IMPACT OF WOODFUEL DEMAND ON MARSABIT FOREST

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DECLARATION

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

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DEDICATION

This work is dedicated to my dearest Mom, supportive sister and brothers:

Wanjiku, Gituchi, Wagitundu and Mwalimu J.B.

Above all, to my fiancée Purity

for her amazing capacity to

love and care.
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LIST OF ABBREVIATIONS

ASAL arid and semi-arid lands
CCD charcoal demand
d.f. degree of freedom
eq. equivalent
E.S.D. energy saving device
FAO Food and Agricultural Organization of United Nations
FWD fuelwood demand
G.K. Government of Kenya
GTZ German Technical Co-operation Agency
hh/HH household
ICD improved cooking device
I.I.S. improved institutional stoves
IPAL Integrated Project in Arid
K.C.J. Kenya ceramic jiko
KSh Kenya shilling
LPG liquefied petroleum gas
MALDM Ministry of Agriculture, Livestock Development and Marketing
M.S. Maendeleo stove
MDP/GTZ Marsabit Development Program in Cooperation with GTZ
MPND Ministry of Planning and National Development
NGO non governmental organization
POPS population size
SEM spouse employment
spp. species
SPSS statistical package for social sciences
T.M.S. traditional metal stove
3-S.F. three-stone fireplace
UNEP United Nations Environmental Program
USAID States Agency for International Development
NOMENCLATURE

\( \sigma^2 \) = variance of population parameter to be estimated

\( \delta^2 \) = the squared "allowable error" in the parameter estimate

\( \beta \) = regression parameter

\( F \) = F-statistic of the estimate

\( m_1 \) = sample size of the first sector

\( m_2 \) = sample size of the second sector

\( n \) = sample size

\( r \) = sample correlation coefficient

\( r^2 \) = coefficient of determination

\( S \) = standard error of the estimate \( \gamma \)

\( S.E. \) = standard error of the estimate of the partial regression coefficient \( \beta_o \)

\( S_x^2 \) = the sample variance of the first sector

\( S_y^2 \) = the sample variance of the second sector

\( \text{Sig.} \ F \) = significance level of F-statistic

\( \text{Sig.} \ T \) = significance level of T-statistic

\( t \) = critical value corresponding to selected confidence limit(\( \infty \))

\( T \) = T-statistic of partial regression coefficient \( \beta_o \)

\( t_0 \) = observed value of \( t \)

\( \mu \) = random disturbance or error term

\( \chi \) = independent variable

\( \gamma \) = dependent variable
ABSTRACT

Marsabit Forest is located in one of the designated ecologically sensitive sites in Africa. The forest is the primary source of wood for fuel, construction and meets other needs for the local communities. The ecological and socio-economic consequences of woodfuel demand from the forest were examined. Empirical field measurements and questionnaires were used for data collection from the local households and institutions. Linear regression and t-Test methods were used for data analysis.

The total woodfuel consumption by the sectors studied was approximately 56000 tons/yr. The rate of deforestation attributable to large-scale harvesting of wood for fuel by the institutions was estimated at 1.6 hectares per year. This resulted in serious loss of indigenous tree species notably, *Olea* spp., *Teclea* spp., and *Diospyros scarbra*. A typical household in the rural areas was found to spend over 90 man-days/yr on wood gathering. Thus women and children, who are primarily responsible for gathering wood, spent enormous amount of time and energy in this exercise at the expense of other productive activities. Moreover, the forest, like other forest resources in the ASAL areas of Kenya, is subjected to the so-called “tragedy of the commons” type of exploitation. Consequently, every member of the community wanted to maximise their individual and/or collective benefit(s) from the common resource without the due consideration to its sustainability.

To control further degradation of the forest, further harvesting of *Olea* spp., which is one of the protected hardwood species in Kenya, should be banned. Woodfuel conservation should be enhanced through wider and more efficient use of energy-saving technologies. Cultivation of *cucurbitaceae* plant species whose roots can be used for fuel is recommended. Suitable planting sites and tree species should be identified to encourage planting of trees in the local schools, around small townships and degraded settlement areas. Cost-effective techniques of harnessing solar energy should be promoted in order to provide the local community with a viable alternative/supplement to woodfuel.
1. **INTRODUCTION**

1.1 Background to the problem

Tropical deforestation is perhaps one of the most devastating environmental disasters occurring in the 20th Century and is bound to persist into the 21st Century. Woodfuel demand, among a host of other natural and anthropogenic factors such as logging for timber, clearing of land for agriculture, or roads, and urban centres advancement into forested areas, is widely recognized for its considerable contribution towards triggering and/or exacerbating both the spatial and temporal dimensions of the global deforestation menace. Indeed, wood has been a primary fuel since man discovered fire and is likely to remain so for many years to come particularly in the so-called developing countries such as Kenya.

With regard to availability, woodfuel comes largely from local wood resources which, in turn, puts enormous pressure on the trees, bushes and shrubs within the proximity of population centres. However, long before the demand for woodfuel leads to complete destruction of the vegetation cover, it can have markedly degrading environmental effects. For instance, excessive pruning or lopping the branches may reduce a tree's capacity for growth, and removal of the more easily felled younger trees may reduce the regenerative capacity of the forest. Also, woodfuel demand is considered a key desertification assessment factor within a broader land-use and socio-economic context (Odingo, 1990).

Fuelwood and charcoal contribute over 95% of the total energy needs in the ASAL regions of Kenya such as Marsabit District (Darkoh, 1991). In the past, these were obtained as "free goods" in the open Savannah woodland around human settlements (Haro, 1990), but presently access to the same is becoming increasingly difficult because of wood scarcity (MPD/GTZ, 1995). Ellis (1984) observed that human utilization of energy resources such as woodfuel had both ecological and socio-economic effects within a particular region. For this study, a simplified schematic model was constructed to illustrate the typical effects of woodfuel demand and to show the parameters examined (Fig. 1.1).
Fig. 1.1: Typical effects of woodfuel demand
1.2 The Marsabit Forest

Marsabit Forest is situated in the Central Division of Marsabit District and the District lies between Longitudes 37° 57" and 39° 21" East and Latitudes 02° 45" and 04° 27" North(Figs.1.2; 1.3). This tropical dry forest is gazetted and covers approximately 15281 hectares(MPND,1994). The forest is situated within the Marsabit National Reserve/Park of 113200 hectares as isolated forested mountain and surrounded by desert country(IUCN/UNEP, 1987). The forest also consists of a number of volcanic craters, several of which contain fresh water. The main vegetation is trees forming dense stands over large areas of approximately 3000 hectares with thick and closed canopies which constitute their own bioclimates and the vegetation is characterized by deciduous thorn trees which grow 5-15 metres high and are indigenous in nature(MALDM,1995).

Furthermore, the forest supports vital abiotic and biotic processes such as irrigation, breeding and migration of birds. The high altitude(1702m) favourably modifies the micro-climate of both within the forest and surroundings. Moreover, the forest is estimated to lose approximately 155 tons/week of wood either for woodfuel, construction and/or other purposes for the local households and institutions such as schools, hospital, prison, and hotels(INTERAID,1995).

The forest is endowed with wide biodiversity, habitats and complex ecosystems that are crucial not only to the local community, but also the rest of the world. The forests is a habit to important species notably elephants, buffaloes, baboons and antelopes(MPND,1994). Moreover, it is estimated that 350 different bird species are found within the forest(IUCN/UNEP,1987). Olea spp., which is classified as endangered by ICRAF(1992) is one of the dominant species in the forest. Furthermore, the forest is an important tourism attraction site situated in an ASAL region. According to IUCN/UNEP(1987), the Marsabit National Reserve/Park, of which Marsabit Forest is a part, is one of the designated ecologically sensitive sites in Africa. This calls for urgent and effective measures to ensure sustainable management and conservation of the forest.
Fig. 1.2: Location of Marsabit District

Source: MPND, 1994
Fig. 1.3: The study area

Source: Adopted from Survey of Kenya, 1988

- o = sample area, 1 = Kituruni, 2 = Hulahula, 3 = Karare, 4 = Songa
- 5 = Badassa, 6 = Dakabaricha, 7 = Golo Iukesas, 8 = Manyatta Jillo
- 9 = Mountain Marsabit (1702m), 10 = Marsabit township
- 11 = Gof chopa Hills, 12 = Marsabit airstrip,
- 13 = Marsabit Forest boundary, 14 = International trunk road (Class A)
- 15 = Marsabit National Park boundary

W = Principal well, WH = Water hole, SP = Spring, BH = Borehole
1.3 Definition of study terms

(i) An ecologically sensitive site refers to an area endowed with unique ecological setting and/or significance and is liable to severe degradation.

(ii) Deforestation refers to loss in tree cover within a particular forest through felling of trees for various end-uses and, in this particular case, for woodfuel.

(iii) Dry/dead wood refers to wood that has been sun-dried in the open for use as fuelwood.

(iv) Household refers to a separate and independent consumption unit with regard to woodfuel.

(v) Institutions refer to the non-household units that offer catering services such as schools, hospital and prison.

(vi) Wet wood refers to freshly felled/lopped wood for use as fuelwood.

(vi) Woodfuel refers to fuelwood and charcoal collectively.

1.4 Statement of the problem

Marsabit Forest, which falls within a designated ecologically sensitive site, is threatened by the rising human pressure within its surroundings. This pressure has been triggered by 4 background factors namely; the rapid growth of Marsabit township which was upgraded to a Municipal Council in 1997 and sedentarization of former pastoral communities around the forest. Also, population within the Central Division tremendously increased from 17268 in 1989 to 35519 by 1993 and over 51% of the population is within the Marsabit township situated 1km from the forest (MPND,1989). Furthermore, the recent Government policy which encourages construction of more boarding educational institutions in ASAL regions such as Marsabit District in order to improve education standards will put further pressure on the forest (MPND,1994). Therefore, demand for wood for use as fuel and construction materials as well as land for agriculture has correspondingly gone up.

The ecological degradation problems attributable to this high demand pressure on the forest
include, but not limited to, deforestation, loss in biodiversity and soil erosion. Taking into account the present and future demand pressure on the forest, it was found necessary to determine the total woodfuel demand by the sectors involved, its characteristics as well as the factors influencing that demand. Hence examine the deleterious ecological effects(impact) on the forest and propose appropriate remedial interventions.

1.5 Objectives of the study

1.5.1 Core objective

Determine the impact of woodfuel demand on Marsabit Forest and propose appropriate remedial interventions.

1.5.2 Specific objectives

1. Determine the woodfuel demand/supply dynamics with respect to Marsabit Forest.
2. Identify approaches towards wider and sustainable adoption of woodfuel-saving technologies within the study area.
3. Identify alternative approaches towards increasing woodfuel supply for the local communities.

1.6 Significance of the study

Determination of woodfuel demand by rural and urban households and institutions from Marsabit Forest will help in estimating the critical demand/supply balance, hence help in maintaining the desired long-term viability of the forest ecosystem. Findings on the appropriate approaches towards wider and sustainable adoption of woodfuel-saving technologies will help in realizing higher levels of woodfuel conservation. Findings on approaches towards increasing alternative wood supply will help in offsetting future exclusive dependence on Marsabit Forest.
The study was conducted in the context of an on-going rehabilitation program (MDP/GTZ), hence the findings of the study will be useful in strengthening the MDP/GTZ’s interventions in line with its environmental conservation objective within the study area in particular, and Marsabit District in general. The findings should also help in formulating Government policies that are in harmony, rather than conflict, with the desired sustainable utilization of Marsabit Forest in particular, and other forests in general.
2: LITERATURE REVIEW

2.1 Woodfuel situation in the ASAL areas of Kenya

There is little specific information or data on the quantities and/or characteristics of energy use in the ASAL districts, this being one of the major issues requiring research (Darkoh, 1991; Darkoh, 1993). Much of the data available at present are of general nature, which have been aggregated at the national and provincial levels. Major research efforts are, therefore, needed in order to fill this information gap with a view to assessing more accurately the energy situation, particularly the predominantly used woodfuel, in the ASAL districts and the likely socio-economic and ecological implications involved. The availability of such detailed and region-specific data would assist in determining both the energy deficit and ecologically degraded areas, hence plan for appropriate remedial interventions. This was therefore the important information gap the study set out to fill with respect to Marsabit District, which is the largest ASAL district in Kenya.

In all the ASAL districts in Kenya, fuelwood and charcoal are the predominant sources of energy. They are the available and affordable forms of fuel and are, therefore, used extensively, if not exclusively (95 to 98%) to provide energy for cooking, heating and lighting (FAO, 1984; Darkoh, 1991; Haro, 1990). While fuelwood use is predominant in rural households, charcoal is the main form of urban fuel. Woodfuel has been considered surplus in the ASAL regions hence, its demand or scarcity regarded insignificant among the nomadic communities of northern Kenya (Haro, 1990).

However, evidence currently emerging out of the areas of concentrated demand indicates that such generalized assumptions are misleading. For example, woodfuel demand by the semi-nomadic Rendille in the vicinity of Korr and Kargi in Marsabit District was estimated to be as low as 217 kg per capita per year, whereas the nomadic families consumed 411 kg per capita per year (Walther and Herlocker, 1981). These authors further observed that 10% and 5% of the woodfuel was cut from live trees or primary biomass among the semi-nomadic and nomadic pastoralists respectively while the bulk
of the rest was collected from dead branches and/or abandoned livestock *bomas* (sheds). Hughes (1985) recorded per capita consumption as high as 1351 and 657 kg for the irrigation scheme and semi-nomadic settlements along the Tana River flood plain forest respectively.

The overall level of demographic growth, the household size, the tendency towards sedentarization or settlement as opposed to nomadism or the rate at which it has been commercialized also determines increase in woodfuel demand. This is the typical situation prevailing around Marsabit Forest and with a greater threat from the adjacent Marsabit township and non-household institutions such as schools, hospital, prison, hotels and bakeries. In Turkana District, charcoal production and marketing is relatively a new practice and its production is inefficient, wasteful and destructive as it involved deliberate felling of important browse trees like *Acacia Spp.* with dense wood and high specific gravity (Haro, 1990). Charcoal production efficiency as low as 5% has been estimated for Turkana area and it is presently produced mainly for urban domestic and small-scale business enterprises. Darkoh (1991) indicated that the traditional earth kiln with a conversion efficiency of 10% is extensively utilized within the study area.

It is observed that before colonial intervention, peasant modes of production in the ASAL regions were essentially closed systems, hence effectively allowing for the availability and regeneration of forest resources to continue. Colonialism and the prevailing post-independence economic policies precipitated the shift to a competitive market economy which weakened the traditional (communal) resource management structures and increased emphasis on individual property rights (Haro, 1990). In addition, some vast areas, particularly the more productive ones, have been gazetted into TrustLand (National parks or Reserves), thus alienating the indigenous communities from their traditional resources. Marsabit Forest, which has been gazetted, is a good case in point. These are therefore part and parcel of the critical transition, which partly explain the prevailing woodfuel crisis, in particular, and land use conflicts in general within the Kenya's ASAL.
2.2. Possible remedial interventions

The problems of wood resource degradation around the increasing sedentary centres in ASAL districts are inherently multi-faceted and complex in nature, hence difficult to control. The present demand characteristics therefore, can only act as a guide to what will follow in future unless certain timely and appropriate measures are taken to contain the current trend. In such districts as Kilifi, for example, the lack of effective control over the cutting of indigenous Kaya forests may be causing irreversible changes in the ecology of rural areas, principally in the carrying capacity and fertility of the soil (Darkoh, 1991). Elsewhere, Mandera, Wajir, Garissa and Marsabit, woodfuel scarcity is causing significant increase in the time and effort that women and children must devote to woodfuel gathering, hence eroding the community’s productivity (MDP/GTZ, 1994; Haro, 1990). Bellamy (1995) observed that the more time and effort a woman spends dealing with the ramifications of environmental decline such as gathering fuelwood, the less time and effort she spends on other productive activities such as farming.

The resultant land degradation brought about by severe deforestation can be rehabilitated provided that the critical regeneration thresholds have not been crossed beyond the ecosystem regenerative capacity (IUCN, 1988). Therefore, intervention strategies to be considered necessitate the understanding of the total role that woody biomass plays within the locality in question because people need, *inter alia*, fuel, poles, food, fodder, tools, medicine, and shade. The feasible and available approaches for dealing with the perceived woodfuel problem in ASAL regions therefore fall into three distinct categories (Darkoh, 1993; Kinyanjui 1984): conservation through widespread adoption and correct use of more efficient woodfuel conversion and utilization technology; increase supplies of wood through introduction of forestry and agro-forestry land use practices and, where applicable, biomass residues utilization; substitution of woodfuel with other forms of energy. This integrated approach is appropriate because, in practically no one situation does it appear possible to solve the woodfuel
problem through one single action. But rather it has been found to be indispensable to combine the various lines of action to obtain an appropriate combination which will address the local conditions and allow for immediate effects as well as more durable impact.

2.2.1 Woodfuel conservation intervention

It has variously been argued that, other factors constant, if the available woodfuel could be utilized less wastefully, the aggregate demand would correspondingly reduce (Fadaka, 1996; UNEP, 1989). These authors further observed that such woodfuel economy, in turn, would incidentally translate into significant socio-economic and environmental benefits. The main challenge in woodfuel conservation has therefore been to design, develop, and widely disseminate and correctly use more efficient and appropriate woodfuel utilization technologies. In other words, technology particularly woodfuel conversion methods, affect the rate of exploitation as well as accessibility to woodfuel.

The heat transfer efficiency of traditional stoves is rated by Hankins (1987) at 5-15% for the three-stone open fires and at 10-18% for the T.M.S. (Fig. 2.1). Field tests have shown that the improved charcoal stove known as the K.C.J. has the potential to reduce the amount of fuel required to cook a standard meal by 30-50%, over a wide range of operating conditions (Fig. 2.2). The dome-shaped M.S. is estimated by GTZ (1993) to conserve fuelwood by between 30-40% (Fig. 2.3). Improved institutional stoves (I.I.S.) are estimated by UNEP (1989) to operate at 30-50% conservation efficiency relative to other traditional stoves (Fig. 2.4). Kimani (1995) indicated fuelwood conservation of between 29-31% in various refugee camps in Dadaab, Kenya and Goma, Zaire. FAO (1984) indicated that the average annual woodfuel demand per capita, estimated at 615-840 kg worldwide, could potentially be reduced to 431-588 kg or 25-30% conservation through widespread and correct use of stoves with 30% conservation efficiency. Hence, woodfuel conservation is considered an appropriate intervention through the use of various woodfuel-saving technologies.
Fig. 2.1: Traditional metal stove (T.M.S.)

Source: Hankins, 1987

Fig. 2.2: Kenya ceramic jiko (K.C.J.)

Source: Hankins, 1987
Fig. 2.3: *Maendeleo* stove (M.S.)

Source: MDP/GTZ, 1995
Fig. 2.4: Improved institutional stove (I.I.S.)

Source: UNEP, 1989
2.2.2 Woodfuel supply intervention

In the context of the ASAL, a conventional forestry-based wood supply approach would be too costly and ineffective to significantly increase biomass supplies (Darkoh, 1991). Although tree planting has been relatively successful in the high potential areas of Kenya, it has met with little success in the ASAL for a number of reasons (Taylor and Soumar'e, 1984). The failure to recognize the importance of trees in their totality, for example, singling out of isolated problems like the fuelwood crisis and neglecting the role of trees as an integral component of land management system and/or a source of other essential wood products. The failure to choose suitable sites and species or mismatching both such that sometimes trees are tried out where the same have never grown previously (Haro, 1990). Planting is conducted through incentive schemes like food-for-work programmes and the destitutes who are normally the beneficiaries of such schemes, attach neither value nor care to trees planted beyond the amount of food received (Kimani, 1995). The benefits of fuelwood plantation are considered by most people to be too far off in the future to provide any realistic and practical motivation towards tree planting. Furthermore, the resource-poor rural populations, existing as they do on the margins of subsistence, cannot afford to forego meeting of present needs to attain those of the future, however noble the latter might sound.

The communal land tenure system practiced in these areas discourages investing in long term projects like tree planting because people do not have any legitimate guarantee of ownership over such resources. This has been identified as a possible impediment to serious tree planting activities by the local community in the study area (MDP/GTZ, 1995). Another constraint is that tree planting, as it were, is a total revolution in the lives of the pastoral nomadic communities (Lusigi, 1980; Lusigi, 1981). It requires skills and it is far more than just digging a hole and placing the seedling there in. Simple as it may appear, this is a practice completely outside the traditional norms of a nomad who is nonetheless an expert, in his own right, with regard to other aspects of range management. The survival of planted trees
in arid areas also necessitates constant watering or expensive ventures like construction of micro-catchments (Oba, 1989). In an environment where availability of potable water is a major problem, continuous watering to ensure tree survival or expenditure of so much capital to sustain a single tree that might not even grow to provide any meaningful benefit becomes difficult.

In spite of these limitations to tree planting, where suitable sites have been identified, new woodfuel supply initiatives should include clear and legitimate definition of ownership and setting up of appropriate royalties and revenue incentives to encourage private production. Agro-forestry or on-farm forestry and woodlots establishment approaches within the private could also prove to be more economical and effective means to higher rates of trees planting (Darkoh, 1991).

2.2.3 Fuel substitution intervention

An alternative strategy to compliment conservation and supply options is the substitution of conventional fuels (kerosene, liquified petroleum gas (LPG), electricity) for traditional woodfuel. Fuel substitution, as a household energy supply strategy, is however faced with a number of serious impediments. Such fuels exert considerable demand on Kenya's limited foreign exchange, hence difficult to justify and finance. Furthermore, the cost of distributing commercial fuels is high and the distribution network, especially in ASAL, is not reliable. Prices are a further constraint since the high retail prices of such fuels and the equipment that uses them, especially in such remote places as Turkana, Garissa, Wajir, Mandera and Marsabit, put these commercial fuels out of reach for most urban, rural populations and institutions alike. In Turkana, for example, Leach (1990) reported that only 300 consumers had electricity connections in Lodwar township. Electric stoves and other energy gadgets were so unaffordable that only 5% of Lodwar households used the same for cooking. The few who used these fuels economized by using charcoal for longer cooking needs, and/or as a back-up in the event of kerosene, (LPG), or electricity shortages.
Leach (1990) further observed that these constraints would certainly persist for many years in light of other competing demands for these substitutes elsewhere and principally, in the commercial and industrial sectors in the country. Logically therefore, as long as these impediments persist, attempts to encourage people to switch to the same as a way of saving wood resources cannot succeed.

2.3 General principles of rural energy demand

The literature cited indicates that woodfuel is the predominant form of fuel within the ASAL regions of Kenya. Hence the following six principles as reported by Hosier (1984) were taken to generally govern that woodfuel demand and its characteristics. The first principle states that the demand of fuelwood depends on its availability and this emerged clearly from Earl (1975) observations regarding the hill people who were resettled in the Terai District of Nepal, India. After a relatively short period of time in the wood-rich valley, their average consumption rates had doubled indicating that the demand for fuelwood is elastic, that is the more available, the higher the demand.

The second principle says that as income increases, woodfuel demand also increases. Openshaw (1978) noted that rural households increased fuelwood demand as incomes increased, but if supplies of fuelwood were available they generally did not switch to charcoal consumption. This relationship could be explained by the observation that energy use by the very poor in developing countries is at the most basic level, hence as income increases, the demand of many goods, woodfuel being one of them, also increases.

The third principle is on substitution and says when fuelwood become increasingly scarce, not only is it used more sparingly, but greater quantities of alternative fuels are sought, and the alternatives may be either traditional or commercial in nature. However, it is not entirely obvious which direction a household would move on the so-called "energy ladder" when faced with a shortage. Under certain conditions, the step is likely to be "down"; to a less sophisticated technology-fuel combination, whereas
under different conditions it might be "up"; to a more sophisticated technology-fuel mix. Wood (1979) indicated that for many rural households, crop residues, plant stalks, and dung serve as the primary alternatives in view of the limited access to more technologically sophisticated fuels. In this particular context, it would be important to infer what options the study population would take if and when faced with an acute woodfuel scarcity.

The fourth principle states that climate plays a critical role both in the demand for, and the availability of woodfuel. Climate influences demand through temperature variations that make it necessary for households to utilize significantly higher amounts of energy for space heating during cold seasons. Best (1979) indicated strong seasonal variations in woodfuel and dung consumption patterns. For instance, in the tropics more woodfuel is consumed during the wet season than during the dry season. In more temperate areas, autumn and winter are the seasons of high woodfuel demand. Climate changes due to an increase in altitude also increase the need for space heating. For example, the need for space heating on the highland slopes of Mountain Kenya would be much higher than down at the coastal plains or other low altitude regions.

Climatic conditions also influence energy demand by determining biomass production rates since areas of low biomass potential like the ASAL, are more easily deforested but less easily regenerated. Conversely, areas of high biomass potential are more quickly able to recover from excessively high levels of woodfuel demand. As Earl (1975) showed in the Terai District of Nepal, hill people living in the high potential wood "surplus" zones demonstrated a much higher woodfuel demand per capita than their relatives who remained on the marginal wood "deficit" zones. This Earl's example will be used to determine the so-called fuelwood "surplus" and "deficit" zones in the study area.

The fifth principle states that household size influences household and per capita energy demand levels. That is, while a large household may consume more total energy than a small household, its per capita consumption may also be lower than that of a smaller household. Assuming there is some fixed
level of woodfuel demand necessary to sustain a household under certain socio-economic conditions, each additional household member increases woodfuel demand less than the previous member. Therefore, the marginal increase in woodfuel demand decreases with each additional household member and the order of correlation of this relationship varies from one region to another (Hosier, 1984).

The sixth and final principle is a planning approach known as the "Gap Theory" concept (Leach and Means, 1988). The basic premise of this theory is that where demand of woodfuel and/or wood products exceeds annual growth or yield rates of the particular vegetation, the difference or the "gap" is made up by cutting the primary tree stocks or the standing biomass. As woodfuel demand rises due to, *inter alia*, population growth, more trees are felled and consequently the annual growth rate of vegetation declines and inevitably, the gap grows bigger and the primary stock is depleted further. In extreme circumstances, this depletion would accelerate towards final deforestation.

With few exceptions, the remedy for closing the "gap" is either massive afforestation, introduction of peri-urban and communal woodlots or demand reduction through interventions such as efficient woodfuel cooking stoves or woodfuel substitution or any combination of the above. However, one inherent limitation in this principle is its apparent failure to appreciate the reality that people are dynamic and resourceful and can therefore act according to scarcity situations (Haro, 1990). This may be through fuel switching, or moving "up" or "down" the fuel "ladder", changing cooking habits or economizing on available fuel. In other words, the magnitudes of deforestation may not necessarily follow the predicted temporal and/or spatial dimensions. The foregoing six principles indicated the interlocking factors and concepts which invariably influenced woodfuel demand in a typical rural and/or urban household sector. Hence, they were used to underpin the analysis of results and discussion in the rest of the thesis and were applied in full view of their inherent limitations, and their relevance and/or applicability within the scope and limitations of the study.
3: METHODOLOGY

The study was carried out between the months of January to March (inclusive) in 1997 and the study area covered the Marsabit Central Division where Marsabit Forest is located. The study employed 2 primary data collection instruments namely questionnaires and empirical field measurements. The 2 methods were used to provide the necessary data pertaining to woodfuel demand and its characteristics by different sectors. The 3 respondent sectors studied include rural households, urban households and institutions within the study area.

3.1 Sample size determination

Sample sizes for urban and rural households were determined according to Peterson (1982). The approximate sample size was given by:

\[ n = \frac{t^2 \sigma^2}{\bar{d}^2} \quad \text{--- Eq. 3.1} \]

From the pilot survey carried out by the researcher, approximately 1 in every 5 households has a woodfuel-saving device within the Marsabit township whereas about 1 in every 15 households has the same in the rural areas, hence \( p = 0.20 \) and 0.0667 respectively. Where \( p \) shows proportion of respondents in the population possessing the parameter (improved woodfuel cooking device) to be estimated.

3.1.1 Urban households sample size

\[ t^2 = 2.72 \quad \text{(given } 1=0.10, t=1.65 \text{ from } t\text{-Table)} \]

\[ \sigma^2 = 0.16 \quad \text{(given } p=0.20, \sigma^2=p(1-p) \text{)} \] is an estimate of the variance

\[ \bar{d}^2 = 0.01 \quad \text{(since sample estimate } = \pm 10\% \text{ of population proportion)} \]

\[ n = \frac{2.72 \times 0.16}{0.01} = 43.52 \]
Hence, urban households sample size should be at least 50 households.

3.1.2 Rural households sample size

\[ t^2 = 2.72 \text{ (given } z = 0.10, t = 1.65) \]

\[ \sigma^2 = 0.062 \text{ (given } p = 0.0667, \sigma^2 = p(1-p)) \text{ is an estimate of variance) } \]

\[ \sigma^2 = 0.0025 \text{ (since sample estimate } = \pm 5\% \text{ of population proportion) } \]

\[ n = \frac{2.72 \times 0.62}{0.0025} = 67.6978 \]

Hence, rural households sample size should be at least 70 households.

3.1.3 Institutions sample size

The 21 institutions which obtain fuelwood supplies from Marsabit Forest were included in the sample (Mburu, 1997).

3.2 Sampling procedure

Systematic random sampling procedure was used. In the rural area, 8 representative village clusters (manyattas) were selected, each having approximately 20 - 30 or more sparsely distributed households. Ten households were then sampled in each village using systematic random sampling, i.e., starting with a household chosen at random and then choosing every other third household after the first. The urban sample was confined to Marsabit town and systematic random sampling was also used i.e., starting with a household picked at random and then choosing every other fifth household. The 21 institutions: schools (7), hospital (1), prison (1), hotels (10) and bakeries (2) which are known to procure their fuelwood supplies directly from Marsabit Forest were sampled. The sampling frame for the study is provided below (Table 3.1).
Table 3.1 The study sampling frame

<table>
<thead>
<tr>
<th>Sector</th>
<th>Institutions</th>
<th>Urban h/holds</th>
<th>Rural h/holds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population (N)</td>
<td>41</td>
<td>2538</td>
<td>1516</td>
</tr>
<tr>
<td>Sample population (n)</td>
<td>21</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>% of Total (N/n)</td>
<td>51.22%</td>
<td>4%</td>
<td>5.27%</td>
</tr>
</tbody>
</table>

3.3 Questionnaires design and data collection

At household level (rural and urban), the following data was collected: (1) data on household size and other socio-economic indicators (e.g. formal education, occupation, type of shelter), (2) data on quantitative (back-/lorryloads) and qualitative (wood species used), availability (gathering time) and cost of woodfuel, and (3) the type(s) of woodfuel cooking device used in the kitchen at the time of the study. At institution level, the focus was (2) and (3) above in addition to information relating to woodlot establishment. However, hotels and bakeries were not studied on the part relating to woodlot establishment. For (3) above, the researcher always sought permission from the respondent to actually see the type of cooking device used in the kitchen to ensure consistence in identification and classification of the various devices either as traditional or improved types.

The above kind of data were collected through the administration of questionnaires, where one set of questionnaire was administered to both rural and urban households (8.1) whereas the other set was administered to the institutions (8.2). Rural and urban households respondents were strictly women who are responsible for woodfuel gathering or buying as well as cooking chores. For institutions, the head and/or owner, after perusing the questionnaire, would advise on the appropriate person to respond. The use of structured questionnaires ensured uniformity and objectivity in the kind of data elicited from the different respondents.
Empirical field measurements

Various empirical field measurements were taken to validate and/or compliment the quantitative information obtained through the questionnaires. To determine the average weight in kilograms of fuelwood removed from Marsabit Forest, a sample of 103 backloads of fuelwood were randomly selected and weighed at 3 entrances to the forest for one week. A backload here means a stack of fuelwood carried by women on their backs. Further, 50 small bundles of fuelwood sold at the Marsabit market were randomly selected and weighed, where a small bundle of fuelwood refers to small pieces of fuelwood sold at the market for KSh10. Also, 30 tins (debes) of charcoal were randomly selected and weighed at different selling points within the market.

The empirical measurements facilitated objective quantification of fuelwood and/or charcoal from the amount of money spent, or the number of bundles or backloads or debes used by a household or a hotel or a bakery per day. On the other hand, the weight of fuelwood removed from the forest by schools, Marsabit Hospital, and Marsabit Prison was estimated on the basis of 1 tractorload = 5 tons and 1 lorryload = 7 tons as previously estimated by INTERAID(1995).

3.5 Methodological limitations

One major limitation was the variations in backload sizes or small bundles of fuelwood obtained at the market. This therefore necessitated taking empirical field measurements of fuelwood removed from the forest and that procured from the market with a view to levelling out these variations. On the other hand, some respondents were unwilling to answer certain questions put to them whereas others, particularly those who trade in fuelwood with or without the official permit from the Marsabit Forest Department, were suspicious about the exercise. Others doubted if such information would benefit them immediately or in future.

The above problems were, however, mitigated by explaining to the respondents the importance of the study and they were also assured that all the information provided would be treated confidentially. Language
A limitation was a limitation while working with rural households. However, this was reasonably overcome through the use of two knowledgeable research assistants from the study area who were drilled on the content and proper administration of the questionnaires by the researcher during the pilot survey.

3.6 Data analysis

Data analysis was divided into 2 sections. The first section used descriptive, the t-Test and graphical techniques for analysis and presentation, whereas the second section used linear regression analysis. The t-statistic and the corresponding degrees of freedom (d.f.) were determined as follows (Helsel and Hirsch, 1995).

\[ t = \frac{X - Y}{\sqrt{\frac{S_x^2}{m_1} + \frac{S_y^2}{m_2}}} \]  

Eq. 3.2

\[ d.f. = \frac{(S_x^2 / m_1 + S_y^2 / m_2)^2}{(S_x^2 / m_1)^2 + (S_y^2 / m_2)^2} \left( \frac{1}{m_1 - 1} + \frac{1}{m_2 - 1} \right) \]  

Eq. 3.3

In the second section, linear regression equations were developed in order to estimate the woodfuel demand as a function of several independent variables. The standard statistical package for social sciences (SPSS) and SLIDEWRITE PLUS(4.00) program were used to determine the regression equations and generate the corresponding plots respectively. The general model of the multiple linear regression equation fitted on the data set was of the following form (Chatterjee, et al, 1991):

\[ \gamma_i = \beta_0 + \beta_1 \chi_{i1} + \beta_2 \chi_{i2} + \cdots + \beta_p \chi_{ip} + \mu_i \]  

Eq. 3.4

For \( \beta_i \)'s = 0, where \( i = 2, \ldots, p \), the multiple regression equation 3.4 above becomes a simple linear regression model. It was assumed that for any set of fixed values of \( \chi_{1}, \chi_{2}, \ldots, \chi_{p} \) that fell within the range of
the data, the linear regression equation 3.4 provided an acceptable approximation of the true relationship between the $y$ and the $x$'s. In other words, $y$ was approximately a linear function of the $x$'s while $\mu$ measured the discrepancy in that approximation for the $i_{th}$ observation. On the other hand, the test of significance for the sample correlation coefficient ($r$) for the simple linear regression equations was determined according to Ott et al (1992).

\[ t_0 = r \frac{n-2}{\sqrt{1-r^2}} \quad \text{Eq. 3.5} \]

where d.f. = n - 2
4: RESULTS AND DISCUSSIONS

4.1 Woodfuel demand/supply dynamics by sector

4.1.1 Institutional sector

The estimated rates of woodfuel demand by the institutional sector are shown in Fig. 4.1 and Table 4.1. The charcoal wood equivalent was determined using a conversion factor of 1 kg of charcoal equals 10 kgs of wood, since the traditional kiln method used in charcoal production within the study area had a conversion efficiency of approximately 10% as reported by Darkoh (1991). Wood equivalent was therefore estimated as the summation of fuelwood and charcoal wood equivalent after the necessary conversion of the charcoal consumed into wood equivalent using 1 kg of charcoal equals 10 kgs of wood.

Table 4.1: Woodfuel demand by institutions

<table>
<thead>
<tr>
<th>Type</th>
<th>n</th>
<th>Fuelwood (tons/yr)</th>
<th>Charcoal (tons/yr)</th>
<th>Total wood eq. (tons/yr)</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools</td>
<td>7</td>
<td>238</td>
<td>--</td>
<td>238</td>
<td>13</td>
</tr>
<tr>
<td>Hospital</td>
<td>1</td>
<td>20</td>
<td>--</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Prison</td>
<td>1</td>
<td>60</td>
<td>--</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>Hotels</td>
<td>10</td>
<td>208</td>
<td>117</td>
<td>1378</td>
<td>72</td>
</tr>
<tr>
<td>Bakeries</td>
<td>2</td>
<td>42</td>
<td>18</td>
<td>218</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>568</td>
<td>135</td>
<td>1915</td>
<td>100</td>
</tr>
</tbody>
</table>

The 1378 tons/yr total wood equivalent demanded by the 10 hotels within the township accounted for 72% of the total wood consumption within this sector (Table 4.1; Fig. 4.1). The high demand of woodfuel by hotels was attributed to at least 3 factors. Hotels depended on both charcoal and fuelwood, and the prevalent practice of cooking on different types of open-fires unlike most schools, which had adopted the improved institutional stoves, which helped in fuelwood conservation.
Fig. 4.1: Woodfuel demand by institutions

- **Demand (tons/yr)**
  - 1400
  - 1200
  - 1000
  - 800
  - 600
  - 400
  - 200
  - 0

- **Type of institution**
  - Hotels
  - Schools
  - Bakeries
  - Prison
  - Hospital

- Colors:
  - Fuelwood
  - Charcoal
  - Total wood eq.
Also use of low efficient T.M.S. increased charcoal demand. In addition, hotels prepared their meals and had to keep them warm on continuous basis, hence their devices were invariably on during the entire operating periods. In contrast, households and schools in particular indicated that they operated on fairly fixed cooking schedules, hence woodfuel was not necessarily used up continuously.

### 4.1.2 Households sector

The per capita woodfuel demand rates in the households sector *vis-a-vis* the woodfuel cooking devices used was used to determine the total woodfuel demand by this sector as shown in Table 4.2 below.

In the urban households, the fuelwood demand by households using 3-S.F. was 3.4 tons/hh/yr and 80% of the households were using 3.S.F; hence this fuelwood demand became 6902 tons/yr. Fuelwood demand by households using M.S. was 2.7 tons/hh/yr and 20% of the households used M.S.; hence this fuelwood became 1372 tons/yr. Therefore, the total fuelwood demand by all the urban households amounted to approximately 8274 tons/yr. On the other hand, the charcoal demand by households using T.M.S. was 1 ton/hh/yr and 42% of households used T.M.S., hence this charcoal demand was 1066 tons/yr.

<table>
<thead>
<tr>
<th>Table 4.2: Per capita woodfuel demand in households sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuelwood (tons/yr)</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Sector</td>
</tr>
<tr>
<td>Urban hhs</td>
</tr>
<tr>
<td>Rural hhs</td>
</tr>
</tbody>
</table>

Key: 1 = traditional woodfuel cooking devices 2 = improved woodfuel cooking devices

The charcoal demand by the households using K.C.J.s was 0.9 tons/hh/yr and 58% of the households used K.C.J.s, hence this charcoal demand was 1325 tons/yr. Therefore the total charcoal demand by all the urban households was 2391 tons/yr. Hence, the total woodfuel demand by this sub-sector, expressed in wood equivalent terms, was approximately 32184 tons/yr as shown in Table 4.3 and Fig. 4.2 below.
In the rural households, the fuelwood demand by households using 3-S.F. was 7.5 tons/hh/yr and 95% of the households used 3-S.F., hence this fuelwood demand was 10800 tons/yr.

The fuelwood demand by households using M.S. was 6.3 tons/hh/yr, and 7% of the households used M.S., hence this fuelwood demand became 6686 tons/yr. Therefore, the total fuelwood demand by all the rural households was approximately 17486 tons/yr (Table 4.3; Fig. 4.2). On the other hand, charcoal demand by households using T.M.S. was 1 ton/hh/yr, and only 27% of the households used T.M.S., hence this charcoal demand was 409 ton/yr. The study did not identify any household using K.C.I. in the rural areas, hence the total woodfuel demand by this sub-sector, expressed in wood equivalent terms, was approximately 21576 tons/yr.

Table 4.3: Total woodfuel demand by sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Fuelwood (tons/yr)</th>
<th>Charcoal (tons/yr)</th>
<th>Total wood eq (tons/yr)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutions</td>
<td>568</td>
<td>135</td>
<td>1918</td>
<td>3</td>
</tr>
<tr>
<td>Urban hhs</td>
<td>8274</td>
<td>2391</td>
<td>32184</td>
<td>58</td>
</tr>
<tr>
<td>Rural hhs</td>
<td>17486</td>
<td>409</td>
<td>21576</td>
<td>39</td>
</tr>
<tr>
<td>Total</td>
<td>26328</td>
<td>2935</td>
<td>55678</td>
<td>100</td>
</tr>
</tbody>
</table>

The total woodfuel consumption expressed in wood equivalent terms by the 2 sectors studied was approximately 55678 tons/yr (Table 4.3). It is noted that the urban households' demand was the highest at 32184 tons/yr or 58% of the total wood equivalent demand (Table 4.3; Fig. 4.3). The high demand by urban households was due to their high dependence of charcoal. Every household in the urban sample was found to be using charcoal, whereas only 27% of the rural households were found to use the same. This was because of the fact that though all the charcoal was produced in the rural areas, most of it was transported to town for
Institutions | Urban h/holds | Rural h/holds
---|---|---
Fuelwood | 3% | 39%
Charcoal | 3% | 39%
Total wood eq. | 3% | 58%

Fig. 4.2: Total woodfuel demand by sector

Fig. 4.3: Distribution in woodfuel demand by sector
Furthermore, a considerable proportion (42%) of the urban households was found to be using the low efficiently T.M.S. In addition, given that charcoal was produced using the traditional earth kiln with a conversion efficiency of 10%, then every unit of charcoal consumed meant that 10 units of wood were needed for producing it.

4.3 Comparative analysis of woodfuel demand between sectors

The t-Test was used to test whether or not the difference in mean per capita wood equivalent demand between sectors was statistically significant. The t-Test formulae (Eq. 3.2 and Eq. 3.3) were applied and the results are shown in Table 4.4 below. The null hypothesis (Ho) tested was: there was no significant difference in the mean per capita wood equivalent demand between the sectors.

<table>
<thead>
<tr>
<th>sector</th>
<th>Demand¹ (kg/yr)</th>
<th>t-value</th>
<th>Critical value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban hhs</td>
<td>1791</td>
<td>8.86</td>
<td>3.373*</td>
<td>0.001</td>
</tr>
<tr>
<td>Rural hhs</td>
<td>2320</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban hhs</td>
<td>1791</td>
<td>28.82</td>
<td>3.965*</td>
<td>0.001</td>
</tr>
<tr>
<td>Institutions</td>
<td>791</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural hhs</td>
<td>2320</td>
<td>25.59</td>
<td>3.922*</td>
<td>0.001</td>
</tr>
<tr>
<td>Institutions</td>
<td>791</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: ¹ = mean per capita wood equivalent demand by sector
* = significant at p = 0.001, hence (Ho) rejected

With the t-Test, the null hypothesis was rejected at 0.1% or p = 0.001, indicating that the mean per capita wood equivalent demand differed significantly between the sectors. That was an indication of the diversity between the respondent sectors, which was accounted for by 2 factors. The mean per capita demand within the institutions was the lowest because a large population was catered for at the same time; hence less
wood per capita was required than at the households sector. Also, the significant difference between the per capita woodfuel demand in urban and rural households was attributed to the degree of availability and affordability of wood as dictated by the distance of each sector from Marsabit Forest.

4.1.4 Factors influencing woodfuel demand by sector

Simple and multiple linear regression equations were developed to estimate fuelwood and charcoal demands by the institutions and households sectors under study. Fuelwood demand (FWD) and charcoal demand (CCD), which were the dependent variables, were regressed against independent variables which were household size (HH), population size (POPS) catered for at institutions, cost of fuelwood/charcoal (COST), the type of cooking device (ICD) used, and spouse employment (SEM). The last 2 independent variables were entered as dummy or dichotomous variables (Chatterjee, et al., 1991; Hamilton, 1992). The regression equations presented below were used to determine how different factors influenced woodfuel demand by sector. They were also used to determine baseline estimates for the expected rate of increase in woodfuel demand by sector.
Table 4.5: Urban households linear regression equations

<table>
<thead>
<tr>
<th>Eq No.</th>
<th>Regression Equation</th>
<th>Estimated Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>FWD = 1893.31 + 175.75 HH</td>
<td>$r^2 = 0.2796$, $F = 2.884$, $\text{Sig.F} = 0.0986$, $S = 1601.17$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 782.8$, $\text{S.E(}$β_1$) = 103.5$, $T(β_0) = 2.418$, $T(β_1) = 1.698$</td>
</tr>
<tr>
<td>4.2</td>
<td>FWD = 5187.27 - 0.57 COST</td>
<td>$r^2 = 0.2471$, $F = 2.211$, $\text{Sig.F} = 0.1462$, $S = 161.57$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 1400.0$, $\text{S.E(}$β_1$) = 0.3823$, $T(β_0) = 3.703$, $T(β_1) = -1.487$</td>
</tr>
<tr>
<td>4.3</td>
<td>FWD = 4023.67 - 1321.0SEM</td>
<td>$r^2 = 0.3841$, $F = 5.884$, $\text{Sig.F} = 0.021$, $S = 1540.34$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 444.66$, $\text{S.E(}$β_1$) = 544.59$, $T(β_0) = 9.049$, $T(β_1) = -2.426$</td>
</tr>
<tr>
<td>4.4</td>
<td>FWD = 3415.32 - 891.23 ICD</td>
<td>$r^2 = 0.2532$, $F = 2.329$, $\text{Sig.F} = 0.1362$, $S = 1613.94$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{E(}$β_0$) = 322.788$, $\text{S.E(}$β_1$) = 583.95$, $T(β_0) = 9.049$, $T(β_1) = -1.526$</td>
</tr>
<tr>
<td>4.5</td>
<td>CCD = 646.97 + 28.62</td>
<td>$r^2 = 0.2524$, $F = 3.267$, $\text{Sig.F} = 0.0770$, $S = 320.82$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 112.191$, $\text{S.E(}$β_1$) = 15.83$, $T(β_0) = 5.767$, $T(β_1) = 1.808$</td>
</tr>
<tr>
<td>4.6</td>
<td>CCD = 2771.16 - 0.52 COST</td>
<td>$r^2 = 0.9058$, $F = 219.227$, $\text{Sig.F} = 0.000$, $S = 140.518$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 132.43$, $\text{S.E(}$β_1$) = 0.035$, $T(β_0) = 20.924$, $T(β_1) = -14.806$</td>
</tr>
<tr>
<td>4.7</td>
<td>CCD = 988.68 - 252.01 ICD</td>
<td>$r^2 = 0.3765$, $F = 7.9298$, $\text{Sig.F} = 0.007$, $S = 307.152$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 70.46$, $\text{S.E(}$β_1$) = 89.49$, $T(β_0) = 14.031$, $T(β_1) = -2.816$</td>
</tr>
<tr>
<td>4.8</td>
<td>CCD = 805.44 - 397.10 SEM</td>
<td>$r^2 = 0.570$, $F = 15.653$, $\text{Sig.F} = 0.6941$, $S = 331.01$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{S.E(}$β_0$) = 82.75$, $\text{S.E(}$β_1$) = 100.35$, $T(β_0) = 9.733$, $T(β_1) = 3.96$</td>
</tr>
</tbody>
</table>
### Table 4.6: Urban households multiple linear regression (fuelwood)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>T</th>
<th>Sig.T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6323.87</td>
<td>3385.15</td>
<td>1.868</td>
<td>0.0745</td>
</tr>
<tr>
<td>SEM</td>
<td>-1392.65</td>
<td>671.64</td>
<td>-2.073</td>
<td>0.0495</td>
</tr>
<tr>
<td>HH</td>
<td>200.90</td>
<td>112.88</td>
<td>1.780</td>
<td>0.0883</td>
</tr>
<tr>
<td>COST</td>
<td>-0.902</td>
<td>0.482</td>
<td>-1.868</td>
<td>0.0745</td>
</tr>
<tr>
<td>ICD</td>
<td>-749.88</td>
<td>644.65</td>
<td>-1.163</td>
<td>0.2567</td>
</tr>
</tbody>
</table>

\[ r^2 = 0.6234 \quad S = 1517.59 \quad F = 2.088 \quad \text{Sig.}F = 0.0865 \]

Eq. 4.9: \( \text{FWD} = 6324 - 1393 \text{SEM} + 201 \text{HH} - 0.9 \text{COST} - 750 \text{ICD} \)

### Table 4.7: Urban households multiple linear regression (charcoal)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S. E.</th>
<th>T</th>
<th>Sig.T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2729.55</td>
<td>188.42</td>
<td>14.486</td>
<td>0.000</td>
</tr>
<tr>
<td>SEM</td>
<td>397.62</td>
<td>56.81</td>
<td>6.999</td>
<td>0.337</td>
</tr>
<tr>
<td>HH</td>
<td>4.828</td>
<td>8.763</td>
<td>0.551</td>
<td>0.508</td>
</tr>
<tr>
<td>ICD</td>
<td>-75.573</td>
<td>48.371</td>
<td>-1.562</td>
<td>0.127</td>
</tr>
<tr>
<td>COST</td>
<td>-0.503</td>
<td>0.042</td>
<td>-11.769</td>
<td>0.000</td>
</tr>
</tbody>
</table>

\[ r^2 = 0.9124 \quad S = 146.52 \quad F = 31.4589 \quad \text{Sig.}F = 0.000 \]

Eq. 4.10: \( \text{CCD} = 2730 + 400 \text{SEM} + 5 \text{HH} - 76 \text{ICD} - 0.5 \text{COST} \)
Table 4.8: Rural households linear regression equations

<table>
<thead>
<tr>
<th>Regression Equation</th>
<th>Estimate Parameters</th>
</tr>
</thead>
</table>
| 4.11 FWD = 7536.84 + 66.52 HH | $R^2 = 0.641$, $F = 13.380$, $\text{Sig.}_F = 0.7155$, $S = 3439.375$  
$\text{S.E}(\beta_0) = 1253.85$, $\text{S.E}(\beta_1) = 18.87$, $T(\beta_0) = 6.011$, $T(\beta_1) = 3.66$ |
| 4.12 FWD = 7736.82 - 3394.75 ICD | $R^2 = 0.3898$, $F = 13.977$, $\text{Sig.}_F = 0.000$, $S = 3170.00$  
$\text{S.E}(\beta_0) = 393.19$, $\text{S.E}(\beta_1) = 908.0$, $T(\beta_0) = 19.677$, $T(\beta_1) = -3.739$ |
| 4.13 FWD = 12627.28 - 111.32 TIME | $R^2 = 0.8275$, $F = 169.520$, $\text{Sig.}_F = 0.000$, $S = 1932.384$  
$\text{S.E}(\beta_0) = 476.31$, $\text{S.E}(\beta_1) = 0.869$, $T(\beta_0) = 26.51$, $T(\beta_1) = -13.020$ |

Table 4.9: Rural households multiple linear regression equation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>T</th>
<th>Sig.T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>12195.783</td>
<td>769.826</td>
<td>15.842</td>
<td>0.000</td>
</tr>
<tr>
<td>HH</td>
<td>64.678</td>
<td>9.911</td>
<td>6.5258</td>
<td>0.000</td>
</tr>
<tr>
<td>ICD</td>
<td>-1280.154</td>
<td>530.191</td>
<td>-2.415</td>
<td>0.4358</td>
</tr>
<tr>
<td>TIME</td>
<td>-111.460</td>
<td>94.594</td>
<td>-1.178</td>
<td>0.9257</td>
</tr>
</tbody>
</table>

$r^2 = 0.86608$, $S = 1623.404$, $F = 40.2189$, $\text{Sig.}_F = 0.000$

Eq. 4.14: FWD = 12196 + 65 HH - 1280 ICD - 111 TIME
### Table 4.10: Institutions linear regression equations

<table>
<thead>
<tr>
<th>Eq. No.</th>
<th>Regression Equation</th>
<th>Estimated Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.15</td>
<td>( FWD = 45819 + 1.00 POPS )</td>
<td>( r^2 = 0.501, F = 2.024, \text{Sig.F} = 0.9616, S = 19631.243 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{S.E(} \beta_0) = 6688.79, \text{S.E(} \beta_1) = 0.241, \text{T}(\beta_0) = 6.850, \text{T}(\beta_1) = 4.149 )</td>
</tr>
<tr>
<td>4.16</td>
<td>( FWD = 51456.32 - 2286.69 \text{ COST} )</td>
<td>( r^2 = 0.1458, F = 0.3040, \text{Sig.F} = 0.5900, S = 19423.138 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{S.E(} \beta_0) = 11683.35, \text{S.E(} \beta_1) = 4146.92, \text{T}(\beta_0) = 4.404, \text{T}(\beta_1) = -0.551 )</td>
</tr>
<tr>
<td>4.17</td>
<td>( FWD = 38142.50 - 11926.70 \text{ ICD} )</td>
<td>( r^2 = 0.3144, F = 1.5356, \text{Sig.F} = 0.235, S = 18637.33 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{S.E(} \beta_0) = 7608.659, \text{S.E(} \beta_1) = 9624.277, \text{T}(\beta_0) = 5.013, \text{T}(\beta_1) = .239 )</td>
</tr>
<tr>
<td>4.18</td>
<td>( CCD = 3576.25 + 67.28 POPS )</td>
<td>( r^2 = 0.9530, F = 69.30, \text{Sig.F} = 0.000, S = 1599.307 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{S.E(} \beta_0) = 790.524 \text{S.E(} \beta_1) = 8.082, (\beta_0) = 4.524, \text{T}(\beta_1) = 8.325 )</td>
</tr>
<tr>
<td>4.19</td>
<td>( CCD = 12653.33 - 4866.67 \text{ COST} )</td>
<td>( r^2 = 0.4926, F = 2.2436, \text{Sig.F} = 0.1778, S = 4594.887 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{S.E(} \beta_0) = 1416.39, \text{S.E(} \beta_1) = 324.90, \text{T}(\beta_0) = 8.93, \text{T}(\beta_1) = 14.98 )</td>
</tr>
</tbody>
</table>

Key: * = not significant (F < Sig.F)

### Table 4.11: Institutions multiple regression equation (fuelwood)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S.E</th>
<th>T</th>
<th>Sig.T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>45418.50</td>
<td>1594.34</td>
<td>28.49</td>
<td>0.0147</td>
</tr>
<tr>
<td>POPS</td>
<td>1.000</td>
<td>0.251</td>
<td>3.984</td>
<td>0.3691</td>
</tr>
<tr>
<td>ICD</td>
<td>-11834.57</td>
<td>1208.28</td>
<td>-1.399</td>
<td>0.1872</td>
</tr>
</tbody>
</table>

\( r^2 = 0.531 \) \( S = 1940.28 \) \( F = 7.7782 \) \( \text{Sig.F} = 0.5284 \)

Eq. 4.20: \( FWD = 45419 + 1 \text{POPS} - 11835 \text{ ICD} \)
Table 4.12: Institutions multiple regression equation (charcoal)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>T</th>
<th>Sig.T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3575.83</td>
<td>555.46</td>
<td>6.900</td>
<td>0.947</td>
</tr>
<tr>
<td>POPS</td>
<td>65.60</td>
<td>9.26</td>
<td>7.083</td>
<td>0.000</td>
</tr>
<tr>
<td>COST</td>
<td>-4864.27</td>
<td>1328.87</td>
<td>-3.660</td>
<td>0.536</td>
</tr>
</tbody>
</table>

\[ r^2 = 0.96617 \quad S = 161.28 \quad F = 23.390 \quad \text{Sig.}F = 0.0023 \]

\[ \text{Eq. 4.21: } \text{CCD} = 3576 + 66 \text{ POPS} - 4864 \text{ COST} \]

4.1.4.1 Statistical significance of r

Since the study data represented a random sample from a larger body of data (the population), the sample correlation coefficient \( r \) was determined according to Eq. 3.5 and the results are shown in Table 4.13 below. The null hypothesis \( H_0 \) tested was: there was no linear correlation between the independent variable \( x \) and dependent variable \( y \) for the simple linear regression equations cited in Tables 4.5, 4.8, and 4.10, or \( H_0: r = 0 \).

4.1.5 Analysis of urban households woodfuel demand

Other factors equal, a larger household would be expected to consume a greater amount of fuelwood than a smaller one since more work, in energy terms, must be performed in cooking food for a larger household. From Eq. 4.1 and Fig. 4.4, household size \( (HH) \) accounted for only about 28% \( (r^2 = 0.2796) \) of the variation in fuelwood demand and each additional household member increased the marginal demand by
nearly 200 kg/hh/year (Table 4.5).

**Table 4.13: Statistical significance for r**

<table>
<thead>
<tr>
<th>Eq No.</th>
<th>n</th>
<th>( r^2 )</th>
<th>( r )</th>
<th>( t_o )</th>
<th>( t_{cv} ) (( \alpha=0.05 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>100</td>
<td>0.2796</td>
<td>0.5287</td>
<td>6.166</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.2</td>
<td>100</td>
<td>0.2471</td>
<td>0.4971</td>
<td>5.67</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.3</td>
<td>100</td>
<td>0.3841</td>
<td>0.6196</td>
<td>7.8169</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.4</td>
<td>100</td>
<td>0.2532</td>
<td>0.5032</td>
<td>5.76</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.5</td>
<td>100</td>
<td>0.2524</td>
<td>0.502</td>
<td>5.747</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.6</td>
<td>100</td>
<td>0.9058</td>
<td>0.9517</td>
<td>30.696</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.7</td>
<td>100</td>
<td>0.3765</td>
<td>0.6135</td>
<td>7.69</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.8</td>
<td>100</td>
<td>0.570</td>
<td>0.7549</td>
<td>11.96</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.11</td>
<td>80</td>
<td>0.641</td>
<td>0.80</td>
<td>11.792</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.12</td>
<td>80</td>
<td>0.3898</td>
<td>0.624</td>
<td>7.055</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.13</td>
<td>80</td>
<td>0.8275</td>
<td>0.8275</td>
<td>19.342</td>
<td>1.645*</td>
</tr>
<tr>
<td>4.15</td>
<td>9</td>
<td>0.501</td>
<td>0.7078</td>
<td>2.651</td>
<td>1.895*</td>
</tr>
<tr>
<td>4.16</td>
<td>9</td>
<td>0.1458</td>
<td>0.3818</td>
<td>1.092</td>
<td>1.895+</td>
</tr>
<tr>
<td>4.17</td>
<td>9</td>
<td>0.3144</td>
<td>0.5607</td>
<td>2.01</td>
<td>1.895*</td>
</tr>
<tr>
<td>4.18</td>
<td>12</td>
<td>0.953</td>
<td>0.9762</td>
<td>14.239</td>
<td>1.812*</td>
</tr>
<tr>
<td>4.19</td>
<td>12</td>
<td>0.4926</td>
<td>0.7019</td>
<td>3.116</td>
<td>1.812*</td>
</tr>
</tbody>
</table>

**Key:** * = significant at \( \alpha=0.05 \), hence \( H_0 \) rejected \( \Rightarrow r>0 \)

+ = not significant at \( \alpha=0.05 \), hence \( H_0 \) not rejected \( \Rightarrow r=0 \)
Fig. 4.4 Urban fuelwood demand versus household size

\[ Y = 1890 + 175X \quad (r^2 = 0.279) \]
In this particular case, the results of simple linear regression suggest a rather weak relationship between fuelwood demand and household size, suggesting that other factors, besides household size, influenced woodfuel demand, and even more significantly.

The cost of fuelwood (COST) accounted for about 25% ($r^2 = 0.2471$) of the variation in consumption, and a unit increase in the cost led to a small reduction in demand of approximately 1kg/hh/year (Eq. 4.2). Other factors equal, the prohibitive cost of alternative fuels like kerosene, LPG and electricity in the study area as reported by Darkoh (1991) was thought responsible for such an occurrence. The author indicated that the effective prices of alternative fuels were too high to offer any meaningful competition for fuelwood, hence the continued dependence on fuelwood.

Equation 4.3 indicates that spouse employment (SEM), for either the husband or wife or both, accounted for 38% ($r^2 = 0.3841$) variation in fuelwood consumption. A typical household, where at least either spouse was employed, consumed about 1321 kg less fuelwood per year than where neither spouse was employed, irrespective of the status of that employment (Table 4.5). In other words, a rise in income on account of spouse employment, implied that households used less fuelwood as they moved "up" the energy "ladder" from fuelwood to charcoal to conventional fuels as observed by Wood (1979) and Hosier (1984). The use of an improved cooking device (ICD), in this case *Maendeleo* stove, resulted in fuelwood consumption decrease of nearly 900 kg/hh/year (Eq. 4.4). This decrease was equivalent to approximately 130 kg per capita fuelwood conservation per annum within the urban households.

Equation 4.5 and Fig. 4.5 indicate that household size (HH) determined 25% ($r^2 = 0.2524$) of variation in charcoal demand. Equation 4.6 and Fig. 4.6 indicate that the cost of charcoal (COST) determined 91% ($r^2 = 0.9058$) of demand and a unit increase in the cost of charcoal led to a small reduction of about 1 kg in charcoal demand/hh/year. Other factors constant, the prohibitive costs of alternative conventional fuels in the ASAL regions of Kenya as reported by Darkoh (1991) put such fuels out of reach for the majority resource-poor urban population.
Fig. 4.5 Urban charcoal demand versus household size

\[ Y = 650 + 28X \quad (r^2 = 0.252) \]
Fig. 4.6 Urban charcoal demand versus cost

Charcoal demand (household (Kg/year)) $10^9$

Unit cost (KShs.)

\[ Y = 2771 - 0.5X \quad (r^2 = 0.906) \]
In other words, even in the event of a rise in the cost of charcoal, the urban households had to continue using the same due to lack of other more affordable alternatives.

From Eq. 4.7 the use of improved cooking devices (ICD), in this case K.C.J., accounted for 252 kg marginal decrease in charcoal consumption/hh/year. This decrease in charcoal consumption was equivalent to 40 kg per capita conservation/year. Equation 5.8 indicates that spouse employment (SEM) accounted for 57% \( (r^2 = 0.570) \) of demand variation and consumption increased by about 400 kg/hh/year if, at least, one spouse got employed, regardless of the status of that employment(Table 4.5). Unlike with fuelwood consumption Eq.4.3), Charcoal consumption (CCD) went up by about 400 kg/yr on account of spouse employment(SEM). Other factors constant, this indicated substitution from fuelwood to charcoal on account of a rise in income since charcoal consumption is typically more in higher income groups than lower ones as observed by Hosier(1984) and Darkoh(1991).

Equation 4.9 indicates that the 4 variables(SEM, HH, COST,ICD) together accounted for about 62% \( (r^2 = 0.6234) \) of the variation in fuelwood demand(Table 4.6). This equation was interpreted to mean that the fact that at least, one spouse was employed (SEM), a unit increase in cost of fuelwood (COST), and use of an improved cooking device (ICD), contributed to 1400 kg, 1 kg, and 750 kg reduction in fuelwood demand/hh/year respectively. In contrast, an additional member in the household (HH) increased demand by 201 kg/hh/year. The population and fuelwood cost in Marsabit township increased by 2.67%(MPND,1994), and KSh 10 per backload of 60 kg per year respectively. Hence, other factors constant, the combined effect of an increase in population and cost of fuelwood would lead to an increase in fuelwood consumption by approximately 1%/yr(Eq.4.9). Equation 4.10 indicates that the multiple effect of the 4 variables (SEM, HH, ICD, COST) accounted for 91% \( (r^2 = 0.9124) \) of the variation in charcoal consumption(Table 4.7). The population and cost of charcoal in Marsabit township increased by 2.67% and KSh 5 per tin\( (debe) \) of 8 kg per year respectively. Hence, other factors constant, the combined effect of an increase in population and cost of
charcoal would lead to a decrease in charcoal consumption by approximately 0.1%/yr (Eq.4.10).

It is observed that the projected 1% annual increase in fuelwood consumption is low. This is because the projection is based on only 2 variables namely, the rates of increase of both population and cost of fuelwood at the time of the study. The data relating to other variables in the study area such as rates of employment and adoption of improved cooking devices were not available at the time of the study. Furthermore, although charcoal demand is projected to decrease by 0.1%/year, in reality it might increase for 2 reasons. The rapid expansion of Marsabit town, which was upgraded to a municipality in 1997. Moreover, the increase in the number of employees, both in the various Government departments and NGOs who were found to consume more charcoal than fuelwood. The noted reduction in fuelwood and charcoal consumption on account of using improved cooking devices justified their wider adoption as an effective remedial intervention in the study area (Eq. 4.9; Eq. 4.10).

4.1.6 Analysis of rural households woodfuel demand

Unlike in the urban sector where the market price of fuelwood and charcoal was treated as an independent cost variable, the time (TIME) expended gathering fuelwood was considered as the opportunity cost incurred during that exercise as indicated by Hosier (1984). This was necessary because the study did not establish any incidence of fuelwood selling in this sub-sector.

Equation 4.11 and Fig. 4.7 indicate that household size (HH) accounted for 64% ($r^2 = 0.641$) of the variation in fuelwood demand (FWD), suggesting a much stronger correlation between fuelwood demand (FWD) and household size (HH) in the rural households than in the urban households (Table 4.8). Equation 4.12 indicates that use of improved cooking device (ICD) reduced demand considerably by 3.4 tons. The 3.4 tons/hh/yr reduction in fuelwood demand in rural households was about 5 times more than that realized by urban households on account of using improved M.S. as shown by Eq. 4.4 (Table 4.5). Other factors constant,
this observation suggests *Maendeleo* stoves were more effectively used in the rural than in urban areas. Rural women indicated that the high opportunity cost incurred while gathering fuelwood compelled those who had adopted *Maendeleo* stoves to use them more effectively with a view to reducing fuelwood consumption. Equation 4.13 and Fig. 4.8 indicate that time (TIME) expended on gathering fuelwood accounted for 83% ($r^2 = 0.8275$) of the variation in demand and every extra hour required to gather fuelwood reduced demand by 111 kg/household/year.

Equation 4.14 indicates that the multiple effect of the 3 variables (HH, ICD, Time) accounted for over 87% ($r^2 = 0.866$) of the variation in fuelwood demand (FWD). Given a population growth rate of 2.67%/yr, and an additional household member increased fuelwood demand by 65 kg/hh/yr, then, other factors constant and using Eq. 4.14, the rural fuelwood demand is projected to increase at 0.1%/yr. This growth rate is quite low since only population variable is considered whereas other variables such as the rate of adoption of *Maendeleo* stoves and rate of increase in time expended on gathering fuelwood should have been accounted for. However this information was not available at the time of the study.

Hosier (1984) working in other rural settings in Kenya reported a correlation of $r^2 = 0.80$ between household size and fuelwood demand whereas the correlation for the same in the rural areas for this study was $r^2 = 0.64$ (Eq. 4.11). Then each extra member in the rural households increased demand by nearly 70 kg/hh/year which was about 2.5 times less than the amount demanded by an additional member (175 kg) in the urban household as shown in Eq. 4.1. This wide differential in the predicted marginal fuelwood demand increase between an additional member in the urban and rural households was attributed to the difference in lifestyles between the two sub-sectors. In other words, the relatively higher income in the urban areas increased the consumption of many goods including energy in form of both fuelwood and charcoal. In contrast, energy use by the rural people, particularly in the ASAL regions, was at the most basic level and predominantly in form of fuelwood. Hence, the noted difference in the predicted per capita fuelwood demand between the urban and
Fig. 4.7 Rural fuelwood demand versus household size

\[ Y = 7540 + 66.7X \ (r^2 = 0.641) \]
Fig. 4.8 Rural fuelwood demand versus gathering time

\[ Y = 12620 - 110X \quad (r^2 = 0.827) \]
rural areas in the study area. This observation agrees with similar findings reported by Openshow (1978) and Hosier (1984).

The survey did not elicit sufficient data on charcoal consumption in the rural areas to run regression tests. This can be attributed to the limited use of the same in these areas since most of the charcoal produced in the rural areas was transported to the urban areas for sale.

4.1.7 Analysis of institutions woodfuel demand

It is noted that all the non-commercial institutions such as schools, Marsabit Hospital, Marsabit Prison depended exclusively on fuelwood, whereas commercial ones such as hotels and bakeries depended essentially on charcoal and a minimum input of fuelwood. Hence, fuelwood prediction focused on the former and charcoal prediction on the latter. Equation 4.15 indicates that population size (POPS) accounted for about 50% ($r^2 = 0.501$) of the variation in fuelwood demand (FWD) while an additional member to that population increased demand by only 1 kg/year (Table 4.10).

Equation 4.16 indicated that the cost of fuelwood (COST) was not significant in determining fuelwood demand (Table 4.10). This can be explained by the fact that all the non-commercial institutions, through concessionary arrangements with Marsabit Forest Department, obtained their fuelwood supplies exclusively from the forest and paid a token levy of KSh 1000 per truck-load. The cost of fuelwood to institutions was therefore inconsequential in determining demand as noted by the Mburu (1997) and the administrative heads of the respective institutions at the time of the study. Hence, as long as such concessionary arrangements continue, cost of fuelwood will not influence its demand by the institutions in question.

Equation 4.17 indicates that use of improved cooking devices (ICD), namely improved institutional stoves, accounted for 31% ($r^2 = 0.3144$) of fuelwood demand (FWD) variation and decreased demand by 12
tons/year (Table 4.10). A typical institution would therefore conserve over 2 five-ton trucks per annum through the use of an improved institutional stove. Equation 4.18 indicated that population size (POPS) accounted for 93% \((r^2 = 0.9530)\) of the total variation in charcoal demand (CCD) and each additional member to the population increased demand by about 67 kg/year (Table 4.10). On the other hand, Eq. 4.19 indicates that the cost of charcoal (COST) accounted for 49% \((r^2 = 0.4926)\) of the variation in demand and a unit increase in cost reduced demand by nearly 5 tons/year (Table 4.10).

Equation 4.20 indicates that for every additional member to the population size (POPS), for instance a school, the fuelwood demand (FWD) went up by a small amount of approximately 1 kg/year. Hence, if all the 7 schools involved in this study admitted a 100 students each, the total marginal fuelwood demand (FWD) increase attributable to such an in enrolment would be no more than 700 kg/yr. In contrast, if there occurred an increase of at least 1 household member (HH) in at least 700 households within the urban area, the corresponding marginal fuelwood demand (FWD) increase would be approximately 141 tons/year (Eq. 4.9). Hence, the population size of a particular consumption unit had an important bearing on the efficiency in fuelwood utilization.

Obviously large consumption units such as schools, used much more total fuelwood than the smaller household units per annum. In per capita terms, however, the former consumed much less than the latter. By extension, therefore, the relatively larger households also contributed to an improvement in the efficiency of fuelwood utilization on account of reduced per capita demand as reported by Arnold (1980). This observation indicated that the larger the population size catered for within a particular woodfuel consumption unit, the better the economies of scale with respect to woodfuel utilization expressed in per capita terms. This situation was due to the size of pots used, and the quantity of food prepared for a large population at the same time.

The regression constant terms \((\beta_0)\) in the foregoing equations represent the extraneous variables not included in the analysis. For example, the types of food prepared, space heating, and perhaps the energy
demand differential between children and adults within the households. They also indicate the error terms involved in the analysis as cited in the general regression model in Eq. 3.4. The foregoing regression equations have provided useful baseline estimates and predictions necessary to continually evaluate and monitor woodfuel demand in the study area. However, their prediction power could be enhanced in 2 ways. Accounting for the extraneous factors that were left out in this study. Also, accounting for important variables whose information was not available at the time of the study, such as the rates in employment and adoption of improved cooking devices, in projecting the growth rate in woodfuel demand.

It was not possible to determine the present and future woodfuel demand/supply balance with respect to Marsabit Forest. The demand was determined (Table 4.3), whereas Marsabit Forest Department was expected to provide data on the specific yield/growth rates for the forest from which the supply estimates could have been derived. The Department, however, explained that the yield rates for the forest had not yet been determined.

4.2: Woodfuel conservation estimates by sector

4.2.1 Institutional sector

Table 4.14 below shows the estimated fuelwood conservation rates by the different institutions through the use of improved institutional stoves. The institutions studied had one common type of improved institutional stove (Fig.2.4) which was made possible through a donor aided project between 1990-93. Therefore, it was easier to obtain data on the rate of fuelwood consumption at the time of the study from all the institutions. However, it was difficult to obtain data regarding the previous rate of fuelwood consumption prior to the installation of improved institutional stoves. This was because the institution head and/or the person(s) responsible for fuelwood procurement, prior to the installation of new devices, were no longer working there at the time of the study.
Table 4.14: Fuelwood conservation by institutions

<table>
<thead>
<tr>
<th>Name</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsabit Boys</td>
<td>480</td>
<td>B</td>
<td>I.I.S.</td>
<td>60</td>
<td>90</td>
<td>33.3</td>
</tr>
<tr>
<td>Moi Girls</td>
<td>160</td>
<td>B</td>
<td>I.I.S.</td>
<td>45</td>
<td>60</td>
<td>25.0</td>
</tr>
<tr>
<td>St.Paul's</td>
<td>200</td>
<td>B</td>
<td>I.I.S.</td>
<td>30</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>S.K.M. Primary</td>
<td>640</td>
<td>B/D</td>
<td>I.I.S./O.F.</td>
<td>52.5</td>
<td>67.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Hospital</td>
<td>70</td>
<td>B</td>
<td>I.I.S.</td>
<td>20</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Prison</td>
<td>100</td>
<td>B</td>
<td>I.I.S./O.F.</td>
<td>60</td>
<td>90</td>
<td>33.3</td>
</tr>
<tr>
<td>Full primary</td>
<td>817</td>
<td>D</td>
<td>I.I.S./O.F.</td>
<td>15</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>St. John primary</td>
<td>497</td>
<td>D</td>
<td>I.I.S.</td>
<td>5.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Catholic</td>
<td>70</td>
<td>B</td>
<td>I.I.S.</td>
<td>30</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Technical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3009</td>
<td></td>
<td></td>
<td>318.1</td>
<td>403.0</td>
<td>26.7**</td>
</tr>
</tbody>
</table>

Key:

1= Present population size  
2= Type of institution: boarding(B) or day(D)  
3= Present cooking device in use: I.I.S. or O.F.(open-fire)  
4= Present rate of fuelwood demand(tons/year)  
5= Fuelwood demand prior to installation of I.I.S.(tons/year)  
6= Conservation efficiency estimate (%)  
*-- no data available  ** mean conservation efficiency

Moreover, proper records of fuelwood procurement were not kept. Thus to estimate the total fuelwood conservation, the percentage mean of 4 institutions where complete data was available was used. The complete data set from the 4 institutions was considered representative enough to permit such extrapolation (Table 4.14). The rate of conservation was estimated as the difference between the rate of fuelwood consumption at the time of the study(present) and rate of consumption prior to installation of I.I.S. expressed as a percentage. The mean conservation efficiency of about 27% was equivalent to 85 tons/yr of fuelwood conservation by the institutions using improved institutional stoves. The estimated fuelwood conservation being realized by each individual institution was such that despite all the institutions using a common design of
improved institutional stove with similar conservation efficiency of 30 - 50% (UNEP, 1989), the magnitude of individual conservation was far from uniform. The highest and least were 33.3% and 15% respectively. This observation indicated that, besides the expected conservation efficiency from the improved institutional stove, the actual magnitude of conservation realized was also influenced by the so-called "end-user behaviour" as reported by UNEP (1989). In other words, how the end-user operated, maintained, and generally handled the device.

Several constraints which were perceived to characterize such "end-user behaviour" within the study area and which, in turn, limited fuelwood conservation in this sector were identified and are shown in Table 4.15 below. Clogging of chimneys was one of the major constraint facing majority of improved institutional stove users. A clogged chimney limited the heat transfer efficiency of the stove by blocking the otherwise free flow of air through the fire-box which was also meant to channel all the smoke outside the kitchen, hence enhance the lighting ability of the stove (Hankins, 1987). This resulted in incomplete combustion leading to release of carbon monoxide and some hydrocarbons, which should otherwise burn to release more heat energy. Furthermore, carbon monoxide and hydrocarbons emitted were serious causes of indoor air pollution (Hankins, 1987). Therefore, a clogged chimney was observed to manifest itself through an increasingly smoky kitchen and difficulties in lighting the stove.

Use of open-fire for preparing "soft foods" such as ugali and rice was another serious constraint. The cooks reported that the improved institutional stoves had the advantage of picking up, and retaining heat for longer periods because of their in-built ceramic insulation. However, the desired quick and convenient regulation of that heat while cooking was very limited with respect to this stove. Consequently, soft foods requiring controlled pot temperatures got burnt and deteriorated in flavor and taste. Alternatively, therefore, they preferred using open-fire for such meals, which in turn eroded the levels of fuelwood conservation considerably.
Table 4.15: Constraints limiting conservation by I.I.S.

<table>
<thead>
<tr>
<th>Constraints</th>
<th>n%*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Clogged chimneys</td>
<td>57</td>
</tr>
<tr>
<td>2. Worn-out fire grating</td>
<td>33</td>
</tr>
<tr>
<td>3. Use of open-fire for &quot;soft foods&quot; (e.g. ugali and rice)</td>
<td>33</td>
</tr>
<tr>
<td>4. Use of wet wood</td>
<td>22</td>
</tr>
<tr>
<td>5. Use of unsplit logs of wood</td>
<td>11</td>
</tr>
</tbody>
</table>

Key: * Proportion of users experiencing the constraint, and does not add up to 100% since a user can be experiencing more than one constraint at the same time.

Worn-out fire grating interfered with the correct positioning or charging of fuelwood pieces inside the small fire-box of the stove, hence limiting the combustion process. That was exacerbated by use of unsplit logs of wood which were difficult to properly charge into the fire-box, hence necessitating keeping the door open while cooking. In the process plenty of heat which should otherwise have gone towards cooking was lost particularly through convection, by virtue of keeping the door open while cooking. Use of wet wood meant that a significant amount of heat energy, which should otherwise have gone towards cooking the food in the pot, was expended in drying up the wet wood.

4.2.2 Households sector

The woodfuel demand/kg/hh/day vis-a-vis the woodfuel cooking devices was used to determine the conservation rates realized by the urban and rural households (Table 4.16). Kimani (1995) indicated that, other factors constant, the approximate fuelwood conservation/kg/hh/day was given by Eq. 4.22 below.
Charcoal conservation/kg/hh/day was given by Eq.4.23 below.

\[
\text{Mean consumption on T.M.S.} = 2.79\text{kg/hh/day}
\]

Thus the resultant charcoal conservation = 0.36 kg/hh/day or 13%. But 1472 households(58%) were using K.C.J., hence the total charcoal conservation by urban households using K.C.J. was about 0.5tons/day or 183 tons/yr.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Fuelwood (Kg/hh/day)</th>
<th>Charcoal (Kg/hh/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban hh</td>
<td>9.01</td>
<td>7.16</td>
</tr>
<tr>
<td>Rural hh</td>
<td>21.09</td>
<td>17.69</td>
</tr>
</tbody>
</table>

Mean demand on 3-S.F. = 9.01 kg/hh/day whereas mean demand on M.S. = 7.16 kg/hh/day. Thus the resultant fuelwood conservation = 1.85 kg/hh/day or 21%. But 508 households(20%) were using M.S., hence the total fuelwood conservation by urban households using Maendeleo stoves was nearly 1ton/day or 365 tons/yr. Mean demand on T.M.S. = 2.79kg/hh/day whereas mean demand on K.C.J. = 2.43kg/hh/day. Thus the resultant charcoal conservation = 0.36 kg/hh/day or 13%. But 1472 households(58%) were using use K.C.J., hence the total charcoal conservation by urban households using K.C.J. was about 0.5tons/day or 183 tons/yr. Mean demand on 3-S.F. = 21.09 kg/hh/day whereas mean demand on M.S. = 17.69kg/hh/day. Thus the resultant fuelwood conservation = 3.4kg/hh/day or 16%. But 1061 households(7%) were using M.S., hence the total fuelwood conservation by rural households using Maendeleo stoves was 3.6tons/day or 1316
tons/yr. The charcoal conservation, if any, in the rural households could not be determined because no use of K.C.J. was reported in this sub-sector. Hence, the total woodfuel conservation, expressed in wood equivalent terms, by institutions and households through use of respective improved cooking devices was approximately 3596 tons/yr (Table 4.17). This conservation was only about 6.5% of the total wood equivalent demand. This suggests that there exist great potential for further conservation through this approach.

The expected conservation assumed that all the institutions and households in the study area in 1997 had adopted the respective improved woodfuel cooking devices and also, these devices operated at the expected mean conservation efficiency of 40% (Hanskins, 1987; GTZ, 1993). It is evident that there was a considerable shortfall between the estimated and expected conservation levels by both sectors studied as shown in Table 4.17 below.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Estimated (tons/yr)</th>
<th>Expected (tons/yr)</th>
<th>Shortfall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutions</td>
<td>85</td>
<td>126</td>
<td>36</td>
</tr>
<tr>
<td>Urban hh</td>
<td>2195</td>
<td>12576</td>
<td>83</td>
</tr>
<tr>
<td>Rural hh</td>
<td>1316</td>
<td>4980</td>
<td>73</td>
</tr>
<tr>
<td>Total</td>
<td>3596</td>
<td>17682</td>
<td>80</td>
</tr>
</tbody>
</table>

Comparatively, Kimani (1995) reported better fuelwood conservation results (29.4-31.5%) in different refugee camps in Dadaab (Kenya) and Goma (Zaire). This was because over 90% of all the refugees were using improved woodfuel stoves. Furthermore, the dissemination package of these technologies incorporated intensive end-user training programmes. In the study area, therefore, the considerable shortfall of 80% between the total estimated and expected conservation can be offset through 2 main approaches. These include ensuring that as many institutions and households as possible adopted these technologies. Also
ensuring that every end-user was adequately trained on the appropriate operation and maintenance procedures concerning his/her device. Such an approach would ensure that the typical constraints that limited conservation at the household sector such as cracked liners, and poorly installed *Maendeleo* stoves could be minimized.

### 4.3 Fuelwood "surplus" and "deficit" areas

The areas of fuelwood "surplus" or "deficit" were determined on the basis of fuelwood availability. The availability variable was, in turn, measured as a function of time expended gathering the same as indicated by Hosier (1984). Fuelwood demand was more in the first four (areas 1 to 4) areas and decreased markedly in the last two (areas 7 to 8) areas (Fig. 1.3; Table 4.18). The first five (areas 1 to 5) areas are situated within the proximity of Marsabit Forest, approximately 1-2 km away whereas the last two (areas 7 to 8) areas are over 15 km from Marsabit Forest.

**Table 4.18: Fuelwood availability in the rural areas**

<table>
<thead>
<tr>
<th>Area</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>hh size</td>
<td>5.9</td>
<td>5.8</td>
<td>5.8</td>
<td>6.8</td>
<td>6.8</td>
<td>7.2</td>
<td>6.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Per capita FWD (kg/yr)</td>
<td>1695</td>
<td>1684</td>
<td>1454</td>
<td>1345</td>
<td>1025</td>
<td>970</td>
<td>842</td>
<td>745</td>
</tr>
<tr>
<td>Time (hrs/yr)</td>
<td>419</td>
<td>315</td>
<td>430</td>
<td>465</td>
<td>600</td>
<td>625</td>
<td>654</td>
<td>663</td>
</tr>
</tbody>
</table>

Key: 1 = Kituruni  2 = Hulahula  3 = Karare  4 = Songa  5 = Badassa  6 = Dakabaricha  7 = Sagante  8 = Manyatta Jillo

The first five (areas 1 to 5) areas, which had a mean per capita fuelwood consumption of nearly 1500 kg/yr and the corresponding time for gathering of about 50 man-days/yr were classified as the "surplus" areas.
On the other hand, the last two areas (7 to 8) areas, which had a mean per capita fuelwood consumption of nearly 800 kg/yr and the corresponding time for gathering of about 90 man-days, were classified as the "deficit" areas. Dakabaricha(6), however, was classified as a transitional zone. The mean per capita fuelwood demand of 1500 kg/yr in the "surplus" areas near Marsabit Forest was very close to the demand by the households along the Tana River flood plain forest which was 1400 kg/yr as reported by Hughes(1985). In contrast, the mean per capita fuelwood demand of 800 kg/yr in the "deficit" areas which are 15 km from Marsabit Forest was much higher than 217 kg/yr for the semi-nomadic Rendille in Korr and Kargi areas of Marsabit District which are over 150 km from Marsabit Forest as reported by Walther and Herlocker (1981). Earl(1975) working in the Terai District(Nepal) reported similar findings whereby the hill people living on the high potential wood "surplus" zones had a higher per capita woodfuel consumption than their relatives who remained on the marginal wood "deficit" zones.

The marked difference in fuelwood consumption between the areas that are near and those that are far from the forest resources indicates the crucial role played by these scarce resources in the provision of energy as well as other needs for the local communities. Hence, Marsabit Forest, like other forest resources found in the ASAL such as the Kaya Forests(Darkoh,1991), was subjected to the so-called “tragedy of the commons" type of exploitation, whereby every member of the local community wanted to maximize their individual benefit from the common resource without the due consideration to its sustainability. Consequently, the degradation of such forest resources increased with the increase in human pressure combined with the typical adverse climatic conditions prevailing in the ASAL.

4.4 Indicators of woodfuel scarcity in the study area

An attempt was made to examine the woodfuel scarcity in the study area and this was discerned through the following 4 indicators and/or practices.
4.4.1 Woodfuel gathering time and/or distance

The suppliers to institutions accessed the forest from the Karare area and covered about 40-50 km, to and fro the institutions within Marsabit town (Fig. 1.3). They indicated that this was less than 20 km they used to cover between 1990-1992. The women who collected fuelwood for sale recalled that about 1993-1994, they took a maximum of 2-3 hours and covered a distance of only 1-2 km. In 1997, they traveled well beyond a Kenya Wildlife Service Camp, located 5 km from the main forest entrance (Abdul's Gate). In total, they covered approximately 10-15 km to and fro, taking over 8-10 hours/day to gather and deliver only one backload (60 kg) to town.

On the other hand, fuelwood was still easily accessible in the villages next to the forest or the "surplus" areas such as Badassa, Songa, Kituruni, and Karare where the distances and time involved were between 2-3 km and 1-2 hours/day respectively (Fig. 1.3). In the "deficit" areas, the problem was most acute and women indicated that they spent over 10 hours/day to gather at most one backload from the woodland vegetation nearest to them. For example, in Manyatta Jillo, women traveled to Gof Chopa Hills, which are over 15 km away.

4.4.2 Increase in woodfuel cost.

The availability and/or accessibility limitations had a marked bearing on woodfuel affordability such that all the users have had to pay more for the same quantity, albeit poor quality, of woodfuel. In 1993-1994, one backload of fuelwood was selling for not more than KSh50 whereas the same sold for KSh150 in 1997. One tin (debe) of charcoal weighing about 8 kg went for KSh30 in 1997 up from KSh25 in 1996. In other words the cost for both fuelwood and charcoal was estimated to increase by 20% annually. Other factors constant, it is observed that the cost for woodfuel will continue to rise more steeply in view of the increasing distances and opportunity costs involved in the woodfuel gathering and production exercise.
4.4.3 Use of crop residues

In the fuelwood "deficit" areas such as Manyatta Jillo and Golo lukesa, only about 3% of the respondents indicated that crop residues had at certain times been used for cooking. This limited use of crop residues in these fuelwood "deficit" areas was inconsistent with Wood (1979) observation that use of crop residues indicated a shift "down" the so-called "energy ladder" in wood-scarce regions. This inconsistency can be explained by the scarcity of these alternative resources due to the marginal farm output in the study area. Furthermore, there exists high competition of crop residues for animal fodder within these remote and arid regions. There was no reported use of crop residues in the fuelwood "surplus" areas such as Karare, Kituruni, Songa, and Badassa as expected.

4.4.3 Alteration of diet

The study did not establish any change of diet attributable to scarcity of woodfuel. Hoskins (1979) observed that in extreme situations of woodfuel scarcity, some households began conserving woodfuel by altering their diets to include foods that needed less cooking. This was, however, not observed in the study area for two reasons. The scarcity of woodfuel had probably not yet reached such extreme situations in 1997 to warrant change of diet. Moreover, majority of the urban and rural populations in the study area depended more on relief food, hence had limited choice on the kind of diet to prepare.
5: IMPACT OF WOODFUEL DEMAND ON MARSABIT FOREST

In this study, impact refers to the deleterious effects that might result from the continuous removal of trees and shrubs from within Marsabit Forest to specifically meet the growing woodfuel demand. Ellis (1984) observed that human utilization of energy resources such as woodfuel had both ecological and socio-economic effects within a particular region. Hence, the effects of woodfuel demand by the different sectors on Marsabit Forest were examined from 2 dimensions, namely ecological and socio-economic.

5.1 Ecological effects of woodfuel demand

5.1.1 Deforestation

In this study, deforestation refers to the tonnage loss of wood removed from Marsabit Forest to specifically meet woodfuel demand by the different sectors studied. The total tonnage loss from the forest, expressed in wood equivalent terms, amounted to approximately 56000 tons/yr (Table 4.3). Furthermore, the type of wood harvested for fuel was more ecologically destructive than the actual tonnage demand might indicate in Fig. 4.3. Institutions such as schools, prison, and hospital accounted for only 3% of the total wood consumption, yet they caused more deforestation per unit of wood consumed due to large-scale logging of dead and/or live wood from the forest.

Joseph and Walubengo (1988) estimated that a typical institution using 30 tons of wood per month or 360 tons/yr clears approximately 3 hectares of forest cover per year. Therefore, other factors constant, the 568 tons/yr of wood harvested by the institutions from Marsabit Forest resulted in a loss of approximately 1.6 hectares of trees per year (Table 4.3). This observation agrees with UNEP (1989) report which indicated that in other parts of Kenya, fuelwood demand by large-scale catering institutions posed considerable deforestation threat to Kenya's wood resource base. Also, Haro (1990) reported that large-scale catering institutions had contributed greatly to the rapid deforestation along the Turkwel riverline woodland in Turkana, Kenya.

On the other hand, urban households caused more deforestation than the rural households for 2
reasons. Every urban household was found to be using charcoal whereas only 27% of the rural households were charcoal produced from within and without the forest. Also, over 12%(1023tons/yr) of the total fuelwood demand by urban consumers (households, hotels, and bakeries) was met by wet wood, particularly the young growing trees in the forest, which were felled and/or lopped by women for sale. Furthermore, it was observed that the trees density had remarkably declined within a 5 km radius from the Marsabit Forest's main entrance(Abdul's Gate) as a result of wood harvesting by women for sale. Moreover, a vast radius of over 1-5 km from the main entrance to the forest had been cleared of the young trees and wildlings and the leaves swept away. The encroachment into live trees, particularly the young ones and sweeping up the leaves contributed to deforestation, limited the natural regeneration process and encouraged soil erosion within the forest. Furthermore, if these trees are not replaced and granted the low rate of vegetation regeneration within the ASAL, the resultant short- and long-term ramifications on the local environment and beyond are bound to be very severe.

The destructive practice of logging live trees by institutions to meet their fuelwood demand is predicted to escalate because of 3 factors. The anticipated rise in demand commensurate with rise in population, and particularly considering the recent Government policy of setting up more boarding educational institutions in the ASAL regions with a view to promoting education standards(MPND,1994). The non-availability and/or prohibitive costs of alternative fuels such as (LPG) and electricity in the ASAL districts of Kenya as reported by Darkoh(1991). The same author indicated that the prohibitive costs and lack of technical know-how had also limited the potential for harnessing solar energy in the ASAL districts. The fact that local institutions had not taken any initiative towards producing their own fuelwood implied that, other factors constant, their exclusive dependence on Marsabit Forest would continue for many years to come. Filipini (1983) and Timberlake(1994) indicated that, inter alia, woodfuel production and consumption using inefficient conversion technologies such as the traditional kiln method and T.M.S. had contributed considerably towards deforestation in Ethiopia. UNEP(1980) reported that opening of the canopy through
ASAL regions such as Marsabit District.

5.1.2 Loss in biodiversity

Woodfuel demand did not only result in the explicit tonnage loss of dead and/or live wood but also involved the loss of tree species through deliberate species selection by the local consumers to satisfy their unique preferences. Typically, the local people exhibited distinct preferences towards particular species for woodfuel production and consumption subject to the availability and/or accessibility of wood. However, more often than not, the preferences were pursued through particular species selection without the due consideration for the ecological limitations prevailing in the study area with regard to natural regeneration of the species in question. For example, institutions relied exclusively on *Olea spp.* whereas 39% of the wood consumed by urban consumers (households, hotels, and bakeries), was also met by cutting down *Olea spp.*. The women and institutions observed that, *Olea spp.*, unlike the rest, burnt with less smoke and produced large pieces of char, thus it required less tending and cooked food faster.

*Olea spp.* is a hardwood species, with steeply ascending branches and a dense crown. It is also a high-density wood and its multiple uses include fuelwood, charcoal, timber, paneling, poles, wood carving, fermentation and flavoring milk, medicine (stem, bark), and bee-forage. This species is among the few indigenous protected species in view of its ecological significance and its slow rate of natural regeneration whereas its artificial propagation is constrained by its poor seeding ability and low germination rate (ICRAF, 1992). Hence, the rapid loss of *Olea spp.* along with other indigenous species such as *Teclea spp.* and *Diospyros scarbra* was clear demonstration of the serious loss in biodiversity from Marsabit Forest.

Gamboa (1997) observed that 99% of a typical forest's biodiversity was accounted for by its non-tree component. The same author argued that although selective logging meant that only particular tree species were removed from a forest, the impact on the remaining trees and other vegetation particularly the arboreal plants, can be devastating. Timberlake (1994) working in Ethiopia indicated that rapid deforestation had led to virtual extinction of certain vital species of flora and fauna. Darkoh (1991) indicated that the destruction of the
indigenous *Kaya* Forests in Kilifi District might trigger irreversible ecological ramifications in the region, such as changes in precipitation patterns, and decline in soil fertility due to soil erosion.

The removal of all the residues, even to the extreme point of sweeping up the leaves within the Marsabit Forest, removed the essential nutrients which should otherwise return to the soil to maintain its fertility and binding structure. In the process of removing the residues, the undergrowth of wildlings, which were critical for forest regeneration, were also removed and/or trampled upon by women. Also, the disruption of bioclimate within the otherwise thick and closed forest affected the wildlife, and other species of biodiversity resident within Marsabit Forest (MALD, 1995).

The massive loss of particular tree species such as *Olea* spp., *Teclea* spp., and *Diospyros scarbra* which are indigenous, hence adapted to the hostile ASAL conditions of the region might, in the long term, trigger irreversible ecological changes in the locality and beyond similar to those predicted by Darkoh (1991) in Kilifi. Furthermore, the lost indigenous species might not be successfully replaced by other exotic tree species since the latter might not withstand the prevailing ASAL ecological conditions as observed by Oba (1989). Moreover, attempts towards replacing indigenous species with exotic ones could, in the long-term, disrupt the indigenous genetic pool and its characteristics by interfering with the otherwise *in-situ* breeding or reproductive systems within the forest (Gamboa, 1997). It is critical to observe that Marsabit National Reserve, of which Marsabit Forest is a part, is one of the designated ecologically sensitive sites in Africa (IUCN/UNEP, 1987). Thus any form of human encroachment is bound to exacerbate the ecological Stress on the forest ecosystems.

5.2 Socio-economic effects of woodfuel demand

5.2.1 Woodfuel scarcity in the study area

The indicators of woodfuel scarcity cited in section 4.4 are a clear demonstration of the socio-economic dimension of woodfuel demand not only in the study area, but also elsewhere as reported by MDP/GTZ (1995), Darkoh (1991) and Ellis (1984). In particular, 2 important practices which were a direct
product of woodfuel scarcity and which have had a notable socio-economic bearing on the local community were identified. The rural women in the fuelwood "deficit" areas such as Manyatta Jillo and Golo lukesa expended enormous time and energy towards gathering fuelwood(Table 4,18). For example, in these fuelwood "deficit" areas women expended approximately 90 man-days/year on gathering fuelwood. Therefore, the more time and energy expended gathering fuelwood, as dictated by the degree of scarcity, the less time and energy they had for other more productive activities such as farming. In the fuelwood "deficit" areas about 3% of the respondents indicated that crop residues had at certain times been used as alternatives to woodfuel. Hence, excessive diversion of dung and crop residues to use as fuel led to reduced livestock fodder, mulch and soil fertility.

5.2.2 Siltation of water points in and around Marsabit Forest

Regular siltation of the numerous water points such as boreholes, wells, and springs that are within and around the forest(Fig.1.3) was used as an indicator of soil erosion attributable to loss of tree cover in the forest. MPND(1994) and MPND(1993) reports indicated that the people and livestock in Marsabit District rely exclusively on springs, boreholes and wells, as there are no permanent rivers in the district. The same reports indicated that there are 3 principal water catchment zones in the district: the upper zone of over 1500 metres on the summits of Mount Marsabit, and Mount Kulal where a number of springs are found. The other zone is found between 1200-1500 metres still on the two mountains. Examples of springs found around Mount Marsabit include Badassa, Songa and Balesa bongole.

Chou and Dregne(1993) observed that water erosion caused both on-site and off-site damages namely, loss in soil productivity and siltation of reservoirs respectively. Regular siltation of watering points in and around Marsabit Forest affected the local community in 4 ways. Extra time and energy, which should otherwise have gone towards other productive work, was necessary to fetch water. Also, the large herds of livestock were required to move longer distances for watering, and in the process exacerbated the soil erosion problem by trampling on the ground as reported by MALDM(1995). Moreover, the need to move livestock
for longer distances for watering purposes was found to complicate range management practices within the affected rangelands (Oba, 1994). Furthermore, enormous human, material and financial resources were regularly needed for desilting and maintenance of the water points as reported by MDP/GTZ (1995). Also, Isaboke (1997) indicated that food-for-work programmes were regularly organized to facilitate such desilting and maintenance activities.

It is noted that women were bearing the brunt of the reported socio-economic effects since they were the ones responsible for fetching both woodfuel and water. Bellamy (1995) observed that the time and energy a woman spent fetching woodfuel and water, was the time and energy not spent on activities that were of essence to development: farming, earning money, childcare, learning hygiene and how to read and write as well as regaining strength after childbirth.

5.2.3 Other long-term effects

Increased soil erosion through high run-off implied less rate of water infiltration and percolation, hence reduced rate of recharge into ground water aquifers within the forest catchment zones. Also, the excessive opening up of the otherwise thick and closed canopies increased the rate of evapotranspiration, hence reducing the amount of water available for recharging into ground water aquifers through percolation. In the long-term, the net effect would be decline in water yields from the catchment zones within the forest and that would be a serious socio-economic impact on the local community and animals.

Marsabit Forest has always been a crucial reserve of fodder for livestock particularly during the common and pro-longed droughts when they were allowed to graze and water inside the forest (Mbunu, 1997). Hence, continued degradation of the forest would effectively destroy the local community's principal source of livelihood that is livestock sales. Also, destruction of Marsabit National Park, which is part and parcel of Marsabit Forest and a site for tourists' attraction, would reduce revenue to the Government in the future.
5.3 Proposed remedial interventions

To mitigate the foregoing impact on Marsabit Forest, 2 key remedial interventions and approaches for their implementation are proposed. They are woodfuel conservation through use of improved cooking technologies and woodlots establishment targeting the local schools. The reported high wood equivalent demand (56,000 tons/yr) and the high shortfall (80%) between estimated and expected levels of conservation through use of various woodfuel-saving technologies, indicate a critical need to ensure wider and sustainable adoption of these technologies (Tables 4.3; 4.17). Hence, the factors limiting, and approaches to enhance wider adoption of woodfuel-saving technologies within the study area were identified.

5.3.1 Factors limiting adoption of woodfuel-saving technologies in the study area

(i) Affordability

With regard to the Maendeleo stove, 21% and 7% of rural and urban households respectively identified cost of the device as a limiting factor. This was despite a remarkable subsidy scheme put in place by the various NGOs whereby the effective price of a liner was only KSh 50 (MDP/GTZ, 1995). With regard to K.C.J.s, about 40% of urban household respondents indicated that they could no longer afford them at the current price of KSh 350 compared to KSh 200 in 1995. This partly explained why majority of them continued using worn out devices because they could no longer afford new replacements.

(ii) Availability of devices

Over 39% of rural households indicated that the distribution centres for liners were too far from their respective villages and/or the liners were not. For instance, there was no distribution centre at Karare, hence women had to travel either to Marsabit town or Logologo to buy the liners. Others in Songa indicated that the procurement procedure was long and tedious. One was required to place an order through one of their representatives and then waited for a long time before the delivery was made. Such inconveniences discouraged many potential buyers.
(iii) Availability and/or cost of woodfuel

The relatively high number of urban households who had adopted K.C.J.s (58%) and Maendeleo stoves (20%) was primarily as a direct need to reduce the demand and hence cost of woodfuel. In contrast, the fuelwood "surplus" areas discussed in section 4.3 had easy access to fuelwood and indeed 23% indicated no need for Maendeleo stoves. In the fuelwood "deficit" areas, over 87% indicated real need in adopting the Maendeleo stoves. They indicated that those women who had adopted Maendeleo stoves made fewer trips to gather fuelwood than those who had not, hence giving the former more time to fetch water and/or perform other chores thereby increasing their individual productivity on time and labour. According to GTZ (1993) and Mburugu (1994), facilitation of women's work was a key incentive towards faster acceptance of woodfuel-saving technologies.

(iv) Limited end-uses of Maendeleo stoves

Over 56% and 19% of the rural and urban households respectively indicated the limited end-uses of Maendeleo stoves as one of their serious shortcoming. For instance, rural women observed that the three-stone open-fire was versatile in the adequate provision of light, warmth and preservation of large pieces of hot char in the hearth. In contrast, the Maendeleo stoves were only useful in conserving fuelwood and cooking faster. Hence, the apparent compromise on versatility in favour of conservation on the part of the Maendeleo stoves represented an important design shortcoming, which, in turn, hampered their desired wide acceptance.

(v) Socio-cultural inhibitions

The study established some important cultural values attached to the three-stone open-fire which were not practicable on the Maendeleo stoves. The Borana community has a cultural practice of disposing the after-birth after child delivery underneath one of the three stones making the hearth. They also used one of the three stones to make fire from rubbing a particular species of wood on the stone. The latter practice was common when a man was newly married, hence starting his own household. The Rendille community
disposed the removed part of the clitoris during clitodictomy underneath one of the three stones.

In this context, those stones remained culturally significant, hence it was difficult to replace them with a Maendeleo stove for the sole objective of conserving fuelwood. This could partly explain why a number of women in the rural areas who had adopted Maendeleo stoves still found it necessary to preserve the three-stone open-fire for the purposes of performing the above rites. However, only about 3% of the rural respondents and none in the urban who reported the existence of the above cultural practices. Other factors equal, this might suggest that these practices were fast getting discarded over time or some respondents concealed this kind of sensitive information. Nonetheless, it is advisable to always bear such practices in mind when planning and evaluating various adoption strategies within the area. In the context of household energy programs, past experiences have demonstrated that despite the availability of a well-designed product, automatic acceptance was not guaranteed because cooking habits all over the world were closely linked to a people's culture and traditions as reported by GTZ(1993) and Matiru(1991).

(vi) Quality of disseminated technologies

The widespread observations of cracked K.C.J. liners and/or liners falling off the metal cladding indicated a serious setback towards adoption. Obviously, several factors such as transportation and mishandling by the users were responsible for such breakage and poor quality might only be one of them. However, other factors equal, the negative impact of introducing appropriate technologies of poor quality cannot be overemphasized. In other words, in the eyes of the target community, the effectiveness and credibility of such technologies became seriously compromised at the critical stage of introduction, hence limiting further adoption.

(vii) The dependency syndrome

Approximately 12% and 25% of urban and rural households respectively recognized the need to adopt the improved woodfuel-saving technologies. However, on the possibility of adoption they indicated that
they were anticipating free donations from the many NGOs and Government departments operating within the District. They argued that they were too poor to be expected to afford the cost of such devices and suggested that *Maendeleo* stoves be provided freely like relief food. In this study, that attitude was characterized as the dependency syndrome.

Granted the low purchasing power within the community, it is emphasized that the idea was not to merely distribute a technical product. But rather to ensure that such a product, whenever adopted, was properly installed and used within a much wider context of an appropriate household management system which, in return, guaranteed maximum returns to the user. The envisaged context would implicitly include a change in the end-user's behaviour, for example, always using dry and split fuelwood, soaking hard cereals, and cutting raw food material into smaller bits prior to actual cooking (MDP/GTZ, 1995). Such practices, in conjunction with the improved cooking devices, would go along way in enhancing the overall woodfuel conservation. Moreover, giving away improved cookstoves was not the best strategy towards putting in place the desired wider and sustainable dissemination programs. On the contrary, free donations invariably promoted dependency and a lack of appreciation for the product, hence possible misuse might occur as reported by GTZ (1993) and Kimani (1995).

Institutions such as schools, Marsabit Hospital and Marsabit Prison were deliberately exempted from this section of the study because they had acquired the improved institutional stoves through donations from organizations such as World Food Program (WFP), Catholic Mission, and INTERAID, hence their individual input towards the adoption was considered minimal.

5.3.2 Approaches to promoting adoption of woodfuel-saving technologies

The following 3 approaches are proposed towards the realization of the desired wider and sustainable adoption of woodfuel-saving technologies in the study area.
(i) Women groups approach

Out of the estimated 7% of rural households who had adopted the *Maendeleo* liners, over 76% acquired them through different women groups operating within their respective villages. Therefore, women groups were considered instrumental in facilitating wider adoption of the technologies in question. However, those groups were identified only in a few villages such as Badassa, Songa, Kituruni and Karare whereas none was identified in the urban area or at the marginal rural lowlands like Manyatta Jillo or Golo Lukesa. Hence, it is recommended that such groups be initiated where they were absent and strengthened in other areas.

(ii) Local contact installers approach

A local contact installer refers to a person drawn from a local village and drilled on how to install and maintain the *Maendeleo* stoves. Only 2 such active women installers were identified; one in Songa and the other in Badassa. Hence, their ability to effectively serve all the interested households at different times was very limited and this might partly explain the high observations of incorrectly installed liners particularly in the rural areas. On the other hand, majority of the urban women knew how to install the *Maendeleo* stoves. Others had even devised their own simple skills of maintaining the cracked stoves, thus increasing their durability. Every buyer of the improved cookstove should therefore be adequately trained on the proper handling, maintenance and repair of her device. It is therefore recommended that the number of properly trained local contact installers be increased commensurate with the physical and population size of each village.

(iii) The integrated approach

It is observed that a number of NGOs and Government departments were pursuing a rather sectoral approach towards the household energy problem. Some organizations and/or departments were mainly concerned with the production and dissemination of woodfuel-saving cookstoves while others concentrated on improved farming systems, environmental conservation and relief food operations. The study recommends
an integrated or "holistic" approach that will facilitate proper combination of the related activities to take place. This will avoid duplication of efforts, hence reduce cost of projects implementation. An example of the envisaged integrated approach is that of the Food for the Hungry International (FHI) demonstration farm at Golo lukesa. On this farm, local farmers are trained on various soil and water conservation measures, improved farming systems such as agro-forestry and on nutritional aspects using the Maendeleo stoves.

5.4 Increasing woodfuel supply intervention

This intervention is particularly crucial because Marsabit Forest is not only the exclusive source of woodfuel but also supplies other needs such as construction materials for the local community, hence the demand pressure on it is considerable. Woodlots establishment initiative targeting schools in the study area would go a long way in offsetting the future demand pressure on the forest.

5.4.1 Limitations to woodlots establishment in local schools

(i) Adverse climatic conditions

The prevailing adverse climatic conditions were a considerable limitation since the characteristic high spatial and temporal variability of the amount of rainfall frequently limited tree-planting efforts. Oba (1989) noted that during occasional droughts when availability of potable water for basic needs became a problem, raising young seedlings was difficult.

(ii) The wild animals and livestock menace

The far-reaching threat posed by these animals, particularly to those schools within proximity to Marsabit Forest, cannot be overemphasized. Several school heads pleaded harassment from local communities if and when they restricted intrusion of livestock onto their compounds. In other words, these communities perceived the schools as their property, hence an extension of their pastureland. This serious menace, therefore, manifested itself as a form of land use conflict between wild animals/livestock and private land use by schools.
(iii) The prevailing fuelwood market

The prevailing fuelwood market that was greatly in favour of schools provided no motivation for them to consider producing their own. Schools paid about 13 times less per unit measure of fuelwood than the other urban users; hence the cost of fuelwood was inconsequential as indicated by the institutions themselves and Mburu (1997). The reported inconsequential cost of fuelwood to schools was a good example of a market which had failed to allocate forest produce such as fuelwood to the best economic use, hence undermining its economic value as reported by Pearce and Warford (1993).

5.4.2 Approaches to promotion of woodlots in local schools

(i) Charge economic prices on forest produce

The cost of fuelwood should be determined not only by the incurred opportunity cost of labour and time for collection but should also reflect some measure of environmental cost. Hence, appropriate surrogate measures should be introduced to objectively estimate such environmental cost. For example, the estimated unit cost which would be incurred in replacing the harvested fuelwood but is discounted at the present value of money, or other necessary inputs. The charcoal cost should also be determined by the value of round wood equivalent needed to produce it rather than simply the charcoal output.

(ii) Royalties for forest produce be determined at the local level

The G.K. (1962) policy requires that royalties for forest produce be centrally regulated by the Permanent Secretary (Ministry of Environment and Natural Resources) or The Chief Conservator of Forests. Such centralized valuation policy was inappropriate because of its inaccurate generalizations of, and insensitivity to the local and unique socio-economic and ecological variations across the country's natural forests. The recommended valuation policy would enable the immediate stakeholders, that is the local community, in conjunction with the local Government forest department, to set reasonable royalties with a view to harmonizing the legitimate community's interests and ecological sustainability.
(iii) Education for local community and schools

Besides educating the local community on the significance of tree planting on their farms, the community should also be sensitized on the need to respect the schools as autonomous entities. It was also in their interest to appreciate schools as centres and/or catalysts for local environmental conservation activities. The schools, on the other hand, should be educated on how to amicably resolve such landuse conflicts. For example, be able to install a fence (possibly a live fence) to keep off the animals without necessarily antagonizing the local people. In addition, the schools needed serious sensitization on the foreseeable consequences of environmental degradation in light of unabated woodfuel consumption, and more so on their inordinate contribution towards that degradation.

(iv) Introduction of appropriate incentives

Suitable incentives should be identified and criteria for their administration agreed upon between the parties involved. Possible criteria would include the number of seedlings planted and their survival rate per year. Then tokens like food, books, prizes, and trophies could then be offered in recognition of outstanding performance against the set criteria. The micro-catchment of indigenous trees observed at the North Horr Catholic Mission through the food-for-work programme is a fitting example to demonstrate the effectiveness of such incentives if only they are properly administered and managed.

5.4.3 Suitable tree species for planting in the study area

Table 5.1 below shows a list of tree species considered suitable for planting in view of the desired end-uses and the ecology of the study area. A number of species on the list have already been grown by a few schools, albeit on small strips as windbreaks. The correct matching of the desired end-uses, suitable tree species and the ecological conditions of the study area would be critical to the realization of any measure of success in the desired exercise of tree planting as indicated by Darkoh(1991) and Oba(1989).
5.4.4 Cultivation of *Cucurbitaceae* species for use as rootfuel

These plants rapidly reproduce large and starchy roots, and also do well in ASAL regions. Laboratory analyses indicate that the heating value of the roots harvested from *C. foetidissima* was similar to that of wood (Shultz, 1991). Thus rootfuel transfers heat to cooking vessels more efficiently than fuelwood. The roots can therefore be selectively harvested, dried in open sun, and then used as fuel. Nelson *et al* (1983) recommends that to optimize on root yield, these plants should be grown at high plant density per hectare, approximately 550 000 plants/ha and be harvested annually. De Veax and Shultz (1985) reported that most of these species were found to have high water-use efficiency, hence well adapted to the ASAL areas such as Marsabit District. Besides offering an alternative source of fuel, the plants can also be effective in controlling soil erosion, since their large and stiff leaves blunt the force of rain whereas their extensive root structure can help in holding the soil together.
Table 5.1: Suitable tree species for planting in the study area

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Management practices</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia nilotica</em></td>
<td>medium to fast growing, lopping, pollarding</td>
</tr>
<tr>
<td><em>A. tortilis</em></td>
<td>slow growing, no coppicing</td>
</tr>
<tr>
<td><em>A. seyal</em></td>
<td>medium to fast growing, lopping, pollarding, coppicing</td>
</tr>
<tr>
<td><em>Azadirachta indica</em></td>
<td>fast growing, lopping, pollarding</td>
</tr>
<tr>
<td><em>(Neem tree)</em></td>
<td></td>
</tr>
<tr>
<td><em>Casuarina cunninghamiana</em></td>
<td>fast growing</td>
</tr>
<tr>
<td><em>(Australian beefwood)</em></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus saligna</em></td>
<td>fast growing, mature in about 10 years, coppicing</td>
</tr>
<tr>
<td><em>(Sydney blue gum)</em></td>
<td></td>
</tr>
<tr>
<td><em>Grevillea robusta</em></td>
<td>medium to fast growing, pollarding, lopping, coppicing, pruning</td>
</tr>
<tr>
<td><em>(Silky oak)</em></td>
<td></td>
</tr>
<tr>
<td><em>Jacaranda mimosifolia</em></td>
<td>fast growing, lopping, pollarding, coppicing, pruning</td>
</tr>
<tr>
<td><em>(Jacaranda)</em></td>
<td></td>
</tr>
<tr>
<td><em>Sesbania sesban</em></td>
<td>fast growing, pruning</td>
</tr>
<tr>
<td><em>(Mexican weeping pine)</em></td>
<td></td>
</tr>
</tbody>
</table>

Source: ICRAF(1992)
6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In summary, the following are the seven key findings of the study.

(i) The total wood equivalent removed from Marsabit Forest to meet woodfuel demand by the local institutions and households was approximately 56000 tons/year. The rate of deforestation is estimated at 1.6 hectares per year.

(ii) Fuelwood "surplus" areas include Kituruni, Hulahula, Karare, Songa, and Badassa whereas the "deficit" areas include Golo lukesa and Manyatta Jillo. This categorization was on the basis of per capita fuelwood demand and the time expended gathering the same such that "surplus" areas had a per capita demand of over 1500 kg/yr and the corresponding gathering time was less than 50 man-days/yr. In contrast, the "deficit" areas had a per capita demand of about 800 kg/yr and the corresponding gathering time was more than 90 man-days/yr.

(iii) Deforestation and the attendant loss of indigenous biodiversity are the key ecological impacts attributable directly to woodfuel demand from Marsabit Forest. The socio-economic consequences affecting the local community include woodfuel scarcity and siltation of water sources due to an increase in soil erosion in the forest. In the long term, water yield from the forest catchment zones may decrease due to increase in runoff and evaporation within the forest.

(iv) The prohibitive costs of alternative conventional fuels such as kerosene, LPG and electricity, and the unreliability that accompany their distribution and supply were major constraints towards substitution of woodfuel. Furthermore, prohibitive costs and lack of technical know-how had limited the harnessing of solar energy for use particularly by institutions in this area.

(v) Institutions did not take conservation measures seriously nor consider producing their own wood for fuel since they could harvest from the forest at a very low cost.

(vi) The local community was found to exploit Marsabit Forest out of necessity to ensure their basic survival due to lack of other affordable alternatives. Also, Marsabit Forest, like other forest resources in the ASAL
areas of Kenya, is subjected to the so-called "tragedy of the commons" type of exploitation. Consequently, every member of the community wanted to maximize their individual and/or collective benefit(s) without the due consideration to the forest's sustainability.

6.2 Recommendations

The following eight recommendations are made:

(i) Impose immediate ban to control the harvesting of particular indigenous species such as *Olea* spp. and *Teclaea* spp., which are seriously endangered.

(ii) Improve the training for the end-users of the energy-saving technologies in order to realize wider dissemination and more efficient use of the improved cookstoves. Feasibility studies are also necessary to examine the potential and constraints for the establishment of sustainable production units for the improved cookstoves in Marsabit District.

(iii) Suitable sites and tree species should be identified to enhance planting of trees particularly in the local schools, around small townships and other degraded settlement areas.

(iv) Community-based tree nurseries are necessary in order to strengthen and promote the crucial practice of tree planting at an individual and/or community levels, hence increase the supply of wood in the future.

(v) Local schools should be promoted as strategic centres for environmental conservation activities by supporting organized and functional students' groups such as Environmental, Young Farmers, 4K Clubs.

(vi) Cultivation of *Cucurbataceae* plant species (cucurbits) whose roots can be used as fuel should be introduced in the area. Cucurbits can also be effective in controlling soil erosion since their large leaves reduce the impact of rain and the extensive roots hold the soil together.

(vii) Cost-effective techniques of harnessing of solar energy for cooking, heating and lighting should be encouraged in order to provide the local community with an affordable alternative/supplement to woodfuel.

(viii) The Government policy (G.K., 1962) on forest conservation which prohibits any economic exploitation of gazetted forests and requires that all payable royalties for and revenue accrued from forest produce be
controlled by the Central Government need to be reviewed. The payable royalties for forest produce such as wood for fuel and construction materials should be determined at the local level and the proceeds used to finance the necessary re-afforestation and conservation activities.

6.3 Recommendations for further research work

(i) Determination of annual yield rates for Marsabit Forest

The annual yield rates for the different types of vegetation in Marsabit District and particularly in the Marsabit Forest, Mount Kulal and Huri Hills should urgently be determined. The findings would be useful in quantifying the supply of wood resources available in the area.

(ii) Integrated ecosystem study

An integrated ecosystem study would help to quantify and elucidate the multi-variate supply/demand relationships on the natural resource base within the study area over and above the examined woodfuel demand. Important areas that need investigation include clearing land for agriculture, pastoralism, construction materials, land use conflicts, water supply, and role of indigenous knowledge/practices in environmental conservation.

(iii) Desertification simulation modeling in Marsabit District.

Marsabit District covers 2 vast desert areas: Chalbi and Kaisut deserts. Moreover the desertification rate in the district is approximately 1.3% per year or vegetation degradation of about 17937 hectares/annum as reported by Awori and Odhiambo(1993). A typical model should encompass at least 2 modules: the natural module, examining the net primary product (NPP) and the human module, examining the human and livestock numbers, agricultural output, and other relevant socio-economic parameters. Similar desertification simulation modeling experiments were underway in the semi-arid Kerqin Sandy Land of Inner Mongolia, China(Tachiiri, et al, 1997).
7: REFERENCES


De Veaux, J.S. and Shultz, E. 1985, Development of Buffalo Gourd (Cucurbita foetidissima) as a Semiarid Starch and Oil Crop, Economic Botany, 39(4), New Young, pp.454-472


Mburu, J., 1997, Marsabit District Forest Officer, personal communication


Odhiambo, M., 1997, Forester, Marsabit District Forest Station, personal communication


8: APPENDICES

8.1 Questionnaires for households sector

(Questionnaire for survey on woodfuel demand from Marsabit Forest)

Date: ___________________ Sample area: ___________________

(NB. Circle your responses accordingly)

1. Total number of family members who regularly feed in this household?

2. What type of fuel do you use?

3. What type of cooking device(s) do you have?(observe)

4. What are other non cooking functions of the cooking device(s) in the house?

(NB: If your response to Qn.3 above is either 2 or 3 or both, go to Qn.5. Otherwise go to Qn.15).

5. How did you obtain your ESD?
   1. Bought it  2. Received it free (specify donor)

6a). If you bought it, where was it bought?-----------

6b). For how much in KSh?----------

7. For how long have you used the ESD?
   1. 0-6 months  2. 1 year  3. 2 years  4. over 2 years

8. How often do you replace your ESD?

9a). What is the condition of your ESD?(Observe)
   1. Good  2. Bad

9b). If bad, specify?(observe)
   1. No door  2. Cracked ceramic  3. No pot rests
   4. Worn out cladding  9. Others

10. Who maintains your ESD?

11. What do you like most about ESD?
    1. Consumes less fuelwood/charcoal  2. Safe(against fire hazards)  3. Durable
    4. Produces less smoke  9. Others

12. What don't you like about your ESD?
    1. Costly to replace  2. Liner cracks easily  3. Small door

13. How did you learn about ESD?
    1. Exhibition/Demonstration  2. Neighbors

(NB: Go to Qn.16)

14a). If you have a 3-S.F., have you thought of buying an ESD?
   1. Yes  2. No

14b). If no, why?
15. Indicate the approximate rate of charcoal/fuelwood consumption as the case maybe.

<table>
<thead>
<tr>
<th>Amount*</th>
<th>Period of use (days)</th>
<th>Cost (KSh)</th>
<th>Gathering time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firewood</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB: * measured in debes/backloads

16. Which is your regular source of charcoal/fuelwood?

   (NB: If your response to Qn.17 is 2 or 3, go to Qn.18. Otherwise go to Qn.20)

17. What kind of wood do you collect from the Marsabit forest/bushland (warma)?
   1. Dead/dry  2. Live/wet  3. Mixed

18. What contribution does the husband make in fetching fuelwood/charcoal?
   1. Money  2. Labor  3. None

19. What species of wood do you prefer for charcoal/fuelwood? (specify in local names)

20. What kind of cooking device would you prefer?

21. What alternative fuel would you prefer to charcoal/firewood?

22. What is the level of formal education of?

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<thead>
<tr>
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<tbody>
<tr>
<td>Husband</td>
<td></td>
<td></td>
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<tr>
<td>Wife</td>
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</tbody>
</table>

23. What is your family's main source of income?

24. The house is made of (observe).
8.2 Questionnaire for institutions

(Questionnaire for survey on woodfuel demand from Marsabit Forest)

Date: ________________ Institution: ________________

(NB: Circle your responses accordingly)

1. What is the population catered for by the institution's kitchen services?
   1. Below 100  2. 100 < 300  2. 300 < 500  3) Over 500

2. What type of fuel do you use?


(NB: If your response to Qn. 3 above is 4 go to Qn. 4. Otherwise go to 14)

4. How did you acquire the improved institutional stove?
   1. Bought it  2. Received it free(specify donor)

5. For how long(years) have you used the improved institutional stove?  1. 0 < 2  2. 2 < 5  3. over 5

6a). What is the condition of your improved institutional stove? (observe). 1. Good  2. Bad
   b). If bad specify?(observe)  1. No door  2. Cracked grating  3. Clogged chimney
   4. Worn out cladding  9. Others

7. Who maintains your improved institutional stove?  1. Installer  2. Cook(s)  3. None

8. What do you like most about your improved institutional stove?

9. What don't you like about the improved institutional stove?
   5. Bother of splitting and drying wood  9. Others

    3. Donor organization(s)(specify)  9. Others
(NB: Qns.11-13 to be answered by the cook(s) while inside the kitchen)

11. Did you receive any training/drill on how to correctly operate the improved institutional stove?
   1. Yes  2. No

12. When is the last time you cleaned the chimney? -------

13. Which of the following operations do you always observe?
   1. Use of dry fuelwood  2. Splitting fuelwood into small sizes (about 1 ft long)
   3. Not over-charging the firebox  4. Closing the door while cooking

14. Why have you not acquired an improved institutional stove?

15. Indicate the approximate charcoal/fuelwood consumption, as the case maybe.

<table>
<thead>
<tr>
<th></th>
<th>1.Amount*</th>
<th>2.Period of use**</th>
<th>3.Cost(KSh)</th>
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<tr>
<td>Firewood</td>
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NB: * measured in truck/backloads ** measured in months/days


17. What species of wood do you prefer for fuelwood/charcoal? (specify in local names)------

(NB: Qns.18-25 apply to schools, prison and hospital only)

18. What is the approximate physical size (hectares) of your compound?-------

19. Have you considered establishing a woodlot on your compound? 1. Yes  2. No
   (NB: If yes go to Qn.20. Otherwise go to Qn.25)

20. How old is the woodlot?------

21. Who takes care of the young trees?------

22. What are the main problems encountered in planting/raising the trees?------

23. Suggest possible approaches to overcoming those problems.------

24. Identify the main species of trees (in local names).------

25. Why have you not planted any trees for your fuelwood and/or other needs?------