Household energy demand and environmental management in Kenya
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This literature review is focused on four issues associated with household energy demand and environmental management in developing countries. These four are: the heavy dependence of households in developing countries on woodfuels; the valuation of woodfuels; environmental degradation in developing countries; and the possible links between the rural energy system and the environment.

Section 1.1 is a review of typical empirical estimates of household energy consumption in developing countries. In view of the fact that firewood and charcoal are the key components of household energy in these countries, this review, especially, considers estimates of firewood and charcoal consumption from selected countries. The FAO time series estimates are of particular relevance in this respect. The estimates by Hosier (1985) are particularly relevant because they are estimates from Kenya, and hence provide a reference point for this study.

The subject matter of section 1.2 is the valuation of woodfuels in developing countries in which the common methods employed are discussed and illustrated with examples from Kenya where this is possible. This section introduces the buyer-consumer and collector-consumer categorisation of firewood consumers. It also emphasises the importance of labour costs in the valuation of collected fuels, and the role played by women and children in collector-consumer households.

Section 1.3 discusses environmental degradation in developing countries, focusing mainly on land degradation which is considered the most critical environmental problem in the developing world. It discusses the response of governments in developing countries to land degradation, and attempts to make a link between this response and woodfuel consumption.
The link between the rural energy system in developing countries and the environment is discussed in section 1.4. The discussion centres around the fact that developing countries are biomass based subsistence economies with a rural energy system heavily dependent upon non-commercial fuels. It is also noted in this section that it is no trivial task for societies in the developing world to achieve sustainable development, faced as they are, with a multiplicity of needs but with limited opportunities in the international arena.

1.1 Estimates of household energy consumption in selected developing countries

The series of FAO *Yearbook of Forest Products* has long provided statistics on woodfuel production worldwide which are widely used and quoted by individual researchers, institutions, and governments. To give an impression of how the findings of the analyses in this thesis compare with data from the FAO series, Table 1.1 presents some of the findings of this thesis alongside FAO (1983, 1995b) estimates for woodfuel production. Results from Bose (1993), Kidane (1991), Kamara (1986), Hughes-Cromwick (1985) and Hosier (1985) are also included for a broader comparison.

The FAO time series data for charcoal and firewood are aggregate production figures computed on the basis of an assumed production per head of population. Hence in using these figures it is implicitly assumed that production equals consumption: per capita demand exhausts per capita supply. In computing the series the FAO further assumes that the annual change in production is proportional to the annual change in population. This implies that woodfuel consumption is driven largely by population dynamics. This is not entirely the case, since population dynamics is only one of the many factors driving woodfuel production and consumption. Others factors include incomes, fuel prices, environmental, and other demographic factors.

Over the years the FAO production figures have been revised when there is new information. For instance in 1980 the figures were revised following a survey in several countries. These figures were revised yet again in 1992. The figures applicable to Kenya are reported in Table 1.1. Note, however, that these figures are not specific to Kenya. Rather they are averages for several countries including Kenya. Armed with these figures and population statistics, it is possible to construct the FAO time series for firewood and charcoal consumption in Kenya or any other country in the sample. The woodfuel consumption figures for Kenya used in Kirori and Spence (1989) and Okech and Nyoike (1990) were synthesised in this manner.

The woodfuel consumption figures used in this thesis were obtained from an original survey of rural and urban households. With this micro-data it is also possible to construct a
series akin to the FAO series. However, information is lost in the aggregation process needed to construct the series. Being time series data, the FAO series can be used to compute both short run and long run elasticities. An example of GDP elasticities for Kenya is given in Table 1.2. However, time series data for Kenya is limited as it only dates back to 1963, hence reliable estimates may not be easily obtained. The cross-sectional data set collected for the analyses in this thesis is larger and richer hence, more reliable long run elasticities can be computed. In addition it is possible to analyse more aspects of household energy consumption than is possible with aggregate data; such as the influence of the household size or the impact of the fuel mix.

Other differences between the woodfuel data collected for this thesis and the data used to generate the FAO time series are technical. For instance, unlike the FAO, this thesis does not distinguish between coniferous and non-coniferous types of firewood. It treats firewood as a homogeneous product. In addition, this thesis uses weight in kilograms as the unit of measure for both charcoal and firewood rather than volume (m$^3$). The FAO series takes the moisture content of firewood and charcoal into consideration, but this thesis does not.

With respect to firewood consumption, the FAO estimates are larger (coniferous) or smaller (non-coniferous) than the findings in this thesis. The divergence in results is attributed partly to the fact that FAO estimates are aggregated over several countries, of which Kenya is but one; and partly because the FAO series distinguishes between coniferous and non-coniferous firewood. The findings in this thesis are therefore like a weighted mean of coniferous and non-coniferous firewood consumption; with non-conifers accounting for approximately two thirds of firewood consumption in Kenya. However, the findings for charcoal consumption are comparable to the FAO estimates in terms of the magnitudes, as can be seen in Table 1.1.

The studies discussed next are different from the foregoing FAO series in that they all analyse the economics of household energy consumption and consider other fuels besides firewood and charcoal. The objectives of the analyses are also basically different from those of the FAO, nevertheless the relevant end products are comparable with respect to the insights they can yield and the uses to which policy makers can put them.

Bose (1993), using data generated in India in 1980, set out to investigate the factors influencing a household’s decision to install electricity; and once installed the factors influencing the consumption. She used a qualitative response model - logit - in her analysis. Her sample contained both electrified and non-electrified households, and some of the variables whose influence she analysed include: household money income, family size, education of the household head, and the distance to the nearest electricity connection.
Table 1.1: Per capita annual consumption of firewood, charcoal and kerosene from selected studies in developing countries.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type of Household</th>
<th>Firewood (1000 kg)</th>
<th>Charcoal (1000 kg)</th>
<th>Kerosene (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FAO (1983)</strong></td>
<td>Coniferous</td>
<td>0.029</td>
<td>0.092</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Non-coniferous</td>
<td>0.747</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>FAO (1995b)</strong></td>
<td>Coniferous</td>
<td>0.030</td>
<td>0.077</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Non-coniferous</td>
<td>0.674</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Bose (1993)</strong></td>
<td>Non-electrified</td>
<td>0.617</td>
<td></td>
<td>9.88</td>
</tr>
<tr>
<td>India</td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrified</td>
<td>0.387</td>
<td></td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kamara (1986)</strong></td>
<td>Urban+Rural</td>
<td>0.488</td>
<td>0.025</td>
<td>7.7</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kidane (1991)</strong></td>
<td>Rural</td>
<td>1.078</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>0.183</td>
<td></td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hosier (1985)</strong></td>
<td>Rural</td>
<td>0.770</td>
<td>0.109</td>
<td>8.5</td>
</tr>
<tr>
<td>Kenya</td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Own survey</strong></td>
<td>Rural</td>
<td>0.439</td>
<td>0.054</td>
<td>7.4</td>
</tr>
<tr>
<td>1995 (Kenya)</td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>0.462</td>
<td>0.105</td>
<td>17.7</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-electrified</td>
<td>0.449</td>
<td>0.070</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrified</td>
<td>0.470</td>
<td>0.071</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: See the indicated references in the bibliography.
The scope of the magnitudes of kerosene and firewood consumption reported by Bose (1993) are comparable with those reported in this thesis. However, electrified households in India consumed on average one third less firewood and kerosene than non-electrified households. In Kenya, electrified households consume approximately 5% more firewood and 20% more kerosene than non-electrified households. In addition, Bose finds electricity income inelastic in India; while in this thesis it is found to be income elastic in Kenya. See Table 1.2. These differences may be attributed to differences in the time perspectives, the country being studied, and the methods of analysis.

A qualitative response model is also used by Hosier and Dowd (1988) who analysed the household’s choice of cooking fuels in Zimbabwe using a multi-nomial logit model. The authors chose to analyse the choice of cooking fuels because cooking is the most important end-use for most household fuels. Their analysis was conducted in the framework of the "energy ladder" hypothesis. In neo-classical economic theory this is no more than the assertion that as incomes rise consumers consume more of the same good and also shift to consuming higher quality goods. This may be illustrated as follows: from the survey data used in this thesis it is observed that in general, as the mean household income rises the fuel mix changes from firewood alone to kerosene+firewood and then to the kerosene+charcoal+firewood mix. Households using fuel mixes that include lpg and electricity which are high quality fuels, also tend to have relatively higher mean incomes.

The findings of Hosier and Dowd with regard to the consumption of firewood, kerosene and electricity in Zimbabwe are comparable with those of this thesis. However, because Hosier and Dowd do not include the household size these can not be included in Table 1.1. As might be anticipated, there is a higher probability of high income households choosing high quality fuels. As for firewood they find that under conditions of scarcity households are more likely to purchase than to gather firewood; and that Larger households are more likely to purchase than to gather firewood. This latter observation, as they report, is a counter-intuitive result. They also find that larger households are more likely to use kerosene for cooking than smaller households. They find the response of the households demand for kerosene to income changes ambiguous; the explanation of which they give as the relatively low excise tax on its retail price compared to other fuels. The ambiguous response of kerosene demand to income changes has also been found by Hughes-Cromwick (1985) for households in Kenya, and by Pitt (1985) for households in Indonesia. Pitt observes that this feature of kerosene demand is common in countries where kerosene is heavily subsidised.

The studies by Kamara (1986) and Kidane (1991) make for an interesting comparison, because both concern sub-Saharan African countries: Sierra Leone and Ethiopia respectively. Both are based on surveys of rural and urban households and both use quantitative econometric models. Kamara estimates separate Engel curves for rural and urban households both in per capita and total energy consumption terms. His Engel curves, specified in the double log format, include two demographic variables: household size and the educational
attainment of the household head. He obtains significant coefficient estimates showing that energy is a normal income inelastic good. See Table 1.2. He finds firewood an inferior commodity in urban households, but normal and income inelastic in rural households. Kerosene turns out to be income inelastic in urban households, but income elastic in rural households. He also finds electricity to be income inelastic in urban households.

With respect to demographic variables; in per capita terms Kamara found that in Sierra Leone larger households consume proportionately less energy. This is especially true for kerosene and electricity in urban households, suggesting the existence of scale economies in household energy consumption. As for education, households whose heads have higher educational attainments consume proportionately more energy. This also holds true for fuels except firewood in urban households where households whose heads have higher educational attainments consume relatively less firewood.

Unlike Kamara, Kidane estimates a demand system and hence is able to establish the relationships amongst the three fuels he analysed namely; cow dung, firewood, and kerosene. His specification of a constant elasticity demand system is similar to Kamara’s double log format of Engel curves. And like Kamara, he also estimates separate demand systems for rural and urban households. The rural households in Ethiopia Kidane finds that cow dung is a substitute for both kerosene and firewood. It is also price inelastic and inferior. He found firewood and kerosene complementary, both were price inelastic, and kerosene was income elastic in rural households. Thus, just as Kamara found in rural Sierra Leone, Kidane also finds kerosene a luxury good in rural Ethiopia. Kidane’s results for urban households are largely insignificant and different from those of rural households. For instance cow dung was a substitute for firewood, but complementary with kerosene. Firewood was price inelastic with an insignificant income elasticity. Kerosene was inferior, and had the wrong price elasticity sign; and both the price and income elasticities were insignificant.

The study by Hosier (1985), based on a survey conducted in Kenya in 1981, is unlike the previous two in that it puts little emphasis on econometric analysis and is focused entirely on rural households. In contrast with Hosier (1985), this thesis considers both rural and urban households, it analyses all the fuels used by households, taking into consideration the fuel mixes used. It also gives specific attention to collected firewood. These are aspects which Hosier did not take into account. It can be inferred from Hosier’s results that the price elasticity for kerosene bears the correct sign. The income elasticity of demand for
Table 1.2: Own-price and income elasticities for household fuels from selected studies in developing countries.

<table>
<thead>
<tr>
<th></th>
<th>Firewood</th>
<th>Charcoal</th>
<th>Kerosene</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FAO Kenya</strong></td>
<td>S.Run: $\varepsilon_{\text{GDP}} = +0.017$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>L.Run: $\varepsilon_{\text{GDP}} = +0.567$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bose (1993)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$\varepsilon_{\text{GDP}} = +0.189$</td>
</tr>
<tr>
<td><strong>India</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kamara (1986)</strong></td>
<td>Urban $\varepsilon_{\text{wY}} = -0.158$</td>
<td>-</td>
<td>$\varepsilon_{\text{kY}} = +0.139$</td>
<td>$\varepsilon_{\text{eY}} = +0.723$</td>
</tr>
<tr>
<td><strong>Sierra Leone</strong></td>
<td>Rural $\varepsilon_{\text{wY}} = +0.330$</td>
<td>-</td>
<td>$\varepsilon_{\text{kY}} = +1.124$</td>
<td>-</td>
</tr>
<tr>
<td><strong>Kidane (1991)</strong></td>
<td>Rural $\varepsilon_{\text{wY}} = +0.05$</td>
<td>$\varepsilon_{\text{wY}} = -0.78$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Ethiopia</strong></td>
<td>Urban $\varepsilon_{\text{wY}} = -0.37$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Hughes Cromwick (1985)</strong></td>
<td>Urban $\varepsilon_{\text{wY}} = -0.37$</td>
<td>-</td>
<td>$\varepsilon_{\text{eY}} = -0.279$</td>
<td>$\varepsilon_{\text{eY}} = +1.599$</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hosier (1985)</strong></td>
<td>Rural $\varepsilon_{\text{wY}} = -0.177$</td>
<td>-</td>
<td>$\varepsilon_{\text{kY}} = +0.052$</td>
<td>-</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Own Survey (1995)</strong></td>
<td>Rural $\varepsilon_{\text{wY}} = +1.266$</td>
<td>$\varepsilon_{\text{wY}} = +0.921$</td>
<td>$\varepsilon_{\text{eY}} = +0.492$</td>
<td>-</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td></td>
<td>$\varepsilon_{\text{wY}} = -1.015$</td>
<td>$\varepsilon_{\text{eY}} = -0.587$</td>
<td>$\varepsilon_{\text{eY}} = -1.386$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{\text{wY}} = +1.394$</td>
<td>$\varepsilon_{\text{eY}} = +1.356$</td>
<td>$\varepsilon_{\text{kY}} = +0.524$</td>
<td>$\varepsilon_{\text{eY}} = +1.479$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{\text{wY}} = -0.868$</td>
<td>$\varepsilon_{\text{eY}} = -1.128$</td>
<td>$\varepsilon_{\text{kY}} = -1.069$</td>
<td>$\varepsilon_{\text{eY}} = -0.756$</td>
</tr>
</tbody>
</table>

Sources: See the indicated references in the bibliography.

* Computed by the author

The subscripts: w refers to firewood; c to charcoal; k to kerosene; e to electricity; and Y to income. GDP is the Gross Domestic Product.
kerosene in Hosier (1985), as computed by this author, indicates that kerosene was a necessity in rural Kenya. This is different from the findings of Kamara and Kidane in which kerosene was found to be income elastic in rural households. The findings of this thesis concur with Hosier's finding that kerosene is income inelastic in rural households; and further indicate that it is also income inelastic in urban households in Kenya. Furthermore, the elasticities for kerosene in the different fuel mixes in which it is used in both rural and urban households are also computed in this thesis. The imputed price elasticity of firewood in Hosier (1985), as computed by this author, indicates that firewood is price inelastic. The findings in this thesis both for collected and purchased firewood concur with that result. In addition in this thesis both collected and purchased firewood are found to be income elastic.

In comparing Hosier's results with those of rural households in this thesis, it is apparent that the per capita consumption of firewood and charcoal have declined by approximately 40% and 50% respectively, between 1981 and 1995. This prompts the speculation that woodfuels have may have become more scarce in the intervening period. Table 1.3 illustrates the changes in firewood scarcity in rural Kenya between 1981 and 1995 using two different indicators. The figures suggest that it requires approximately eight times more effort to obtain firewood in 1995 than it did in 1981. Firewood scarcity and its measurement are discussed further in Chapter 7 where firewood scarcity profiles are constructed and analysed.

### Table 1.3: Changes in firewood scarcity in Kenya between 1981 and 1995

<table>
<thead>
<tr>
<th>SCARCITY MEASURE</th>
<th>1981</th>
<th>1995</th>
<th>Change factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to source (km)</td>
<td>0.62</td>
<td>2.4</td>
<td>3.87</td>
</tr>
<tr>
<td>Time taken to collect a days supply (min)</td>
<td>63.4</td>
<td>125.1</td>
<td>1.97</td>
</tr>
</tbody>
</table>

Sources: Hosier (1985) for 1981; and own survey for 1995
The study by Hughes-Cromwick (1985) somewhat complements Hosier’s work because it analyses urban household energy use in Nairobi - the largest city in Kenya. Like Hosier (1985), it is based on a cross-sectional survey conducted in 1981 with the respondents divided into six income groups. Its findings that on average a Nairobi household consumed 129 kilograms of firewood per week; and 11.5 kilograms of charcoal per week are comparable with those of this thesis. However since Hughes-Cromwick did not publish household sizes it is not possible to compare the findings in per capita terms as in Table 1.1. However, the elasticities for electricity and charcoal, which are given in Table 1.2, indicate that Hughes-Cromwick found charcoal to be an inferior commodity in Nairobi households. This is different from the findings of this thesis in which charcoal was found to be normal and income inelastic in both rural and urban households.

Hughes-Cromwick found the consumption of kerosene to be a "mystery" and the utilisation of firewood to be anomalous. Witness the following quotations:

On kerosene:
"... While it is clear that paraffin [kerosene] energy consumption is prevalent among the lower income groups and is therefore negatively related to household income, it is not apparent that one could accurately forecast changes in this energy demand based on income" (Ibid, p.278)

The ambiguity alluded to may be attributed to the subsidy on kerosene which makes it relatively cheap and hence affordable to low income households. This is the phenomenon discussed earlier in reference to the study by Hosier and Dowd (1988) for Zimbabwe, and Pitt (1985) for Indonesia. The findings in this thesis do not concur with Hughes-Cromwick’s observation on income elasticity. However, with regard to price elasticity there is some evidence of ambiguity: for instance in urban households using the electricity+lpg+kerosene+charcoal fuel mix, the own price elasticity for kerosene has the wrong sign, being positive rather than negative. Such ambiguity with price elasticity can also be observed with electricity. But in the case of electricity the price is not determined by market forces, rather it is fixed by the authorities.

Hughes-Cromwick on firewood:
"... While one would expect [firewood] to be used primarily by the low income households, the sample households reported [firewood use among the highest income groups.]" (Ibid, p.274)

Due to this unforeseen outcome, she excluded firewood from further analysis. However, she conjectures that since the income groups were based upon location the pattern of firewood use was due to the spatial distribution of the firewood sources. What Hughes-Cromwick may not

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1 The elasticities for lpg from Hughes-Cromwick (1985) are as follows, with comparable elasticities from this thesis given in parentheses:

\[ e_{1V} = +0.035 \quad e_{0l} = -3.090 \]

\[ (+0.602) \quad (-0.523) \]
have realised is that there is a tendency amongst high income households in urban centres to
use firewood for space heating purposes.

From estimates of both Engel curves and demand functions, the findings in this thesis
indicate that purchased firewood is income elastic. This is unlike the findings of Kamara and
Kidane both of whom found firewood income inelastic, and even inferior. The inferiority of
woodfuels was also noted by Abaka (1990) who estimated Engel curves for woodfuels in
Ghana using time series data. The inferior nature of woodfuels is of significance in the sense
that it makes firewood demand a decreasing function of income. Hence, as incomes rise
firewood consumption should decline absolutely; which is an important consideration for
policy makers concerned with the over-exploitation of woodfuel resources.

In summary this thesis aggregates household energy by monetary value and by Joules,
and goes on to estimate energy demand functions for rural and urban households separately
in Chapter 4. Next, each fuel is considered individually and Engel curves estimated for each
by the specification used by Working (1943) and Leser (1961). In Chapter 5, a flexible
functional form; the linear approximate version of the almost ideal demand system, is
estimated for household fuels in Kenya. This version of the almost ideal demand system is
extended to include demographic variables.

1.2 Valuation of woodfuels

In the literature, household energy in developing countries is usually categorised either as
commercial or non-commercial. However, as the following definition by Kosmo (1987),
which also highlights this dichotomy, shows these terms do not necessarily convey the concept
of traded or non-traded commodities:

"Commercial energy refers to fuels that are regularly bought and sold in the market
place such as petroleum fuels, coal and electricity. These are produced and distributed
by the modern sector or state corporations. Non-commercial energy generally refers
to energy derived from plant and animal materials. It includes crop and animal
residues, wood, charcoal, and other biomass fuels that are either produced by the
consumers themselves or are traded infrequently. They are consumed largely by the
non-market sectors of the economy."

According to Laarman (1987) the term "non-commercial" refers to the channels through which
most fuelwood, crop and animal residues, and some charcoal are appropriated; and has
nothing to do with whether, say, the firewood is purchased or collected. Thus despite the fact
that woodfuels are generally referred to as non-commercial fuels they can be acquired via
commercial channels. More detailed discussions on the terminologies associated with
commercial and non-commercial fuels can be found in Roberts (1987), Dunkerley (1987),
Leach, et al (1986); and Hall, Barnard, and Moss (1983); to mention a few sources. In this thesis a distinction is made between purchased and collected firewood, each of which is analysed separately.

An important issue in the analysis of household energy consumption in developing countries is the extent to which woodfuels have been commercialised and the factors motivating it. For the policy maker, the largely non-commercial nature of woodfuels particularly firewood, makes it difficult to formulate enforceable economic or fiscal control over resource exploitation. The contribution of this thesis is the establishment of the proportion of households in Kenya that use purchased firewood; and the analysis of the factors motivating households to use purchased firewood.

A special characteristic of most firewood consumers in developing countries is that they tend to be both consumers and producers of woodfuels. Specifically they can be divided into:

(i) **collector-consumers**, who collect the firewood they need. Nomadic communities living in conditions of open access, common property, or communal ownership are a good example;

(ii) **producer-consumers**, who produce woodfuels on their farms such as subsistence farmers under conditions of fairly strict individual land tenure;

(iii) **buyer-consumers**, who buy woodfuels; usually urban households and rural households that rely entirely on the market for their woodfuel needs.

There are consumers who fall into either two or all three of the above categories. For instance there are households that both collect and buy, or both produce and buy, or do all three: collect, produce, as well as buy part of firewood needs. In subsequent discussions and analyses in this thesis the households are divided into the two major categories of those that use purchased firewood and those that use collected firewood. This grouping refers to the method by which the household obtains the bulk of its firewood supply. Buyer-consumers fall into the group that use purchased firewood, whereas collector-consumers and producer-consumers make up the group of households that use collected firewood.

Collector-consumers and producer-consumers obtain woodfuels through non-commercial channels, while buyer-consumers acquire theirs via the market. Hence, prices and incomes in a firewood economy consuming both purchased and collected firewood are both monetary and non-monetary. Thus, formal demand analysis in which consumers with an entirely monetary income make purchases from a market in which all prices are monetary is not necessarily applicable; since part of the consumers income is in the form of collected firewood. Furthermore, exchange may involve money or labour or a combination of the two.

Labour costs are therefore important in determining the shadow price of collected firewood, since collected firewood is otherwise free. However, it may be inappropriate to value the labour involved in fuel collection at the going wage rate because the alternative of wage labour is not always open. Labour markets in developing countries are thin. They are
even thinner for women since there exist unequal employment opportunities between men and women. Yet it is women and children who play the greater role in the collection of firewood. Witness the following quotation from Deaton (1995 p. 1801):

"... there is little agreement on how to value time. If labour markets are sufficiently well developed so that every one can work as many hours as they wish at the market wage, then that wage would be the appropriate price for imputing time. But if people have limited opportunities for work, as is often the case for women in many parts of the world, the appropriate rate would be less, perhaps very much less."

The involvement of women and children in firewood collection is discussed at some length by Bose (1993), and by Hills (1995). The findings of this thesis indicate the heavy but not exclusive involvement of women and children in firewood collection in Kenya. In the separable agricultural household model of firewood production and consumption estimated in this thesis, time is valued at the going wage rate. The analysis takes into account the differences in urban and rural wages, as well as between various rural areas. An important outcome of the analysis is the shadow price of firewood.

In many developing countries firewood is an open access, common property, or communal property resource; so there may be unrestricted access to the resource system. In addition, the modern institutions of a monetized economy do not usually work efficiently in developing countries. The result is that firewood tends to be underpriced, and hence there is little incentive for its efficient use. This is a classic example of the adverse interaction known as "the tragedy of the commons" (Hardin, 1968). It is often the upshot of this argument that the open access or common property nature of woodfuel resources retards the commercialisation of firewood. In Kenya most land in the high altitude zones, where agricultural potential is high, is individually owned. In the other parts of the country the process of land sub-division is in progress. So there are households occupying land over which their tenure is yet to be decided. When an individual or household is allocated a piece of land a title deed is issued to confirm ownership. This secures their tenure and confers them use rights under the land laws of Kenya. Range-lands inhabited by pastoral communities are still communally owned and so are the common property of the communities concerned. Some government owned land may be regarded as open access property if the government is unable to exclude other users from the land, such as charcoal burners and wood gatherers in the Tsavo.

In this thesis it is argued that the assignment of property rights do influence the households environmental management practices such as the use of purchased firewood, conservation, tree planting, and the use of agricultural residues as fuel. It is further argued that issues of property rights are not the only reason firewood is under-priced, the wage gap between the rural and urban sector is also a contributing factor to the under pricing.

Questions regarding the valuation of labour, and the role of property rights make the determination of accounting prices for woodfuel resources a complex issue. The approaches
suggested in the literature, enable only a partial determination of the shadow price, usually the use-value. However, this leaves the intrinsic and option values un-accounted for and therefore renders shadow prices biased. Yet, it is impossible to quantify the intrinsic worth or option value. Hence, the biased shadow price is all there is to work with and therefore gives valuable information. Pearce and Turner (1990; p 130) refer to the option value as being a potential benefit rather than the actual present use-value. And, the intrinsic value as residing in the nature of the thing and being unrelated to either actual use or the option to use the thing.

There are direct and indirect methods of determining the shadow price of firewood. The direct method involves using the market price of firewood; while the indirect methods involve the use of proxies. See Hufschmidt et al (1983) for an example of both. The market price of firewood is not a good measure of the firewood's true value because it does not take into account the intrinsic and option values. Neither is the shadow value of firewood based on labour costs; for this too does not account for the intrinsic and option values.

Some of the indirect approaches to the pricing of firewood are discussed below. They include:

(i) The determination of stumpage value by the cost based method of determining wood replacement costs: This is often used for plantation wood as in Openshaw and Feinstein (1988). It is therefore not discussed any further in this thesis because the sample of respondent households did not include households operating wood plantations,

(ii) The use of travel and time costs as proxies for firewood prices:
The basis of this method is the notion that the low value to mass ratio for firewood makes firewood transportation costly. Distance travelled and time expended per unit of firewood collected therefore serve as rationing devices and hence may be used to shadow price firewood. See Laarman (1987) for an example of the use of this method.

As a further illustration: by imputing a monetary value to the time required to collect firewood in rural Kenya, Hosier (1985) computed the opportunity cost (\( p_{cw} \)) of collected firewood using the expression \( p_{cw} = t^* (\theta \omega) \). Where \( t \) is the time required to collect a kilogram of firewood; \( \theta \) the probability of being employed; and \( \omega \) the prevailing wage rate. Thus \( \theta \omega \) is the expected value of the monetary wage. Hosier reports the median value for the opportunity cost of collected firewood as KSh 0.05/kg. Similar computations based on the findings of this thesis gives the opportunity cost of collected firewood as KSh 0.04/kg in constant 1981 KSh. Therefore in real terms it is apparent that there has been little change if any in Hosier's concept of the opportunity cost of collected firewood. This approach is refined further in the context of a separable agricultural household model in Chapter 8 in which the shadow price of collected firewood is found to lie between KSh 0.07/kg and KSh 0.33/kg in
constant 1981 KSh.

(iii) The estimation of woodfuel prices in terms of the prices of marketed substitute goods: This approach is used when a given woodfuel is a substitute or complement of a tradable input. Openshaw and Feinstein (1988) illustrate this method by computing a 1988 kerosene substitute price for charcoal in Nairobi, Kenya as KSh 1.10/kg of charcoal for households using the "sheet metal jiko" and KSh 1.83/kg of charcoal for households using the "Kenya ceramic jiko". Their computation is based on the assumption that the end use for both kerosene and charcoal is cooking. Similar computations based on the findings of this thesis yield a kerosene substitute price for charcoal in urban households of KSh 1.56/kg with the "sheet metal jiko" and KSh 2.60/kg with the "Kenya ceramic jiko" at constant 1988 KSh. This implies a 42% increase in the real kerosene substitute price for charcoal between 1988 and 1995. Note that in most fuel mixes including the two fuels, they tend to have a substitute relationship, which therefore lends credibility to this approach. This method is not discussed further in this study preference being given to the extension of method (ii) above.

(iv) Dynamic programming techniques: The specific aspect of this technique of interest here is optimal control theory. Household production models are usually the starting point in this approach. See Wiedenmann (1991), and Dasgupta and Mäler (1995) for examples. The appeal of the household production model lies in its ability to accommodate the simultaneity of production and consumption associated with firewood; and the incorporation of the optimal control theory framework gives insight into the dynamics of the environmental capital resource base. However, unless specific functional forms are employed for the consumption and production sides of the model, only a qualitative analysis is possible. This is the most common approach; and often uses phase diagrams to analyse simple cases.

For instance, Wiedenmann (1991) models the supply of heat with a household production function in which the utility function includes food consumption and heat. He does not employ specific functional forms, nevertheless the result is still a complex dynamic system in which he demonstrates qualitatively that the marginal utility of firewood is identical to the sum of the private marginal costs of firewood collection and distribution and the shadow price of firewood. His model is discussed further in Chapter 8.

Quantitative solutions to household production models formulated in the framework of optimal control theory are fairly complicated owing to the complex nature of the dynamic behaviour of the production and consumption of households. This is one reason why these models are usually analysed with unspecified functional forms. Nevertheless, even in a simple two-period model of household production,
unambiguous results are difficult to obtain. Both in dynamic and static household models the general effects of price changes on the optimal choice of labour, leisure, and consumption are indeterminate and depend on substitution and income effects and on the households net production situation (Max and Lehman, 1988). Simplifications of the household production model for firewood have also been analysed by logit and probit procedures because of difficulties associated with the direct empirical estimation of the household utility function; and the multiple use functions of the firewood resource base - usually forests (Binkley, 1987).

In this thesis purchased firewood is valued directly using market prices; while the shadow price of collected firewood is estimated within the framework of a static agricultural household model which is a variant of the household production model discussed above. The data set used here is cross-sectional, hence it is not possible to estimate a dynamic model.

1.3 Environmental degradation in developing countries

In the view of the international community, the environmental problems that receive the most emphasis in developed countries such as acid rain and global warming tend to overshadow those that mainly affect developing countries. Yet environmental problems affecting developing countries such as land degradation are no less important. The Brundtland Report captures this inter-dependence strongly:

"There are no separate crises: environmental crisis, development crisis, energy crisis, food crisis: they are all one and the same 'global' crisis, which affects developing countries in particular." WCED (1987).

Environmental degradation is defined as the non-optimal exploitation of renewable natural resource systems. It carries the negative connotation that the observed rate of resource use is the incorrect time path - such as too rapid a harvest rate of forests or fisheries, the unmitigated loss of soil fertility, or excessive dumping of pollutants into the atmosphere or water-bodies. The exploitation of non-renewable natural resources such as oil and mineral ores, is not considered degradation whatever the time path of the rate of use.

The focus of this thesis is land degradation; which is defined as the loss or reduction of the productive capacity of land due to a combination of natural processes (physical, chemical, and biological) and human activities. The human activities of concern in this respect are socio-economic in nature and include over grazing, deforestation, low input agriculture, and industrial activities. Land degradation includes the loss or reduction of soil fertility, vegetative cover, and the outright loss of soil through erosion. It therefore follows, logically, that conservation is the deliberate effort to restore or maintain the productive capacity of land. The conservation activities of interest in this analysis include soil, water, and woody biomass
Land degradation is currently considered the most important ecological problem in most developing countries (Graaf, 1993). The most important forms of land degradation being soil erosion, deforestation, overgrazing, and nutrient depletion i.e. loss of soil fertility. Although both human factors and natural processes are responsible for degradation, human factors have become by far the most critical, especially population pressure, poverty, institutions, and technology. Graaf (1993) provides an analysis of each of these factors; while Grepperud (1996) gives an empirical analysis of population pressure and land degradation in the Ethiopian highlands; and Dasgupta and Maler (1995) give a detailed discussion of poverty and institutions. Grepperud uses a soil erosion severity index (SESI) developed by Kuru (1986) as a measure of land degradation to test the hypothesis that under comparable physical conditions heavily eroded areas occur in highly populated regions. The results of his analysis confirm that human activities are primarily responsible for degradation. Baker (1983) views land degradation in Kenya purely as a social and political phenomenon in which the ruling elite control large portions of productive but idle land, while the masses are either concentrated in un-economically small plots of land, forced into less productive marginal lands, or are rendered landless. Baker argues that under these circumstances, land degradation is inevitable. This is the trend of analysis followed by Larson and Bromley (1990) who argue that degradation can be an optimal response to economic and environmental circumstances. They aptly illustrate this with Perrings' (1989) definition of poverty in developing countries as a situation where dis-savings exist in the form of resource degradation to maintain a subsistence level of consumption.

Degradation is, generally speaking, a slow process. For instance woodfuel resources recede gradually; declines in crop yields are gradual and not necessarily uniform; unless gulleys or rills appear on farm land soil erosion goes on virtually unnoticed. Hence, to quantify land degradation it is necessary to have indicators. An ideal indicator should combine various forms of degradation as these often occur simultaneously. It must also be a specific and objectively verifiable measure of changes brought about by a given activity. But, as Graaf (1993) points out, finding such an indicator is difficult either at the local or national level. However, he makes an attempt to classify a group of twenty developing countries, including Kenya, by their dominant land degradation features. These features are:

(i) deforestation and downstream effects;
(ii) soil erosion, downstream effects, and nutrient losses;
(iii) exhaustion, soil erosion, and nutrient losses.

According to this classification, the dominant degradation features in Kenya are exhaustion, soil erosion, and nutrient losses (ibid Table 1.8).

The diminishing supply of woodfuel resources is of key interest in this thesis. Indicators of this aspect of environmental degradation include:

(i) increasing distances to the sources of supply;
(ii) increasing amount of time and effort expended in obtaining a unit amount of woodfuel;

(iii) decline in the quality of available woodfuels, and the corresponding increase in the use of poorer quality woodfuels and firewood substitutes such as agricultural residues.

For detailed discussions of these aspects of land degradation see Brouwer et al (1997), and Ghimire (1994).

Governments in developing countries have responded to firewood scarcity and associated aspects of land degradation by promoting various conservation measures. These include re-forestation, afforestation and agro-forestry, as well as specific soil and water conservation measures. Improvements in agricultural practices are also promoted in order to alter the extractive nature of the existing agricultural practices.

Both success stories and disappointments have been reported in the literature. For instance, both the studies of Kidane (1991) for Ethiopia, and Hassan and Hertzler (1989) for Sudan, report excessive harvesting of fuelwood resources and the ensuing land degradation. While, Holmgren, Masakha, and Sjoholm (1994) report successful tree planting activities in Kenya, with a 4.7% annual growth rate of the standing volume of woody biomass outside forests. Thus agro-forestry and social forestry have achieved some success in Kenya, and this is a pointer to the importance of agriculture in the provision of energy. Yet the solution is not energy-forestry per se, which is not competitive with agriculture since woodfuel prices are too low relative to other agricultural products. See Desai, et al (1986).

Patel, Pickney, and Jaeger (1995) found farmers in Muranga district in Kenya to be responsive to tree planting incentives. They also found tree planting to be a competitive activity in Muranga. The findings of Holmgren et al (1994) and Patel et al (1995) discount the existence of a persistent fuelwood "gap" reported by Mungala and Openshaw (1977) for Machakos district in Kenya. The notion that population pressure leads to a declining tree cover is also discounted using a simulation model in which Patel, Pickney, and Jaeger (1995) demonstrate that as land continues to be sub-divided tree cover may actually rise. This agrees with the findings of this thesis that on-farm tree density is an increasing function of population pressure; and that on-farm tree density is higher in smaller farms.

In this thesis the discussion of firewood scarcity is taken up in Chapter 7 where the firewood scarcity profiles are constructed using the indicators listed above along with other variables. The firewood scarcity profiles are then analysed in the context of the specific environmental characteristics of the sampled districts.
1.4 Linking the rural energy system with the environment

The majority of the population in developing countries reside in rural areas and depend directly on the natural resource base for their livelihoods. The environment provides inputs for production, amenities, and life supporting services such as clean air and water (Dasgupta and Mäler, 1995). For this reason the impacts of environmental degradation on the welfare of rural households is very strong. For instance, declining soil fertility affects crop yields and hence incomes and nutrition; dwindling woodfuel resources mean longer distances to travel and more time spent foraging for firewood which affects household labour management profoundly. There is therefore a very close affinity between rural households and their environment in the developing world. Dasgupta and Mäler (1995) refer to developing countries as biomass-based subsistence economies because of the direct dependence of the rural people in these countries on plant and animal products.

The rural energy system is heavily dependent on woodfuels and agricultural residues. Hence, the management of the woodfuel resource base impacts on the quality of the environment. Energy-related environmental management practices of concern in this thesis include conservation, tree planting, the use of agricultural residues as fuel, and the commercialisation of firewood. These activities require the co-ordinated efforts of the individual land owning households, concerned institutions, and the government. However, very few developing country governments have attempted to link energy use with environmental planning (Hills, 1995). This may be because of the low priority accorded such efforts in countries with what seem to be more urgent needs to be met from limited resources. Besides, rural households have a relatively lower purchasing power, and hence would be particularly vulnerable if fiscal or regulatory measures were imposed to control the exploitation of woodfuels, even where this exploitation damages the environment (ibid). See also Mungala and Openshaw (1977).

Governments in third world countries do recognise that with regard to energy resource exploitation there is more than just environmental conservation to consider. Energy is a basic necessity, essential for survival and development hence, concerns for basic needs and economic growth must be taken into account. This should include concern for inter-generational justice; which is presumed under sustainable development, the concept which has gained widespread acceptance and endorsement as a universal goal (WCED,1987). Thus, short of developing innovative policies, third world governments have limited options among the traditional energy policy prescriptions. The successful increment of woody biomass resources outside of forests in Kenya can be considered an example of innovative energy policy. This policy has its origins in the LEAP system.

The government of Kenya was the original beneficiary of the LEAP (Long-range Energy Alternatives) system developed by the Stockholm Environmental Institute. This is a
system for energy and environmental analysis which was used to develop policy options that the government of Kenya has since incorporated into the national energy policy (Heaps et al, 1993). The success of agro-forestry in Kenya mentioned in Section 1.3 above is in some measure due to this system. Nevertheless, energy and environmental systems are not static, hence a continuous monitoring and analysis of the existing policies is necessary in order to keep development on a path that "... ensures the needs of the present generation, without compromising the ability of future generations to meet their own needs." WCED (1987). This thesis is a modest contribution in this respect: monitoring the status of household energy demand and environmental management; and the management of Kenya’s energy policy.

Chapter 9 of this thesis is an analysis of energy-related environmental management practices of households in Kenya. Such practices include, conservation, tree-planting, and the use of agricultural residues for fuel. In Chapter 10 the government of Kenya’s management of the country’s energy policy is analysed in the light of the findings of this thesis.
Chapter 1: Endnotes

1. The following are the six most frequently used fuel mixes in households in Kenya; being used by approximately 90% of the households. The corresponding mean incomes of the households both in the urban and rural sectors are also shown.

<table>
<thead>
<tr>
<th>FUEL MIX</th>
<th>URBAN</th>
<th>RURAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity+lpg+kerosene+charcoal</td>
<td>8,070</td>
<td>n.a.</td>
</tr>
<tr>
<td>Electricity+kerosene+charcoal</td>
<td>7,660</td>
<td>45,060</td>
</tr>
<tr>
<td>Kerosene+charcoal</td>
<td>6,250</td>
<td>11,220</td>
</tr>
<tr>
<td>Kerosene+charcoal+firewood</td>
<td>4,920</td>
<td>6,190</td>
</tr>
<tr>
<td>Kerosene+firewood</td>
<td>4,250</td>
<td>1,425</td>
</tr>
</tbody>
</table>

Mean household income (KSh./month)

Source: Own survey; 1995.


<table>
<thead>
<tr>
<th>FIREWOOD</th>
<th>KEROSENE</th>
<th>ELECTRICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>(kg/day)</td>
<td>(lt/week)</td>
<td>(kwh/month)</td>
</tr>
<tr>
<td>RURAL</td>
<td>15.5</td>
<td>0.6</td>
</tr>
<tr>
<td>URBAN</td>
<td>5.6</td>
<td>2.5</td>
</tr>
<tr>
<td>NATIONAL</td>
<td>15.0</td>
<td>0.8</td>
</tr>
<tr>
<td>% using</td>
<td>74</td>
<td>62</td>
</tr>
</tbody>
</table>

Source: Hosier and Dowd (1988); Table IV-1 p.88

3. Hosier (1984, p.49, 51) reports two OLS estimates for annual fuelwood and kerosene consumption, respectively:

(i) \[ P = 4133.9 - 171.3T + 226.4HH + 790.3DD \]

where:
- \( P \) = Fuelwood consumption per annum
- \( T \) = Time spent gathering a kilogram of firewood
- \( HH \) = Household size
- \( DD \) = Dummy variable indicating use of a whole grain diet.

(ii) \[ P = 38.1 - 6.4PR + 4.4HH + 0.00045Y + 45.1DP \]

where:
- \( P \) = Kerosene consumption per annum
- \( DP \) = Dummy variable indicating the use of kerosene for cooking
- \( PR \) = Price of kerosene
- \( Y \) = Cash income.

No standard errors or t statistics are reported, hence the significance of the parameter estimates cannot be established. However, if the time spent gathering firewood is used as a proxy for the price of firewood the imputed price elasticity of demand, \( e_P \), for firewood is computed as -0.177. Thus firewood is price inelastic in Hosier's 1981 sample of rural households.

The price elasticity for kerosene could be computed similarly but the mean price is unavailable. However, the income elasticity of demand, \( e_Y \), for kerosene is computed as 0.052; indicating that Kerosene is a necessity in this rural sample.

4. Larson and Bromley (1990) distinguish between common property and open access on the basis of two axioms:

(i) composition axiom which requires that complete control must be vested in a well defined group for a socially efficient use.

(ii) authority axiom which requires that the well defined group must also act with a unified purpose.

The table below indicates which of these axioms are satisfied by common property, open access, and communal ownership:

<table>
<thead>
<tr>
<th>axiom</th>
<th>common property</th>
<th>open access (free access)</th>
<th>communal ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>(ii)</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Open access and free access have the same meaning but they are not the same as common property. Under open access there is no "group", since the open or free nature implies the absence of property. Under individual tenure or communal ownership unity of
composition and authority is achieved, hence resource use should be efficient and socially optimal; at least in principle.

The disaster of open access has usually been wrongly attributed to common property. Furthermore, common property does not imply communal ownership which Demsetz (1967, p.353) describes as "a right which can be exercised by all members of the community".

Larson and Bromley show that the composition and authority axioms are not sufficient to ensure that resources are not degraded.

5. As noted by Dasgupta and Mäler (1995), Contingent Valuation Methods (CVMs), which is another approach to the estimation of accounting prices of environmental resources, are useful when valuing amenities, such as recreational parks.

6. According to Grossman and Krueger (1991); World Bank (1992); and Seldon and Song (1994); for some environmental and natural resource indicators, it has been noticed that as per capita income increases, the level of degradation first increases, reaches a maximum, and subsequently declines. This describes an inverted "U" pattern similar to the relationship noted by Kuznets (1955) for income inequality; hence the term environmental Kuznets curve. This term was first used by Selden and Song (1994) with regard to air pollution.

7. Dasgupta and Mäler (1995) discuss the definition of sustainable development in some detail. They point out that the focus should be on present and future well being; and on the methods of determining how well being is affected by policy. Moreover, the definition should encompass an aggregate social well being function which allows future generation's well beings to be reflected in a function defined over the well beings of all generations.