1990 – 2001 Kakamega forest station registered an average rainfall of 1900 mm per annum (RoK, 2001a).

1.2.2 Settlement patterns, land ownership and usage rights

The forest stands as an island in a densely populated area where human density exceeds 500 persons per square kilometer (Wachira, 1995). The main settlement and establishment of shambas in and around the forest by the Abaluhyas took place in the late 19th and early 20th centuries. The people living around Kakamega forest are predominantly part of the 17 sub-ethnic groups of the Luhya community who practice small-scale farming of traditional agricultural crops as the dominant economic practice. Migration and interaction with other communities is common and contributes to accelerated erosion of forest biodiversity (Mogaka, 2000).

These communities directly derive their subsistence and financial needs through collection of forest products, hunting and shifting cultivation. Land in the forest adjacent sub-locations was finally demarcated and title deeds given to the families between 1971 and 1974. During 1959-1964 periods, special rules were issued under the Forest Act allowing bonafide residents of Kakamega District a wide-ranging unlicensed use of the forest. However, some of these privileges have been withdrawn through presidential ban affecting all gazetted forests in Kenya (KIFCON, 1992$_a$).

The staple crops grown are maize, beans, pulses, bananas, sweet potatoes, cassava and other root crops. Land holding ranged between 0.10 and 16.3 ha per household with an average of 2.4 ha, although 60% of the households own less than 2.0 ha. About 76% of the households have private rights to their farms, while the other 24% just have user rights. Cattle is considered to be a capital asset which can be sold in times of financial stress and also features prominently in cultural and traditional uses (Mungatana, 1999).

1.2.3 Kakamega forest flora

Nationally, it is unique for being the only representative of the western moist equatorial rainforest transition zone and the only lowland forest remaining in Western Kenya. From studies conducted in the area, tree species richness is high with no single genus being dominant at a given site. The common genera include *Celtis, Antiaris, Zanthoxylum* and important timber trees include Elgon Teak (*Olea capensis), Aningeria* and *Prunus*. . Overall plant endemism is low since most species occur in the lowland or highland zones either side, with only the climber *Tiliacora kenyensis* endemic[6] to Kakamega (KIFCON, 1992a).

The main tree species are *Croton megalocarpus, Celtis duradii, Aningeria altissima, Ficus exasparate, Fantumia clastica and Bosquea phoberos. Croton macrostachys and Olea capensis* are of special concern since though abundant in the past, they have been over exploited for timber in construction industry. Indigenous tree species preferred for woodfuel include *Markhamia lutea, Maesopsis eminii, Prunus africana, Bridelia micrantha and Diospyros abyssinica* (KIFCON, 1992b).

Kakamega forest is where Guineo-Congolian vegetation intermixes with Afro-montane species. 350 bird species have been recorded in this forest. Similarly, there are 35 De Brazza's monkeys left in the adjacent small Kisere forest (471 ha). Reduction in birds population is a concern especially if forest fragmentation and clearance continuous unabated (MENR, 1994).

1.2.4 Household income

The community's source of cash income revolves around formal employment and remittances, agricultural and livestock production activities, small scale enterprises and forest-based activities (Mogaka, 2000). Most of the income of the district is generated from agricultural sector and only little income comes from the non-agricultural activities since there are very few industries in the district (RoK, 1997a). The main cash crops grown in the area include sugar cane, tea and coffee. Maize and beans are the main staple food crops grown but sometimes sold when produced in excess and/or when families are under financial stress. Generally, there is high rate of local un-employment caused by the growing number of young people entering the labour market each year and lack of job opportunities outside the farm. Un-employment was a subject of further research to establish how it influences deforestation.

An estimated 26,000 households representing a population of 114,000 people and 3,300 households' representing 17,000 people are using Kakamega and Malava forest respectively to supply at least one essential household need. Animal grazing and fuelwood collection are the most important activities. In addition, 70% of the households have at least one source of monetary income originating from the forest with charcoal being among the most widespread activities (KIFCON, 1992a; ROK, 1999).

The average value of crop production is Ksh. 14,000 a year per household, including cash sales of about Ksh 5,000. The average income from livestock (livestock and livestock products sales) is approximately Ksh. 3,000 per household. Milk sales are negligible as most of it is consumed by the farm family (KIFCON, 1992a).

The national total annual direct value of forest utilisation by forest adjacent households is estimated at Ksh. 378 million to the forest adjacent communities (KIFCON, 1992a). Of the value of forest adjacent households, 37% comes from grazing, 29% from charcoal, 16% from firewood and the remaining 18% from the extraction of timber, gold, polewood and seedlings/wildlings (KIFCON, 1992a; KIFCON, 1992c). The recorded sale of fuelwood in Kenya for the period 1996 – 1999 was 47,825 m^3 valued at Ksh. 3.7 million (RoK, 2001b). The value of the benefits obtained from Kakamega forest is estimated at Ksh 1.945 million per year (RoK, 1997a).

The estimated average net household income was Ksh. 38,000 (US$ 1,350), equivalent to US$ 110 per capita. Forest produce supplies almost 75% of this average household income (Emerton, 1991). The extraction of forest products generates an estimated income of Ksh. 26,000 per year for the 'average' forest adjacent household with approximately half of the earnings from forest products sales (KIFCON, 1992a). Of the total income derived from forest sources, some 50% can be considered as sustainably extracted. The proportion of forest use for cash-income was higher than that for subsistence (Mogaka, 2000). Kakamega forest is a source of woodfuel, timber, medicine, pasture for domestic animals and some areas are of cultural values to the local people. The forest plays a critical role in the prevention of soil erosion, protection of water catchments areas, wildlife habitat as well as conservation of biodiversity.

In areas with higher levels of farm – related un-employment, a greater number of people are dependent on extracting forest products to generate income. For instance, there is likely to be more brick making and charcoal making in these areas. Those communities close to the forest depend on it completely for fuelwood and practice less storage of firewood. Indigenous tree species are culturally preferred for fuelwood and exotics are generally considered inferior. Women and children mainly do the collection of firewood. Men are usually restricted to carrying large logs and in all heavy work required in woodfuel preparation. Average daily firewood consumption is 10.5kg with an average daily per capita consumption of 1.31 kg. Most firewood collection takes place in Alosi and Buyangu blocks (National reserve). Firewood collection is prohibited in National reserves (KIFCON, 1992b; Gibson, 1991).

1.2.5 Credit and forest adjacent households

The availability of credit directed towards forest adjacent community's priotised needs is limited due to the high principal interest rate (34.65% for the period 1991 and 2000) charged by the local banks and other financial institutions[7] (RoK, 2000 and RoK, 2001b). The re-discounted average interest rate pegged on the 91 day treasury bills for the period 1994 and 2000 was 19.0% (RoK, 1997a and RoK, 2001b). The various financial institutions located in Kakamega town include Kenya Industrial Estates (KIE), Agricultural Finance Cooperation (AFC), Kenya Commercial Bank, Barclays Bank, Standard Chartered Bank, Savings and Credit Societies, Post Bank, Industrial and Commercial Development Corporation (ICDC), etc.

In the agricultural sector, the majority of the farming community[8] lacks capital resources to invest in commercial agriculture due to tough conditions to be fulfilled on the loans, major institutions have inadequate funds for agricultural credit, lack of collateral such as Land Title Deeds, preparation of feasibility studies for project are too expensive, banking system tends to be conservative in their dealing with informal sector borrowers who are considered risky and require a high credit administrative cost and poor repayment records. The local people in Kakamega district were beginning to understand the need for credit for their day to day operations. Women and children above 18 years are unable to obtain the credit because they lack collateral. Access to credit will ensure that the local community is engaged in various economic activities thus reducing pressure on the forest as attributed to un-employment.

1.2.6 Basis for selection as study site

Kakamega forest was selected for study based on the following reasons:

- Its location in a densely populated area thus posing as an important interplay between ecological and human factors;
- The forest being the only Guineo-Congolean forest that is currently existing in Kenya;
- The forest being an important source of biodiversity conservation locally and internationally, unique animal and plant species, many threatened species and endemic species; and
- The forest has great potentials for eco-tourism, research, cultural and religious values.

1.3 Statement of the problem

In Kenya, deforestation[9] takes place at an increasing rate due to low price charged for the forest goods and services, the low rate of woodlot establishment by the forest adjacent local communities, population pressures, cultural problems, poor enforcement of the regulations, understaffing within the FD and ready markets for the products. The continuous deforestation of Kakamega forest result into environmental degradation, loss of economic benefits, uncontrolled firewood collection, unsustainable timber logging practices, rampant incidences of charcoal burning, forests encroachment for agricultural land and soil erosion and shortage of wood supply in the long run, high incidences of poverty and ignorance, loss of wildlife habitats and biodiversity. Exploitation has often been destructive because Forest Department rules have been widely ignored (MENR, 1994; Wass, 1995; KIFCON, 1992a; Heltberg *et al* 2000; RoK, 2001a and RoK, 1997a).

Kigomo, 1990, reported that Kakamega forest had suffered extensive encroachment mainly from agricultural pressure and its size had considerably reduced by less than a quarter of its former size before the World War II. It was estimated that the annual rate of deforestation was 245 ha for the period 1959 to 1980. KIFCON (1994) forecasted that if the unsustainable exploitation rate continued, the forest was going to survive for only twenty-five years i.e. by the year 2020. The problems were compounded by the inability of the FD to monitor the subsistence use of the Kakamega forest complex thus creating an opportunity to overhaul the licensing and policing system to keep the forest at sustenance levels. This study seeks to address the problem of unsustainable harvesting forest products using the example of fuelwood. The absence of any mechanisms to monitor or control legal fuelwood extraction by the forest adjacent households and the failure of the Forest Department (FD)[10] to enforce the ban on grazing and timber extraction, threaten the continued existence of the remaining natural forest (KIFCON, 1992a).

Further, Kakamega forest with a relatively well developed road network makes it possible to access urban and peri-urban centres thus influencing local community's perception and preferences regarding forest resources. This is a potential incentive towards forest degradation though it depends on the nature of costs borne by the beneficiaries. If this un wanted destruction practices will deny the local community of their livelihood.

1.4 Goal of the study

The broad objective of this study is to identify key social and economic factors that influence the quantity of fuelwood collected in Kakamega forest with a view to making recommendations for sustainable[11] conservation of natural forests in Kenya.

1.4.1 Specific objectives

1. To assess the socio-economic characteristic of forest Kakamega forest complex adjacent communities;
2. To estimate the annual quantity of fuelwood collected from the Kakamega forest complex; and
3. To determine the socio-economic factors that significantly influence the quantity of fuelwood harvested from Kakamega forest complex using econometric tools.

1.5 Hypothesis

H_01: 100% of households depend on Kakamega forest for their fuelwood needs.

H_02: Socio-economic factors significantly influence the quantity of fuelwood harvested Kakamega forest

1.6 Justification

Fuelwood is the most important biomass energy source, therefore, increasing demand results into increased cutting of standing stocks of wood because annual yields are insufficient to support demand. Urbanization and consequent demand for charcoal are the other major causes of acute problems of wood-destruction in an energy economy that remains dominated by the harvesters of wood. Many plant species with potential as sources of medicine, oils and chemicals remain un discovered, therefore, the rampant loss of forests threatens the achievement of this noble goal. It has been hypothesized that un-planned clearance of forests causes an irreversible wastage of potentially valuable biological resources without any sustained economic gain.

Due to an increase in population, rising demand for fuelwood collection will continue to deplete the vegetation over large areas resulting into replacement of useful plant species by less preferred species. Alternatively, the government continue to incur management costs in trying to control the illegal use of the forest by the forest adjacent communities and rehabilitation of degraded areas. Research is desired to generate information on the rate of exploitation and the socio-economic factors responsible for the action of deforestation so that the necessary remedial action could be taken. This information will guide future policy debates, form a basis for decision making and provide the basis for intervention to halt forest destruction.

1.7 Scope of the study

This study was confined to 235 respondents living in five forest adjacent sublocations namely; Buyangu, Virhembe, Ishiru, Lunyu in the case of Kakamega forest and Tande for the case of Malava forest. Malava forest was included in this study so as to obtain a wider coverage of the subject under study. The information captured included household characteristics, fuelwood species, fuelwood sources, consumption, marketing, cash income, expenditure, fuelwood procurement, un-employment, conversion technologies and effect of seasonality on the quantity collected from the forest. Fuelwood was the only forest product covered under this study due to its wide use as compared to other forest products.

CHAPTER 2: LITERATURE REVIEW

Literature review was done to obtain the magnitude of the problem; identify information gaps and contribute to the knowledge of science. Aspects covered under literature survey include local communities and the forests, social and environmental impacts and markets and pricing of environmental goods and services. These issues are discussed herein below.

2.1 Local communities and the forests

The local communities are dependent on the forests for a wide range of resources and services. Policy makers often emphasize economic growth as the most important way to reduce poverty, raise living standards and manage the environment. In most cases, natural resources are viewed as free goods for extraction whereas waste is returned to the environment without due consideration of the costs implications. Scientific evidence shows that economic development depends directly on the quality of the environment and the goods and services it provides. For example, society uses and depends on the environment as the "sink" or repository for its pollution and waste (Furtado *et al* 2000). As the communities strive to co-exist with environment undue pressure is usually placed on the resources therein as witnessed from the rampant incidences of over-exploitation. This un-ethical behavior can be attributed to poverty, un-employment, technological advancement, institutional and market failures, etc.

The United Nations Conference on Environment and Development, Known as the Earth Summit, held in Rio de Janeiro in 1992, endorsed the goal of sustainable development. Agenda 21 was intended to achieve this goal and establish actions that foster sustainable development. The concept of sustainable development emerged as a desired goal of society (Furtado *et al* 2000). The four main functions performed by the forests can be categorized as: regulatory (sustains life support systems, such as tropical forests), production (the environment's inputs are a direct contribution to economic activity – fuelwood, timber, etc.), carrier (and natural resources such as clean air and clean water contribute to the quality of life e.g. physical health) and information (valued as an amenity with intrinsic worth i.e. people appreciate natural landscapes and enjoy them through recreational activities).

The maximum sustainable yield of a single-species, for instance, forest, is defined as the yield that can be sustained with a given harvesting effort over time. If more of a resource is harvested beyond the maximum sustainable yield, populations will decline over time, because their regenerative capacity (growth) will have been exceeded. The relationship between productivity and the intensity of use is unique to renewable biological resources and the environment in general. The maximum sustainable yield was used for harvesting of a single-species resource, but was later expanded to tropical forestry systems, agroforestry ecosystems and eventually to the combination of biophysical and socio-economic systems. Sustainability demands that humanity should strive to coexist with nature. The focus for such harvesting should be on sites, ecosystems and silvicultural practices that ensure regeneration maintain site potential and allow ecologically mature forests to develop (Church and Richards, 1998).

Sustainable development is a dynamic balance between economic, ecological and sociological imperatives and benefits over time, so that future generation will have the same potential and opportunities for human livelihood and development as current generation. Ecosystems can tolerate stress to varying degrees. In their natural state they are usually not functioning at their optimum level of either production or assimilation capacity, but have a point beyond which degeneration processes begin. The most cost-effective approach is not to go beyond the optimum tolerance level, which implies trying to prevent environmental problems rather than trying to correct them after they have occurred.

In most instances institutional arrangements usually ignore the contribution of the local communities in the conservation of natural resources. The local people are neither involved nor consulted on various issues when decision making are being made. Participatory forest management is the integrated involvement of local people living near a forest alongside other agencies in activities intended to maintain or enhance forest conservation while improving their well being. Some of the necessary ingredients in successful local community conservation efforts include the following: local people to contribute to the production and productivity of the management regime and a reduction in institutional conflicts. This is the only opportunity for local community to share equitably in the benefits and costs enjoyed or borne by different stakeholders. In most cases the involvement of the local community usually absent resulting in unsustainable practices.

The protection of biological resources has benefits as well as opportunity costs. While everybody shares the benefits, the opportunity costs are borne entirely by the people who live in the vicinity of the protected areas. This means that the benefits of the protected areas are symmetrically distributed across all the people, but the costs have to be asymmetrically borne by the local people. There is lack of awareness on the contribution of natural resources to the well being of local community thus leading to depletion of biodiversity.

Management by local communities of the woody resource and its utilisation promote better cutting practices, distribute logging pressure over a wide area and give the population an economic return from sustainable management of fuelwood resource. Therefore, any strategies taken in the fuelwood chain to achieve sustainable production, raise rural revenues and ensure better management and hence protection of the environment are much welcomed (Peltier *et al*, 1995). It is the aim of this study to contribute towards achieving this goal.

2.2 Social and environmental impacts

Worldwide, there is increasing concern over deforestation and environmental degradation in Sub-Saharan Africa and their effects on the economic future of the continent. Africa's population is still largely rural and depends on agriculture for its income. Population growth results into increased demand for fuelwood, building material and other products traditionally extracted from the natural vegetation resulting into accelerated rate of deforestation, increased wind and flood erosion and declining productivity of agricultural lands in what appears to be an ever-widening spiral of environmental degradation (Kamau, 1996; Hankins, 1989).

Evaluating environmental impacts is an important part of cost-benefit analysis, economic efficiency, equity, financial and administrative feasibility studies. The trend has been to analyse the impact of overall, macroeconomic policies on the environment. The impacts of economic activities can be divided into three broad categories: physical, biological and sociological impacts. Retaining the structure of natural ecosystems results into relented genetic resources, which is important for biodiversity conservation.

Incorporating environmental considerations into cost-benefit analyses essentially involve identifying impacts and imputing a value to them. It requires increased education and information about the environment so as to make the environment a central focus for decision making across all levels of government, private sector activities, communities and individuals.

Environmental degradation is defined as the excess exploitation of renewable natural resource systems. It implies connotations that the observed rate of resource use is in the incorrect time path (too rapid harvesting rate of a forest). The rate of soil fertility, excessive dumping of pollutants in the atmosphere or water bodies remains un-investigated. The human activities of concern in this respect are socio-economic in nature and include overgrazing, deforestation, low input agriculture and industrial activities. The focus for this study is forest degradation, which is defined as the loss or reduction of reproductive capacity of forest land due to impact of human activities

There is no doubt that the greatest challenge facing Kenya's environment is the excessive removal of the tree cover. Today, clearing for agricultural production, charcoal production and firewood collection are removing trees from Kenya's landscape at an alarming rate. Traditional societies make use of wood charcoal and agricultural wastes for their energy needs. Typically the diversification of the energy sources will ensure that our natural resources are well protected for the current and future generations.

In Kenya, forest use is primarily defined and regulated through the issuance of licenses, the establishment of restrictions and imposition of fines or imprisonment of illegal forest users. Cutting trees inside gazetted forests without a license is illegal though significant amount of fuelwood is collected from natural forests through collection of dead wood (KIFCON, 1992b). The recognition of customary rights though common sometimes is largely overridden by the imposition of a wide range of bans and prohibitions on utilisation of the forest reserves. Despite these attempts, forest depletion continues un-abated.

An estimated 104,000 m^3 of fuelwood is annually removed from Kakamega forest (KIFCON, 1992a). In the absence of a licensing system for subsistence use in Kenya, the foresters have little idea of the quantity of fuelwood being extracted and are unable to monitor the rate of off-take by the forest adjacent households. Illegal removal of forest produce and grazing in the forest are widespread, frequently with the collusion of the Forest Guards (KIFCON, 1992b). Areas with denser population such as Shiru, Southern Ileho, Muhudu and Mukulusi exhibit a higher intensity of use of forest products. Despite some effort to enforce its protected status, the Kakamega forest is still being cleared for timber, charcoal production, cultivation (Cords, 1999; Kokwaro, 1984), fruits, mushrooms, herbal medicines, vegetables, sand for building, green manure, the opportunity to prospect for gold and clay for building.

Over 96.2% of the local community values Kakamega forest for at least one role or function (Mogaka, 2000). 68.6% value the forest as a source of income with poles/posts, firewood and charcoal being the main products for commerce. Charcoal production is stimulated by a high demand for fuelwood by the four urban centres around Kakamega forest. In effect, a relatively small proportion, 19.5%, of households used charcoal as a source of energy. Given that a large proportion of charcoal is produced within the Kakamega municipality in addition to the relatively good communication links is probably the explanation that counts for the high number of households who consider charcoal production as a source of cash-income. Given this scenario, the destruction of the forest is inevitable given the economic base of the local people, in-efficient production methods and subsistence needs.

2.2.1 Domestic energy production and consumption

Several types of fuels including fuelwood (firewood and charcoal), electricity, liquefied petroleum gas (LPG) and kerosene are consumed at the household level though woodfuel provides most of the energy. Fuelwood is sourced from rural areas and over dependence on it has negative implications for the resource base and environmental quality. As a renewable resource, wood is inexpensive relative to other sources of fuel such as petroleum products. The continued escalation in prices for imported world fossil fuels, the huge amounts of capital required for installing hydroelectric and geothermal power stations and problems of technology transfer hinder the transition from woodfuel to more efficient and cleaner forms of energy. Even if these other forms of energy were made available, the economic situation at the household level (low incomes and meager resources of production) prevents the majority of the people from investing in the efficient devices necessary for their use.

The average fuelwood consumption in Kenya was estimated at 6.6 cubic metres per annum per household (Barnes *et al,* 1984). Charcoal consumption was estimated at 1.6 bags while paraffin was estimated 4.3 litters per month within the same period. Rural households, which are heavily involved in the monetary economy depends upon fuelwood for 90% of their domestic energy.

In Nepal, Malawi, Tanzania, Ethiopia, Upper Volta and Mali families depend on wood for over 90.0% of their household energy needs. In Guatamala, 80.0% of rural population use wood as their sole cooking fuel and a further 15% rely on it to meet part of their energy needs (Eckholm *et al, 1984*). In Kenya, Zimbabwe and Senegal where the proportion of total national needs supplied by wood is somewhat lower, rural people depend almost entirely on wood (Eckholm *et al, 1984*). Excessive reliance on fuelwood coupled with increased population led to deforestation, increased risks of desertification and decreased potential biomass production.

Studies indicate that the domestic energy crisis, resulting from charcoal and firewood scarcity was complex and increasingly imposing a great burden on many families in developing countries (Chiama, 1996). Woodfuel scarcity and commercialisation has led to higher prices for charcoal and firewood in urban and rural areas respectively, increased the time spent on fuelwood collection which presents enormous burden on many rural households. The commercialization of a formerly free good can pose special dangers of lack of access to the poor and the landless.

Climate influences supply and demand for woodfuel through temperature variation as significant amounts of energy is required for space heating. Household size, ceremonies (circumcision, funeral, etc.), age, type of food cooked, etc. also influences household and per capita energy consumption levels. Some households have begun conserving woodfuel through diet switching behaviour e.g. cooking foods, which require less cooking time. Usually, rural households' increases wood consumption as income increases but while supplies are available they generally do not switch to charcoal consumption. The trend is different for the urban population; an increase in income may trigger many households to consume less traditional fuels due to appliance purchases, labor savings and a propensity to consume fuels of higher level of sophistication.

When household average fuelwood consumption were computed on the basis of household dietary patterns, households relying on a whole-grain diet was significantly higher than that for households whose main staple was not whole – grain based. The latter group used an average of 3,867 Kg of fuelwood per household per annum while the former group consumed approximately 5,221 kg per household per annum. A household consuming predominantly maize and beans as the main stable food utilised about 1,400kg more per annum than it would were it dependent upon ugali or other non – whole grain dishes (Barnes *et al,* 1984; KIFCON, 1992b).

Based on Barnes *et al's* model, all the variables explained roughly 21% of the variation in fuelwood consumption. The constant, β_0, in the equation ($\beta_0 = 4{,}133.9$) is large by most standards and represents variables not included in the equation as well as an error term (Barnes *et al,* 1984). Therefore, research was required to address the issue of un-explained variables in the error term. This model was adopted in this study for its simplicity, allows variation in elasticity over the range of data and the ease of fitting it with least square regression (Ojuki, 2001; Upton, 1979).

Therefore, theoretical model is defined as:

$$F = 4133.9 - 171.3T + 226.4\ HH + 790.3\ DD$$

Where

F = Fuelwood consumption

T = Time spent gathering one kilogram of wood

HH = Household size

DD = Dummy variable indicating the use of a whole – grain or non-whole-grain diet.

Nyang, 1999, used the Cobb- Douglas production model to explain the rural household firewood production and consumption. This model incorporated land and labour adjusted for household size and for the distances, that member of household walk in search of firewood. The model applied for those households that use family labour in the collection of firewood and transport the firewood on their backs, shoulders and heads. The model explained 35.17 % of the output thus the need for further research to establish the other factors. This model will not be used in this study due to the difficulties in getting the natural log of zero since zero level of input give zero levels of output, cannot show both increasing and diminishing marginal returns in a single response curve and does not give a technical optimum thus leading to an over-estimate of the economic optimum (Ojuki, 2001; Upton, 1979).

Firewood is basically used for cooking, space heating, lighting, cultural ceremonies such as funerals particularly in the rural setting. The other use for firewood include brick making, fish-smoking, brewing, iron mongery, pottery, brown sugar manufacturing, tea drying, tobacco curing and white sugar refining among other agroindustrial uses. The most widely used firewood-cooking device is the open-hearth. It can be used indoors or outside in the open. It consists of three stones arranged in a triangular pattern on the floor or ground, hence the alternative names: three stone – hearth or as the Armacher, Hyde, etc. The efficiency is low which makes the consumption of fuelwood very high making the harvesting of fuelwood from forest to become un-sustainable.

Rural households either produces charcoal for sale or for own use. Charcoal production is traditionally carried out in earth-kilns consisting of a pile of wood arranged on the ground and covered with earth underlined with grass. Charcoal is used for cooking, space heating and for ironing. Nine tons of wood gives one ton of charcoal, thus giving an energy conversion efficiency of 11% (Nyang, 1999). The charcoal production process, known as pyrolysis, involves the controlled burning of wood in limited supply of air to minimise the oxidation of carbon and its subsequent loss as carbon dioxide (CO_2). The product (charcoal) is almost pure carbon with approximately twice the energy (32.4 MJ/kg) value of the firewood (15.5 MJ/kg) (Nyang, 1999). 34% of charcoal manufacture takes place in Shiru/Ikuywa, Central, East and West blocks of Kakamega forest (Gibson, 1991). In Kenya, urban charcoal consumption ranges from 100-170 kg per head per year.

The felling of trees for charcoal production as practiced in Kakamega forest result in change in the structure of the canopy a decline in the atmospheric humidity at the understorey and a shift in plant species composition in favour of the invasion species, which proliferate in such forest openings. Some trees of special commercial value may be reduced in numbers such that their populations are no longer viable.

At national and local levels, factors hypothesized to influence the forest loss include increasing population pressure and high demand for land (inequality in land tenure), technological improvements and innovation in forest resource exploitation, relatively low agricultural productivity, energy crisis, widespread poverty[12] with increasing reliance on forest biomass as the main source of energy (Mogaka, 2000; Lwayo, 2000; Mungatana, 1999; Colchester, 1995$_a$). Further more low morale and understaffing in the Forest Department, rural construction practices and livestock production practices, inadequate intervention measures and institutional arrangements that do not take into consideration local values of forest resources in the planning and decision making process contribute towards deforestation in Kenya.

2.3 Markets and pricing of environmental goods and services

Markets do not accurately reflect the social cost of the environment for several reasons. For instant, the environment is considered as a public good. Public goods are characterized by non excludability and non-rivalry. Non excludability means that the resource in question will be supplied to all groups and all groups can benefit from it, because no one group can be excluded (Furtado *et al* 2000). Conventional markets always function to efficiently allocate resources among competing uses. For biological resources, these conditions are partly fulfilled when the resources are privately owned, backed with legally enforced rights and the flow of market information is perfect. Kakamega forest is a state managed resource and subject to abuse since it is primarily considered as public property.

Alternatively, economic policies such as subsidies, price controls, exchange controls and ownership controls can result into inefficient resource utilization outcomes. A common example of policy failure is keeping prices below market prices. This generates inefficiency and can lead to excessive or wasteful use of natural resources. The market should also streamline environmental considerations into program and project planning. Countries should modify their national accounts to include environmental services. In Kenya, value of the forests products are usually determined by the concerned government regulatory bodies in this case, the Forest Department, which does not give the due regards to the prevailing market prices thus rendering the forests products from natural forests to be cheaper thus resulting into over-exploitation. Direct market prices provide the best estimates of Wood and Tree Products (WTP) and reflect stakeholders' decision making realities. The challenge confronting conservationist should focus their roles and that of the market to correct for the environmental externalities.

There are few incentives to motivate local communities to invest in the conservation of biodiversity. The positive attitude that local communities had towards forest conservation had shifted to that of perceiving forests as sources of cash income. Forest adjacent communities with easy access to forest products markets have different altitudes towards forest conservation compared to those without access to markets. Individuals without access to markets find the resource useful for subsistence while those with access to the market find the resource as a source of cash income (Campbell, 1997).

Economic and environmental issues associated with the demand and supply of fuels for the household sector is a priority issue for study in light of the long-term problems of deforestation and soil erosion arising from the current patterns of traditional fuel consumption and problems of financing and pricing substitute products; such as kerosene (Siddayao and Griffin 1993). Market prices, labor opportunities, the availability of substitutes (to fuelwood) and measure of access to the basic resources were the most reliable predictive variables for fuelwood consumption and production (Amacher *et al,* 1996).

The development of commercial woodfuel market within forest adjacent villages and its environs has radically changed the way local people regard the question of woodfuel supplies. When people sell wood, there is a cash incentive for them to grow trees if this is the most profitable use for their land. But there is a greater incentive to cut them down either from their land or from communal areas and nearby forest reserves. The growing cash markets for fuelwood is the potential cause of forest depletion and a potential channel for remedial action must be established. The spread of commercial wood markets increase competition for local wood resources and when not accompanied by public regulating and support for sustainable forestry, it accelerates deforestation (Eckholm *et al, 1984*). This study will seek to address these issues by looking at the marketing of fuelwood in the study area and how it has influenced the rate of resource use.

A valuation exercise by KIFCON (1994) on the off-take of timber, firewood, carving wood, charcoal production and poles from Kakamega forest estimates a conservative figure of US$ 1.7 million a year from indigenous forests. The annual illegal indigenous timber and charcoal extraction only from Kakamega forest may be as high as 100,000 cubic metres (ICIPE, 2000). Better roads have resulted in accelerated forest destruction as urban charcoal market becomes accessible (Eckholm *et al, 1984*).

In many developing countries' cities and towns, the purchase of fuelwood is placing strain on the over-stretched budgets of urban poor. Paying more for fuel implies less is spent on food, education, health, decent houses and other necessities. In the past, most rural areas, fuelwood was seldom bought and sold but with the changing economic situation the practice has changed.

CHAPTER 3: RESEARCH METHODS

This chapter provides conceptual framework upon which the study is based; the types of data required for the study; sources of data and data collection methods, sampling procedures and data analysis techniques.

3.1 The conceptual framework

A wide range of factors influences the value stakeholders place on Kakamega forest complex. It has been hypothesized that factors such as distance from the forest, household size, levels of income, land size, real or perceived benefits, attitude, cultural and social inclination, wealth, gender, weather and agro-ecological zones and population influence the extent to which local household rely on the forest. Therefore, the conceptual model adopted for this study can be defined as:

$$Q_h = \beta_o + \sum_i^n \beta_i X_i + \mu$$

The variables considered in these analyses were:

Q_h Quantity of fuelwood in m^3 harvested from the natural forests per year

X_1 Quantity of fuelwood in m^3 harvested from the farm per year

X_2 Monthly household cash income in Ksh

X_3 Market price of 25 kg bundle of fuelwood from natural forests

X_4 Market price of a bag of charcoal weighing 40 kg on the average

X_5 Market price of 25 kg bundle of firewood from the farm

X_6 Land size - hectares

X_7 Family size – members who permanently reside on the farm

X_8 Age of the head of household

X_9 Members of the household who are not on paid up employment

X_{10} Time spent on firewood collection per week: hours

X_{11} Approximate distance in kilometres to the source of fuelwood

X_{12} Gender involved in marketing of fuelwood – (male = 1; Female = 2; or Else = 3)

X_{13} Level of education of Head of household – (No formal = 1; Primary = 2; Secondary = 3; Tertiary = 4)

D_1 Origin of the head of household – (Native = 1; immigrant = 0)

D_2 Mode of transport for fuelwood – (Head = 1 or else = 0)

3.1.1 Definition of variables

The above variables were grouped into dependent and independent variables. The quantity of fuelwood harvested from the forest is the dependent variable while the independent include quantity of fuelwood obtained from the farm, family cash income, prices of firewood from the forest and farm, price of charcoal, land size, family size, age of head of household, education level of head of household, members of the family not on salaried employment, origin of head of household, gender of the member of household involved in the marketing of fuelwood, distance and time spend on fuelwood collection per week.

3.1.1.1 Dependent variable

The annual quantity of fuelwood harvested (i.e. subsistence and income) from the Kakamega forest at the household level measured in m^3 was the model's output. Firewood was collected in the form of headload. During field work the weight headload of firewood was taken in kilograms then converted into cubic metres. The conventional way of quantifying volume is in cubic metres.

3.1.1.2 Independent variables

i. Quantity of fuelwood collected from the farm

It was postulated that the quantity produced from the farm was considered to have an inverse relationship with the quantity collected from the forest. Similarly, the weight was weighed then converted into cubic metres. The higher the quantity of fuelwood harvested from the farm the lesser the level of dependence on the forest.

ii. Household cash income

Household income was the most difficult parameter to estimate. It was much easier to estimate the income from educated individuals. In some cases income was indirectly estimated from household total expenditure. Daily, monthly and yearly estimates were obtained and income per month calculated. It was hypothesized that the quantity collected from the forest reduced with an increase in income due to the switching effect.

iii. Market price of firewood from natural forests

The firewood market price at the household level was established in Kenya shilling per 25 kg bundle. The prices varied with distance and state of development of the market.

The market prices were well established in market centres and areas where brewing and brick making. The higher the price the lesser the quantity collected from the forest.

iv. Price of charcoal

Charcoal is one of the more refined fuels than firewood especially preferred by urban dwellers. A gunny bag of charcoal weighed an average of 40-kg. The price for charcoal, obtained from the charcoal producers and/or dealers. Consumers, too, provided information on prices and markets. It was expected that as the price of charcoal rose individual shifted their preference towards the consumption of firewood. While most households relied almost entirely on fuelwood, they would have preferred to use charcoal if their income permitted.

v. Market price of firewood from the farm

Firewood harvested from the farms was sold by the roadside and the price was established for a 25-kg bundle from the respondents who were the consumers of the resource. Fuelwood from the farm was the main substitute of the firewood from the forest. It was expected that as the price for on-farm firewood rose, more fuelwood from the forest would be consumed.

vi. Land size

Land size was estimated in hectares and was acquired by the respondents through inheritance or purchase. Larger landowners substitute private fuels generated on the farm for forest fuelwood i.e. forest fuelwood and wood from the farm are substitute. Large parcel of land provide an opportunity to plant more on-farm trees and therefore less of forest fuelwood would be consumed.

vii. Family size

The family size comprised of the nuclear family and other dependants who permanently resided on the farm. When the size of the family increased the fuelwood resource consumed by the same family was assumed to increase.

viii. Age of the head of household

It was considered that the advanced age of the head of the household reflected experience and high decision making capacity i.e. management skills. Older heads of households were considered to be more knowledgeable on environment matters hence the need to conserve it. It was expected lesser quantity of fuelwood would be consumed by more elderly headed households.

ix. Members of the household not on paid up employment

Un-employed members of the household are considered the most destructive group since they meet their livelihoods through forest produce sales. The quantity of fuelwood harvested from the forest was expected to be directly proportional to un-employed persons per household.

x. Time spent on firewood collection per week

The longer the time spent on fuelwood collection the lesser the quantity per unit time. The return time taken to collect 25 kg of fuelwood was approximated in hours. Time input into the variable was influenced by the scarcity of fuelwood, distance from the forest and the number of individual involved in the actual fuelwood collection process.

xi. Gender involved in marketing of fuelwood

Gender refers to male and female and their roles in the community. It was anticipated that fuelwood sales contributed greatly to deforestation, therefore, the impact of gender in the menace. Men future prominently where financial gains are involved while women and children are more responsible with subsistence needs. More quantity of fuelwood was harvested where men were involved because they adapt other modes of transport such as bicycles.

xii. Origin of the head of household

The head of household was categorized as native or immigrant. This parameter is treated as a dummy. The origin of an individual usually tends to influence his behaviour and attitudes in the society. Immigrants tend to bring new technologies to their new areas of settlement and are likely to harvest more fuel than the local communities.

xiii. Level education of head of household

Education was considered as a proxy variable for management skills and as such it was divided into no formal, primary, secondary and tertiary. The lack of formal education was postulated to have a significant influence on the use of the forest. No formal and primary levels of education were taken as a disadvantage when it came to decision making. It was postulated that this group lacked the capacity to get alternative means of livelihood like salaried jobs and therefore the incentive to depend on the forest for income.

Secondary and tertiary levels of education were considered more educated but more likely to secure employment in the formal sector. This group was expected to cause less damage to the forest as compared to the no formal and primary level of education holders. Less educated members of the community were expected to harvest more fuelwood as compare to the educated groups

xiv. Distance to the forest

The distance from the home to the forest was estimated in kilometres. Distance was directly proportional to the quantity of fuelwood collected from the forest. The longer the distance covered, the less the quantity of fuelwood collected from the forest and vice versa. The maximum distance taken was 5 km.

xv. Mode of fuelwood transportation

The mode of fuelwood transportation had a bearing on the quantity of fuelwood harvested from the forest. Most of the transportation of fuelwood was by head though it changed with the quantity extracted. In addition to the headload, ox-cart and pick-ups were also used. This variable was treated as a dummy variable.

The collected data based on the following assumptions:

1. Members of the forest adjacent community fully co-operated and provided the correct information. The accuracy of the data collected highly depended on the respondent's ability to recall past experiences. Illegal forest exploitation was treated with a lot of suspicion.
2. All forest adjacent households behave in the same way.
3. A spot survey was considered adequate in capturing the variation in the consumption of fuelwood patterns throughout the year and the socio-economic characteristics of the forest adjacent people;

4. Fuelwood was obtained from the forest at a cost i.e. market price; and
5. Fuelwood collected from the forest not influenced by urban or industrial wood demand;

3.2 Data types, sources and collection techniques

Primary and secondary data formed the main sources of information. Quantity estimation, market price determination, observation, schedules/questionnaires and interviews were the main data collection techniques used in primary data collection. The secondary data collection was sourced from the existing sources. The information collected include the market price, land holding and use, income, weather, gender issues, fuelwood species, fuelwood consumption and sales, harvesting technologies, constraints/problems encountered by the local people in their effort to source for fuelwood, wood conversion technologies, time taken in fuelwood acquisition per week, age of head of household, education status of head of household, approximate distance to the forest, mode of transporting fuelwood and family size.

3.2.1 Schedules

Primary data was collected using pre-determined schedule/questionnaire (Appendix 2). The schedule was pre-tested using a few respondents to determine its suitability after which the necessary amendments were effected. Field enumerators were identified and trained on the procedures to execute the schedules. Completed schedules were cross-checked by the investigator to ensure that the right information had been collected and there were no missing links.

3.2.2 Observations

Direct observations in the field were adopted to complement the schedule data collection technique. This technique was used to minimize the biases in the other techniques and to give coverage to other aspects not covered in the questionnaire. This technique was considered important especially where the respondent in one way or another felt shy to discuss the subject matter. Aspects that were observed included the gender involvement in the procurement of firewood, distance covered, time taken to collect a headload of firewood and the size of the headload.

3.2.3 Interviews and focused group discussion

Interviews were conducted with individuals, government officials, village elders, NGO's officials and opinion leaders who acted as key informants on the fuelwood situation in the study area. Participatory based techniques were employed in this exercise with the aid of a checklist to guide the interview. Focused group discussions were used where the respondents happened to be more than one. General information on trends in resource use, demand supply scenarios, areas of heavy destruction, markets and pricing were generated using this technique. This formed the basis for the household survey.

3.2.4 Market price analysis

Direct market price or cost approach was used to assess the direct use value of the forest resources. Benefits and costs not captured by the market were treated as externalities. The price of fuelwood was established at the household level and/or from fuelwood dealers in the nearby market centres. It is common to find stacks of fuelwood along the road and therefore marketing of fuelwood was an established enterprise in the study area.

3.2.5 Estimation of quantity of fuelwood

Estimation of the volume of fuelwood was done based on earlier studies conducted around Kakamega where a headload of firewood weighed an average of 25 kg. One cubic metres of fuelwood weighed 725 kg whereas one stack of firewood was equivalent to 3 cubic metres (Emerton, 1994). First the average headload of fuelwood was weighed using a spring balance and based on the above information the volume was determined in cubic metres. Yields of charcoal from the earth kiln are known to be in the ratio of 1 to 8.6 tonne of air dry wood whereas improved methods are in the ratios of close to 1 to 3.3 tonne of dry wood (Kamara, 1986; Gibson, 1991).

3.2.6 Secondary data

Secondary data included published and non-published sources. These sources included textbooks, journals, government publications, magazines and newspapers. The following institutions were visited for this purpose: World Bank, Food and Agriculture Organization (FAO), UNEP, KEFRI, National Library of Kenya, International Union for Conservation of Nature and Natural Resources (IUCN), British Council and ICRAF, Moi University and Egerton University libraries. Government ministries/departments, NGO's, and individuals were other valuable sources of information.

3.3 Sampling

Sampling is divided into sample size and sampling procedure.

3.3.1 Sample size

More than 52 villages located in 18 sub-locations and covering an area of 150 km^2 are found around Kakamega forest. These villages are home to 114,000 people, which form 26,000 households according to the 1999-population census (RoK, 1999). Each village consist an average of 1,437 households in the range of between 30 to 7,000 households (RoK, 1999). The survey covered 235 households representing 3.5% of the total households. Five sub-locations were included in the study with four sub-locations being located around the Kakamega forest while one sub-location was found located around Malava forest block. Malava forest is surrounded directly by three sub-locations with a population of 17,000 people who make 3,300 households (RoK, 1999). Table 2 shows the various sub-locations that were sampled.

Table 2: Size of the study sample

Sub location	Total household	Sampled household	% sample
Buyangu	751	44	5.9
Virhembe	1732	40	2.3
Lunyu	1495	46	3.1
Shiru	1770	46	2.6
Tande	1021	59	5.8
Total	**6769**	**235**	**3.5**

The unit of study was the household (members of the nucleus family, members of extended family and workers). A household as used in this study is defined as a group of people sharing the same "cooking pot". In many surveys, the definition of a household is essentially arbitrary i.e. comprise (ing) a person or group of persons generally bound by ties of kinship who live together under a single roof or a single compound, share a common source of food and are answerable to the same head' (Nyang, 1999).

3.3.2 Sampling procedure

Cluster and random sampling techniques were used in this study. Cluster sampling is a technique where the population is divided into subdivisions or classes. In this study the forest adjacent sub-locations represented the various clusters. Cluster sampling was used because of the economic advantage it possesses. Estimates based on cluster samples are usually more reliable per unit cost (Kothari, 1990).

The random sampling technique was used in sampling the respondents from the sample units. A list of the head of households was obtained from the Kakamega forest conservation project, which is managed by International Centre for research in Insects and Pests (ICIPE). Random sampling was carried out using a scientific calculator to select the respondents from the list. Random sampling technique ensures that each member of society has an equal chance of being selected (Kothari, 1990).

3.4 Data analysis

Excel and Statistical Package Social Scientists computer packages were used in data analysis. Descriptive statistics and regression analysis techniques were carried out on the data. Descriptive statistics analysis was performed to generate both qualitative and quantitative data sets that provide synthesized information like the frequencies, mean, sum and percentages. The information obtained from descriptive statistics was used in tabulation and/or plotting of graphs.

A linear regression model was fitted where the coefficient of determination (R^2) was generated to provide information on the goodness of fit of the model. The higher the value of R^2 the greater the percentage of variation of the dependent variable explained by the regression plane i.e. the better the goodness of fit of the regression plane to the sample observations. The t – statistics was used to test the factors that significantly influence the quantity of fuelwood harvested from the forest.

CHAPTER IV: RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics and considerations

4.1.1 Head of household

The average age of the head of household was 45 years. About 54.5% of the heads of the household had attained primary level of education. 11.9% had no formal education, 23.8% had attained secondary education while 9.8% had attained tertiary level of education i.e. college or university education. 88.1% of households were male headed. 59.1% of the respondents were women indicating the importance of the subject to this group.

4.1.2 Family size and un-employment

The subject on fuelwood collection cannot be analysed in isolation since it is subject to the same labour, land and natural resource constraints as the other household development activities. It was established that on the average the family was composed of seven members, four of who were not on paid up employment. The un-employed members were the risk group since they illegally derived their livelihood from the forest. There was a general feeling that the growing number of un-employed individuals could not find employment in the formal sector.

4.1.3 Gender in fuelwood collection

Gender is an important factor in fuelwood production and consumption as it relates to the roles and responsibilities of the various members of the family. It was established that 94.5% of women were responsible for fuelwood collection mainly for the household consumption. 57.1% of the respondents marketed fuelwood. Of this, 49.4% were men while women accounted for 7.7%. The rest of the respondents did not market any fuelwood. Therefore, men are responsible for the rampant incidences of forest degradation since they are responsible for the marketing of fuelwood.

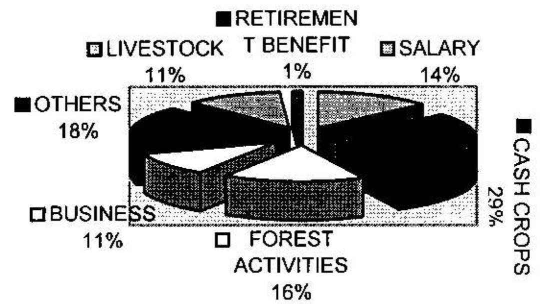
4.1.4 Land ownership

Kakamega forest complex adjacent communities practice mixed farming. Apart from growing crops, farmers keep livestock and grow trees on their farms. The average land holding in the study area is 1.45 hectares in the range of 0.04 ha to 40.49 ha. 80% of the respondents have less than 2.0 ha. This estimate compares very well with the range of 0.10 to 16.3 ha as estimated by Mungatana, 1999. The land ownership is by inheritance (74.5%) or purchase (21.7%) and/or leasehold (0.90%). The settlement pattern of the head of household i.e. native or immigrant is an important factor in the consumption of the fuelwood from the forest. Those who had purchased their land are the immigrants into the forest adjacent area. Lack or loose land ownership rights severely constraints land use practices (Oniang'o, 1995). The sustainability of land use and agriculture and standard of living are further jeopardised by the lack of success, on the part of men who do not seek casual or contract employment outside the area, to generate any significant income.

4.1.5 Household cash income

Farming was the main economic activity at the household level though its contribution remains small. Income was indirectly computed from expenditure in the event where respondents were not able to provide information on their income. On the average, 59.4% of the household income was spent on the purchase of foodstuffs, purchase of farm input (11.1%) and paying school fees (11.0 %) among other things. The mean household monthly income derived from different sources was Ksh. 6,000. The average per capita income[13] is approximately Ksh. 860 ($ 11) per month. This income is relatively lower than the poverty line of Ksh. 980 for rural areas and therefore very little, if any was directed towards development. Figure 1 gives details on respondents deriving their income from different sources: salary (Ksh. 5,200), cash crops (Ksh. 1,700), forest activities (Ksh. 1,965), business (Ksh. 1,950), livestock (Ksh. 1,100), retirement benefits (Ksh. 1,450) and others (Ksh. 1,000). Forestry activities, contributes Ksh. 23,580 per year per household, which compares well with Ksh. 26,000 (Mogaka, 2000).

Figure 1: Income analysis by source and % household



4.1.5.1 Income through farming

Sugarcane was the main cash crop and contributes 38% of the total earnings from agriculture in the study area. It was established that sugarcane was mainly grown in

Buyangu sub-location due to its proximity to the West Kenya sugar factory. Tea was mainly grown in Virhembe, Shiru and Lunyu sublocations. Though majority of the households grew maize, the earning from this crop was smaller than the earnings realised from sugarcane farming. Maize contributed 23% of the total earnings. Nappier grass was predominantly grown around Malava forest and highly marketed as compared to the other crops by contributing 10% of the total income from farming. Mean earnings from agriculture are summarised in Table 3.

Table 3: Monthly income from agricultural enterprises

Enterprise	**N**	**Mean - Ksh**	**% Total income**
Sugarcane	64	1793.8	37.6
Maize	140	502.0	23.0
Nappier grass	7	4574.3	10.5
Tea	9	3194.4	9.4
Beans	83	228.0	6.2
Vegetables	34	408.0	4.6
Banana	24	270.5	2.1
Livestock products	5	1032.0	1.7
Potatoes	11	318.2	1.2
Others	27	422.5	3.7

N Number of respondents

Despite the fact that KIFCON, 1992a had estimated the income from agriculture at Ksh. 5,000, the average income from agriculture was Ksh. 1,700 attributed to unfavourable price offered for agricultural crops in the study area.

4.1.6 On-farm fuelwood requirements

Farms contribute 8.1% to the total fuelwood demanded at the household level whereas 0.3% was obtained from the neighbour's farms. Tree growing by the forest adjacent

communities has not been taken seriously. Observations showed that most household members gather wood and do not plant or cultivate trees but prefer to meet the cost associated with fuelwood harvesting from the forest. The market, cultural and institutional failures partly explain the laxity in tree planting. 62 different on-farm tree and shrub species were documented in the study area. The most important ones included *Eucalyptus grandis, Cupressus lustanica* and *Croton macrostachys.* Appendix 3 gives the list of on-farm tree species. Table 4 provides the main reasons why farmers invested in tree growing. Fast growing and multipurpose trees and shrubs were preferred. In addition their subsistence and commercial potentials enhance their choice.

Table 4: Perceived uses of on-farm trees

Purpose	**% Households**
Fuelwood	66.8
Poles and posts	53.2
Soil, water and environmental conservation	42.6
Timber production	35.3
Fruits	11.9
Source of income	8.5
Medicine	3.0

It was established that 3.14 m^3 of fuelwood was obtained from the farms. Most of the wood harvested from the farms are consumed at the household level in the form of firewood (64%) and charcoal (28%). Three percent of the fuelwood was consumed at the neighbour's farm while 4.5 % of the wood was sold as charcoal and 0.50% as firewood.

4.1.7 Fuelwood prices and markets

Commercialisation of fuelwood was rapidly expanding in the study area. A total of 42.0% of the respondents were trading in fuelwood i.e. 39.0% of them marketing fuelwood from the forest and 3.0% were marketing fuelwood from the farms while 6.0% marketed both fuelwood from the forest and the farm. The rest (58.0%) did not market any fuelwood. Field observations indicated that those marketing fuelwood from the forest constituted upto 60.0% of the respondents. Few respondents were willing to discuss the subject of fuelwood marketing due with unsustainable harvesting practices associated with fuelwood hence the fear to be arrested. The ready fuelwood markets/consumers were created by the working class, brick makers and local brewers (11.9%), local hotels (11.1%) and to a small extent urban centre dwellers (3.8%).

Ten per cent of the respondents had been trading in fuelwood for the last nine years. The driving factors in engaging in fuelwood trade are mainly poverty (6.0%) and lack of employment (21.7%). There exists a simple marketing structure as illustrated in Figure 2. The dominant link was between the collectors and consumers. The channel has started becoming complex with middlemen and stockists getting into the picture. The channel linking harvesters, middlemen, stockists and consumers is still very weak though of great impact to the environment. This weak linkage may be explained from the problems associated with the use of forest.

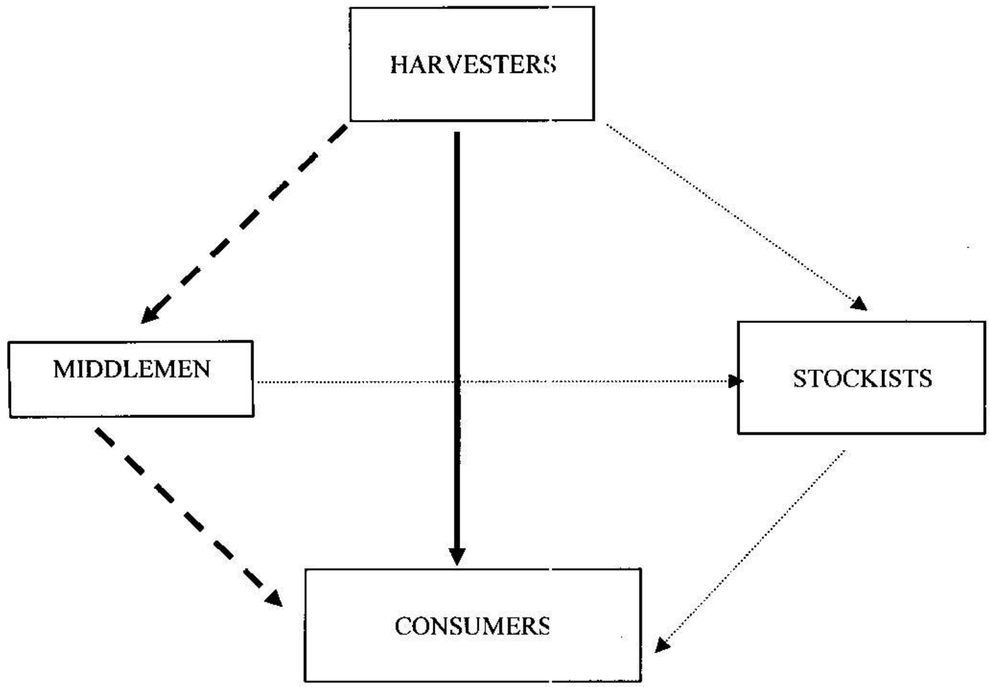


Figure 2: A developing fuelwood marketing structure

The problems associated with trade in forest produce include risks in the forest (0.9%), low price (2.1%) and delays in payments (0.4%). The risks included arrests, impounding of products and implements and stealing of products especially charcoal. The price for fuelwood was more or less static mostly within the two kilometre radius to the forest due to the small number of individuals that are willing to purchase the product. Those collecting fuelwood for income had to trek long distances in search for buyers. Delays were experienced in cases where deliveries were made late due to restriction from the enforcement agents.

The prices for the fuelwood are basically negotiable and vary from place to place. On the average firewood from the forest fetched Ksh. 46.00 per 25 kg of firewood as reported by 62.0% of the respondents while 50.0% and 34.0% of the respondents reported that 25 kg of firewood collected from the respondent's farm and neighbours farm respectively was selling at Ksh. 41.00 for 25-kg headload. Given the high price attached to firewood from the forest as compared to the farm explains the importance the forest adjacent communities' place on the forest as a source of fuelwood.

Charcoal was sold at an average price of Ksh. 168 per bag weighing an average of 40 kg (52.0% of the respondents) giving an average monthly income from the sales of fuelwood from the forest as Ksh. 2,321.00 (39.0% of the respondents) while charcoal from the farm was valued at Ksh. 660 (9.0% of the respondents). More income was realised from firewood sales than charcoal. The improved trade in fuelwood can be attributed to good road network with in the Kakamega forest. Observations revealed that over 70% forest adjacent communities obtain fuelwood from the forest for sale.

The fuelwood from natural forest contributed 93.9% of the total earning from the forest-based activities. Whereas, firewood sales contributed 63.7% of the earning realised from the natural forests, on-farm fuelwood sales contributed 6.1% to the overall income from wood based products. The small income from the on-farm tree product sales gives an indication of how farmers have failed to invest in tree planting. Most respondents still view the forest as a public resource and this explains the minimal effort towards the of on-farm tree farming.

4.2 Fuelwood requirements from Kakamega forest

Firewood was the main source of energy as attributed to 99.1% of the respondents. Firewood was cheap and readily available. Overall per capita fuel supply was 4.32 m^3.

The poorer households (48.5%) supplemented firewood use with agricultural wastes. Households, who enjoy better source of income use of kerosene (43.4%), charcoal (33.2%) and liquefied petroleum gas (2.1%). Sawdust, less popular source of energy, was used by 0.4% of the households. The degree of energy substitution in the study area was relatively low as attributed to the cost implications for the case of liquefied petroleum gas or the remoteness of some of the energy source such as sawdust.

4.2.1 Fuelwood species

The Kakamega forest adjacent communities use 70 different trees and shrubs for fuelwood. The prominent species are *Diospyros abyssinica, Croton megalocarpus, Olea capensis, Celtis africana, Strychnos usambarensis, Craibia brownii* and *Prunus africana.* Appendix 4 gives a full list of firewood and charcoal species. Households had turned to the use of shrubs without the desired characteristics or species protected by taboos e.g. *Erythrina abbysinica* due to the prevailing fuelwood scarcity. The most preferred species were considered to be those that are smokeless on burning and easy to split. Indigenous species were preferred over exotic ones such as eucalypts, cypress and pine as reported by 3.4%, 1.3% and 2.6% respectively. Heavily exploited species, as reported by the respondents were *Diospyros abyssinica, Celtis africana, Croton megalocarpus, Manilkara butugii and Craibia brownii* in that order (Appendix 5).

4.2.2 Harvesting technologies

Rules and regulations governing the subsistence use of Kakamega forest grants the forest adjacent communities the rights to collect and use any dry wood for firewood. It was illegal to carry any implement when collecting firewood from the forest. Despite this regulation, the local people still carried implements such as axes (34.5%), pangas (56.6%), crosscut saw (18.3%), jembes (7.7%), fork-jembes (2.6%), spades (4.3%), wedges (0.4%), empty gunny bags (2.6%) and ropes (70.6%). Power saws were also in use as reported by 0.9% of the respondents. The fact that these implements were in use meant that live wood was being harvested against the current regulation. Most of the fuelwood was collected during the dry season when most labour was not in high demand.

4.2.3 Quantity collected from the forest

Fuelwood from the forest contribute 91.6% of the total fuelwood consumption with an average per capita fuel supply of 4.32 m^3. Figure 3 gives details on fuelwood use and marketing. This gives the total off-take from the forest of 112,320 m^3 valued at Ksh. 150 million per year. The market price was calculated at Ksh. 1,334 per m^3 as compared to the government control price of Ksh. 77 per m^3. The high per capita fuelwood consumption was attributed to cold weather (91.9%), commercialisation of the fuelwood resource especially charcoal and use in the expanding cottage industry e.g. brewing, brick making and pottery. From this data we reject the null hypothesis that forest adjacent households depends entirely on the forest for their fuelwood supplies.

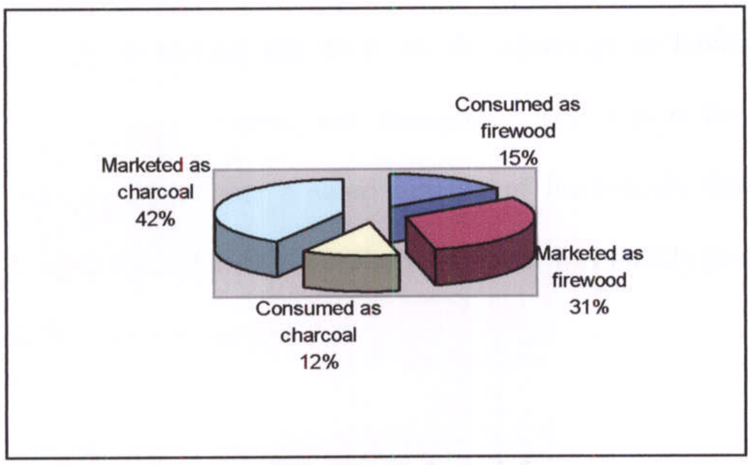


Figure 3: Distribution of fuelwood use and marketing

The study revealed that the use of the firewood from the forest for domestic purposes (cooking and heating) was sustainable since per capita firewood consumption was calculated at 0.99 m^3, which was within the national estimate of about 1.0 – 1.5 m^3 while the average annual per capita fuelwood consumption for East Africa has been estimated at about 2.1 m^3 (Monela *et al,* 1993 and Eckholm *et al, 1984*). The ever increasing demand for wood for charcoal production and for sale as firewood makes the practice unsustainable. 27.6% of all the fuelwood removed from the Kakamega forest was consumed within the household with half being consumed as charcoal. Fuelwood that went into charcoal production formed the bulk of the wood harvested from the forest. The amount of wood that went into charcoal production was 41.5% of the total while the quantity marketed as firewood formed 30.9%.

Production of charcoal using the traditional methods in pits or piles commonly referred to as the earth kiln was common in the study area. In Shiru sub-location, an earth-kiln could produce between 10 and 40 bags of charcoal.

Compared to the consumption of firewood, charcoal is far less consumed by the households studied and yet it had the advantage of having clean burning, higher heat density, easy to store and transport. The reason for the low level of charcoal consumption is that a small number of households who owns stoves designed for cooking with charcoal. Similarly, charcoal was mainly produced for financial gains but not for subsistence use.

Virtually all respondents use fuelwood for cooking while 61.7% and 15.5% use it for heating and lighting respectively. 35.0% of the respondents used it for making borne fire especially during funerals. Further, firewood is used in brewing (8.5%), brick making (7.7%), pottery (3.0%) and ironing (0.90%).

4.2.4 Distance and time spent on fuelwood collection

Field results show that women spent an average of two and half hours per week to collect firewood from the forest as attributed to 98.3% of the respondents. This was below the time of between eleven and fifteen hours per week (Barnes *et al,* 1984) or 20 to 24 hours per week collecting fuelwood (Eckholm *et al, 1984*). The time devoted to wood collecting varies greatly even within the same country. As prices rise and wood becomes a market commodity, landless labourers and tenant farmers may be denied traditional rights to collect wood or residues. The good indicator of scarcity of fuelwood is the distance traveled in search of good quality fuelwood. The average distance from the forest was 1.6 km as reported by 96.6% of the respondents. An increase in the distance covered to collect firewood influence the quantity, price and gender defined roles. If the distance traveled becomes great enough, charcoal may become the fuel of preference.

4.2.5 Mode of transport

Transportation of fuelwood from the forest was by head hence the common reference to headload. 99.1% of the households, mainly women transported their fuelwood by this

mode of transport. These results are in agreement with what was established elsewhere by Brouwer *et al*, 1997, that 95% of all fuelwood collectors were female. Where men were involved in the transportation of fuelwood then the mode of transport changed slightly: shoulder, ox-cart, bicycle and open van. The mode of transport changed in commercial interests. For this case, 0.9% of the households transported their fuelwood by ox-cart, 1.7% by bicycle and 0.4% by open van. Many respondents were not willing to discuss the various modes of transport since they considered them to be un-sustainable. Each household spent roughly an average of 31 hours per week on fuelwood collection.

4.2.6 Problems/Constraints in fuelwood collection

The main problem confronting the forest adjacent communities in the use of the forests for various purposes was harassment (beating, rape and denied

access for livestock watering in the forest) by the game rangers and/or forests guards (62.6%). Harassment was more pronounced in Kenya Wildlife Service managed areas. Further, the respondents reported the following problems: arrests (50.6%), imposition of heavy fines (39.6%), wildlife destruction of crops within the neighbouring farms, snake bites (23%), bribery to gain access to the forest (16.6%) accidents like from falling logs

(0.9%) and crossing the swollen Yala river with a headload of firewood or bag of charcoal.

4.3 Results of regression and correlation coefficient analysis

The multivariate statistical analysis, regression and correlation techniques were used to determine the relationships and dependencies among the variables. The description of the relationship between two or more variable is called regression analysis, while investigation into the strength of such relationships is called correlation analysis (Harnett, 1982).

4.3.1 Results of regression analysis

Data included in the regression analysis comprised of a total of 158 respondents. The data was subjected to regression analysis using the linear regression function. Table 5 presents the results of the regression analysis. The value of R^2, 0.891, gave the indication of the goodness of the model. The variables under consideration explained upto 89% of the output. Further, t statistic was generated to assist in identifying those parameters that significantly affect the output. Barnes *et al's* model could only explain 21% of the variables affecting the quantity of fuelwood consumed at the household level. The low coefficient of determination was attributed to the fewer number of variables included in the model.

Table 5: Results of regression analysis

Variable	β	Std. Error	t
(Constant)	31.031	27.576	1.125
X_1	-1.704	.821	-2.076*
X_2	-0.002	.002	-.923
X_3	.222	.230	.963
X_4	-.177	.096	-1.840
X_5	-.390	.187	-2.088*
X_6	2.329	.982	2.371**
X_7	.723	.713	1.015
X_8	0.055	.221	.249
X_9	-.396	1.172	-.338
X_{10}	.627	.139	4.521***
X_{11}	-2.589	2.236	-1.158
X_{12}	7.253	3.500	2.072*
X_{13}	1.997	2.790	.716
D_1	7.052	4.351	1.621
D_2	-9.435	7.354	-1.283

* Significant at 90 per cent confidence interval

** Significant at 95 per cent confidence interval

*** Significant at 99 per cent confident interval

$R = 0.944$ $R^2 = 0.891$

The results of a linear regression analysis show that the quantity of fuelwood harvested from the farm, price of firewood from the farm, land size, time spent on firewood collection per week and gender in marketing of fuelwood significantly affect the quantity of fuelwood harvested from the forest at 90 and above per confidence interval. We accept the null hypothesis for these variables. The alternative is accepted for variables on household cash income, price of firewood from the forest, price of firewood from the farm, family size, and members not on paid up employment, age of head of household, distance, education of head of household and mode of transport.

A positive coefficient indicates that an increase in inputs results into an increased output. The significant factors that exhibit a positive coefficient are land size, time spent on firewood collection per week and gender in marketing. It is expected that as the time spent on firewood collection increases, less firewood was harvested. Since this is not the case, the effect of time factor is overtaken by factors like purchase of fuelwood. Contrary, a positive sign may mean cooking of more meals per day as income increases and also by the fact that firewood is obtained from the forest.

A negative coefficient indicates that an increase in the factor under consideration decreases the quantity of fuelwood harvested from the forest. Significant factors that exhibit a negative coefficient are quantity of fuelwood harvested from the farm and price of charcoal. The negative sign implies that as income increases there was a tendency for individuals to shift to more refined fuel sources such as kerosene, charcoal and liquefied petroleum gas.

The quantity of charcoal produced from the farm had an inverse bearing on the quantity of fuelwood collected from the forest. This means that when endowed by fuelwood resource on the fuelwood from the forest. This factor is closely related with land size. The land size was directly proportional to the quantity of on-farm fuelwood thus lesser the reliance on the forest.

Time spent by each household on fuelwood collection is directly proportional to the quantity that was collected from the forest. Time is a measure of labour input into any production system and therefore the more time devoted into the practice the more the output. More fuelwood was collected when more time was devoted to collection.

The price of fuelwood from the forest had a direct relationship with the quantity collected from the forest. In places where the prices were higher, more fuelwood was in demand. In such places, you are likely to find the working class, hotels and local brewers. The ready market therefore tended to influence the quantity of fuelwood harvested from such areas.

An increase in price of charcoal was accompanied by a reduction in the quantity of firewood collected from the forest. The price of charcoal increased as you move away from the forest. The quantity of firewood collected from the forest was influenced by the distance.

The price of firewood from the farm had a positive influence on the fuelwood collected from the forest. High prices reflect scarcity and in such cases even the supply from the forest was limited. The distance to the forest affects the observed relations of price of on-farm firewood and quantity of fuelwood from the forest.

Education was a proxy variable for management and was not a direct indicator of energy consumption under the present conditions because it enhances the prospects of income generation. The insignificant role of education is due to the growing commercialisation of fuelwood and the increasing population.

Substitution effect, can explain why an increase in cash income was accompanied by a reduction in the quantity of fuelwood consumed from the forest. As the income increased, households switched to other superior sources of fuels such as kerosene and liquefied petroleum gas.

The distance had a negative effect on the quantity of fuelwood harvested from the forest. This was explained from the fact that firewood had a minimum economically viable distance. Transportation by head is influenced by the distance coverage.

Gender significantly influenced the quantity of fuelwood consumed at the household. A positive coefficient means that those households, which did not market any fuelwood at all, were harvesting more fuelwood from the forest. The quantity harvested was influenced by family size and distance rather than the marketing aspect. Further, the respondents were aware of the criminal behaviour of illegal harvesting of fuelwood.

Households that claimed their origin to the study area consumed more fuelwood than the immigrants. Many of the respondents who had their ancestry traced to the study gave the forest the name of "Our forefathers' forest" implying that the right of ownership of the forest was due to their ancestors rather than the government.

Transportation of fuelwood from the forest was mainly head as the other modes (ox-cart, bicycles and pickup) were considered unsustainable. Family size had a positive influence on the quantity of fuelwood collected from the forest. The bigger the family the more the quantity of fuelwood harvested from the forest. The homes headed by more elderly head of household consumed more fuelwood from the forest meaning that this group considered the forest to belong to their ancestors and therefore the right to use it without any reference to any authority.

Un-employment has an inverse relationship with the quantity of fuelwood collected from the forest. This is explained by factors such as distance from the forest, strict enforcement of the law in areas managed by KWS, level of awareness on the value of the forest and education level. The un-employed were mainly the youth who had been sensitised on the environment through schools and awareness programmes organised by NGOs as KEEP.

4.3.2 Tests on multicollinearity

The independent variables were subjected to the Spearman's correlation coefficient analysis. The correlation coefficient analysis was performed on a 235 X 15 dimensional data matrix using Spearman's correlation test. The results show both positive and negative correlation among the 15 variables under study (Appendix 6). Multicollinearity occurs when two or more of independent variable are strongly (but not perfectly) related to one another which denotes the presence of linear relationships among explanatory variable. If the correlation coefficient for these variables was equal to one, the parameters become indeterminate. The standard errors, the bivariate correlation coefficients and R^2 were used to test for multicollinearity. None of these criteria was a satisfactory criterion for the presence of multicollinearity (Koutsoyiannis, 1977).

The results of the Spearman's correlation analysis show that the presence of multi-collinearity was weak since most of the coefficient factors were below 0.5. When each independent variable was introduced into the model, the factor on coefficient of multiple determinations, r^2, increased from 0.012 to 0.891 showing that the model was free from multi-collinearity. Standard errors kept on increasing and decreasing a pattern usually associated with the presence of some level multi-collinearity. The variables on credit and effect of weather could not be entered into the model due to overlapping effect i.e. multicollinearity. The model was accepted despite the low level of multi-collinearity because it was interesting in predicting future trends. The equation with the highest goodness of fit and magnitude of the coefficient of determination (R^2 = 0.891) was accepted.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study on fuelwood exploitation was conducted in five sub-locations around Kakamega forest using a structured schedule. Interviews and observations were used to supplement the schedules. The household survey involved a sample of 235 randomly selected respondents. It was established that each family was composed of seven members with four of them being un-employed. The estimated household monthly income was Ksh. 6,000 derived from crop sales, livestock production, salary/retirement benefits, forest based activities and business. The average land holding was 1.45 ha with 80% of the respondents having less than 2.0 ha.

The results show that the average per capita fuelwood consumption was 4.32 m^3 per year, which was above the estimated national consumption rate of 1 m^3 – 1.5 m^3 per capita per year. 15% of the fuelwood was directly consumed as firewood whereas 12% was consumed in the form of charcoal. 42% of wood was sold as charcoal while 31% was sold as firewood. Commercialisation of fuelwood from the forest means that the practice was unsustainable. The results of a regression analysis show that the quantity of fuelwood harvested from the farm, price of firewood from the farm and gender in marketing were significant at 90% confidence interval. The land size was significant at 95% confidence interval while time spent on fuelwood collection per week was significant at 99% confident interval.

5.2 Recommendations

Policy interventions directed towards research, awareness creation on the value and importance of the forest, promotion of micro-enterprises and incentive packages, taxation measures, on-farm tree planting, fuel substitution, diffusion of improved harvesting and conversion technologies are necessary if forest degradation is to be halted. A combination of conservation measures should be adopted if the forest has to be conserved for future generations.

On-farm tree planting: The long-term strategy to alleviate pressure is to encourage development agencies to invest in on-farm tree planting as attributed to 61% of the respondents. The aim should be to increase both the number and the productivity of trees grown on the farms. This policy measure calls for provision of subsided seedlings, selection of high performing tree species, monetary incentives/ credit facility for planting and continued growth of trees and enhanced information to farmers. Tree growing requires the commitment and support of the local community for enhanced on-farm production/supply. When on-farm tree planting is intensified then subsistence and income generation will be guaranteed.

Efficient use and substitution of fuels: Improved end-use efficiency of energy conversion technologies will reduce the fuel requirement. Efforts towards introduction of improved cooking stoves and charcoal production kilns should be made. The adoption of efficient combustion equipment (ceramic jikos, kuni mbili and institutional jikos) will raise efficiency from 5 to 90% in addition to shortened cooking time and improved aesthetic value in your kitchen. Substitution from fuelwood to crop residues, biogas, kerosene and sun and wind power does not cause forest degradation and can reduce pressure on natural forests. Studies conducted in rural Turkey showed that using traditional stoves wastes 92-97% of the energy obtained from fuelwood and as a result, fuelwood consumption was increasing rapidly (Türner and Kayguzug, 1996).

Research: Further research on enrichment planting, incentive programmes, credit provision, growth models, cost-benefit analysis, adoption of improved cook stoves, pricing procedures, social and economic impacts assessment of past projects and licensing procedures is needed to streamline decision making. Decisions made on the harvesting of the forest should be based on sound research data. Most of the individuals who exploit the forest illegally usually concentrate their activities at the centre of the forest. Rarely does the Forest Department undertake the inventory of the forest stock, making it difficult to realise when the forest is threatened.

Licensing: It is time that local communities started paying for the collection of firewood through issuance of permits or tickets. This will act as a disincentive to regulate the number of individuals utilising the forest. The forest regulations and the presidential ban should be enforced to ensure that the forest is not driven to extinction especially in Shiru where the forest was seriously affected by charcoal production activities. The FD, the main law enforcement agent, faces a number of problems that require attention. The problems include shortage of staff, low working morale among staff and lack of field gear. The government needs to improve the working conditions of the staff through award of better salaries and provision of vehicle to facilitate movement for the goal of sustainable conservation.

Income generating activities: The introduction of income generating projects was one of the indirect strategies of reducing pressure on the forest through credit facility. The targeted projects are bee keeping, dairy production and farming and promote eco-tourism. This strategy will empower the local people economically so that they do not resort to the forest for their livelihood. Empowering the local communities through income generating activities provides social, economic or policy incentive aimed at reducing pressure on the forest. The forest adjacent local communities who bare most of the cost of conservation should be rewarded and/or compensated for their effort. The local people could be employed on short-term basis to provide the scarce labour. The local communities could form vigilant groups, which can patrol the forest and arrests any wrong doers. Experience show that local people conserved forests based on beliefs, taboos, customary regulations and rules, etc. and therefore the need to integrate their indigenous knowledge into the conventional management strategies.

Awareness programmes: Awareness programmes to educate the local people on the value and importance of the forest should be promoted. Most people are unaware of the many ecological and environmental function provided by the forests and therefore the need for education. Experiences show that schools, women groups, youth groups, the church, chief's barazas are the entry points to the forest adjacent communities.

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NOTES

[1] A forest is defined as a continuous stand of trees at least 10 metres tall with their crowns interlocking.

[2] Riswan and Hartanti (1995) define degradation as a temporary or permanent deterioration in the density or structure of vegetation cover or its species composition.

[3] Gazettement denies and/or restricts the right of local communities to control, have free access and to claim ownership to the forest resource.

[4] Kakamega forest comprises several separate blocks of forest (Muriuki and Tsingilia, 1990), of which Kakamega forest itself is by far the largest; the smaller, isolated areas of Kisere and Malava forests lie to the north of the forest block. Bunyala, Maragoli and Kaimosi forests are situated to the north-east, south and southwest of Kakamega forest respectively. Two major rivers, Yala and Isiukhu, as well as many smaller watercourses, run through the forest. The forest covers an area of approximately 265 km^2. About 45 km^2 is protected for wildlife as national reserve and nature reserve (Tattersfield, 1996). According to Muriuki and Tsingilia (1990), about 48% of the forest supports indigenous forests stands, the remainder containing plantations and grasslands clearings of both natural and athropologenic origin.

[5] The Kenya Wildlife Services was created as parastatals in 1990 from the former department of Wildlife Conservation and Management, which had been suffering from a number of management problems leading to poor management and rapid deterioration of the wildlife resource (MENR, 1994 and Wass, 1995).

[6] A species is considered endemic when its natural habitat and range is limited to one particular geographic area, usually formed by a biologically isolated ecosystem (Cords, 1999).

[7] Sjostrand (1993) as reported in Mogaka (2000), define institution as a human construct for a coherent system of shared (enforced) norms that regulate individual interactions in recurrent situation.

[8] In economic terms, Mogaka, 2000, define a community as being composed of people who share interests and control over particular economic reserves and they may not necessarily live together or have any socio-cultural ties.

[9] The term 'deforest' means to remove, kill or destroy all or most of the trees of a forest so that reproduction is impossible except by artificial means. Deforestation is in most cases used to refer to the loss of natural forest cover. Deforestation is one of the most

destructive human impacts on the tropical forest ecosystem and it is done with some special purpose, for example shifting and permanent agriculture, illegal cutting, mining, resettlement or transaction programmes, road and railways, logging and conversion into other ecosystems (Riswan and Hartanti, 1995). Deforestation as used in this context refers to the excessive removal (legal and illegal) of forest product.

[10] Forest Department falls under the Ministry of Environment and Natural Resources and is the main government agency concerned with the conservation and management of indigenous forests in Kenya (MENR, 1994 and Wass, 1995).

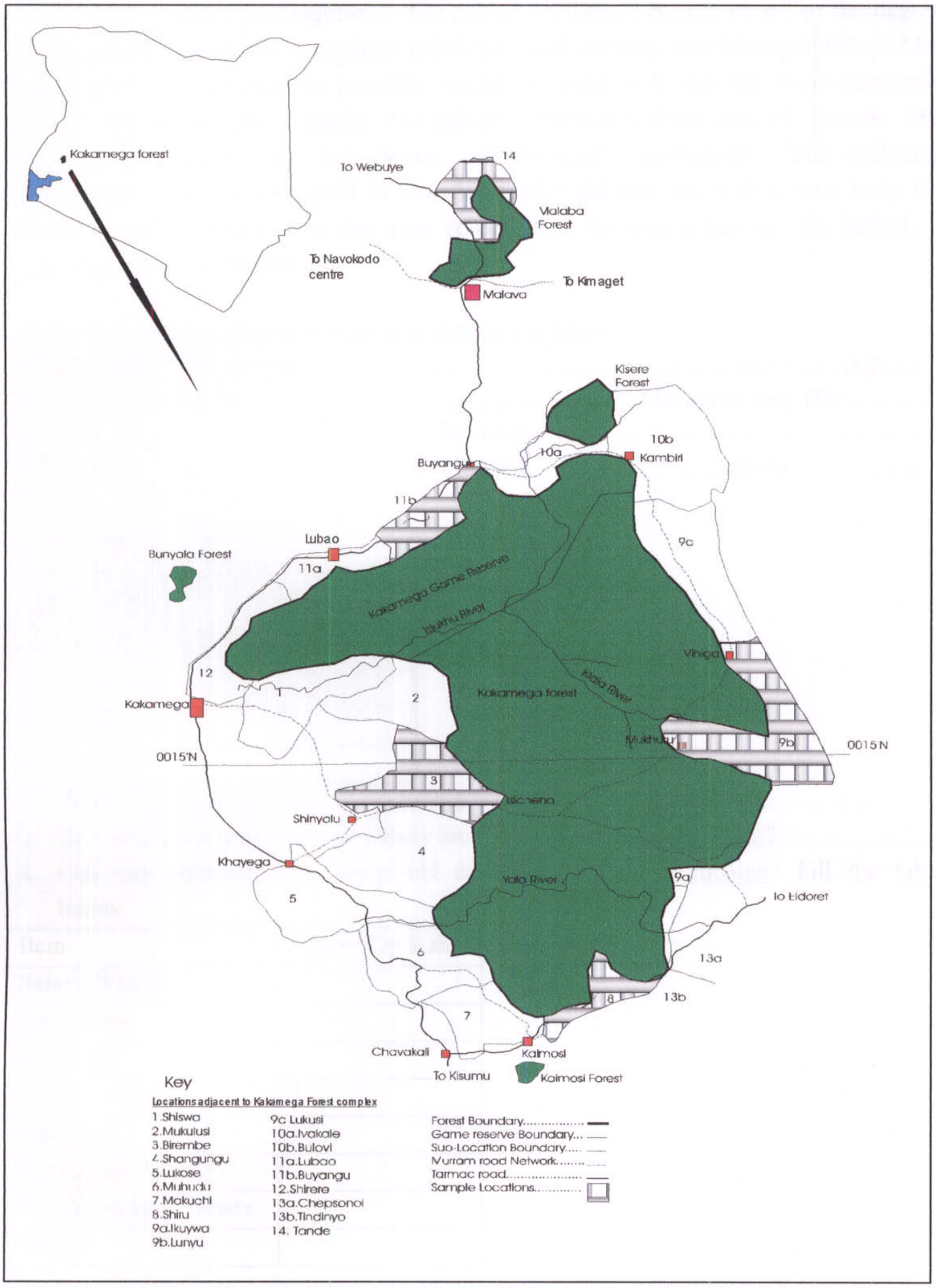
[11] According to Colchester, 1995_b sustainable use means not just conserving biological diversity, fauna and flora, but also maintaining ecological functions such as soil quality, hydrological cycles, climate and weather, river flow and water quality. It also implies maintaining supplies of natural produce – game, fish, fodder, fruits, nuts, resins, dyes, constructional materials, fuelwood, and so on – essential to the livelihoods of the local people. Thus, sustainability is fundamentally linked to concepts of social justice and equity, both within generations and between generations, as well as both within nations and between nations.

[12] Based on the National development plan 1997 – 2001, poverty manifests itself in the form of hunger, illiteracy and lack of access to basic education, drinking water, minimum health facilities and shelter. According to the 1994 welfare Monitoring and Evaluation Survey (WMES) the level of absolute poverty in rural areas was 47% while in urban areas the rate was 29%. The absolute poverty line was Ksh. 980 per capita per month for rural areas and Ksh. 1,490 per capita per month for urban areas (RoK, 1999).

[13] Per capita income is an important measure of the prosperity of a country because it indicates the amount of wealth accruing to the population from its productive activities.

APPENDICES

APPENDIX 1: The location of Kakamega forest



APPENDIX 2: Forest Adjacent Communities' Survey Schedule

This research is being conducted by Mr. Albert Luvanda Makee (Reg. No. AGR/PGR/11/2000) as a requirement in partial fulfillment for the award of the degree of Master of Philosophy in Agricultural Resource Economic and Management of Moi University. The information provided would be used to assess the socio-economic factors influencing the quantity of fuelwood harvested from natural forests. The information given to the interviewee will be kept confidential. The collected information will be very useful in directing policy debates and will form a basis for future research. Please, note that your co-operation towards achieving this **GOAL** is very important. Thank you.

GENERAL INFORMATION ON THE RESPONDENT
Name of head of household .... Sex ...... Age ...
Name of respondent ....Sex ...... Relation with HH ....
District...................................... Division ....
Sublocation................................ Village .... Date ....

A. PERSONAL DETAILS

1. What is the Education status of head of household?

Education level	Tick (✓)
No formal education	
Primary level	
Secondary level	
Tertiary level	

2. What is your family size (i.e. including workers and relatives)? ....
3. How many members of your family are not on paid up employment? ....
4. Can you estimate your household daily/monthly/annual income? Fill the table below.

Item	Amount in Ksh.
Salary/Wages	
Cash crops	
Livestock	
Forest activities	
Business	
Retirement benefit	
Donations from others	
Others	

5. Can you estimate your household daily/monthly/annual expenditure? Fill the table below.

Item	Amount in Ksh.
Food	
Clothes	
Housing	
Traveling	
School fees	
Health	
Farming (inputs)	
Donations to others	
Total	

6. What is your total land size? (including any parcel owned elsewhere) …… acres
7. Are you native or you migrated into this area? ………………………………………
8. List major crops grown on this farm? Fill table below

Crop	Yield per annum		Market price - Ksh
	consumption	sale	

B. HOUSEHOLD FUELWOOD REQUIREMENTS

9. Which is your main source of energy on this farm? ………………………………
10. Which other energy source(s) do you use on this farm?

Source	Tick (√)
Kerosene	
Charcoal	
Agricultural wastes	
LPG	
Others (specify)	

11. How many headloads of firewood do you use or sell on this farm per week? Fill table below

Source	Consumption	Sale	Total	Market price
Forest				
On-farm				
Neighbour's farm				
Total				

12. For what purpose do you need firewood from the forest? Fill table below

Purpose	Tick (√)
Cooking	
Heating	
Lighting	
Brick making	
Funeral	
Brewing	
Others	

13. What is the market price for the firewood per headload in this area? Forest species (Ksh) .... On-farm species (Ksh) .... Neighbour's farm (Ksh.) ....
14. Which mode of transport do you use to bring firewood from the forest? ....
15. What quantity of charcoal in bags do you use or sell per week?

Source	Consumption	Sale	Total	Market price (Ksh)
Forest				
Farm				
Neighbour's farm				
Total				

16. Give details on the most preferred fuelwood species used on this farm? Use local names

Species	Firewood.	Charcoal	Source

17. Which of the above fuelwood species are more difficult to get now than five years ago? List ....
18. What is the gender of those involved in firewood/charcoal collection from the forest? (i). for consumption .... (ii). for sell ....
19. What is the estimated distance from your home to the forest? .... Km
20. How many man-hours do they use on the process of sourcing for firewood? ....
21. Does weather affect your demand for firewood? Y/N Explain ....
22. For how long have you been trading in firewood/charcoal? ....
23. What prompted you to start a business in firewood/charcoal? ....
24. Who are your main firewood and/or charcoal customers? ....
25. Who are involved (market channels) in charcoal/firewood trade? (collectors, middlemen, stockist, consumers) List ....

26. Which implements do you use in the collection/harvesting of firewood/charcoal? List (e.g. axe panga, cross cut saw, ropes, etc) ....
27. What constraints do you face in the sourcing of firewood/charcoal for the household from the forest? List (wild animals, harassment by KWS/FD guards, frequent arrests, etc ....
....
28. How best can this forest be managed for the benefit of future generations? (Use incentives, involve local communities, intensify patrols, intensify on-farm tree planting, etc.) ....
....

C OTHER COMMENTS

29. Any further comments ....
....

D. INTERVIEWEES COMMENTS

Name of interviewee................................ Date.............. Time taken ....
How do you judge the mood of the respondent...
Interviewee's judgment on the quality of information given by the respondent ....
Other comments ....
....

★ Thank you for providing me with this valuable information ★

APPENDIX 3: On-farm trees and shrubs around Kakamega forest

Local name	Scientific name	% HH	Status
1. Ikambi	*Eucalyptus grandis.*	68.5	Tree
2. Cypress	*Cupressus lustanica*	38.7	Tree
3. Musutsu	*Croton macrostaychis*	26.4	Tree
4. Mukado	*Persia americana*	12.8	Tree
5. Shipera	*Psidium guajava*	11.9	Tree
6. Munyerenyende/Shikangania	*Bridelia micrantha*	11.5	Tree
7. Lusiola	*Markhamia lutea*	10.2	Tree
8. Paini	*Pinus patula*	7.20	Tree
9. Muhembe	*Mangifera indica*	6.8	Tree
10. Mulaha	*Comretum collinum*	6.4	Tree
11. Grevillea	*Grevillea robusta*	6.0	Tree
12. Munamusai/Musila	*Harungana madascarensis*	5.1	Tree
13. Shikhuma	*Zanthoxyllum gilettii*	4.3	Tree
14. Mukomari	*Cordia abyssinica*	4.3	Tree
15. Liparapandi/Mulungwasi	*Eriobotrya japonica*	4.8	Tree
16. Jakaranda	*Jacaranda mimisifolia*	3.8	Tree
17. Mutukuyu	*Olea capensis*	3.4	Tree
18. Musienze	*Ficus tremula*	3.4	Tree
19. Mwiritsa	*Prunus africana*	3.0	Tree
20. Mukhungula	*Combretum molle*	3.0	Tree
21. Mukhonje	*Tarminalia mollis*	3.0	Tree
22. Musopia	*Bischofia javonica*	2.6	Tree
23. Mutondo	*Funtumia africana*	2.1	Tree
24. Mutere	*Maesopsis eminii*	2.1	Tree
25. Musioma	*Syzigium guineense*	2.1	Tree
26. Musine	*Croton megalocarpus*	2.1	Tree
27. Musangula	*Rhus natalensis*	2.1	Tree
28. Munyama	*Trichilia emetica*	2.1	Tree
29. Lusui	*Diospyros abyssinica*	2.1	Tree
30. Wattle	*Acacia mearnsii*	1.7	Tree
31. Mutsulio	*Spathodea campanukata*	1.7	Tree
32. Musembe	*Entada abyssinica*	1.7	Tree
33. Luvambo	*Nuxia congesta*	1.7	Shrub
34. Bottle brush	*Clestimon*	1.7	Tree
35. Tsikhule	*Sesbania sesban*	1.3	Tree
36. Mutoto	*Ficus natalensis*	1.3	Tree
37. Murembe	*Erythrina abbysinica*	1.3	Tree
38. Munyenya	*Acacia abyssinica*	1.3	Tree
39. Ambrella	*Terminalia mentalis*	1.3	Tree
40. Shikoye	*Strychnos usamarensis*	.90	Tree
41. Mukumu	*Ficus thonningii*	.90	Tree
42. Lutaro	*Teclea nobilis*	.90	Shrub
43. Shikarambwe	*Lantana camara*	.40	Shrub
44. Mweyu/Mweywe	*Celtis africana*	.40	Tree
45. Mwarubaini	*Azadirachta indica*	.40	Tree
46. Mwanzu	*Polysias fulva*	.40	Tree
47. Muyefwe	*Albizia gumifera*	.40	Tree
48. Muwili	*Prunus africana*	.40	Tree
49. Musiema	*Trichilia dregaena*	.40	Tree
50. Mukunga	*Acacia lahar*	.40	Tree
51. Mukhuyu	*Ficus sur*	.40	Tree
52. Mukhomori	*Vanguaria apiculata*	.40	Tree
53. Muhande	*Craibia brownii*	.40	Tree
54. Mufutu	*Vitex doniana*	.40	Tree

55. Mufiristi	*Lepisanthes senegalensis*	.40	Tree
56. Ludolio	*Manilkara butugii*	.40	Tree
57. Lipopo	*Carica papaya*	.40	Tree

HH Household

APPENDIX 4: Fuelwood Trees and Shrubs of Kakamega Forest

Local name	Scientific name	Firewood		Charcoal		Status
		N	RNK	N	RNK	
1. Lusui/Mwilima	*Diospyros abyssinica*	137	2.09	102	3.87	Tree
2. Musine	*Croton megalocarpus*	84	3.15	79	2.34	Tree
3. Mutukuyu	*Olea capensis*	76	2.97	62	3.37	Tree
4. Mweyu/Mweywe	*Celtis africana*	67	2.54	54	2.06	Tree
5. Shikoye	*Strychnos usamarensis*	60	2.75	41	3.00	Tree
6. Mwiritsa/Muwili	*Prunus africana*	57	3.19	47	2.11	Tree
7. Muhande	*Craibia brownii*	53	3.95	46	2.46	Tree
8. Mutaro	*Teclea nobilis*	49	3.55	35	3.49	Shrub
9. Shikhuma	*Zanthoxyllum gilettii*	46	4.09	41	3.93	Tree
10. Musutsu	*Croton macrostaychis*	40	3.70	36	3.72	Tree
11. Ludolio	*Manilkara butugii*	38	3.00	37	1.97	Tree
12. Mulaha	*Combretum collinum*	34	4.47	28	3.68	Tree
13. Mutondo	*Funtumia africana*	33	4.82	25	4.80	Tree
14. Munamusai/Musila	*Harungana madascarensis*	22	4.50	19	4.47	Tree
15. Mukomari	*Cordia abyssinica*	22	4.18	19	4.58	Tree
16. Mumbarakaya	*Trilepisium madascariense*	21	4.62	17	4.94	Tree
17. Munyerenyende/Shikangania	*Bridelia micrantha*	21	4.05	15	3.13	Tree
18. Lusiola	*Markhamia lutea*	20	4.45	20	4.40	Tree
19. Mukhonje	*Tarminalia mollis*	20	3.40	19	2.95	Tree
20. Shiarambatsa	*Blighia unijuta*	19	4.32	15	3.93	Tree
21. Musakala	*Trema orientalis*	19	3.95	17	3.53	Tree
22. Mufiristi	*Lepisanthes senegalensis*	18	4.44	8	5.00	Tree
23. Munyama	*Trichilia emetica*	17	4.47	12	4.67	Tree
24. Litumusi/Maboda/Indama	*Piper umbellatum*	17	4.29	14	5.21	Shrub
25. Mutere	*Maesopsis eminii*	16	4.13	14	3.79	Tree
26. Musopia	*Bischofia javonica*	15	3.93	13	4.31	Tree
27. Musangula	*Rhus natalensis*	14	5.21	9	4.22	Tree
28. Mwandala/Mwanda	*Heinsemia diervikoides*	14	5.14	9	4.33	Tree
29. Mukhungulu	*Albizia gumifera*	12	3.17	12	3.92	Tree
30. Shyunza	*Celtis mildbraedii*	12	2.67	11	2.73	Tree
31. Mukhungula	*Combretum molle*	11	4.09	13	3.46	Tree
32. Musamia	*Bequaertiodendron oblanceoletum*	11	3.73	11	3.82	Shrub
33. Munyenya	*Acacia abyssinica*	10	4.80	6	3.500	Tree
34. Shipera	*Psidium guajava*	10	4.10	9	2.78	Tree
35. Shikoloho	*Cassipourea ruwenzorensis*	9	3.11	6	3.83	Tree
36. Musioma	*Syzigium guineense*	9	3.00	9	2.67	Tree
37. Murembe	*Erythrina abbysinica*	8	7.13	8	6.88	Tree
38. Mukangu	*Aningeria altissima*	8	4.63	7	4.29	Tree
39. Mululu	*Chrysophyllum albidum*	7	6.00	7	6.00	Tree
40. Mung'alikoro	*Premna angolensis*	6	5.33	6	5.17	Tree
41. Lirakalu	*Acanthus pubescens*	6	5.33	5	5.20	Shrub
42. Luvambo	*Nuxia congesta*	6	5.00	5	5.00	Shrub
43. Likhome	*Chaetacme aristata*	6	4.83	1	2.00	Tree
44. Musienze/Muserevenze	*Ficus tremula*	6	2.50	6	2.82	Tree
45. Mukhuyu	*Ficus sur*	5	4.00	5	4.60	Tree
46. Mufutu	*Vitex doniana*	5	3.60	5	4.20	Tree
47. Mulundu	*Antiarias toxicaria*	4	5.00	4	5.00	Tree
48. Shingololotsi	*Fagaropis angolensis*	3	5.67	2	4.22	Tree
49. Luherere/Muterere/Vusherere	*Rubus apetalus*	3	5.33	1	4.00	Shrub
50. Shirakalu	*Rawsonia lucida*	3	5.00	2	7.00	Shrub
51. Shikambi	*Triumfetta macrophylla*	3	3.67	2	3.50	Shrub
52. Mukavakava	*Ficus lutea*	3	3.33	2	3.50	Tree
53. Musaa	*Celtis gomphophylla*	3	2.67	4	3.20	Tree
54. Muti – mayai/ Munuku	*Morus lactea*	2	6.50	2	5.50	Tree
55. Mukhutu	*Ehretia cymosa*	2	6.00	2	6.00	Shrub
56. Mutoto	*Ficus natalensis*	2	5.55	1	6.00	Tree
57. Muhudu	*Vitex fischeri*	2	5.50	2	5.00	Tree
58. Muharia	*Periploca linearifolia*	2	3.50	2	2.50	Herb
59. Mumonyio		2	2.50	1	3.00	Tree

60. Mukhunzuli	*Albizia macrophylla*	2	2.00	2	2.5	Tree
61. Musembe	*Entada abyssinica*	1	9.00			Tree
62. Mukumu	*Ficus thonningii*	1	7.00	1	6.00	Tree
63. Navisinzi	*Casaeria battiscombei*	1	7.00			Tree
64. Museno	*Ficus exasperata*	1	6.00	1	4.00	Tree
65. Shikarambwe	*Lantana camara*	1	6.00			Shrub
66. Musavakwa	*Vernonia auriculifera*	1	3.00	2	5.50	Shrub
67. Shisimbari	*Clausena anisata*	1	3.00	1	6.00	Shrub
68. Muvulu	*Annona senegalensis*	1	3.00	1	2.00	Shrub
69. Musiema	*Trichilia dregeana*	1	3.00	1	4.00	Tree
70. Mukunga	*Acacia lahar*	1	3.00			Tree

N Number of respondents; RNK Rank

APPENDIX 5: Local perceptions of threatened trees and shrubs of Kakamega forest

Local name	Scientific name	%HH	Status
1. Lusui	*Diospyros abyssinica*	22.6	Tree
2. Mweyu/Mweywe	*Celtis africana*	16.6	Tree
3. Musine	*Croton megalocarpus*	14.0	Tree
4. Ludolio	*Manilkara butugii*	12.8	Tree
5. Muhande	*Craibia brownii*	10.6	Tree
6. Lutaro	*Teclea nobilis*	9.4	Shrub
7. Mutukuyu	*Olea capensis*	8.9	Tree
8. Shikoye	*Strychnos usamarensis*	8.9	Tree
9. Mukhonje	*Tarminalia mollis*	8.5	Tree
10. Mwiritsa	*Prunus africana*	6.8	Tree
11. Mulaha	*Comretum collinum*	4.7	Tree
12. Shikhuma	*Zanthoxyllum gilettii*	4.7	Tree
13. Munyama	*Trichilia emetica*	4.3	Tree
14. Mutondo	*Funtumia africana*	4.3	Tree
15. Mukhungulu	*Albizia gumifera*	3.4	Tree
16. Shiarambatsa	*Blighia unijuta*	3.4	Tree
17. Mukomari	*Cordia abyssinica*	3.0	Tree
18. Mwanda/Mwandala	*Heinsemia diervikoides*	3.0	Tree
19. Mumbarakaya	*Trilepisium madascarense*	2.6	Tree
20. Munyenya	*Acacia abyssinica*	2.6	Tree
21. Musamia	*Bequaertiodendron oblanceoletum*	2.6	Tree
22. Munamusai/Musila	*Harungana madascarensis*	2.1	Tree
23. Shikoloho	*Cassipourea ruwenzorensis*	2.1	Tree
24. Mululu	*Chrysophyllum albidum*	1.7	Tree
25. Musakala	*Trema orientalis*	1.7	Shrub
26. Munyerenyende/Shikangania	*Bridelia micrantha*	1.3	Tree
27. Shyunza	*Celtis mildbraedii*	1.3	Tree

HH Household

APPENDIX 6: Results of multicollinearity analysis

a). Spearman's Correlation coefficients

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	D_1	D_2
X_1	1.000														
X_2	.065	1.000													
X_3	-.190	-.125	1.000												
X_4	-.368	.159	.478	1.000											
X_5	.183	.068	.209	.167	1.000										
X_6	.161	.373	.102	.325	.175	1.000									
X_7	.052	.208	-.011	.063	.065	.290	1.000								
X_8	-.016	.008	.111	-.039	.202	.172	.383	1.000							
X_9	.142	-.010	.060	.134	-.018	.055	.513	.328	1.000						
X_{10}	-.072	-.032	.281	.215	.004	-.109	.007	.102	.149	1.000					
X_{11}	-.094	-.114	.428	.200	-.106	-.167	-.113	-.004	-.011	.318	1.000				
X_{12}	-.074	-.095	.153	.118	.100	.014	.062	.058	-.130	-.154	-.059	1.000			
X_{13}	.055	.330	-.169	-.090	-.096	.175	.128	-.146	-.056	-.199	-.080	-.086	1.000		
D_1	.103	-.161	-.057	-.149	.037	-.271	-.162	-.227	-.099	.026	-.066	.109	-.088	1.000	
D_2	.018	-.118	.093	-.058	-.101	.007	-.147	.022	.044	.073	.097	-.086	-.273	.004	1.000

b). Estimated equations

FUNCTION	β_0	β_1	β_2	B_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}	β_{13}	B_{14}	β_{15}	r	R^2
F(X_1)	12.493 (1.175)	-0.302 (0.241)															0.109	0.012
F(X_2)	12.612 (1.489)	0.0001 (0.000)															0.038	0.001
F(X_3)	11.564 (3.336)	0.049 (0.071)															0.061	0.004
F(X_4)	7.170 (4.574)	0.0416 (0.000)															0.148	0.022
F(X_5)	21.956 (3.5200	-0.189 (0.084)															0.216	0.047
F(X_6)	11.077 (0.906)	0.142 (0.230)															0.043	0.002
F(X_7)	7.332 (1.615)	0.572 (0.1970															0.199	0.040
F(X_8)	9.270 (2.607)	0.050 (0.056)															0.063	0.004
F(X_9)	8.381 (1.207)	0.816 (0.245)															0.230	0.054
F(X_{10})	6.561 (0.806)	0.434 (0.049)															0.553	0.306
F(X_{11})	10.512 (0.970)	0.658 (0.466)															0.098	0.010
F(X_{12})	14.191 (1.478)	-1.315 (0.682)															0.133	0.018
F(X_{13})	9.211 (2.000)	1.053 (0.820)															0.089	0.008
F(D_1)	12.799 (1.402)	-1.246 (1.605)															0.055	0.003
F(D_2)	10.580 (1.522)	1.304 (1.690)															0.054	0.003
F(X_1X_2)	11.965 (2.079)	-0.304 (0.257)	0.0001 (0.000)														0.112	0.013
F(X_1..X_3)	7.093 (5.996)	-0.656 (0.333)	0.001 (0.000)	0.108 (0.103)													0.306	0.093
F (X_1,X_4)	17.675 (11.37)	-1.348 (0.627)	0.001 (0.001)	0.077 (0.178)	0.0418 (0.063)												0.370	0.137
F(X_1..X_5)	13.266 (13.65)	-0.655 (0.779)	0.001 (0.001)	0.176 (0.217)	-0.023 (0.076)	-0.149 (0.187)											0.402	0.162
F(X_1...X_6)	16.635 (11.76)	-1.152 (0.687)	0.001 (0.001)	0.074 (0.187)	-0.059 (0.066)	-0.010 (0.158)	2.364 (0.863)										0.621	0.385
F(X_1...X_7)	13.316 (11.58)	-0.960 (0.678)	0.0003 (0.001)	0.134 (0.186)	0.066 (0.064)	-0.121 (0.155)	1.848 (0.902)	0.872 (0.569)									0.669	0.447
F(X_1 X_8)	9.023 (12.27)	-0.941 (0.658)	0.001 (0.001)	0.115 (0.182)	-0.076 (0.063)	-0.122 (0.152)	2.259 (0.898)	0.507 (0.582)	0.126 (0.181)								0.722	0.522
F(X_1..X_9)	7.887 (12.44)	-0.985 (0.665)	0.001 (0.001)	0.095 (0.185)	-0.064 (0.065)	0.088 (0.158)	1.869 (1.019)	0.677 (0.621)	0.130 (0.183)	-0.682 (0.818)							0.734	0.539
F(X_1..X_{10})	8.707 (11.10)	-0.374 (0.586)	0.0004 (0.001)	-0.013 (0.173)	-0.033 (0.056)	-0.117 (0.137)	1.724 (0.871)	1.116 (0.587)	0.110 (0.154)	-0.681 (0.754)	0.441 (0.133)						0.853	0.728
F(X_1 X_{11})	8.421 (10.89)	-0.528 (0.587)	-0.002 (0.001)	0.164 (0.221)	0.045 (0.055)	-0.258 (0.175)	1.673 (0.855)	1.241 (0.584)	0.169 (0.159)	-0.825 (0.748)	0.533 (0.150)	-2.768 (2.200)					0.869	0.755
F(X_1..X_{12})	20.842 (14.95)	-1.238 (0.830)	0.0002 (0.001)	0.267 (0.234)	-0.136 (0.094)	-0.376 (0.199)	2.394 (1.037)	0.639 (0.766)	-0.011 (0.217)	0.072 (1.053)	0.580 (0.153)	-3.329 (2.218)	4.468 (3.745)				0.883	0.779
F(X_1..X_{13})	10.341 (14.63)	-0.996 (0.764)	0.001 (0.001)	0.378 (0.220)	-0.155 (0.086)	-0.429 (0.183)	2.073 (0.957)	0.532 (0.698)	0.025 (0.198)	0.794 (1.028)	0.593 (0.139)	-3.277 (2.016)	5.730 (3.465)	4.781 (2.473)			0.912	0.832
F(X_1... D_1)	1.432 (15.64)	-1.480 (0.831)	0.0004 (0.002)	0.310 (0.227)	-0.125 (0.090)	-0.423 (0.192)	2.102 (1.000)	0.498 (0.715)	-0.155 (0.214)	0.169 (1.199)	0.618 (0.143)	-3.386 (2.224)	6.515 (3.374)	3.218 (2.715)	6.908 (4.503)		0.932	0.869
F(X_1 D2)	31.01 (27.58)	-1.704 (0.821)	0.002 (0.002)	0.222 (0.230)	-0.177 (0.096)	-0.390 (0.187)	2.329 (0.982)	0.723 (0.713)	0.055 (0.221)	-0.396 (1.172)	0.627 (0.139)	-2.589 (2.236)	7.253 (3.500)	1.253 (2.790)	7.052 (4.351)	-9.435 (7.354)	0.944	0.891