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Analysis of Wood-Energy Production and Consumption Strategies Among Small-Scale Farmers in Central Kenya

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ANALYSIS OF WOOD-ENERGY PRODUCTION AND CONSUMPTION STRATEGIES AMONG SMALL-SCALE FARMERS IN CENTRAL KENYA

By

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ABSTRACT

ANALYSIS OF WOOD-ENERGY PRODUCTION AND CONSUMPTION STRATEGIES AMONG SMALL-SCALE FARMERS IN CENTRAL KENYA

By

Albert Makanga Mwangi

This study focuses on wood-energy production and consumption strategies among small-scale farm households in central Kenya. The specific objectives were: (1) to determine how households had responded to specific wood-energy policies, and (2) to identify factors that were associated with household adoption or non-adoption of the strategies. Different programs aimed at addressing wood-energy shortages in Kenya were initiated or strengthened during the 1980s. They included fuelwood or multipurpose tree planting, development and dissemination of improved stoves and fireplaces and promotion of increased accessibility to wood-energy substitutes. Household adoption levels for policy-supported strategies have remained low despite promotion efforts.

Cross-sectional survey data from two villages in Nyeri district were collected and used to determine the factors associated with adoption of the Kenya Ceramic Jiko, the "Kuni Mbili" stove/fireplace, kerosene stoves, electric cookers, and fuelwood or multipurpose tree planting. Adoption rates varied from as low as 1 percent for electricity to 43 percent for the Kenya Ceramic Jiko. Different parametric and non-parametric tests were used to

evaluate differences between the two villages. Probit analysis was used to examine the factors associated with household adoption or non-adoption. Important policy variables included extension visits per year, income levels, years of formal education received by head of household, access to different fuels, area of farm-land owned, household size, and locational characteristics of the villages.

Policy recommendations included: use of research results to direct policy; improvement of information flows between policy makers, extension agents, and technology-users; increased support of agroforestry; and better program coordination. Recommendations for further research included: examining more areas where efficiency gains in energy production and consumption can be made, extending the study to cover the drier parts central Kenya, and conducting regular case studies in order to better understand the adoption process over time.

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I. INTRODUCTION

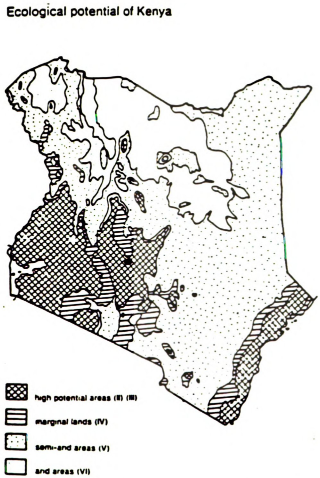
Background and Problem Setting

This study addresses wood-energy related policies in central Kenya. In this context, wood energy refers collectively to fuelwood, charcoal, sawdust or any other form in which wood is used for domestic cooking and heating in the rural areas of Kenya. Fuelwood and charcoal are the principal forms of energy used by most rural Kenyans. Here, the wood-energy shortage has reached a crisis state. In facing this crisis, energy choices must be made. Wood-energy production and consumption choices include various strategies that rural households take (1) to increase the supply of wood energy and suitable substitutes and (2) to ensure that available supply is efficiently used. Individuals, the government and development agencies are addressing the problem with various measures.

Resource and Population Concerns

The wood-energy problem is severe in both high and low potential agricultural regions of Kenya. Figure 1.1 shows the agro-climatic zones of Kenya. The zones are based on a Food and Agriculture Organization (FAO) study and are widely

Figure 1.1 Agro-climatic zone map of Kenya

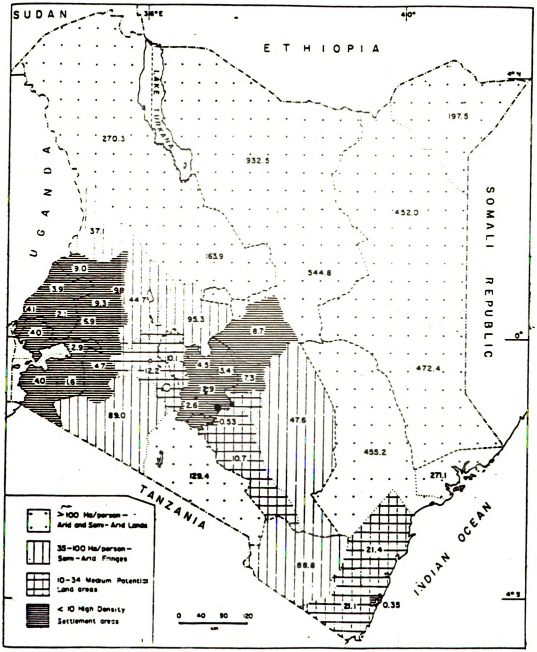


Source: Juma and Namuye, 1987.

used as a system of land classification. The high potential agricultural areas examined in this study are mainly in the region including agro-climatic zones I, II, and III which have an average annual rainfall of 800-1700 mm (Teel, 1984). The typical natural vegetation in zone I is moist forest with average annual rainfall of 1100-1700mm. Zone II has average annual rainfall of 1000-1600mm; the typical natural vegetation is moist to dry forest. Dry forest and moist woodland are the typical natural vegetation in zone III where the average annual rainfall is 800-1400 mm. The low potential areas include marginal (semi-humid to semi-arid, zone IV), semi-arid (zone V), arid (zone VI), and very arid (zone VII) agro-climatic zones which are characterized by low rainfall and high evapo-transpiration rates.

Low agricultural potential areas, which are more ecologically delicate and susceptible to degradation, have lower population densities than high potential areas. Most of Kenya's rural population, however, live in the high potential arable lands where there are many competing land uses. These are the areas with critical fuelwood needs (Bradley et al., 1985). Figure 1.2 shows the 1989 projected land availability per capita for different districts in Kenya (Odingo, 1988). Total district area and projected 1989 population were used to compute the values shown. Most high potential areas had a per capita land availability of less than ten hectares (1 hectare = 2.47 acres). Nyeri

Figure 1.2 Projected 1989 per capita land availability for Kenya



Source: Odingo, 1988.

district had 4.5 hectares per capita. The low levels of technological inputs such as fertilizers make maintaining long-term land productivity difficult for these areas.

The Central Province of Kenya is representative of high potential areas. It has 3.1 million of the country's total 1989 population of about 23 million (G.K., 1991). The two study sites are located in Nyeri district which has a population of 613,000 (ibid.). The other four districts in the province (Murang'a, Nyandarua, Kirinyaga, and Kiambu) hold the rest of the population. The arable areas of these districts are relatively densely populated. Land holdings are generally small and intensively used. Salem and Van Nao (1981) noted that as population increases, agriculture becomes more intensive and the amount of land left under fallow at any one time is reduced considerably. This has been the case in much of central Kenya. The population has grown rapidly in the last generation or so, and land has become increasingly scarce.

Wood-energy Programs

To address wood-energy needs, many programs were initiated or strengthened in the country during the 1980s. Funding for programs has involved investments by individual farmers, the government, private volunteer organizations and international development agencies.

Scherr (1989) noted the activities of some government agencies involved in environmental conservation and energy programs. In 1971, the government established the Rural Afforestation and Extension Services (R.A.E.S.) program under the Ministry of Environment and Natural Resources. Its mandate was to promote tree planting outside the national forest reserves by farmers, organizations, groups, and institutions. The RAES program has evolved into the Forest Extension Services Division (FESD) established in 1989 and given a broad mandate. The Division encourages the different groups mentioned above to grow trees for firewood, poles, fodder, fruit, shelterbelts, and aesthetics among other reasons. The Rural Tree Development Support Project (RTDSP) under the FESD supports the development of woodfuel production, inter-agency cooperation, and the dissemination of wood energy development and use packages that can help farmers become self-sufficient in wood energy (FESD Newsletter, 1990). Other programs are also included.

The Ministries of Agriculture and Livestock have been promoting tree planting for soil conservation and fodder production. From its inception in 1980, the Ministry of Energy had a specific mandate to promote tree planting for fuelwood and to encourage the efficient utilization of all forms of energy. The Ministry has used an "agroforestry centers" model to establish a network of centers which promote tree planting and efficient energy use throughout the country. The six major centers include Wambugu Farmers

Training Center in the central highlands (the region where this study was conducted), Mtwapa Center in the coastal region, Bukura Center in the western highlands, Ngong Center near Nairobi, Kitui Center for the arid/semi-arid regions, and the Kisii Center for the Lake Victoria basin (MOERD, n.d.).

Specific Policies

Several policy alternatives for dealing with the wood-energy problem in the rural areas of Kenya have been proposed or implemented. They include increasing wood-energy supplies, promoting alternatives to wood energy, and encouraging efficient energy use. Another option is switching to faster cooking foods. This option has, however, not been given much emphasis by the agencies reviewed in this study. In many cases, energy alternatives are promoted by the government. In others, farmers have recognized their needs and embarked on their own programs.

Specific policies that have been proposed or implemented include the following:

(1) Planting more trees on family farms for fuelwood and charcoal (G.K., 1989),

(2) Expanding the land area reserved for government afforestation programs (G.K., 1989),

(3) Providing a wood-energy conservation scheme based on reducing the effective price of kerosene and

encouraging its use as an energy alternative (G.K., 1989),

(4) Developing and promoting the use of more efficient stoves especially the Kenya Ceramic Jiko, the "Kuni Mbili" stove/fireplace, and sawdust stoves (Joseph and Kinyanjui, 1982; Jones, 1988), and

(5) Accelerating rural electrification so that more families can use electricity for cooking, heating and lighting (G.K., 1986).

The first strategy, tree planting, has received the greatest policy and resource allocation emphasis so far. This alternative assumes that owners of private land can increase the amount of biomass available for energy purposes through adopting various types of agroforestry practices or by establishing farm woodlots. Critical issues in promoting tree planting include the following: the specific wood products desired, where trees should be planted, the species that should be planted, the source(s) of seedlings, the target group(s) for planting programs, tree tending and harvesting, and finally, the distribution of benefits from trees among members of the same household who may have different interests in the trees. A good understanding of these issues is essential to the effective promotion of tree planting by small-scale farmers.

Tree growing is one possible use of land. Benefits from tree growing include cash, labor savings, environmental protection, increased availability of consumable wood products, or even increased leisure time by cutting down on the amount of time needed to collect fuelwood, for example. For some farmers, particularly the poor ones, growing trees that can be sold as fuelwood or other products in times of emergency cash needs, such as school fees for the children or medical expenses, can be an important consideration.

Due to the existing population pressures in the high potential agricultural areas, it is unlikely that any private land will ever be turned over to the government for tree planting projects as proposed in the second strategy. This option would probably work only in areas that have low population or low arable potential. In central Kenya, such land is limited. Private land owners can, however, increase the amount of land under tree management through agroforestry or planting woodlots. Also, the existing public forest lands can be managed to provide more of the fuelwood needs of rural communities. In fact, some villages are becoming more dependent on public forests. In the Island Farms sublocation (hereafter referred to as Village 1), farmers initially settled on fairly well-wooded land parcels under the Million Acre resettlement scheme after Kenya got independence from Britain in 1963. Landless Kenyans were given low-interest, long-term loans to acquire land that was formerly held by British settlers. Over the years, farmers have cut down most of the original trees on their land and now rely heavily on national forest lands for fuelwood and charcoal.

The third strategy, use of kerosene as a wood-energy substitute, was proposed in the 1989-93 National Development Plan. Generally, only a small proportion of rural households use or are likely to use kerosene for their daily cooking and heating. In Kenya, profit margins from the retail sale of kerosene have historically been relatively small. In 1983 for example, the ratio of retail to border price was 1.07 (Kosmo, 1989). This meant that kerosene at retail outlets was only 7 percent more expensive than the price at the port of entry. Retailers were therefore making a very small profit. Large subsidies may be needed to ensure a shift from the consumption of fuelwood to kerosene, and this may lead to high foreign exchange costs since Kenya is an oil-importing country. Results for similar policies have not been good in countries like Zambia and Indonesia where they have been tried (Foley, 1986; Mercer and Soussan, 1992).

An early effort to improve efficiency and convenience in cooking and heating was the introduction of the traditional metal stove in the early 1900's; it has been adopted widely (Juma and Namuye, 1987). This is partially due to the simplicity of the technology. It can be made by local blacksmiths using scrap sheet metal and very few tools. Unfortunately, this charcoal-burning stove loses a lot of heat and wastes a lot of fuel.

Efficiency improvements in wood and charcoal use are important policy considerations. Macklin (1984) noted that the complete dissemination of improved stoves could save up to 50 per cent of the firewood and charcoal being used at the time of his study. There would also be additional savings in terms of the time used in fuelwood collection. These estimates are based on the unrealistic assumption of complete adoption. The data from the study areas indicate that adoption levels for many of the technologies are still low. This emphasizes the importance of an adoption study.

Traditional pit kilns are used in the production of most of the charcoal in Kenya. These kilns are inefficient and have conversion efficiencies of 9 to 14 percent (ibid.). More efficient charcoal kilns have conversion efficiencies of up to 30 percent. Shah et al. (1992) found that commercial partial-combustion kilns had carbonization efficiencies of between 26 and 38 percent on a dry wood basis. Such commercial kilns, however, require higher capital outlay and large quantities of output to be viable investments. When conversion losses are added to losses due to inefficient stoves, it becomes apparent that total heat loss can be enormous. More research is needed to establish how better charcoal-making technology can be widely adopted. More efficient stoves such as the Kenya Ceramic Jiko could make an even greater impact if appropriate charcoal-making technology were also adopted.

The Kenya Ceramic Jiko (KCJ) is an improved charcoal stove that reduces energy losses by using a ceramic lining for insulation. Hyman (1986) reported that households could save 25 percent of their charcoal expenditures by switching to the improved stove. This stove is a recent technology in Kenya; it was developed in the early 1980s. Juma and Namuye (1987) noted that even though the adoption of the stove appears to be increasing, there is no reliable information on its production and use. In addition, they also noted that the profile of the early adopters of the stove was unclear, and that the impact of such technologies on forest and tree resource depletion was also not well understood.

The "Kuni Mbili" stove or fireplace is a newer technology designed to replace the three-stone fireplace. The traditional three-stone fire place consists of three stones placed near each other in a triangular design so that a cooking pot can be placed on the stones. The fuelwood is set on fire directly under the cooking pot. The "Kuni Mbili" stove/fireplace prevents heat loss from burning fuelwood by using a ceramic lining similar to the one used in the KCJ. The fireplace is designed and fitted in a fixed position in the kitchen while the stove is a portable unit. This is one of the important strategies considered in this study.

The final strategy, rapid rural electrification, is an important component of Kenya's overall energy program and has been funded through government investments and subsidies to the Kenya Power and Lighting Company (Anonymous, 1989). Nearly all electricity used in Kenya is produced by hydroelectric power plants. Between 1979 and 1989, the output of hydroelectric power in Kenya increased by 88 per cent (World Resources Institute, 1992). One major geothermal power station (Olkaria in the Rift Valley Province) is also in use. The government projects electricity demand to grow by 6.2 percent per year in the 1990s (G.K., 1989). The government expects that "wider distribution of electricity, coupled with rising incomes, will reduce the demands for kerosene for lighting and for fuelwood" (G.K., 1986). One facet of this study examines whether, and if so, why, some households have shifted away from using wood energy to using electricity for cooking and heating. Electricity was available only in Kihugiru sub-location (hereafter referred to as Village 2), which became a beneficiary of the rural electrification program in the mid-1970s.

Fuelwood Use

Fuelwood and charcoal are the main sources of domestic energy for cooking and heating for most Kenyan households. Table 1.01 shows 1983 fuelwood and charcoal use levels by sectors (MOERD, 1986). At that time, between 75-80 percent of the national energy needs were met by fuelwood and charcoal (ibid.). Rural households were using 74 percent of the fuelwood and 36 percent of the charcoal. Urban households, on the other hand, used only 1 percent of the fuelwood and 45 percent of the charcoal. The trends are unlikely to have changed dramatically during the last eight years. Industries and institutions used much lower

Table 1.01 Fuelwood and charcoal use by different sectors

	Percent of National Consumption	
Sector	Fuelwood	Charcoal
Rural households	74	36
Urban household	1	45
Informal industry	15	17
Large industry	8	0
Institutions	1	1

Source: MOERD, 1986.

quantities of fuelwood than rural households.

In urban areas where 19 per cent of the Kenyan population lives (G.K., 1991), household energy-use strategies are quite different from those in rural areas. Kimuyu (1990) evaluated the effect of urbanization and changes in the structure of the Kenyan economy between 1963-85 and reported that there was a significant effect on the demand for many fuels. He concluded that "spatial population distribution and chosen development strategies create energy requirements of specific magnitudes and structure." An earlier study by the Government of Kenya (G.K.) also showed that urban and rural households have different energy-use patterns (G.K., 1980). In general, urban households are more dependent on commercial fuels such as kerosene, gas, and electricity whereas rural households are more dependent on fuelwood and charcoal.

It is estimated that 46 percent of the fuelwood used in Kenyan households comes from family farms, 28 percent from national forests, and 25 percent from range lands (G.K., 1989). These proportions may vary considerably at regional and sub-regional levels. Baker (1986) noted that national forest reserves covered 3.5 percent of the national territory in 1970 and had declined to 2.5 percent in 1980. Due to the limited area of national forest lands, fuelwood will increasingly have to be produced on family farms.

Households appear to have paid little attention to some of the government supported programs stated above. Although one objective of the rural electrification program is to supply energy for domestic use for example, it is does not appear to have substituted for fuelwood in any significant amount in Village 2. In fact, only 1 percent of the households surveyed in Village 2 reported that they used electricity for cooking and heating. Factors associated with the adoption of various energy strategies need to be critically examined.

Research Objectives

In Kenya, the wood-energy production and consumption strategies arising from different government policies include planting more trees on family farms, using more kerosene as a fuelwood substitute, using more efficient fuelwood and charcoal stoves (the KCJ, and the "Kuni Mbili" stove/fireplace), and rural electrification. The specific objectives of this study are:

(1) to determine how study households have responded to specific wood-energy policies which were put in place or strengthened during the 1980s, and

(2) to identify factors that are associated with household adoption or non-adoption of the strategies.

Results of this research will provide a basis for recommendations on suitable implementation approaches for wood-energy policies.

Current literature on fuelwood supply and demand situations in Kenya and other developing countries supports the need for adoption studies such as the current one (e.g. Bradley et al., 1985; FAO, 1989; FAO, 1990). Observed wood energy needs of study area households also appear to be relatively high. This research has a potential contribution in answering questions related to better provision of energy to rural households. In addition, wood energy shortages may have adverse nutrition impacts on the household members especially in situations where certain foods may be avoided due to high energy requirements for their cooking.

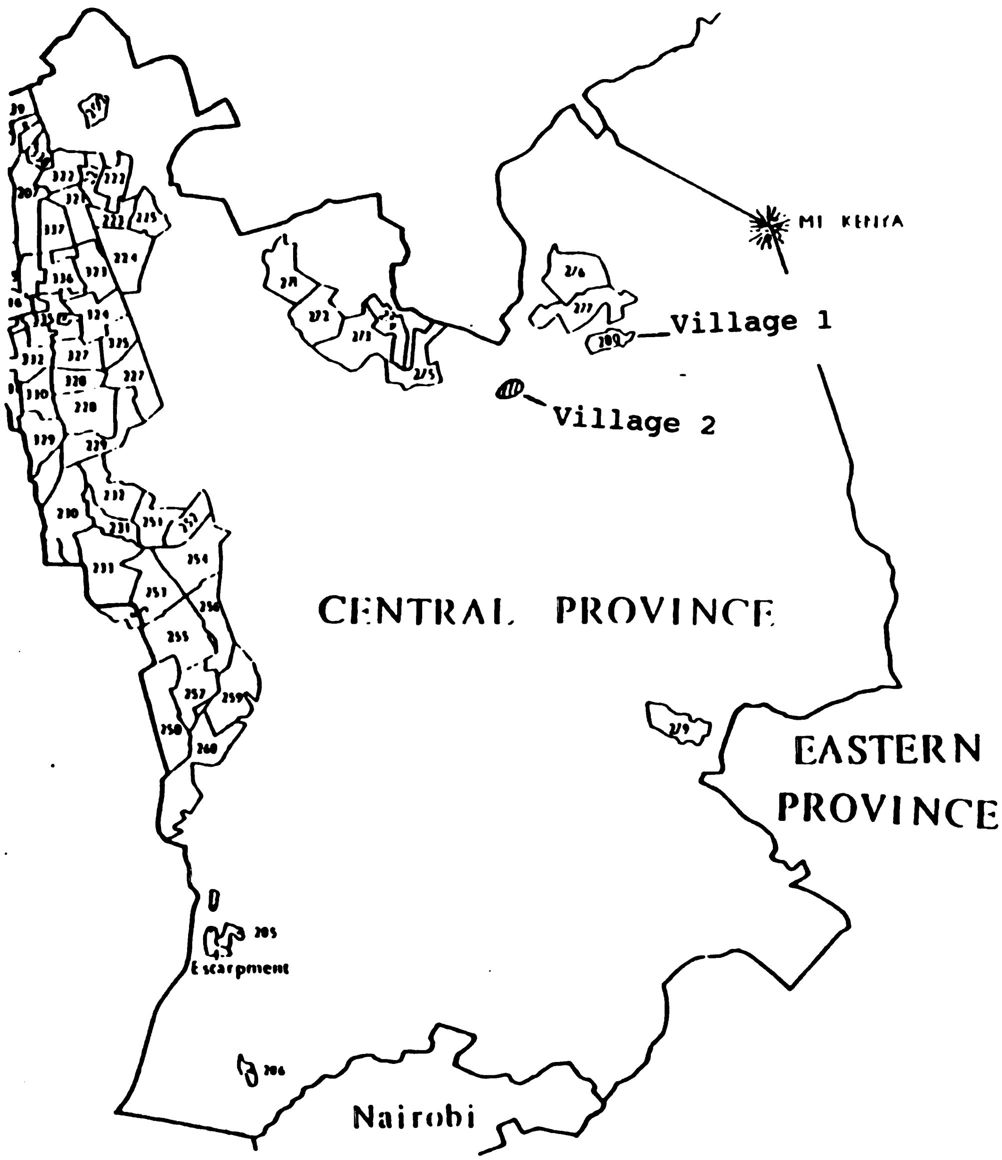
Scope and Limitations

This research involves a case study of two villages in the highlands of central Kenya. The general location of the villages is shown in Figure 1.3. The rationale for selecting these two villages is explained in Chapter 3. Small-scale agriculture, which incorporates food crops, cash crops and livestock, is the main activity in both villages. Village 1 relies more on horticultural and dairy products as sources of income while Village 2 relies on tea and coffee.

The area covered by this study represents a small proportion of the otherwise large region of central Kenya. The ethnic composition of the two villages in the region is fairly homogeneous. There are, however, local geographic and economic variations. Caution must therefore be exercised in extending case study results to other regions. The current study is based on a survey of 306 farmers. A comprehensive study of the whole region would require a much larger sample and more resources.

As a one-time cross-sectional study, the results generally reflect the situation in the two villages at the

Figure 1.3 Map of central Kenya showing the location of the two villages



Source: Survey of Kenya, n.d.

time of the study (July-September 1991) . Thus, it is difficult to explain some village differences which may be due to historical reasons. In the mid-1970s, for example, world coffee prices were very good and many farmers in Village 2 were able to build good permanent homes and to support the development of the rural infrastructure. At the time of the survey, however, coffee prices were very low, and this tended to give the impression that reported incomes were not very significant in explaining residents' higher standard of living relative to Village 1. To the extent possible, relevant anecdotal historical information is included in the discussion of the situations in these villages.

Probit analysis was used to examine the factors associated with adoption or non-adoption of different wood-energy production and consumption strategies. For each of the specified wood-energy production and consumption strategies, a binary probit model was developed. Since the two villages were statistically different for many independent variables, probit models were generated independently. Data for the two villages were also combined and used to generate probit models for the enlarged sample. The assumption here was that the two villages reflected two strata from different socio-economic and bio-physical conditions within central Kenya. Dummy variables were used to test for village effect in the combined models.

Dissertation Organization

This dissertation is organized into five chapters. Chapter 1 is the introduction. Chapter 2 reviews different wood energy production and consumption policies and relevant studies that have been carried out in Kenya and elsewhere. The importance of wood energy to rural households and the constraints associated with obtaining adequate supplies is also discussed. The roles of different government and non-governmental agencies are examined in the context of the adoption or non-adoption of different strategies.

Chapter 3 presents the conceptual and analytical methods used in the study. A theoretical justification is presented for selecting probit analysis over the general linear model, the linear probability model, the logit model, or the Tobit model. Rationales are also presented for selecting the two villages, the sample sizes, and the survey procedure. Parametric and non-parametric tests used for comparative analysis are also explained.

Chapter 4 presents a discussion of results. They include parametric and non-parametric test results, correlation analysis, and probit models generated for the various strategies in the two villages. A discussion is also included of the goodness of fit and the significance of the models in explaining factors associated with adoption or non-adoption of wood-energy production and consumption strategies.

Finally, policy implications of this study are discussed in Chapter 5. Recommendations for future research are also presented.

II. LITERATURE REVIEW

Literature related to wood-energy production and consumption is discussed in this chapter along with technologies that increase the efficiency of fuelwood and charcoal. Possible alternatives to fuelwood and charcoal are also discussed. Literature on the diffusion of innovations and analytical techniques used is discussed in Chapter 3. Relative to Chapter 1, specific aspects include an expanded discussion of research and development work carried out by various agencies, implications of wood-energy shortages, different approaches to the problem, and policy and household responses.

Research and Development Work by Various Agencies

Following the oil crisis of the early 1970s and the Sahelian drought in the same period, many African countries were forced to re-evaluate their energy policies as well as the delicate nature of their environments. In Kenya, a rather slow process of evaluating household and industrial energy needs was initiated. There were few studies on the wood-energy problem in the 1970s. Additional studies on the fuelwood problem in Kenya, however, appeared throughout the 1980s.

Organizations involved in planning and executing wood-energy programs include different government ministries and agencies and non-governmental organizations. The major government organizations include the following: Ministry of Energy and Regional Development (MOERD), Ministry of Environment and Natural Resources (MENR), Ministry of Agriculture (MOA), Ministry of Livestock Development (MOLD), Kenya Forestry Research Institute (KEFRI), Kenya Agricultural Research Institute (KARI), Permanent Presidential Commission on Soil Conservation and Afforestation (PPCSCA), and national universities. Non-governmental organizations include the Green-Belt Movement, CARE-Kenya, and Kenya Energy Non-Governmental Organizations (KENGO), among others. Most of these organizations have primarily pursued an agroforestry (production) approach to the fuelwood problem. Agroforestry addresses the supply side of the fuelwood shortage. The PPCSCA, KARI, KEFRI, KENGO, and CARE-Kenya all participate in programs that include multi-purpose tree planting. The Ministry of Energy and KENGO have also been actively involved with demand-side policies. Kenyatta University has a stove testing unit at its appropriate technology center while Moi and Egerton

Universities are involved in agroforestry teaching and research.

Agroforestry has emerged as a popular strategy of dealing with wood-energy deficits among farmers. The International Council for Research in Agroforestry (ICRAF) based in Kenya is an international agricultural research center. It has several field research sites in Kenya. ICRAF (1990) quotes Paul Harrison (author of The Greening of Africa) and agrees with his argument that: "Agroforestry is not only the most promising approach to reforestation and the supply of fuelwood, it is also, in yield-boosting forms like windbreaks and alley cropping, the most hopeful avenue for intensifying African agriculture over the next five to ten years, increasing food production and reducing exposure to drought with few or no outside or imported inputs. Agroforestry is arguably the single most important discipline for the future of sustainable development in Africa." Some reports suggest that agroforestry for fuelwood has not been very successful since private farmers place a higher priority on higher-value products such as building poles and pulpwood (Mercer and Soussan, 1992). Organizations promoting agroforestry need to appreciate its potentials and limitations.

The International Council for Research in Agroforestry was founded in 1977 and opened its headquarters in Nairobi, Kenya in 1978 (ICRAF, 1990). The primary objective of ICRAF was to support agroforestry research and disseminate agroforestry information among developing countries. In the mid-1980s, the objective was reviewed and more emphasis is now given to generating appropriate agroforestry technologies and strengthening national research capacity. In fulfilling its objectives, ICRAF hopes to increase the social, economic, and nutritional well-being of people in developing countries. In their combined efforts to increase the growing of multi-purpose tree species by farmers, all of these agencies are performing useful roles.

In 1981, the United Nations Conference on New and Renewable Sources of Energy was held in Nairobi, Kenya. The consensus at the conference and in subsequent policy discussions was that most developing countries would continue to rely heavily on wood for their domestic energy needs in the foreseeable future (Engelhard, 1992). Countries such as Kenya therefore needed to come up with appropriate institutions for formulating and implementing appropriate policies for new and renewable sources of energy. The new sources of energy included technologies such as methanol (a gasoline substitute) which had not been widely used in the past. Renewable sources of energy, on the other hand, included energy sources whose stock could be regenerated. Examples included biomass (fuelwood, charcoal, crop residues etc.), biogas, wind, and solar power. The new Ministry of Energy in Kenya was given the responsibility of exploring the potential of all these technologies.

The pursuit of new and renewable sources of energy has generally produced mixed results. Foley (1992) noted that many of the new and renewable sources of energy programs advocated and supported during the 1980s failed for various reasons. Failed programs included solar energy, small hydroelectric projects, biomass gasification, biogas, and ethanol production. Failure was mainly due to technical and maintenance problems, high costs, and unjustified pessimism about oil prices. He suggested that there is a need for greater rigor in economic and technical analysis. Wood-based energy technologies are low cost compared to many of the above technologies, and they are likely to succeed where many other technologies have failed.

Wood-based energy technologies have been actively supported by the Ministry of Energy and Regional Development. The Ministry has also provided a coordinating role for interested governmental and non-governmental organizations. Its role and that of the Ministry of Environment and Natural Resources were discussed in Chapter 1.

The Ministry of Energy and Regional Development came up with an agroforestry-based institutional development strategy in 1986 (MOERD, 1986). In 1980, it had requested the Beijer Institute of the Royal Swedish Academy of Sciences to perform a woodfuel cycle study to obtain some empirical data on the magnitude of the woodfuel crisis and to make suitable recommendations. The Institute recommended increased support of agroforestry programs, development and dissemination of efficient wood-burning and charcoal-burning technology, and development of new and renewable forms of energy (MOERD, 1986). Wood-energy production and consumption programs such as the Kenya Renewable Energy Development Project (KREDP), the Kenya Woodfuel Development Project (KWDP), and the Special Energy Program (SEP/GTZ) were direct results of the initial research studies and subsequent follow up.

Implications of Wood-Energy Shortages

On a national basis, wood-based fuels represent 75 per cent of the country's energy resource base. Among households, 95 per cent of the energy needs are met from woodfuels (Macklin, 1984); fuelwood and charcoal are the major woodfuels. Wood-energy shortages will create serious consequences (including nutritional problems) as rural populations grow.

Population growth rates have remained high in Kenya although they appear to be slowly declining (G.K., 1991). The estimated population growth rate between 1979 and 1989 was 3.34 percent. These high population growth rates may lead to greater pressure on wood energy stocks in many of the high potential areas.

Intensive agricultural activities and rapid population growth have greatly increased pressures on the land. Macklin (1984) reported that most of the high potential areas of the country tend to be net importers of woodfuels from surrounding areas. Many of those areas are ecologically delicate, and the environmental consequences of harvesting can be severe. Such consequences include deforestation, soil degradation, erosion, pollution of rivers, siltation of water reservoirs, and loss of economic opportunities for many communities.

In parts of Africa, lack of fuelwood has a very direct impact on human nutrition (Poulsen, 1978). Most staple foods such as maize, millet, sorghum, cassava and yams require prolonged cooking. The high costs of domestic energy may therefore affect the health of rural populations. In addition to the supply of more wood energy and substitutes, more research on crops that require less cooking time would be appropriate.

The Search for Solutions

In an overview of woodfuel supply and demand in Kenya, Buck (1980) summarized some important socioeconomic variables to be considered in research studies. The variables included land tenure impacts, resettlement programs, resistance to change, affordable energy alternatives, and different socioeconomic characteristics of households. These factors among others are examined in this strategy adoption study. Empirical evidence to explain the determinants of wood-energy consumption and production adoption among small-scale farm households is needed.

In the early 1980s Skutsch (1983) performed an evaluative study of village afforestation programs in Tanzania focusing on social and economic motivations behind successful and unsuccessful afforestation programs. Her principal findings were that: (1) people with acute firewood needs were keenly interested in establishing and maintaining woodlots, (2) people in the rural areas had substantial knowledge about tree planting and management, (3) extension services were not very effective in following up the work on trees planted, (4) transportation of seedlings to the planting sites in the planting seasons was often inadequate, and (5) that communal forestry projects needed to be more efficiently organized. The study did not include a sufficient analysis of economic factors that may motivate tree planting. Moreover, the socioeconomic conditions on communal farms in Tanzania were significantly different from any that one may observe in the high potential agricultural areas of central Kenya. The study nevertheless provided some general indicators on why people do or do not plant trees in light of official policies that encourage this activity.

Allen and Barnes (1985) performed a cross-national analysis of deforestation for 39 countries in Africa, Asia and Latin America for the period 1968-1978. They found that the past rate of wood production (which included tree cutting for fuelwood) was an important variable in understanding the rate of deforestation. The authors reported that the rate of deforestation in Kenya was estimated at 2 percent per year between 1976 and 1980. Excessive cutting of trees for fuelwood thus poses a serious environmental problem. French (1988) had a pessimistic view of deforestation in sub-Saharan Africa and argued that it can only be slowed down and cannot be completely halted.

Magrath (1984) reviewed some studies on the microeconomic aspects of agroforestry. He concluded that microeconomic studies of agroforestry in developing countries are very few and much more work needed to be done. Foley (1986) agreed with this view and argued that the economic analysis of the wood products consumer behavior is very important if the potential impacts of proposed policies were to be well understood. Research in this area is still inadequate and much more remains to be done.

Many individuals and organizations look at the wood energy problem from the physical supply side only. Bradley (1988) cautioned that domestic energy "development programs that stop at the mere provision of yet more trees fail to genuinely address the issue of woodfuel energy." The fuelwood problem is complex and requires a multifaceted and multidisciplinary approach at both the national and local levels. Mercer and Soussan (1992) concurred and noted that another supply-side policy has been the manipulation of fuelwood prices. Pricing policies seek to influence fuelwood supply by applying royalties and stumpage fees, as well as fuelwood taxes and subsidies. Fuelwood- and charcoal-pricing policies do not appear to have been widely used in Kenya. In the case of Village 1, fuelwood from national forests appeared to be heavily subsidized compared to fuelwood prices in transactions between farmers.

Between 1983 and 1986 the Kenya Woodfuel Development Project carried out studies on three high agricultural potential districts, namely, Kisii, Muranga and Kakamega (see Figure 1.3). The studies concluded that integration of wood production on the farm was complex and deeply rooted, that as population density increased, the quantity of managed biomass increased, and finally that the amount of land devoted to tree production appeared to increase as population density increased (Bradley, 1988). These somewhat surprising conclusions indicate that farmers do indeed respond to wood scarcity and higher prices associated with it. The response mechanism, however, is not well understood.

Fuelwood has become a market good in many of the high agricultural potential areas of Kenya (Ngugi, 1988). Ngugi's study was an attempt to explain how cultural factors have influenced the fuelwood shortage. The conclusion of the study was that the shortage was due to economic and social factors such as limited areas of farm land and increasing population. There is, however, no statistical analysis given to indicate the significance of different social or economic factors. In the Baringo Fuel and Fodder Project (BFFP) located in the semi-arid region of northern Kenya, past project failures have been attributed to the failure to consider local needs which are crucial in the adoption of any new practices (Hall et al., 1992). In the dissemination of technologies that address wood energy production and consumption, local needs and preferences must be taken into account.

Bhatia (1987) noted that reported wood energy consumption in areas with deficits tends to conceal the magnitude of the underlying shortages. Such shortages may be associated with insufficient local production, distributional constraints, low incomes, or government policies that are in place. Data on fuelwood production and consumption are also often poor for many developing countries (Onyebuchi, 1989). Kenya faces many of the above constraints and some of them are examined in this study.

In a study carried out in the Llocos Norte region of the Philippines, selected policy options related to fuelwood production and use were evaluated (Dixon, 1986). The study evaluated a government-sponsored tree planting project, the introduction of an improved wood stove, and the substitution of a traditional wood stove with a kerosene stove. The research was based on primary data collected through extensive surveys. A benefit-cost analysis framework was used to compare the policy options. The study explained some useful policy analysis methods that can be used in studying the fuelwood problem in Kenya.

Scherr and Muller (1989) noted that farmer surveys are an important method of assessing the adoption of agroforestry technologies. They also indicated that many unanswered socioeconomic questions on these technologies still remained. Avila (1990) concurred and also argued that one of the goals of on-farm research should be "to assess the impact of agroforestry technologies and to monitor and evaluate the way farmers adopt and modify them." Schultz (1964) argued that traditional farmers, though poor, are efficient in the allocation of available resources. If that argument is accepted, it can then be argued that the adoption of wood energy production and consumption strategies will be consistent with the resource endowment of the farmers other things being equal. The poorest may be expected to adopt only the most basic technology package if any at all, while wealthier ones can be expected to consider adoption of more advanced packages since they can bear greater risks. The larger socio-economic and bio-physical context within which the farmer operates is also important and is discussed in Chapter 3.

Summary

Fuelwood policy analysis is crucial for Kenya and other developing countries that are still heavily dependent on wood energy. As already mentioned, supply-side and demand-side policies must be comprehensively addressed. Supply-side policies include tree planting (e.g. large-scale plantations, social forestry, agroforestry, and natural forest management) and fuelwood pricing. Demand-side policies on the other hand include increasing the efficiency of wood energy use (e.g. fuel-efficient stoves, improved charcoal kilns) and the substitution of wood energy with modern fuels.

Mercer and Soussan (1992) noted some of the research gaps in the above policy issues. This study is designed to answer some pertinent questions related to the adoption of tree planting, fuel-efficient stoves, and wood energy substitutes. Other research concerns they noted include questions related to different fuels, lack of adequate data on demand and supply elasticities, foreign exchange needs, kerosene pricing policies, poor access or infrastructure in rural areas, and higher costs of the more efficient technologies.

This chapter has reviewed different research and development work carried out by various agencies as well as research that illustrates the importance of a study on the factors associated with adoption or non-adoption of wood-energy production and consumption strategies. Many studies indicate that improvements in the use of wood-energy production and consumption technologies offered to rural households in the 1980s can still be made. Swinkels and Scherr (1991) reviewed additional agroforestry and wood-energy related studies.

III. RESEARCH METHODS

In this chapter, the conceptual and analytical frameworks used in this study are discussed along with related literature. Sampling design, sample selection, parametric and non-parametric tests, the econometric model selection process, and details on probit analysis are presented. This information provides a theoretical background against which the determinants of adoption or non-adoption are evaluated.

Conceptual Framework

This study is based on the diffusion of innovations and utility maximization theories. Schultz (1964) described the small-scale farmer as a rational economic agent who attempts to maximize his or her utility in consumption subject to the resource constraints that he or she faces.

In positive economic analysis, a utility function is ordinal and can be replaced by any increasing transformation of itself (Layard and Walters, 1978). This implies that strategies or consumption bundles providing higher levels of satisfaction will be preferred to those providing less. This explanation of consumption is based on assumptions that: the decision maker is rational, he/she faces various constraints, and the individual's past experiences and societal preferences will influence his/her individual choice (Randall, 1987). Utility theory helps us to systematically and conceptually understand how individuals prefer one item over another. The utility derived from the adoption of a particular strategy will be expressed as a function of the characteristics of the strategy as perceived by the individual, and the socioeconomic characteristics of the individual.

Pharo (1982) evaluated the substitution potential of wood energy for other fuels among households and firms in the American economy. Firms seek to minimize costs and for any two fuels, cost is minimized when the marginal rate of substitution between them is equal to their price ratio. Utility theory was an underlying assumption in his analysis. The main objectives of the research were to: (1) evaluate cost efficiency of woodfuels before and after the Arab oil embargo, (2) evaluate the most efficient situations for woodfuels, and (3) make comparisons between costs and savings. Time series data of energy and prices over a fourteen-year period (1967-1980) were used. Only 21 per cent of the annual woodfuel supply potential was found to be economical for exploitation. Woodfuels were found to be marginally better substitutes for oil only after labor costs were disregarded. If labor costs were included, natural gas and coal appeared to be better substitutes after the oil crisis.

Peacock (1972) examined farmer adoption of new agricultural practices in Northeast Brazil using diffusion of innovation theory. He examined how different socioeconomic and personality variables affected the adoption of new agricultural practices. In this current study, both economic and non-economic variables are also considered in evaluating the determinants of adoption or non-adoption of different wood energy production and consumption strategies. Figure 3.1 illustrates the hypothesized household, environmental, and choice characteristics that influence adoption or non-adoption; it provides the conceptual model used in this study.

The attributes of the socio-economic environment include markets, infrastructure, research, extension, and land tenure. Household attributes include land, labor, capital, and farmers' goals. Examples of attributes of strategies include cost, efficiency, safety, and ease of use. The knowledge base (experiences) for old and new technologies is also important in deciding whether or not to adopt. Households are assumed to be utility maximizers in consumption and profit maximizers in production. The observed outcome is adoption or non-adoption of specific strategies. Variable relationships in the adoption process

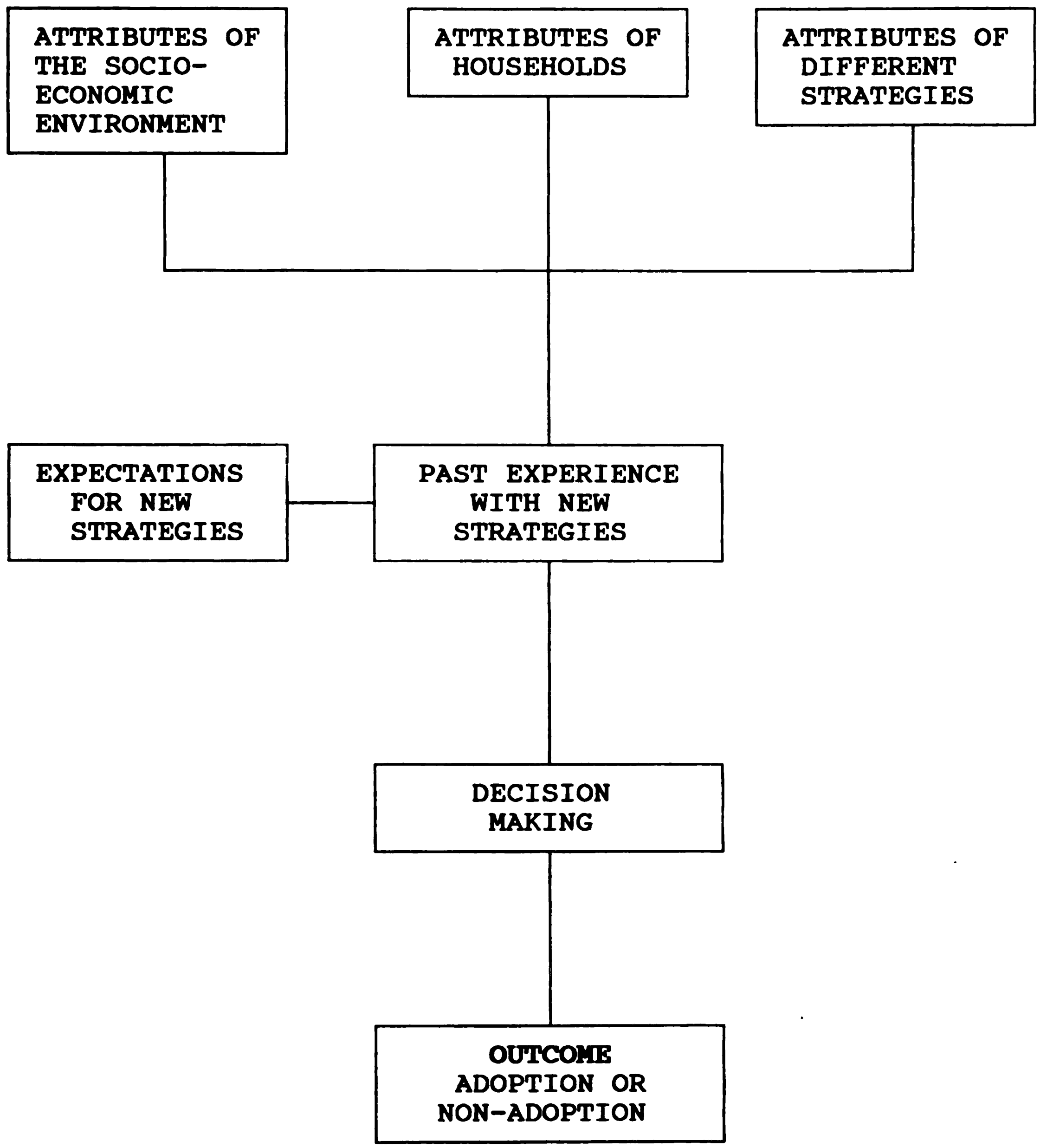


Figure 3.1 Flowchart of the adoption process

are dynamic and the temporal dimension of the adoption process is important.

Rogers (1983) described the theory on the diffusion of innovations in a comprehensive way. Innovativeness was described as the "degree to which an individual is relatively earlier in adopting new ideas than other members of his social system." Adoption or acceptance of various innovations was seen as emanating from interpersonal interactions at various social levels. The three major challenges in classifying adopters were noted as follows: (1) the number of adopter categories to conceptualize, (2) the proportion of members of society to be included in each category, and (3) the definition of the categories. Adopter categories need to be exhaustive, mutually exclusive, and based on one classificatory principle. Means and standard deviations have been used in developing what are often referred to as the ideal adopter categories (ibid.). The five ideal categories are: innovators, early adopters, early majority, late majority, and laggards.

The characteristics of an adopter of a particular strategy include socioeconomic, personality and communication behavior variables. Socioeconomic variables include age, education level, social status, resource ownership, and economic orientation. Personality variables include among others attitudes towards change, attitude towards education, fatalism and aspirations. Communication behavior variables include social participation in activities such as meetings and agricultural shows, contacts with change agents, exposure to the mass media, knowledge of innovations, and the degree of opinion leadership. These variables are included in the probit model specifications and are examined for household data in this study area.

Voh (1982) carried out a study on the adoption of recommended farm practices in a Nigerian village using stepwise regression analysis to calculate an adoption index. He obtained the following parameter signs for the variables studied: leadership role (positive), level of formal education (positive), level of literacy (positive), number of farm sites (negative), household size (negative), urban contact (positive), contacts with extension agents and various sources of advice (positive), empathy for others (positive), and involvement in non-farm occupations (positive). The statistically significant factors were leadership role, level of literacy, extension contacts, empathy, level of education, urban contact, additional occupation, and socioeconomic status, in that order. The model explained 32 per cent of the variability in adoption behavior. The first four variables explained 31 per cent of the variability. Voh concluded that it was important to investigate what the other significant variables might be.

Analysis Process and Model Specification

This study uses probit models to estimate adoption and non-adoption of household energy strategies. Probit models are based on probability units (Aldrich and Cnudde, 1975). The model selection process is explained further in the section on econometric models. Though model formulation occurs late in the analysis process (Figure 3.2), it affects the nature of questions in the survey and statistical tests. The survey conducted was used to obtain data on strategies and household wood-energy production and consumption characteristics.

Data relevant to the conceptual adoption process displayed in Figure 3.1 were collected. These data were then used for various statistical tests (e.g., mean differences and correlational analysis), model building and policy analysis.

The general specification of the probit model is as follows:

$$Y_i = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots + b_nX_n + e_i$$

where:

Y_i = 1 if a household has adopted strategy i (i=1,2,3,4), and 0 otherwise. i = 1 for adoption or non-adoption of fuelwood tree planting, i = 2 for adoption or non-adoption of the "Kuni Mbili" stove or fireplace, i = 3 for adoption or non-adoption of the Kenya Ceramic Jiko (Stove), and i = 4 for adoption or non-adoption of kerosene as a fuelwood

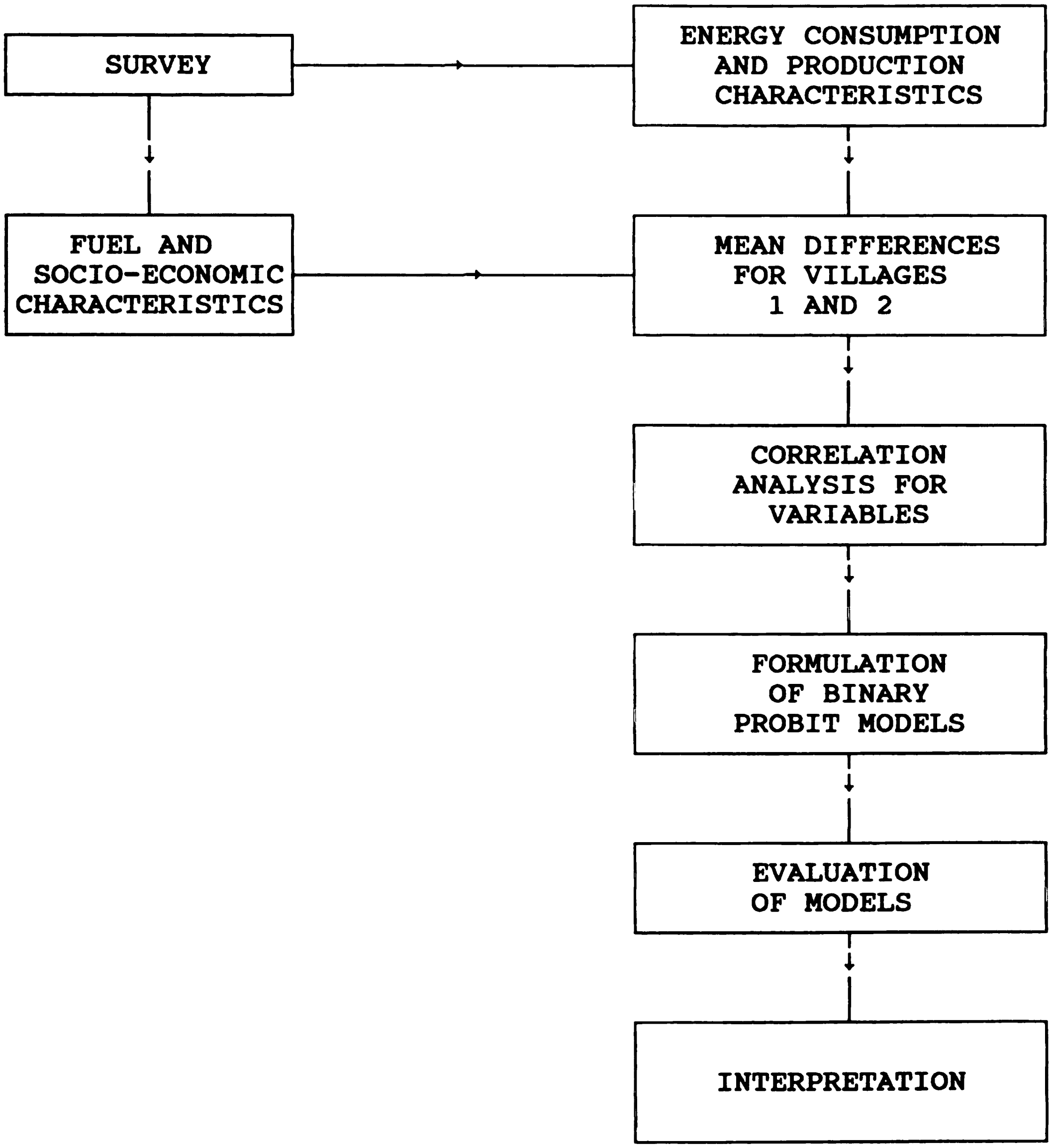


Figure 3.2 Flowchart of steps in the analysis process

substitute.

b_0 = intercept

$b_1 \ldots b_n$ = parameters

$X_1 \ldots X_n$ = independent variables that are associated with the probability of adoption or non-adoption of an individualstrategy. (Specific variables are presented in the variable selection section).

e_1 = error term

After data collection, parametric and non-parametric tests are used to determine whether or not the two villages are statistically different. If they are, village-specific models for wood energy production and consumption strategies will be developed. This can be accomplished by having individual models (e.g., Village 1-Kenya Ceramic Jiko) or by combining village data and using dummy variables (0, 1) to test village effects.

After estimation, the probabilities and response elasticities in probit models are evaluated at the mean values of the explanatory variables. Response elasticities represent the percentage change in the probability of adoption of a particular strategy as a result of a one percent change in the value of an explanatory variable (e.g., household income, age of the head of household, and educational level of the head of household).

Variable Selection

Based on studies by Voh (1982), Rogers (1983), Akinola (1987), Dennis (1990), Polson and Spencer (1990), and Hodges and Cubbage (1990) among others, the independent variables and a priori relationships shown in Table 3.01 were developed. Variable definitions are included as Appendix 1.

The primary attributes of an innovation thought to influence adoption include the relative advantages of the new innovation, compatibility with the existing social system, how complex it is to understand and use a particular innovation, whether an innovation can be tried on a limited experimental basis (trialability), and whether the results of an innovation are visible to potential adopters (observability). Rogers (1983) confirmed that these attributes were significant in many studies. Other studies such as Olson (1982) and Gottschalk (1982) generated consistent results. Olson investigated the adoption of statewide forest planning in Michigan while Gottschalk studied the diffusion of several educational and criminal justice programs. Besides the five primary attributes given above, there may be other special features that may facilitate or hinder the adoption of innovations. This study is primarily concerned with households as adopters of innovations.

The operationalization of innovation adoption as a dependent variable may take three forms (Downs and Mohr,

Table 3.01 Research variables and their expected relationship to adoption

Variable[a]	Expected Relationship to Adoption
Farm size (AREA)	+
Area under cultivation (AC91)	+
Net Area (NAREA)	+
Land tenure structure (TN1, TN2, TN3, TNP)	+ or -
Size of household (HSZ)	+
Age of head of household (AGE)	-
Educational level of head of household (EDH)	+
Income[b] (CREV, TREV, THHX)	+
Attitude of head of household towards the future, i.e. economic outlook (ECOU)	+ or -
Leadership position (LEAD)	+
Gender of head of household (GNDH)	+ or -
Contacts with extension services (EVPY)	+
Access to different sources of information (RHPD, NPPM, TVHPD)	+
Participation in agricultural shows and meetings (SH10, MTATT)	+
Attributes of the strategies (COST, CLEANLINESS, SAFETY, AVAILABILITY)	+ or -
Labor availability[c] (LBAV)	-

[a]See Appendix 1 for variable definitions and units of measure.

[b]Income variables were created from itemized lists of sources of income and expenditures that were developed in consultation with the small-scale farm households.

[c]Labor availability in man-days per year was computed by listing all persons working on the farm, number of hours spent working per day, and days per year worked.

1976). Binary (yes or no) answers can be used to categorize adopters and non-adopters. Second, the duration that a particular innovation has been used could also be used as a dependent variable that measures adoption. Finally, the extent of innovation adoption within a household or organization may also be used. The three dependent variables are conceptually different and the determining variables may also be different. In this study, a binary dependent variable is used. The rationale for this choice is presented under the model selection process in the section on econometric models.

In a recent study, Rauniyar and Goode (1992) examined the adoption of seven modern agricultural practices by small-scale farmers in Swaziland. The objectives of their study were to determine if the adoption of different practices is interrelated and to determine the nature of that relationship if it did exist. They treated adoption as a continuous variable. Factor analysis was then used to develop adoption indices. However, most technology adoption studies treat different technology choices as independent of each other. Similarly, this study treats the adoption of different strategies as being independent of each other.

As the research objectives indicate, the ultimate goal is to identify the predictors of adoptive behavior with regard to fuelwood production and consumption strategies. Rogers (1983) indicated methods used to predict innovativeness included multiple correlation, configurational methods, and probability models. As noted previously, this study uses a probability model in the prediction process.

Sampling Design and Procedures

Sampling Frame

For this study, the sampling frame was small-scale farm households in central Kenya. The primary data collection effort in the two villages was also complemented by secondary data from several public agencies such as the Central Bureau of Statistics (Ministry of Finance and Planning), the Ministry of Energy, and the Ministry of Environment and Natural Resources.

A simple random sample of households in each of the two villages was taken. The households of interest were the registered parcels in the study areas. The names of landowners were obtained from land registry and verified with cooperative society records. A simple random sample was drawn from each village using a random number table.

Survey Type

A cross-sectional survey was used. It was selected over trend, cohort, or panel surveys because of the time and resources available for the field work. A trend survey requires several measurements over time for the same general population. A cohort survey on the other hand draws new samples at different times from the same specific population. Panel studies involve studying the same individuals repeatedly (Finsterbusch, 1983).

Since the study was designed to investigate some strategies which have been in place for periods of up to ten years, an attempt to obtain some longitudinal data was made by asking questions about strategies and attitudes in the past. Answers to questions about the past may be less accurate than answers to questions about the present, but in the absence of good secondary data, this may be the only way to get a glimpse of the past.

Face-to-face interviews were used in this study. The low levels of literacy among the heads of households and the limited availability of telephones greatly reduced the potential for using telephone surveys, leave and pick-up questionnaires, and mail surveys. Face-to-face interviews are more expensive than; however, they generally ensure a higher response rate and better answers where questions are of a technical nature and may thus require further explanation.

Dillman (1978) described telephone and mail survey instrument design and discussed some points which are also important in face-to-face interviews. He stressed lowering the costs to respondents in terms of time taken, effort required, and psychological discomforts. An effort to maintain trust and anonymity was also required. These factors were given due consideration and the questionnaire was approved by the University Council for Research in Human Subjects (UCRHS) at Michigan State University as having taken the necessary precautions to protect the respondents (Appendix 2).

Survey Pretesting

The 43-question questionnaire (Appendix 3) was pretested in both villages. Each of the enumerators interviewed five households.[1] The responses were discussed intensively during the enumerator training sessions to ensure that they were all clear. Some questions were dropped while others were modified for clarity. Pretesting helped ensure that questions provided the information sought. For example, after finding that few households kept good records of incomes and expenses, it was decided that elaborate questions on monthly incomes and expenses be asked and used to compute the annual values needed for this study.

The training process involved several day-long meetings with all the enumerators over a period of two weeks. All questions were discussed with them to ensure they fully

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[1]Four enumerators were recruited in Village 1 and five in Village 2. Most of them were college students. A teacher and an agricultural extension agent were recruited as part of the Village 2 survey team.

understood the final version of the questionnaire. Several trips to the Ministry of Energy training center at Wambugu Farmers Training center near Nyeri town were made. They were designed to familiarize the enumerators with agroforestry and wood-energy technologies related to this study. The head of household was interviewed when he or she was present. If not available, the spouse was interviewed. If neither was available, the person who managed the farm on their behalf was interviewed.

Sample Size

The sample size selected was based on tests to be used, levels of significance desired, variability in the independent variables, funds available, and estimated incidence of different strategies in the population.

During the questionnaire pretesting stage, enumerators were asked to seek information on the proportion of households using different strategies. This figure was used to compute the minimum sample size required to meet the objectives of the study. Sample size selection guidelines provided by Cochran (1983) were used. The crucial steps in selecting the sample size are:

(1) developing a statement on our expectations from the sample

(2) finding some equation that connects the sample size with the desired precision level

(3) estimating the unknown parameters

(4) deciding whether to create subgroups and then pick subsamples among them with the sample size being the sum of the subsamples

(5) finding a method for reconciling the differences in the level of precision in measuring different variables

(6) evaluating the sample size to see whether sufficient resources are available to attain it.

The above steps were followed in selecting the sample size. A significance level of $\alpha = 0.05$ was selected. This significance level is consistent with other studies (Spector and Mazzeo,1980; Aldrich and Cnnude, 1975). The selected significance level allows a 1 in 20 chance of rejecting a true null hypothesis. A very low α would imply a large sample size. There is also an associated higher probability of accepting a false null hypothesis. The following sample size determination formula for $\alpha = 0.05$ was used (Cochran, 1977):

$$n = \frac{4PQ}{25}$$

where:

n = sample size

P = the expected percentage of adoption (based on pretests and secondary data when available) of a specific strategy in a village

Q = 1-P

$\sigma_p = \sqrt{\frac{PQ}{n}}$ (standard deviation of P)

Based on pre-test data and discussions with enumerators, the expected incidence of the "Kuni Mbili" stove/fireplace was used to estimate the appropriate sample sizes. The a priori expectation was that most rural households used at least the three-stone fireplace which could be replaced with a "Kuni Mbili" stove with a minimum investment cost. This strategy was therefore used as a baseline against which the adoption of new technologies was evaluated. For Village 1, P was estimated at 10 percent and Q at 90 percent. The estimated sample size was therefore 144. In Village 2, P was estimated at 11 percent and Q at 89 percent. A sample size of 157 was therefore estimated. In the actual study, samples were slightly larger.

Finsterbusch et al. (1983) suggested that samples of 40 to 80 could provide useful information on population characteristics and attitudes if used cautiously. He further noted that such relatively small samples may be sufficient if the study is not going to play a critical role in the decision-making process. For this study, simple random samples of 145 households in Village 1 and 161 households in Village 2 were selected. Within each village, all registered land parcels had equal probabilities of being selected as part of the survey sample.

The original number of households settled in Village 1 in 1962 was about 270. At the time of the survey (July-

September, 1991), there were 324 registered land parcels. This increase has been due to subdivisions of the original parcels either for sale or for distribution to children of the original settlers. There are also landless households that live in the village. The dairy marketing cooperative records listed a total of 558 members. This figure included the following: households that had been allowed by landowners to live on their land and derive a livelihood either partially or completely outside their farms, households of employees of the landowners, and households of relatives of the landowners. The official 1979 census figures indicated a total of 469 households and a population density of 217 people per square kilometer (G.K., 1980). The 1989 census results had not been published at the time of this study.

In Village 2, land registry records indicated a total of 565 land parcels. As in Village 1, this number only included the registered landowners. Landless households are also present in Village 2 as indicated by census figures. In 1979, there were 338 households and a population density of 368 people per square kilometer in the village (G.K., 1980). The number of households during the 1989 national census had not been published at the time of this study.

In designing the questionnaire, the guidelines provided by Finsterbusch et al. (1983) and Yambo (1982) were followed to the extent possible. The guidelines recommended clear, specific, short, closed-ended, positive, objective, comfortable and appropriate questions.

Administering the Survey

The 43-question questionnaire required an average of one hour to complete. Sometimes the questioning took longer since farmers wanted to explain some aspects of the problems they faced in greater detail. In some cases, they would invite the enumerators to observe the trees they had planted as well as the cooking stoves that they were using. The heads of households, their spouses, or their representatives were available in nearly all cases. Repeat visits were made as necessary to ensure that the appropriate individuals were interviewed.

Data Entry and Initial Analyses

Computer coding and data entry was done after the survey was completed. QUATTRO PRO 3.0 spreadsheets were used for data entry (Borland International, 1991). PARADOX 3.5 was used as a database management tool (Borland International, 1990). SYSTAT 5.0 was used for statistical analysis (Wilkinson, 1990). SYSTAT Probit (Version 1.3) was initially used in model formulation (Steinberg, 1988). At a later stage in the analysis, a switch was made to LIMDEP, Version 6.0 (Greene, 1992). The reason for the switch was that LIMDEP was more effective in calculating partial derivatives needed to estimate the elasticities at the mean values of independent variables. LIMDEP also generated a cross-tabulation of correct versus incorrect predictions as well as other measures of goodness of fit. The likelihood ratio test was used as the measure of the goodness of fit for probit models. Cross-tabulation provided a useful insight to the models' predictive power. Results from LIMDEP and SYSTAT were otherwise consistent.

The two villages were expected to be different in a number of parameters, hence, the selection of independent samples from each village. Prior to any model building, tests were run to establish whether the two villages were statistically different. The parametric t-test and the Mann-Whitney U test were used; these are discussed in the next section. For many of the important variables, the two villages were statistically different. Therefore, they were treated as different populations for the purpose of this analysis.

Summary of Survey Efforts

The population under study was defined as the households of small-scale agricultural landowners in the high potential areas of central Kenya. Village 1 and Village 2 were selected to capture the diversity of wood energy sources (national forests versus privately grown trees) and the different impacts of fuelwood shortages in the region. Within the high agricultural potential zone of central Kenya, Village 1 is similar to other villages which have been settled since independence in 1963 whereas Village 2 represents an older, more established village. Accessibility and expected support from local administration officials were also considered. Random samples were selected in the above context.

A concise definition of the sampling frame and the selection of a random sample reduced the possibility of a sampling bias. Subjective sampling leads to a sampling bias and this makes it difficult to statistically interpret the data (Hammond and McCullagh, 1978). A sampling bias is the difference between the expected value of the population estimator and the population quantity being estimated.

The questions used in the survey were clarified as needed following the pretest to eliminate any biases that may have resulted from instrument design. Another potential source of bias is where a substantial difference between the sampled and target population exists. Care was taken to ensure that the lists used did not exclude certain sections of the population that should have been a part of the sampling frame. Non-land owners were not considered part of the sampling frame for the purposes of this study. The principal focus was on land owners who had more latitude in making land-use decisions (e.g., planting trees). Moreover, collecting information on landless residents would also have immensely increased the cost of the study since no previous lists existed. In determining the technologies used for cooking and heating, the sampled households were asked to answer some questions on technologies used by other households living on their land. A future study designed to evaluate technology adoption by households that do not own land can take care of this limitation. Non-response can be another source of bias if it is extensive. Face-to-face interviews were used, and non-response was not a major problem.

Parametric and Non-parametric Tests

In testing the stated research hypotheses (see Table 3.1), a significance level of $\alpha = 0.05$ was selected. Appropriate statistical tests are selected to determine the probability that the problem data may have been a chance phenomenon under the null hypothesis. If the probability is less than the selected α, the null hypothesis is rejected at the specified significance level.

Hammond and McCullagh (1978) noted three important considerations in the selection of statistical tests for research hypotheses. They are: (1) data characteristics, (2) relative cost-effectiveness of different tests, and (3) assumptions made about the background populations from which the data are derived. The data collected in this study included nominal, ordinal, interval and ratio measurement scales. Data on interval and ratio scales can be subjected to more powerful tests (e.g., the parametric t-test) than data on nominal and ordinal scales. Assumptions on the background populations determine whether parametric or non-parametric tests are used. The Mann-Whitney U-test is the non-parametric equivalent of the t-test. It possesses about 95 percent of the power efficiency of the t-test.

Parametric tests can only be applied to data that are at least on an interval scale. The principal assumption in these tests is that the background population is approximately normally distributed. If a small sample size (less than 30) is to be used, it is required that the population be nearly normal. The t-test, which is the most power-efficient test, is used in the hypotheses tests when normal distribution can be safely assumed.

Normal distribution is completely determined by two parameters; the mean and the standard deviation. The reasons for its use include the following: (1) it is extensively and accurately tabulated, (2) some variables are approximately normal, (3) simple transformations may induce normality for other variables, and (4) repeated samples yield normally distributed values (Central Limit Theorem). In this study, the SYSTAT Lilliefors chi-square goodness of fit test was used to test for normality (Wilkinson, 1990). It standardizes the variables and tests whether the standardized versions are normally distributed and then examines whether the observed distribution in the sample is likely to be different from a normal distribution. The variables' original means and standard deviations do not affect the test. The distributions of research variables were not significantly different from normal in either village. Therefore, variable transformations were not necessary.

Non-parametric tests are also referred to as distribution- free tests. They make no assumptions on the distribution of the background population and typically use some simple aspects of the sample data such as signs of the measurements, order relationships, and category frequencies. When the sample size is small or moderate, it is best not to assume normality unless overwhelming evidence to the contrary exists. As the sample size increases, there is a tendency towards normality. In a study on income distribution in central Kenya, Kmietowicz and Webley (1975) found that income had a log-normal distribution. A prior assumption that income was normally distributed may have led to misleading analysis if parametric tests only were used. Using non-parametric tests or otherwise transforming such variables improves the analysis. As mentioned above, data transformation was unnecessary in the current study.

Some of the variables in this study are difficult to measure on meaningful numerical or ratio scales (e.g. attitude towards tree planting, preferences for specific methods of cooking, etc.). Appropriate non-parametric tests in this study include the binomial test for differences of proportions or numbers, sign tests, and the Mann-Whitney U test. More details on specific tests are provided in Chapter 4.

Econometric Models

Econometric models provide an empirical content to economic relationships. The model-building process seeks to develop models that adequately characterize a given data set. The first step is to assume a set of models which are all equally probable (Grasa, 1989). The true model M is "a member of a class of models M such that the distributional characteristics prescribed by M on a given population P are the same as those generated by P (Grasa, 1989)." The econometric model selection process thus involves looking at a wide range of models that may be applicable and then narrowing down the choices based on research hypotheses and population characteristics. Specification errors may result from omitted variables and inclusion of irrelevant variables (Greene, 1991).

The probable models for this analysis include ordinary least squares regression, linear probability models, binary choice models (probit and logit), and models with limited dependent variables (Tobit) (Maddala, 1983; Greene, 1991). Discriminant analysis may also be used but it is more appropriate for generating rather than testing hypotheses (Johnston, 1980). Factor analysis could also be used (Rauniyar and Goode, 1992).

The ordinary least squares regression model can be specified as follows:

$Y = XB + e$

where:

Y = an $n*1$ matrix of dependent variables,

X = an $n*k$ matrix for n observations and k independent variables,

B = a $k*1$ matrix of unknown parameters, and

e = random disturbance term.

e is $N(0,\delta^2)$ and $\text{Var } e = E[ee'] = \delta^2 I$.

The general linear model above assumes that: there is no multi-collinearity, e_i is white noise with mean zero, the random part is independent of the random regressors, and the vector e has an n-variate normal distribution. The parameters of the model are calculated using the formulae shown.

$B = (X'X)^{-1} X'y$

$\delta^2 = e'e/n-k$

where:

$e = y-X(X'X)^{-1}X'y = (I-X(X'X)^{-1}X')y = My$,

$M = I-X(X'X)^{-1}X$,

(M is a symmetric idempotent matrix which premultiplies any vector y to produce the vector of least squares residual in the regression of y on X).

I = an identity matrix,

X = a matrix of independent variables, and

y = a vector of dependent variables.

In a situation where the dependent variable can only take two values, the models described later are superior to the general linear model. The general linear model analyzes one dependent variable at a time. For example, in a study where the dependent variable is the adoption of a specific technology, the general linear model can be misleading since it is based only on individuals who had adopted. In so doing, current non-adopters are excluded from the analysis. Non-adopters should be viewed as displaying rational market behavior which also needs to be explained. Leaving them out could lead to an omitted variable problem.

The variables examined in this study relate to whether an innovation is accepted or rejected. Judge et al. (1988) noted that "questions about whether to produce or consume rather than how much to produce or consume" are of great interest to the economist. This study is concerned with such questions. The research interest is in modeling choice behavior of small-scale farm households when they are faced with the decision of whether or not to adopt a particular wood-energy production or consumption strategy.

The strategies evaluated are the adoption or non-adoption of: (1) fuelwood tree planting, (2) the "Kuni

Mbili" fireplace, (3) the Kenya Ceramic Jiko, (4) kerosene as a wood-energy substitute, and (5) electricity as a wood energy substitute. Some farmers were also found to be using innovative strategies such as liquid petroleum gas, solar power, and sawdust stoves. The numbers were however too small to allow adequate statistical analysis of the users. A general discussion of such cases is presented in Chapter 4 and is based on the average characteristics of those households.

The linear probability model is considered to be computationally simple and has been used in a variety of studies (Amemiya, 1981; Debertin et al., 1980). Like other binary choice models, let Y_i be a binary dependent variable with Y = 1 for adoption (e.g., if the Kenya Ceramic Jiko (KCJ) has been adopted), and Y = 0 for non-adoption (e.g., if the KCJ is not adopted). If there are 145 observations (i = 1,2, ..., 145) as in Village 1, the model is set up as below.

$$Y_i = X'_i B + e_i$$

where:

(1) Y_i is a Bernoulli random variable, and

$E[Y_i] = Pr[Y_i = 1] = X_i'B$.

Since $X_i'B$ is unbounded, the model can generate probabilities outside the unitary range. Such probabilities can not be logically interpreted.

(2) The disturbance term e_i can only take two values since

Y_i can only take two values.

$E[Y_i] = X_i'B$,

$e_i = 1 - X_i'B$ with probability $X_i'B$ when $Y_i = 1$

$(Y_i = 1 \Rightarrow 1 = X_i'B + e_i \Rightarrow e_i = 1 - X_i'B)$, and

$e_i = -X_i'B$ with probability $1 - X_i$ when $Y_i = 0$

$(Y_i = 0 \Rightarrow 0 = X_i'B + e_i \Rightarrow e_i = -X_i'B)$.

(3) e_i is heteroscedastic since $\text{var}(e_i) = E[y_i](1 - E[y_i])$. The variance of the error term varies systematically as independent variable values change.

It has also been argued both theoretically and empirically that the diffusion of innovations has a curvilinear relationship (Akinola, 1987). The above features of the linear probability model make it unsuitable for this study. Models that can overcome its problems can be developed.

Logit and probit models are alternatives to the linear probability model. The logit model assumes a logistic cumulative distribution function in the error term which is specified as follows (Kmenta, 1986):

$$F(\alpha + \beta X_i) = \frac{1}{1 + e^{-\alpha - \beta X}}$$

As in the case of linear probability models, the binary dependent random variable is assumed. Multinomial cases (more than two dependent variable categories) can be developed for both logit and probit models. Logit models have been used widely in biological sciences and in econometrics. Some studies which use logit models include Beggs et al. (1981), Bagi (1983), Capps and Kramer (1985), Hodges and Cubbage (1983), Lee and Stewart (1990), Teachman and Polonko (1988), Park and Kerr (1990), and Mitchell and Preissler (1991).

In binary choice models, it is assumed that the attributes of a particular choice and the households socioeconomic characteristics determine the average utility derived from adopting particular strategies. For example, a small scale farm household's decision to use firewood or kerosene, may be influenced by the attributes of the fuel (e.g. cost and perceived safety) and also by the attributes of the individual (e.g. income, age, and educational level).

A binary-choice, probit model is used in this study. Following Dennis (1990) and Skog (1986), it can be assumed that households seek to maximize expected utility in choosing different strategies. The utility derived from the choice of a particular strategy was expressed as follows:

$$U_{io} = U_{io} + e_{io} = a_o + Z_{io}b + W_ic_o + e_{io}$$

$$U_{i1} = U_{i1} + e_{i1} = a_1 + Z_{i1}b + W_ic_1 + e_{i1}$$

where:

i = household = 1, 2, 3, ..., I,

1 = choice to adopt is made,

0 = choice to adopt is rejected,

U_{io} = utility derived by household i from choice 0,

U_{i1} = utility derived by household i from choice 1,

Z_{io} = vector of characteristics of alternative 0 as perceived by household i,

Z_{i1} = vector of characteristics of alternative 1 as perceived by household i,

W_i = a vector of socioeconomic characteristics of the i^{th} household,

a, b, and c express the relationship between utility and associated attributes,

e_{io} = random disturbance term,

e_{i1} = random disturbance term, and

U_{io} and U_{i1} are random.

Household i makes choice 1 if $U_{i1} > U_{io}$ or if the unobservable random variable $Y_i^* = U_{i1} - U_{io} > 0$. Y_i is the observable random variable, where:

$Y_i = 1$ if $Y_i^* > 0$

$Y_i = 0$ if $Y_i^* \leq 0$

$$Y_i = (Z_{i1} - Z_{io})'b + W_i\,(c_1 - c_o) + (e_{i1} - e_{io})$$

$$= [(Z_{i1} - Z_{io}),\ W_i] \begin{bmatrix} b \\ c_1 - c_o \end{bmatrix} + e_i^*$$

$$= X_i'B + e_i^*$$

The probability distribution of the error term (e_i^*) may take different forms, and the assumptions made determine the model choice. A probit model assumes standard normal errors, and a logit model assumes logistic error terms. Linear probability models, however, assume uniform distribution of the error terms (Maddala, 1983).

The cumulative distribution function for the standard normal distribution, which is used in the probit model, is specified as follows (Kmenta, 1986):

$$F\ (\alpha + \beta X_i) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\alpha + \beta X} e^{-w} dz_i$$

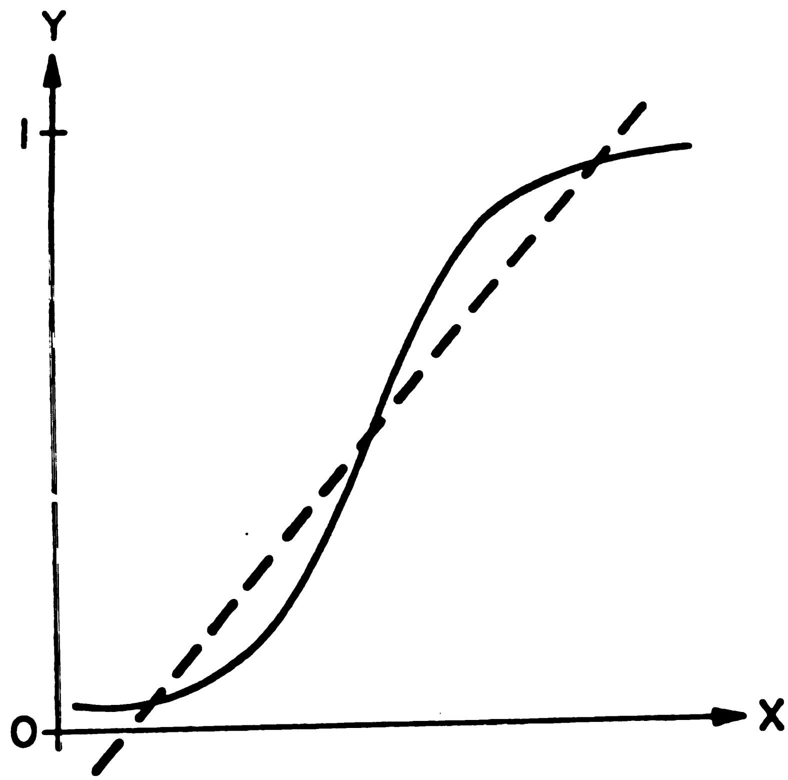
where $w = Z_i^2/2$

Both probit and logit formulations have an S-shaped distribution. Figure 3.3 illustrates their difference with the straight line formulation used in ordinary least squares regression.

Dennis (1990) carried out a study on forest harvest decision making by non-industrial private forest owners in New Hampshire and used a probit analysis to estimate the probability of timber harvesting given the attributes of a forest, the owner, and socioeconomic variables. Skog (1986) carried out a study on factors influencing county-level household fuelwood use in the United States. A probit model was developed to explain the probability of households using wood with certain socio-economic characteristics and located in given environments.

Purnama (1990), used Tobit analysis to study household energy consumption in Java, Indonesia. The model estimated the probability of a household selecting a particular type and amount of energy. His results indicated that it would be feasible to encourage alternative fuels and reduce the

Figure 3.3 Comparison of ordinary least squares estimate and "typical" S-shaped relationship with a dichotomous dependent variable



Source: Aldrich and Cnudde, 1975.

use of fuelwood. Tobit models are useful in specifying quantities and probabilities of various possible outcomes. The current study confines itself to questions of whether or not certain strategies are adopted and does not therefore use the Tobit analytical framework.

The policy question for Kenya relates to increasing fuelwood production while also complementing these efforts with other strategies that lead to more efficient wood-energy use. Various fuelwood substitutes are considered.

The choice between probit and logit models appears to be largely a matter of the researcher's preference. Kmenta (1986) noted that the two models are similar when we are considering dichotomous dependent variables. This is the situation in the present case where we are interested in whether a wood energy production or consumption strategy is adopted or not. Results can however be significantly different if we are considering more than two dependent variables (Hausman and Wise, 1978). Such cases are referred to as multinomial models. Parameter estimates may also differ if a lot of observations are at extreme probability values (Aldrich and Nelson, 1984).

Sellar et al. (1986) used a logit model in a contingent valuation study of the demand for recreational boating (a non-market good) in Texas. They argued that the logit was simpler to estimate and compared well with the probit. The logit model assumes independence from irrelevant alternatives in a multiple-choice situation.

Probit and logit models can provide useful policy analysis information on the probabilities of adoption or non-adoption of various strategies. After evaluating the range of models that could be used in this study, probit models appear to be best suited for the analysis. In summary, they are appropriate for the following reasons: (1) the dependent variable is conceptualized as a binary choice, (2) the attributes of households and different wood energy production and consumption strategies can be observed or derived, (3) the calculated probabilities are bounded between 0 and 1, (4) they compel the error term to be homoscedastic, (5) they generally require fewer observations than logit models, and (6) the probit model is effective even when strategies are close substitutes.

The probabilities in probit models are commonly evaluated at the mean values of the explanatory variables. The effect of a unit change in an explanatory variable on the probability of adoption depends on the specific value of the explanatory variable under consideration (Gunderson, 1974).

Response elasticities for any changes in the explanatory variables can also be calculated. They represent the percentage change in the probability of adoption of a particular strategy as a result of a one percent change in the value of an explanatory variable.

The elasticity is usually evaluated at the mean value of the explanatory variable.

The coefficients in probit models indicate the effects of changes in the independent variables on $F^{-1}(P_i)$. P_i is the probability of adopting strategy i. The coefficients can not be interpreted directly like those in the OLS model (Aldrich and Nelson, 1984). Instead, coefficient signs, significance level, and elasticities are used. Initial values of the independent variables and coefficients determine the magnitude of change in the probabilities. The following relationships illustrate this:

$$P_i = F(X_i'B)$$

$$X_i'B = F^{-1}(P_i)$$

$$\frac{\partial P_i}{\partial X_{ik}} = F(X_i'B)$$

where:

P_i = probability of adopting strategy i,

F = probability density function,

X_i' = vector of independent variables,

B = matrix of parameters to be estimated,

k = index of independent variables, and

$\frac{\partial P_i}{\partial X_{ik}}$ = response elasticity for independent variable

An iterative process was used in determining the variables that would remain in the final models reported. The testing process began with an examination of the *a priori* expectations presented in Table 3.1 and correlation analysis. The variables retained in the final models were those that either had strong a priori expectations or relatively high t-statistics for the independent variables.

The goodness of fit for the models developed may be measured by the likelihood ratio test, MacFadden's R^2, the log-likelihood function, or the percentage of correct predictions (Aldrich and Nelson, 1984; Polson and Spencer, 1990). If desired the coefficients of linear probability, logit, and probit models can be transformed in order to make them comparable (Kmenta, 1986).

Summary

This chapter has presented the conceptual and theoretical foundations upon which this study was based. Sampling, survey administration, model selection, and variable selection were also discussed. The merits of using probit analysis over other techniques was presented. Different software packages that may be used to carry out the analysis were also described.

IV. RESULTS AND DISCUSSION

This chapter presents the results of specific parametric and non-parametric tests used to examine differences between villages and between adopters and non-adopters. Then, probit models based on factors hypothesized to influence adoption or non-adoption of different strategies are presented. The process of statistical inference from LIMDEP output is also described. Finally, the significance of the models is discussed.

Tests for Mean Differences

To determine whether there were statistical differences between Village 1 and Village 2 and between adopters and non-adopters, the parametric t-test and the non-parametric Mann-Whitney U-test were used. SYSTAT was used for this part of the analysis.

The data being analyzed were unpaired measurements on different scales. In comparing two sets of data, the t-test for independent samples is appropriate for data on interval and ratio scales. The Mann-Whitney test is more appropriate for categorical data (Hammond and MacCullagh, 1978).

The t-test is the most widely used and is the standard against which the power efficiency of other tests is measured. The t-test assumes that background populations from which the samples are taken are normally distributed and that the standard deviations are equal. To test the normality assumption, the Lilliefors Chi-square test for normality was applied to different variables (Wilkinson, 1990). The analysis indicated that the distribution of the variables used for the t-test was not significantly different from normal at $\alpha = 0.05$.

The null hypothesis was that there was no difference between the means of the populations of which Village 1 and Village 2 were samples. The selected level of rejection was $\alpha = 0.05$. The two-tailed critical t-value for large samples at that rejection level is 1.96. The null hypothesis of no difference in the means is rejected for all values of t above the critical value.

The Mann-Whitney U-test, on the other hand, is one of the most powerful distribution-free tests and has close to 95 percent of the power of the parametric t-test. It also works well with small, medium, and large samples. The test makes no assumption about the characteristics of the distribution. The test can also be used with categorical data. It examines whether the differences in the means of two independent samples are statistically significant. The U-statistic is calculated by considering sample sizes and scores from two samples as a single set and then ranking the entire group from lowest to highest. If the null hypothesis of no mean difference is true, the observations from the two samples should be fairly well mixed. Conversely, if the two samples are from different populations, observations from one sample will be banded together. A rejection level of $\alpha = 0.05$ was also used in this case.

Discussion of Mean Difference Results

Village Comparisons

In the initial selection of the two villages, it was hypothesized that they were different in a variety of important parameters such as income, wood energy availability, development of rural infrastructure, and duration of settlement. Before probit analysis for the two villages could be done, it was necessary to establish whether the villages were statistically different. Such a difference would justify the running of separate probit models for the two villages or including a village dummy variable in combined data models.

Table 4.01 shows a comparison of mean values using the parametric t-test. In the t-test, significant differences were observed for area of land owned (AREA), total revenue (TREV), crop revenue (CREV), age of the head of household (AGE), extension agent visits to the farms (EVPY), household size (HSZ), hours spent listening to the radio (RHPD),

Table 4.01 Comparison of mean values using the parametric t-test

Variable[a]	Village 1 Means	Village 2 Means	t-statistic
AC91	2.80	2.47	1.94
AREA	9.63	4.65	5.37*
CREV	40033.03	23235.34	5.20*
FIC	15093.23	9155.19	4.61*
SAVINGS	5579.15	1261.44	0.99
TEXP	35295.32	28050.86	3.26*
THHX	20751.54	18895.67	1.15
TREV	41400.62	29312.29	3.22*
AGE	54.68	49.31	3.46*
EDH	5.95	4.86	-0.30
HSZ	5.16	6.24	-3.72*
TIC	3.08	1.51	7.50*
TIM	24.90	23.23	1.11
EVPY	4.86	9.66	-4.15*
RHPD	2.54	3.55	-4.00*
SH10	2.66	2.17	1.31
CCBM	0.95	0.41	6.25*
CGAM	0.04	0.08	-1.26
CRHM	0.86	10.20	-9.29*
FWHM	12.10	14.76	-6.15*
KELM	7.25	5.94	1.49

* Significant at $\alpha = 0.05$

[a] See Appendix 1 for variable definitions.

Table 4.01 (continued)

The variables above are grouped as follows:
1. Farm Area--AC91, AREA
2. Financial Information--CREV, FIC, SAVINGS, TEXP, THHX, TREV
3. Household Characteristics--AGE, EDH, HSZ, TIC, TIM, DSHH
4. Exposure to Information--EVPY, RHPD, SH10
5. Fuel Quantities Used per Month--CCBM, CGAM, CRHM, FWHM, KELM

headloads[2] of fuelwood and crop residues (FWHM and CRHM), bags of charcoal used monthly (CCBM), farm input costs (FIC), and time spent in collecting fuelwood (TIC). Variables not significantly different included area under cultivation (AC91), level of savings (SAVINGS), total household expenditure (THHX), years of formal education received by head of household (EDH), number of years the family has been settled on the land (TIM), attendance to agricultural shows in the preceding ten years (SH10), cylinders of gas used per month (CGAM), and liters of kerosene used per month (KELM).

The average area of farm land owned (AREA) is 9.6 acres in Village 1 and 4.7 acres in Village 2. The former is a resettlement scheme created about thirty years ago while the latter village has been settled for many generations. In both villages, population has grown over the years and land

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[2]A headload is the quantity of fuelwood that can be conveniently carried on the back from the source to the home where it is eventually used. This task is almost always performed by women. Average headload size may vary with age of the person, as well as the species and condition of the fuelwood.

parcels are relatively small.

Crop revenues (CREV) are statistically different. Coffee and tea are the main crops for Village 2, and the world market prices for them have been fairly low during the last few years. Village 1, on the other hand, depends on horticultural and dairy products and the households appear to be doing relatively well. Total revenues (TREV) are also significantly different for the two villages at the specified level. Farm input costs (FIC) are, however, significantly different and this is probably a reflection of the different input (land, labor, capital, and technology) requirements for coffee, tea, horticulture, and dairy production. The total household expenditures (THHX) are not significantly different, and this appears to indicate that consumption levels are fairly similar.

There are several differences related to fuel usage. Village 1 has more physical access to fuelwood but uses fewer headloads of fuelwood per month (FWHM) on average compared to Village 2. However, it (Village 1) does use more charcoal bags per month (CCBM) than Village 2. These differences are examined further in probit analysis. More headloads of crop residues per month (CRHM) are used in Village 2; this is probably associated with the relative costs of alternative fuels. Tea and coffee twigs from annual pruning are also used. Households in Village 1 spend twice as much time in collecting (TIC) a headload of fuelwood compared to Village 2. This probably reflects the distances that have to be travelled to collect fuelwood from national forests. For Village 2, access to fuelwood from national forests is limited.

Results of the Mann-Whitney U-test are presented in Table 4.02. The U-statistic revealed further significant differences between the villages in the percentage of households adopting the Kenya Ceramic Jiko (KCJU), use of the traditional metal stove (TMSU), land tenure categories (TN1, TN2, TN3 and TNP), use of the "Kuni Mbili" stove/fireplace (KUMU), and use of kerosene stoves (KESU). The Kenya Ceramic Jiko is used by 43 percent of the households in Village 1 and only 4 percent of the households in Village 2. Households in this village may be responding to higher prices of charcoal compared to prices in Village 1. Village 2 appears to use the "Kuni Mbili" fireplace more than Village 1. In relative terms, this probably reflects the greater scarcity of fuelwood in Village 1.

Tree planting activities (TPHSIO) in the two villages during the preceding ten years (1982-1991) were also significantly different. Forty-five percent of the households in Village 1, and 20 percent in Village 2 reported having planted multi-purpose trees during the specified period. Village 1 was established as a resettlement scheme and most of the households are first

Table 4.02 Comparison of mean values using the U-test

Variable[a]	Village 1 Means	Village 2 Means	U-statistic
FUKE	2.77	2.68	12741.0
FUGA	2.88	2.91	11421.0
FUFW	1.03	1.14	10893.0*
FUEL	3.00	2.98	11817.5
FUOT	2.94	2.98	11573.0
FUCR	2.08	2.34	8711.0*
FUCC	2.06	2.65	5316.0*
TPHS10	0.45	0.20	14585.0*
KUMU	0.15	0.26	10390.5*
ELEU	0.00	0.01	11527.5
SDSU	0.00	0.04	11237.5*
OTHU	0.04	0.09	11140.5
TSFU	0.88	0.83	12181.0
KCJU	0.43	0.04	16236.5*
KESU	0.08	0.27	9521.0*
TMSU	0.63	0.37	14801.0*
DSHH	2.27	1.99	12875.5
LEAD	0.46	0.33	13223.5*
TN1	0.88	0.32	18126.0*
TN2	0.02	0.36	7709.0*
TN3	0.10	0.32	9110.0*
TNP	0.08	0.14	11043.5

* Significant at $\alpha = 0.05$

[a] See Appendix 1 for variable definitions
The variables above are grouped as follows:

1. Fuel Used by Households--FUKE, FUGA, FUFW, FUEL, FUOT, FUCR, FUCC
2. Cooking and Heating Technologies used by Household--KUMU, ELEU, SDSU, OTHU, TSFU, KCJU, KESU, TMSU
3. Household Characteristics--LEAD
4. Land Tenure Structure--TN1, TN2, TN3, TNP

generation farmers and have full private ownership rights over their land. Full-land ownership rights are very important in making long-term management decisions such as tree planting. Only 10 percent of the households in Village 1 had restricted land ownership rights (TN3, inherited but still shared) as compared to 33 percent in Village 2. Households in Village 2 cited land shortage as a major constraint to their tree planting.

Table 4.03 shows the adoption rates for different strategies in the two villages. The adoption rate for the Kenya Ceramic Jiko in Village 1 is 43 percent and 4 percent in Village 2. Average charcoal prices are significantly different in the two villages. At least one trader in the main shopping center in Village 1 had a large stock of KCJ for sale. Village 2 households used an average of 0.41 bags of charcoal per month (CCBM) as compared to 0.95 bags per month for Village 1. In Village 1, 88 percent of the households reported using the three stone fireplace (TSFU) and 63 percent the traditional metal stove (TMSU). The corresponding figures for Village 2 were 83 percent for the three stone fireplace (TSFU) and 37 percent for the traditional metal stove (TMSU).

The mean difference tests have established that the two villages are statistically different. The probit models for the two villages are therefore run independently. An aggregation of data from the two villages was nevertheless

Table 4.03 Adoption rates (percentages) for policy supported strategies in the two villages

Strategy	Village 1[a]	Village 2[b]
New Strategies[c]		
KCJU	43	4
ELEU	N/A	1
KESU	8	27
KUMU	15	26
TPHS10	45	20
Old Strategies[d]		
TSFU	88	83
TMSU	63	37

[a] n=145
[b] n=161
[c] New strategies include the Kenya Ceramic Jiko, electric cookers, kerosene stoves, the "Kuni Mbili" stove/fireplace, and tree planting in the preceding ten years.
[d] The old strategies include the three-stone fireplace (TSFU) and the traditional metal stove (TMSU) which are supposed to be replaced by more efficient technologies.

done to evaluate whether stronger adoption models could be generated with the combined data. Those results are presented and discussed in a later section of this chapter. The underlying assumption for this type of analysis was that the two villages were subsamples representing two strata in the population. A dummy variable was used to test for village effect.

Adopter/Non-adopter Comparisons

Relative to adoption, the following independent variables are examined: size of household, farm size, age of head of household, educational level of head of household, income, land tenure structure, contacts with different sources of information, knowledge of different strategies, participation in agricultural shows and meetings, leadership roles, gender, labor availability, and area under cultivation (Voh,1982; Rogers,1983; Akinola, 1987; Dennis, 1990; Polson and Spencer, 1990; Hodges and Cubbage, 1990). Results of these probit analyses provide information on the household characteristics associated with adoption or non-adoption of different strategies.

Table 4.04 presents the number of households using different combinations of strategies. When all five strategies are considered together, 30 households in Village 1 and 69 in Village 2 had not adopted any of them. A t-test and a U-test were carried out to examine whether there were

Table 4.04 Number of households using different combinations of strategies

Number of strategy combinations[a]	Village 1 n=145	Village 2 n=161
<u>With All Strategies</u>		
3	6	4
2	33	25
1	76	63
0	30	69
<u>Without TPHS10</u>		
3	0	1
2	12	13
1	71	64
0	62	83

[a] Strategy combinations are KCJU, KUMU, KESU, ELEU, and TPHS10.
See Appendix 1 for variable definitions.

any statistical differences between the households of those who adopted at least one consumption technology and those who adopted none. Results are presented in Tables 4.05 (t-test) and 4.06 (U-test). The four fuelwood- and charcoal-saving or substituting technologies were considered.

Most of the adopters had either 1 or 2 strategies. When tree planting (TPHS10) was excluded, the numbers adopting none of the consumption-based technologies were revealed to be fairly high. Based on correlation analysis, many of the wood-energy saving technologies tended to be substitutes to each other. Households tended to adopt only one or two technologies at a time.

Farm input costs (FIC), total expenditures (TEXP), time spent in fuelwood collection (TIC), cylinders of gas used per month (CGAM), liters of kerosene used per month (KELM), use of charcoal (FUCC), use of the three stone fireplace (TSFU), use of the Kenya Ceramic Jiko (KCJU), and use of kerosene stoves (KESU) were important distinguishing variables for adopters and non-adopters in the two villages. Other variables such as area under cultivation (AC91) and extension visits per year (EVPY) were unique for adopters and non-adopters in each village.

Adopters in Village 1 were characterized by less area under cultivation (AC91), higher crop revenue (CREV), higher education (EDH), lower duration of residence in the village (TIM) for example. In village 2, they were characterized

Table 4.05 Comparison of adopters and non-adopters, Independent t-test

Variable[a]	Village 1 Without TPHS10	Village 2 Without TPHS10
AC91	-2.97*	0.48
AREA	-0.03	-0.28
CREV	3.47*	1.34
FIC	2.29*	2.02*
SAVINGS	1.80	-0.15
TEXP	3.71*	1.98*
THHX	4.25*	1.13
TREV	3.57*	1.15
AGEH	-3.33*	-0.74
EDH	3.17*	1.43
HSZ	0.67	2.16*
TIC	3.51*	-2.15*
TIM	-2.23*	-0.40
EVPY	1.62	3.49*
RHPD	1.15	3.16*
SH10	3.15*	0.98
CCBM	3.93*	1.67
CGAM	2.27*	1.98*
CRHM	-0.94	2.16*
FWHM	-1.37	-2.53*
KELM	2.66*	3.30*

* Significant at $\alpha = 0.05$
[a] Variable definitions are in Appendix 1.

Table 4.06 Comparison of adopters and non-adopters, Mann-Whitney U-test

	Village 1	Village 2
Variable[a]	Without TPHS10	Without TPHS10
FUKE	2428.5	4693.0*
FUGA	2747.0	3530.0*
FUEL	2562.0	3320.0
FUOT	2436.0*	3240.0
FUCR	2196.0*	3281.5
FUCC	3307.5*	3770.5*
KUMU	1921.5*	1535.5
ELEU	2562.0	3154.0
SDSU	2562.0	3229.5
OTHU	2596.5	3139.0
TSFU	3111.0*	3955.0*
KCJU	640.5*	2946.5*
KESU	2196.0*	1452.5*
TMSU	2873.5	2881.5

* Significant at $\alpha = 0.05$
[a] Variable definitions are in Appendix 1.

by higher expenditures (TEXP, FIC), higher household size (HSZ), and lower time in collecting fuelwood (TIC).

Duration of Use

The average duration for which a technology has been in use is also important in evaluating adoption. Table 4.07 shows the average duration of use for different technologies in the two villages. The four energy-saving or wood-substituting technologies have been promoted for about ten years. The Kenya Ceramic Jiko (KCJU) had been adopted for an average of 3.3 years in Village 1 and only 1.4 years in Village 2. Similarly, the "Kuni Mbili" stove/fireplace had been adopted for an average of 3.3 years in Village 1 and 3.8 years in Village 2. The corresponding values for electricity and kerosene are as shown.

Attributes of Strategies

Another important dimension to adoption is the attributes of the strategies. Table 4.08 summarizes the desirable attributes cited by households as important to adoption. Responses were not provided by some adopting households and this limits the analyses of the role of attributes that could potentially be carried out with more complete data. In addition to the attribute data, some concerns on some of the technologies were also raised. Costs, suitability for multiple uses, and lack of

Table 4.07 Average duration of technology use in years

Technology[a]	Village 1 Means	Village 2 Means
TSFU	25.5 (n=130)[b]	23.6 (n=132)
TMSU	21.6 (n=95)	10.8 (n=132)
KCJU	3.3 (n=60)	1.4 (n=7)
KUMU	3.3 (n=18)	3.8 (n=41)
KESU	11.0 (n=12)	9.1 (n=41)
ELEU	0.0 (N/A)	9.5 (n=2)
SDSU	N/A	1.7 (n=6)
OTHU	N/A	8.3 (n=11)

[a] See Appendix 1 for variable definition.
[b] Number of households reporting duration of use.

Table 4.08 Attributes for different strategies

Technology	Attributes Village 1	 Village 2
KCJU	Better than previously used technology (TMSU) Easy to use Culturally acceptable in village Charcoal-saving Clean Trialability (can be dropped easily if found unsuitable) Observability (had seen it used and liked it)	Better than TMSU Easy to use Acceptable in village Trialability Observability Warmth Safe Convenient Efficient Not smoky <u>Concerns</u> Not available locally Too small Costly No knowledge of it
KUMU	Better than TSFU Efficient Acceptable in the village Easy to use	Efficient Safe Improvement over previous technology Easy to use Acceptable Trialability Observability Quick cooking Cheap
ELEU	N/A	Observability Improvement over previous technology <u>Concerns</u> Costly

Table 4.08 (continued)

Technology	Attributes: Village 1	Village 2
KESU	Easy to use Improvement over current practice	Better than previously used technology Easy to use Acceptable in village Trialability Observability Fast Convenient Cheap Safe <u>Concerns</u>: Costly
TMSU	Warmth Improves on TSFU Easy to use Acceptable in village Clean Durable Cheap	Improvement over TSFU Easy to use Trialability Observability Acceptability Cheap Warmth Fast Clean <u>Concern</u> Charcoal is costly
TSFU	Easy to use Accepted in village Observability Fuelwood abundant Cheap Warmth Multipurpose Convenient	Acceptable in village Observability Warmth Easy to use Improvement Copes with green wood Safe Adequate fuelwood Cheap
SDSU	N/A	Cheap
OTHU	N/A	Improvement Trialability Observability Fast (gas) Clean (gas) Fast (gas)

information were cited as problems for the efficient or wood- and charcoal-saving technologies considered in the study. In general, these responses were consistent with those noted by Rogers (1983) and which were discussed in Chapter 3.

Probit Results

This section discusses the twelve probit model results obtained for the two villages. The first eight models deal with the adoption of the Kenya Ceramic Jiko (KCJU), the "Kuni Mbili" stove/fireplace (KUMU), kerosene stoves (KESU), and tree planting in the preceding ten years (TPHS10) in Villages 1 and 2. The next four models are based on combined data. Electricity had such a low-use rate for heating and cooking that no significant model could be developed. The two households that were using electricity are described using basic descriptive statistics such as means. A discussion of models estimated, important policy variables, and interpretation follows.

Assessing Estimation Results.

The individual coefficients in probit models are the parameter estimates for the independent variables. The associated standard errors and t-statistics as generated by LIMDEP probit are also presented. The estimates of coefficients are asymptotically unbiased and efficient.

This means that coefficients are valid as approximations and would be expected to improve as sample size was increased.

The t-statistic tests the null hypothesis that a particular coefficient is zero. The estimated coefficients are B/σ, with σ assumed to be equal to 1 (Latrielle, 1992). Significant variables are identified as being associated with the likelihood of adoption or non-adoption. Probit estimates are maximum likelihood estimates.

In ordinary least squares regression analysis (OLS), the F-statistic tests the hypothesis that all coefficients except the constant are zero. For probit analysis, the likelihood ratio test is used (Aldrich and Nelson, 1984). The Likelihood ratio statistic (c) is calculated as follows:

$$c = -2 \log (L0/L1) = -2(\log L0 - \operatorname{Log} L1)$$

where:

c = likelihood ratio statistic.

L1 = value of the likelihood function for the full model as estimated.

L0 = Maximum value of the likelihood function if all coefficients except the intercept are zero.

The calculated χ^2 tests the null hypothesis that all coefficients except the intercept are zero. For example, in probit model KCJ1 (Table 4.09),

-2 LLR (calculated χ^2, 5 DF) = 61.674

χ^2 TAB (5, 0.05) = 12.832

The critical value from Chi-square tables show the probability that χ^2 calculated is the result of a chance distribution. The larger the value of χ^2 TAB (relative to χ^2 calculated), the smaller is the probability that null hypothesis is correct. The degrees of freedom are based on the number of coefficients minus one. The above model is significant based on these criteria. All the probit models presented in this study are significant and are evaluated in the same manner.

The percentage of adopters and non-adopters correctly predicted can also be used as another measure of the goodness of fit for the models developed. The predictive power of the models based on this criterion is discussed later.

Probit analysis does not have a statistic comparable in interpretation to R^2 in regression analysis. Aldrich and Nelson (1984) caution that even though analogous statistics such as the pseudo-R^2 and McFadden's R^2 can be developed, such summary measures should be used with "extreme caution, if at all."

The single village probit models evaluated in this study appear in Tables 4.09 through 4.14, 4.16, and 4.17. Each model is for a specific wood-energy production or consumption strategy. As indicated earlier, the only production strategy considered in this study was the growing of fuelwood or multipurpose trees. The models for each of the two villages are evaluated together to provide a contrast as to what differences existed, if any. The factors associated with the adoption of different technologies are then discussed.

For all probit models, elasticities for the independent variables at the mean levels were calculated using the procedure explained in Chapter 3. These values indicate the percentage change in probability of adoption associated with a one percent change in the mean value of the independent variable. The change may be positive or negative signifying that the probability of adoption either increases or decreases. These values were calculated using LIMDEP (Version 6.0). The values and signs of these elasticities are useful in interpreting the results since they indicate which policy has a greater impact on the probability of adoption. The lumpiness of units such as extension visits (EVPY) and age of the head of household (AGE), however, is a limitation in the interpretation of the elasticities. For example, the effect of a 1-percent increase in extension visits on adoption at the mean may be extremely low. Marginal changes (elasticities) nevertheless provide useful information on important policy variables.

Significant variables in the models may also be ranked by elasticities. This involves using mean value data and the calculated elasticities to determine the percentage by which the probability of adoption or non-adoption changes as a result of a 1-percent change in the independent variable.

For the Kenya Ceramic Jiko models which appear in the next two sections (KCJ1 and KCJ2), the top three variables in rank from highest to lowest using the above procedure were: liters of kerosene used per month (KELM), extension visits per year (EVPY), and age of head of household (AGE). The more commonly used procedure of explaining elasticity is to present results for each probit model. Then, quantitative results from different models are not inappropriately combined.

All probit models are presented in tabular rather than equation format so that standard errors, t-statistics, and elasticities can be efficiently included. The equation specification format was presented in Chapter 3. Model KCJ1 which follows in the next section may, for example, be specified as $Y_i = 0.5766 - 0.0393(AGE) + 0.0295(EVPY) + 0.0735(KELM) + 0.5E{-}04(THHX) - 0.3046(MEMFEOF)$. Y_i is a binary dependent variable while the other variables are as defined in Appendix 1. Variables for which strong _a priori_ expectations of significance existed are retained in the final model presentation even when they are insignificant to illustrate their effects (or lack of effects) on adoption or non-adoption.

The model structure presented for different technologies is based on prior hypotheses about the variables considered to be associated with adoption or non-adoption based on literature and personal observations (see

Table 3.01). In addition, correlation analyses results were used to determine the variables to be included in a single model. For example, in Village 2, farm input costs (FIC) and crop revenues (CREV) had a correlation coefficient of 0.739 and could therefore not be used in the same model due to potential multicollinearity problems. Similarly, total revenue (TREV) and crop revenue (CREV) had a correlation coefficient of 0.975 in Village 1.

Adoption of Kenya Ceramic Jiko in Village 1 (Model KCJ1)

The adoption of the Kenya Ceramic Jiko in Village 1 presents a rather unique situation; forty-three percent of households sampled have already adopted it. There were a number of explanatory variables that were statistically significant and associated with the adoption of this charcoal-using stove. Results are presented in Table 4.09. Age (AGE, negative coefficient), extension visits per year (EVPY, positive coefficient), liters of kerosene used per month (KELM, positive coefficient) and total household expenditure (THHX, positive coefficient) were statistically significant.

As expected, older heads of households (AGE) were found to be less likely to adopt the Kenya Ceramic Jiko than the younger heads of households. This is consistent with much of the literature reviewed. Younger heads of households tend to be more mobile, more educated, and more anxious to

Table 4.09 Probit results for the adoption of Kenya Ceramic Jiko (KCJ1) in village 1.

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	0.5766	0.5325	1.083	
AGE	-0.0393	0.0102	-3.863*	-0.015
EVPY	0.0295	0.0175	1.688	0.012
KELM	0.0735	0.0281	2.616*	0.029
THHX	0.5E-04	0.1E-04	4.416*	0.2E-04
MEMFEOF	-0.3046	0.2894	-1.052	-0.120

Log-likelihood = -68.421
-2LLR (CHI-SQ, 5DF) = 61.674
*Significant at $\alpha = 0.05$
CHI-SQ TAB = 12.832
[a] See appendix 1 for definition of variables
[b] Elasticity computed at mean values for independent variables

try new methods than older heads of households. Although these factors are important, resource endowments of the individuals are also likely to be important and age alone is certainly not sufficient in determining adoption.

Total household expenditures (THHX) were statistically significant. In Village 1, most of the households relied on agricultural revenue for their livelihood. Total household expenditure tended to be higher than crop revenue (CREV) and this possibly reflected the existence of non-farm income or borrowing. The expected positive sign of the coefficient was consistent with the a priori expectation. On average, it was expected that high expenditure households were also likely to have higher incomes. Higher household expenditures were thus associated with the likelihood of adopting the stove (positive coefficient).

The presence of members of households who were employed off-farm (MEMFEOF) was statistically insignificant. The financial contribution of such family members was initially expected to be positive.

Kerosene was used for cooking and heating by 8 percent of the households in Village 1. Based on this model, the liters of kerosene used per month (KELM) had a positive and significant coefficient at $\alpha = 0.05$. The a priori expectation was that the coefficient sign could be either positive or negative. Kerosene can be used as a substitute (negative sign) for or to complement (positive sign) charcoal in cooking and heating. In this case, it appears that kerosene is more of a complement since its increased use tends to be associated with more use of the charcoal-based Kenya Ceramic Jiko. Kerosene stoves cook fast and some charcoal-users may prefer them when less cooking time is crucial.

The elasticities show the responsiveness of the likelihood of adoption or non-adoption to changes in different independent variables. A 1-percent increase in the number of extension visits (EVPY), for example, leads to a 0.012 percent increase in the likelihood of the adoption of the Kenya Ceramic Stove in Village 1. High elasticities indicate that adoption can be influenced through appropriate policy changes directed at those variables. Increased support of extension services, for example, would be a helpful policy in facilitating adoption. Programs that increase household income are also likely to encourage adoption of the Kenya Ceramic Jiko. All the elasticities presented in subsequent models are conceptually interpreted in the same way.

Adoption of Kenya Ceramic Jiko in Village 2 (Model KCJ2)

Table 4.10 presents model KCJ2 (probit analysis results for the adoption of KCJ in Village 2). The statistically significant variables at $\alpha = 0.05$ were the liters of kerosene used per month (KELM), the acreage owned by the

Table 4.10 Probit results for the adoption of Kenya Ceramic Jiko (KCJ2) in Village 2.

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-6.1252	1.716	-3.569	
HSZ	0.0993	0.0976	1.017	0.6E-03
KELM	0.0889	0.0307	2.898*	0.6E-03
AREA	0.0669	0.0305	2.198*	0.4E-04
THHX	0.4E-04	0.2E-04	2.787*	0.3E-06
MEMFEOF	1.6130	1.012	1.594	0.010

Log-likelihood = -16.39
-2LLR(CHI-SQ, 5DF) = 24.797
*Significant at α =0.05
CHI-SQ TAB = 12.833
[a] See appendix 1 for definition of variables
[b] Elasticity measured at mean value of independent variable.

household (AREA), and the total household expenditure (THHX). These variables were positively related to the likelihood of adoption. Household size (HSZ) and the presence of family members who were employed off-farm (MEMFEOF) were insignificant. Large households in general were considered likely to use more fuel and therefore have an incentive to increase efficiency. Family members employed off-farm were likely to contribute to household income and to come across information on new technologies.

As indicated earlier, Village 2 faced a more acute fuelwood and charcoal shortage compared to Village 1. Many socioeconomic variables were also different for the two villages as shown earlier in Tables 4.01 and 4.02. In addition to liters of kerosene used by a household per month (KELM), total household expenditure(THHX), and whether a member of the household was employed off- farm (MEMFEOF) which were significant in Village 1, farm area (AREA) was found to be significant for Village 2.

Only 4 percent of the households surveyed in Village 2 were using the Kenya Ceramic Jiko. Twenty-seven percent of the households, on the other hand, reported using kerosene stoves for cooking and heating. Based on anecdotal evidence, the low level of adoption for the KCJ was probably due to lack of adequate information on this technology. About 37 percent of the households surveyed indicated they were using the traditional metal stove which the KCJ was designed to replace. This can be compared to 43 percent in Village 1 who reported using the KCJ and 63 per cent who reported using the traditional metal stove (Table 4.02).

There is a rather high positive correlation coefficient (0.538) between liters of kerosene (KELM) and bags of charcoal used per month (CCBM). This indicates that there was a tendency for households using more kerosene to use more charcoal as well. This possibly reflects a situation where the two fuels are used to complement each other.

Fuel price may affect adoption, but in some cases is relatively equal for adopters and non-adopters. There were a number of petrol (gas) stations in the small urban center near Village 2. This may have eliminated the middlemen who retail kerosene in Village 1. The middlemen buy it from the petrol stations and then sell at higher prices in retail outlets. At the same time, charcoal had to be transported in trucks over relatively long distances to Village 2. The average price per bag therefore tended to be higher in Village 2 (Ksh 105.70 versus Ksh 60.20). Transportation costs were lower in Village 1.

Farmers with large tracts of land were generally expected to have higher crop revenues (CREV). Total household expenditures (THHX) were found to be significant in determining the adoption of KCJ at $\alpha = 0.05$. The poorest households may continue to rely on fuelwood even when labor (time spent in collection) and fuelwood costs are relatively high due to relatively higher costs of substitutes.

The elasticities in this model are low, and relatively high investments in the desirable policy variables would be needed to increase adoption. Income increasing policies would be helpful since households are more likely to spend money on new technologies as incomes rise. A focus on farmers with larger farms may also facilitate adoption.

Adoption of Kuni Mbili Stove/Fireplace in Village 1 (Model KUM1)

Table 4.11 presents the results for this technology. Fifteen percent of the households in Village 1 had adopted this technology. This can be contrasted with eighty-eight percent of the households who reported using the three-stone fireplace and were therefore potential adopters.

The statistically significant variables at $\alpha = 0.05$ included acres of land owned (AREA, positive), headloads of crop residues used (CRHM, negative), leadership role in the village (LEAD, positive), attendance to agricultural shows (SH10, positive), and total revenue (TREV, negative). The coefficient signs for AREA, CRHM, LEAD, and SH10 were consistent with *a priori* expectations. The existence of a member of the household who worked off-farm (MEMFEOF) was insignificant. Higher household incomes make other energy options feasible and this may explain the negative total revenue (TREV) coefficient. Households with leaders,

Table 4.11 Probit results for the adoption of "Kuni Mbili" stove/fireplace (KUM1) in Village 1

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-0.4125	0.4368	-0.944	
CRHM	-1.6995	0.5753	-2.954*	-0.108
LEAD	1.2766	0.4599	2.776*	0.081
AREA	0.0886	0.0281	3.159*	0.006
SH10	0.1711	0.0531	3.221*	0.011
TREV	-0.4E-04	0.1E-04	-2.719*	-0.2E-05
MEMFEOF	-0.5142	0.3894	-1.320	-0.033

Log-likelihood = -42.802
-2LLR (CHI-SQ, 6 DF) = 34.348
*Significant at α =0.05
CHI-SQ TAB = 14.449
[a] See appendix 1 for definition of variables
[b] Elasticity computed at mean values for independent variables.

regular agricultural show attenders, larger tracts of land, and high consumption of crop residues as a fuelwood substitute were more likely to adopt this technology. Identifying households with these characteristics is a useful first step in facilitating more adoption of the "Kuni Mbili" stove/fireplace.

The elasticities for the independent variables are as shown. Participation in agricultural shows and leadership role have relatively high elasticities. Policy variables in order of importance were LEAD, SH10, and AREA. Focusing extension information on leaders, charging low gate fees to encourage show attendance, and advising farmers with larger tracts of land may enhance the adoption of this technology.

Adoption of "Kuni Mbili" Stove/Fireplace in Village 2 (Model KUM2)

The "Kuni Mbili" stove/fireplace had been adopted by twenty-six percent of the households surveyed. At the same time, 83 percent of the households reported using the traditional three-stone fireplace at least part of the time. The adoption rate was higher than for Village 1.

Model results are presented in Table 4.12. The quantity of crop residues used per month (CRHM) and the number of extension visits per year (EVPY) were significant in influencing adoption of the Kuni Mbili stove/fireplace.

Table 4.12 Probit results for the adoption of "Kuni Mbili" stove/fireplace (KUM2) in Village 2

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-1.6670	0.280	-5.986	
CRHM	0.0315	0.009	3.383*	0.010
EVPY	0.0199	0.010	2.034*	0.006
TREV	0.6E-05	0.4E-05	1.528	0.2E-05
LEAD	0.2249	0.2574	0.874	0.069
MEMFEOF	0.3015	0.2365	1.275	0.092

Log-likelihood = -80.069
-2LLR (CHI-SQ, 5 DF) = 22.563
Significant at $\alpha = 0.05$
CHI-SQ. TAB = 12.8325
[a] See appendix 1 for definition of variables.
[b] Elasticity computed at mean value of independent variable.

Both had positive coefficients. As mentioned earlier, crop residues were widely used in Village 2. This reflected the relatively higher physical scarcity of fuelwood in this area. Tea and coffee prunings were considered valuable sources of fuel. More extension visits per year (EVPY) were found to positively associated with adoption. Extension contacts provide new information to farmers and their households. It is likely that farmers who seek and receive extension services are more likely to be adopters of the "Kuni Mbili" stove/fireplace. As extension visits increase, households are more likely to acquire knowledge on new technologies. This is consistent with findings in agricultural economics literature. Total household revenue (TREV) and leadership role (LEAD) were not statistically significant in influencing adoption.

Response elasticities were also relatively low for the different variables. Significant gains in adoption can be made by promoting extension activities and also concentrating on communities that are using plenty of crop residues for cooking and heating.

Adoption of Kerosene Stove in Village 1 (Model KES1)

The policy approach with regard to kerosene has been to subsidize it so that it is more widely available at low prices. Average prices of kerosene in Village 1 were KSh 9.80 per liter compared to KSh 9.03 per liter in Village 2

(Table 4.05). Only 8 percent of the households in Village 1 reported using kerosene for cooking and heating (Table 4.3). As can be observed in Table 4.13, the significant variables were age (AGE, negative coefficient), extension visits per year (EVPY, positive coefficient) and the education level of the head of household (EDH, negative coefficient). Initial expectations were that kerosene stoves would be used by younger, better educated, more wealthy, and more progressive households. Leadership role (LEAD), member of household working off-farm (MEMFEOF), and total revenue (TREV) had statistically insignificant coefficients. Kerosene users in this village are likely to be younger. The older heads of households in the village were less likely to adopt kerosene stoves as expected. The negative coefficient sign on educational level, however, was inconsistent with expectations. It is possible that younger and more educated heads of households preferred other energy alternatives. More educated heads of households were considered more likely to be involved in both on-farm and off-farm activities which would encourage them to use fast cooking technologies such as the kerosene stove. The older but less well-educated heads of households in this village could also have had similar pressures on their time due to involvement in non-farm economic activities. Extension visits play an important positive role in promoting adoption. Households that have interest in extension information are more likely

Table 4.13 Probit results for the adoption of Kerosene Stove (KES1) in Village 1

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-2.2314	30.85	-0.072	
AGE	-1.0935	0.0197	-2.791*	0.6E-03
EVPY	0.0585	0.0246	2.381*	0.6E-03
LEAD	0.6133	0.4008	1.530	0.007
EDH	-0.2243	0.1003	-2.236*	-0.002
MEMFEOF	4.4580	30.83	0.145	0.049
TREV	0.2E-05	0.6E-05	0.409	0.3E-07

Log-likelihood = -27.878
-2LLR(CHI-SQ, 6DF) = 27.027
*Significant at $\alpha = 0.05$
CHI-SQ TAB = 14.449
[a] See appendix 1 for definition of variables.
[b] Elasticity computed at mean value of independent variables.

to be aware of different technologies and their relative merits or demerits.

The elasticity for the educational level of the household (EDH) identifies it as the most useful policy variable in the model. In the short run, it is difficult to change average education levels. However, long-term investments in formal and informal education could contribute significantly to the adoption of energy-saving technologies. A deliberate effort to focus extension information on younger heads of households would also be appropriate.

Adoption of Kerosene Stove in Village 2 (Model KES2)

In the case of Village 2, twenty-seven percent of the households reported using kerosene for cooking and heating. Probit results for this strategy are presented in Table 4.14. Extension visits per year (EVPY) were found to positively and significantly influence the adoption of kerosene stoves at
$\alpha = 0.05$. Age (AGE) was insignificant only at $\alpha = 0.05$. Extension visits (EVPY) and age (AGE) were also significant for kerosene stove adoption in Village 1. Individuals who receive extension support on a regular basis appear to be more willing to try out new technologies. There is inadequate evidence that younger heads of households are more likely to be associated with adoption at the specified

Table 4.14 Probit results for the adoption of Kerosene Stoves (KES2) in Village 2

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-0.1065	0.5258	-0.203	
AGE	-0.0150	0.0086	-1.737	-0.005
EVPY	0.0238	0.0104	2.277*	0.007
LEAD	-0.4690	0.2877	-1.630	-0.145
TREV	0.3E-05	0.4E-05	0.743	0.1E-05
RHPD	0.0651	0.0519	1.254	0.020
TIC	-0.1756	0.1163	-1.510	0.054

Log-likelihood = - 83.835
-2LLR(CHI-SQ, 6 DF) = 19.198
*Significant at α = 0.05
CHI-SQ TAB., 6 DF = 14.449
[a] See appendix 1 for definition of variables.
[b] Elasticity computed at mean value of independent variable.

significance level. Time spent in fuelwood collection (FIC), and leadership role (LEAD), total revenue (TREV), and exposure to radio information (RHPD) were statistically insignificant. Kerosene subsidies are likely to favor those individuals who actively seek and receive extension advice. These are usually the more progressive members of the community.

The elasticities for the independent variables indicate that increased extension services would facilitate faster adoption of this technology.

Adoption of Electricity in Village 2

As shown in Table 4.03, only 1 percent of the households in Village 2 reported using electricity for heating and cooking. Due to the small number of electricity users in the sample, no significant models could be generated at the specified significance level. Installation costs of electricity, purchase costs of appliances, and high monthly bills may be hindrances to wider adoption of electricity for cooking and heating especially for low-income rural households.

A comparison of mean values for some variables is presented in Table 4.15. Electricity users appear to have above average revenues (CREV, TREV), expenditures (TEXP, THHX), education (EDH), age (AGE) and frequency of visits from extension agents (EVPY). On the other hand, their use

Table 4.15 Comparison of electricity user means against Village 2 Means

Variable[a]	Village 2 Means	Electricity-Users Means
AC91	2.47	2.05
AREA	4.65	3.95
CREV	23235.34	26100.00
TEXP	28050.86	47390.00
THHX	18895.67	40190.00
AGE	49.31	54.0
EDH	4.86	5.5
HSZ	6.24	8.5
TIM	23.23	28.5
EVPY	9.66	18.0
SH10	2.17	2.0
CCBM	0.41	2.0
CRHM	10.20	6.0
FWHM	14.76	6.0

[a] See Appendix 1 for variable definitions.

of crop residues (CRHM) and fuelwood (FWHM) is below the village average.

People who are leaders in their communities tend to be better off than the average village resident and may also view the adoption of new technologies as being consistent with their social status. They therefore tend to become early adopters. The two households adopting electricity for cooking and heating had members with leadership roles in the community. The small group of households using electricity implies that other energy alternatives are used more widely.

A more comprehensive study of electricity users in Village 2 would involve obtaining a list of all users from the Kenya Power and Lighting Company and treating them as a unique stratum. A sub-sample could then be drawn and used to evaluate the adoption of electricity for cooking and heating. Characteristics of those households could then be analyzed and compared with those of the village as a whole.

Adoption of Tree Planting in the Preceding 10 Years in Village 1 (Model TPH1)

The reported adoption of tree planting in Village 1 was 45 percent as compared to 20 percent in Village 2 (Table 4.03). Village 1 is located in a region that was historically well-wooded. The stock of wood on private farms however appears to have declined during the past three decades (personal communication with farmers). A government tree nursery was located close to this village, and this may have encouraged all categories of small-scale farmers to participate in tree planting. Seedling prices were also low. Their counterparts in Village 2 often cited lack of land as the main obstacle to tree planting while Village 1 residents cited game damage, insect damage, and lack of adequate water supplies as their main obstacles to planting.

Table 4.16 presents the model results for tree planting in Village 1. Larger, higher income households (HSZ, TREV) appear to be the ones more likely to plant trees. Larger families may increase the pool of resources available to the household which may in turn enable them to plant trees. The pool of resources may include finances, labor and ideas. Farmers with large tracts of land (AREA) are less likely to adopt tree planting. Such farmers probably do not perceive lack of wood for future use as a risk since they may already own adequate reserves. Farmers with higher incomes can also afford more energy alternatives and hence the positive and statistically significant coefficient for total revenue (TREV).

The elasticities in this model indicate that a focus on farmers with smaller than average farms might yield faster adoption results. Such farmers are likely to be aware of the need to plant more trees and effort can be focused on providing logistic support to them. That may, for example, involve making sure seedlings are available at planting time

Table 4.16 Probit results for the adoption of tree planting (TPH1) in the preceding 10 years in Village 1

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-0.8687	0.3969	-2.188	
HSZ	0.1594	0.054	2.951*	0.062
TREV	0.1E-04	0.4E-05	2.320*	0.4E-05
AREA	-0.0655	0.023	-2.833*	-0.025
SH10	-0.0698	0.040	-1.730	-0.027
TN1	0.3408	0.3845	0.886	0.1323
TN3	-4.0110	45.21	0.089	1.556

Log-likelihood = -86.216
-2LLR (CHI-SQ, 6 DF) = 27.027
*Significant at $\alpha = 0.05$
CHI-SQ TAB = 14.449
[a] See Appendix 1 for definition of variables
[b] Elasticity evaluated at mean value of independent variables.

and providing extension support as needed. Policies that increase household incomes would also facilitate adoption of tree planting. Information on family sizes may also be used to identify households that would be more likely to adopt tree planting.

Adoption of Tree Planting in the Preceding 10 Years in Village 2 (Model TPH2)

Twenty percent of the households surveyed in Village 2 reported having planted fuelwood or multipurpose trees in the preceding ten years. Model results are presented in Table 4.17.

The statistically significant variables related to tree planting in the preceding ten years were: headloads of fuelwood used per month (FWHM, positive), and total household expenditure (THHX, negative) at $\alpha = 0.05$. Household size (HSZ) was insignificant at $\alpha = 0.05$. Land tenure coefficients (TN1 and TN2) were also statistically insignificant.

Initially, it was expected that individuals without restrictions in land ownership rights were more likely to adopt tree planting. The current results do not provide evidence in support of this hypothesis. The three tenure structures conceptualized for the two villages do not capture major differences in the likelihood of households to adopt tree planting. Even though lack of adequate land was

Table 4.17 Probit results for the adoption of tree planting (TPH2) in the preceding 10 years in Village 2

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	2.3791	0.5091	-4.673	
FWHM	0.0456	0.0154	2.976*	0.011
THHX	-0.3E-04	0.1E-04	-2.106*	-0.7E-05
HSZ	0.1136	0.0587	1.935	0.027
RHPD	0.0674	0.0540	1.248	0.016
EVPY	0.0084	0.0110	0.763	0.002
TN1	0.2708	0.3167	0.855	0.065
TN2	0.2665	0.3030	0.880	0.064

Log-likelihood = -69.246
*Significant at $\alpha = 0.05$
-2LLR (CHI-SQ, 7 DF) = 22.082
CHI-SQ TAB = 16.013
[a] See Appendix 1 for definition of variables
[b] Elasticity computed at mean value of independent variables.

often cited as a major reason for not planting trees, farm area (AREA) and the net area (NAREA) variable were not statistically significant and are not included in the final model presented here. This seemed to indicate that other factors were more important. If labor availability was a crucial concern, the households using more fuelwood were likely to place a higher value on cost and time savings as a result of growing their own fuelwood. Generally, labor availability did not appear to be a crucial problem. As household expenditures increased, the headloads of fuelwood consumed tended to decrease. Higher income and expenditure households are more likely to adopt different technologies and fuels. The elasticities for total household expenditure (THHX) and headloads of fuelwood used per month (FWHM) indicate their sensitivity to policy interventions.

Combined Data Models

Models KCJC, KUMC, KESC, and TPHC (for the Kenya Ceramic Jiko, "Kuni Mbili" stove/fireplace, kerosene stoves, and tree planting respectively) were estimated using combined data for the two villages. The full results are presented in Appendices 6, 7, 8 and 9. A short discussion of the results follows.

For model KCJC (Appendix 6), the significant variables at $\alpha = 0.05$ were: age of head of household (AGE, negative sign), time spent in fuelwood collection (TIC, positive sign), liters of kerosene used per month (KELM, positive sign), total household expenditure (THHX, positive sign), farm area (AREA, negative sign), and village dummy variable (DUMMY, positive sign). Younger heads of households, increase in distance from the source of fuelwood, more reliance on kerosene, relatively small farm sizes, high household expenses and village dummy variable (DUMMY) are associated with the adoption of the Kenya Ceramic Jiko in the two villages. Policies directed towards increasing incomes and subsequently the consumption levels of households facilitate adoptions. Focus on younger heads of households and those with relatively small tracts of land may also help increase adoption.

Results for the adoption of the "Kuni Mbili" stove/fireplace are presented in Appendix 7. The statistically significant variables at $\alpha = 0.05$ were leadership role (LEAD) and the headloads of crop residues used per month (CRHM). Both had positive coefficients. Individuals faced with acute fuelwood shortages tend to use more crop residues, and a deliberate policy focus on this group would encourage them to use the "Kuni Mbili" stove/fireplace to save whatever fuelwood may be available. As observed in literature and some of the other models, leaders are likely to be early adopters of technology. Getting appropriate information to them would therefore be very helpful.

In the kerosene stove model (Appendix 8), extension visits per year (EVPY) and hours of radio exposure per day (RHPD) were significant at $\alpha = 0.05$ with positive signs indicating that the two sources of information were associated with adoption. Age of head of household (AGE) and education level (EDH) were significant with negative coefficient signs at $\alpha = 0.05$. Younger and less educated heads of households were thus more likely to be associated with adoption. The village dummy variable was significant indicating differences in the two villages play a role in adoption.

Tree planting adoption (Appendix 9) was different for the two villages. Acres of farmland owned (AREA) and household size (HSZ) were statistically significant factors associated with adoption at $\alpha = 0.05$. Farmers with large tracts of land also tended to be less inclined to plant while those with large households (HSZ) were more interested possibly due to their greater need for wood products.

Discussion of Decision Variables

The variables used in probit model building are briefly defined in Appendix 1. The importance of the variables is highlighted in this section under the following categories: farm area, financial information, household characteristics, exposure to information on different technologies, quantities per month of different fuels used, specific fuels chosen by households, specific cooking and heating technologies used by households, and land tenure structures.

Farm Area. The farm area variable was conceptualized in two ways: the total amount of land owned (AREA) and area under cultivation in 1991 (AC91). Village 1 had an average ownership of 9.63 acres of which an average of 2.80 acres were reported to be under cultivation in 1991 (Table 4.). Village 2 on the other hand, had an average ownership of 4.65 acres with an average of 2.47 acres under cultivation during the same year. Many of the households that had not planted trees in Village 2 stated that they were limited by the amount of land available. Village 1 had a net land area (NAREA) of 6.83 acres which, theoretically, could be at least partially be planted with trees. Village 2 on the other hand had an average net area (NAREA) of 2.18 acres.

It was initially hypothesized that households that owned large tracts of land were likely to be better off economically and hence more likely to adopt new wood-energy technologies (positive probit coefficients). It was also hypothesized that such households would on average have larger acreages under cultivation compared to smaller farms. Studies by Dennis (1988), Purnama (1990), Polson and Spencer (1990), and Akinola (1987) support the case for positive probit coefficients for farm size. Farmers with relatively small tracts of land were viewed as less likely to adopt new technologies due to their limited resource base. The probit analyses results however indicated that farm area and net area were not significant factors in many of the strategy choices.

Financial Information. The collection of financial information for rural households was somewhat difficult. In Village 1, horticultural crops were marketed throughout the year and the prices varied with supply and demand. The farmers were asked to give what they considered an average price for their produce during the preceding year as well as the quantities sold. In the case of products such as milk, where there was only one major buyer (i.e., Kenya Cooperative Creameries), average prices were easier to obtain. The generated list of product prices and quantities was used to calculate crop revenues (CREV). Farmers were also asked to recollect the various farm input costs they had incurred during the previous year. Costs and quantities were used to estimate the total farm input costs (FIC). Household expenses were also listed and added up to obtain total household expenditure (THHX). In some cases total household expenditures appeared to capture non-farm income better. Other financial variables such as total revenue (TREV), total expenditures (TEXP), and savings (SAVINGS) were created from mathematical transformations of the financial information collected.

In Village 2, coffee and tea production information was more readily available. Tea payments to farmers were made on a monthly basis while those for coffee were made on a quarterly basis and records were better kept. The situation was otherwise similar to that in Village 1 with regard to other financial information. Financial status was important in the adoption of some strategies as the probit results have demonstrated.

Household Characteristics. These characteristics were mainly observed and recorded for the head of the household and the spouse. The household variables included age of the head of household (AGE), years of formal education received (EDH), household size (HSZ), duration of stay in the village (TIM), and leadership roles held by members of the household (LEAD). These characteristics were expected to provide some insights on household characteristics that may influence the adoption of different strategies. Probit models developed indicate that certain household characteristics are associated with the adoption of different strategies.

Exposure to Information. Exposure to information was evaluated in terms of access to sources of knowledge on different wood-energy production and consumption policies. The different sources examined included visits by extension agents from different government agencies (EVPY), attendance at agricultural shows (SH10), public meeting attendance (MTATT), and hours spent listening to the radio (RHPD). Other sources of information such as television (TVHPD) and newspapers (NPPM) were also considered but there were very few farmers who had access to them.

Quantities of Fuel Used per Month. The quantities of different fuels used by households were provided by the head of household, spouse, or his/her representative. The quantities were measured in terms of bags of charcoal (CCBM), cylinders of liquified petroleum gas (CGAM), headloads of crop residues (CRHM), head-loads of fuelwood (FWHM), and liters of kerosene (KELM). For electricity, monthly payments to the Kenya Power and Lighting Company were used as a surrogate measure of the quantity consumed. This decision was made because printed electricity bills were not always readily available.

Fuel prices varied between the two villages as shown in Table 4.18. Fuelwood from national forests in Village 1 had an average price of Ksh 0.60 per headload. Village 2 did not have this alternative. The cheapest option for those without adequate fuelwood supplies of their own was buying from neighbors at an average price of Ksh 32.50 per headload (Ksh 279.50 per stack) The market price per stack for Village 2 was Ksh 207.60 per stack. This was lower than the price of Ksh 279.50 charged for the same quantity from a

Table 4.18 Average prices for different fuels and strategies for Village 1 and Village 2

Fuel or Strategy	Village 1 average price (KSh[a])	Village 2 average price (Ksh)
Kerosene	9.80/liter	9.03/liter
Charcoal	60.20/bag	105.70/bag
Basic electric cooker	N/A	122.73/unit
Electricity bill	N/A	176.60/month
KCJ	102.60/unit	107.00/unit
Kerosene stove	232.50	251.75/unit
Market fuelwood	N/A	207.60/stack
Neighbor fuelwood	22.70/headload	279.50/stack
		(32.50/headload)
Own fuelwood	15.00/headload	237.17/stack
		(27.58/headload)
Traditional metal stove	54.20/unit	59.71/unit
National forest fuelwood	0.60/headload	N/A

[a] 1 US$ = Ksh 26.00 (approximately) at the prevailing exchange rate between July-September, 1991. One shilling is equal to one hundred cents.

neighbor's land. Market prices were expected to be higher than prices for fuelwood from a neighbor's farm, and this is an aspect that may require further study to explain why they were not. Fuelwood merchants may have had access to low cost fuelwood sources. Kerosene, charcoal, and stove prices also varied. Some of the price differences are difficult to interpret since they may have been influenced by historical factors that could not be captured by a cross-sectional study such as this. Kerosene stoves in Village 1, for example, may appear cheaper on average because relatively few households had adopted them and traders were probably selling their old stock of equipment and accessories. They could therefore keep the prices low to encourage households to buy them. Village 2, on the other hand, shows a relatively higher adoption rate for kerosene stoves. If stoves are fast-moving products in the stores, new stock is likely to be purchased at higher prices. As expected, the Kenya Ceramic Jiko and the traditional metal stove were clear substitutes in Village 1. A small positive correlation was observed in Village 2. With the low level of adoption, individuals probably still use both stoves interchangeably.

Choice of Cooking and Heating Technologies. This study dealt with factors associated with the adoption of different wood-saving or wood-substituting technologies. The choices were clearly explained to the respondents to ensure that answers were related only to the strategies of interest. As noted previously, the strategies included the Kuni Mbili stove/fireplace (KUMU), the Kenya Ceramic Jiko (KCJU), electric cookers (ELEU), and kerosene stoves (KESU). The incidence of traditional metal stoves (TMSU), three stone fire place (TSFU), sawdust stoves (SDSU), and any other technologies (OTHU) was also noted.

The percentages of households using improved cooking and heating technologies were summarized earlier in Table 4.03. The old technologies were still widely used at the time of the study. Table 4.19 shows the correlation coefficients for old and new technologies for Village 1. Table 4.20 shows the corresponding results for Village 2. Overall, most of the technologies tended to be substitutes for each other as indicated by the many negative correlation coefficients in both villages. The "Kuni Mbili" stove/fireplace and the three-stone fireplace, for example, are reasonably good substitutes as evidenced by a relatively high negative correlation coefficient (a high -0.915 for Village 1 and -0.425 for Village 2). The correlation coefficient for KCJU and TMSU in Village 1 was 0.259. Similarly, electric cookers (ELEU) and the Kenya Ceramic Jiko (KCJU) are substitutes for the traditional metal stoves (TMSU) with correlation coefficients of -0.250 and -0.230, respectively in Village 2. Electric cookers and Kenya

Table 4.19 Pearson's correlation coefficients for important old and new technologies used for cooking and heating in Village 1

	KCJU	KESU	TMSU	TSFU	KUMU
KCJU	0.000				
KESU	-0.112	1.000			
TMSU	-0.259	-0.084	1.000		
TSFU	-0.077	-0.115	-0.025	1.000	
KUMU	-0.124	0.090	0.068	-0.915	1.000

Table 4.20 Pearson's correlation coefficients for important old and new technologies used for cooking and heating in Village 2

	ELEU	KCJU	KESU	KUMU	SDSU	TMSU	TSFU
ELEU	1						
KCJU	0.251	1					
KESU	0.059	-0.060	1				
KUMU	-0.066	0.085	-0.031	1			
SDSU	-0.022	-0.042	-0.045	0.036	1		
TMSU	0.031	0.027	0.124	-0.001	-0.014	1	
TSFU	-0.250	-0.230	-0.067	-0.425	0.088	-0.004	1

Ceramic Jiko have a small positive correlation coefficient. The other technologies had very low correlation coefficients.

Household Fuel Choice. Fuel choice by households was an important concern in this study. As a result, explicit questions on the choices were asked. The fuel choices considered included kerosene, gas, fuelwood, electricity, crop residues, and charcoal. An "others" category was also included to accommodate unanticipated fuels or fuels used by very few individuals in the population. Some unique options such as solar energy did show up. The current study does not include a probit analysis of such options.

An important preliminary question was whether the choices of different fuels by a household were correlated. Tables 4.21 and 4.22 show the correlation coefficients associated with the use of different quantities of fuel per month for Village 1 and Village 2 respectively. Most of the Village 2 correlation coefficients were negative indicating the substitutability of different fuels. The bags of charcoal (CCBM) and the headloads of fuelwood (FWHM) used in Village 2 for example had a correlation coefficient of -0.157. This means that as the quantity of charcoal used by a household increased, the quantity of fuelwood used decreased by a small amount. The corresponding value for Village 1 was 0.181. The quantity of liquified petroleum

Table 4.21 Pearson Correlation Coefficients for Quantities of Fuels Used per Month in Village 1

	CCBM	CGAM	CRHM	FWHM	KELM
CCBM	1.000				
CGAM	0.652	1.000			
CRHM	0.132	-0.059	1.000		
FWHM	0.181	0.050	0.087	1.000	
KELM	0.538	0.698	-0.094	0.114	1.000

Table 4.22 Pearson's correlation coefficients for quantities of fuels used per month in Village 2

	CCBM	CGAM	CRHM	KELM	FWHM
CCBM	1				
CGAM	0.462	1			
CRHM	-0.041	-0.159	1		
KELM	-0.005	0.113	0.080	1	
FWHM	-0.157	-0.242	-0.021	0.162	1

gas (CGAM) was, on the other hand, positively correlated with the bags of charcoal (CCBM) and liters kerosene (KELM). The correlation coefficient for kerosene and gas is very small. Gas is generally expensive and its users probably use charcoal as a substitute some of the time. Since there is no policy incentive supporting the use of liquified petroleum gas; it is not examined further in this study.

The results in Table 4.22 revealed a small negative correlation (-0.005) between the quantity of charcoal used and the liters of kerosene used per month in Village 2. This sign is consistent with expectations, but the correlation is very small. Kerosene and kerosene stoves tend to be more expensive than traditional or improved charcoal stoves such as the KCJ.

Land Tenure Structures. Land tenure was hypothesized to be a crucial factor in determining the adoption of tree planting practices in the preceding ten years. Three categories of tenure were conceptualized. They were: wholly privately owned (TN1), inherited and shared (TN2), and inherited but not shared (TN3). The tree planting strategy (TPHS10) deals with the wood-energy supply side. Most of the farmers who had planted trees in the preceding ten years consistently cited fuelwood need as an important consideration in the decision to plant. In all the model results however, tenure was insignificant. It is likely that the three tenure systems identified in central Kenya confer similar rights to land use and households, therefore, respond to tree planting similarly.

Predictive Ability of the Models

Table 4.23 presents the predictive ability of the models developed. Predictive ability results are generated by LIMDEP Version 6.0 in terms of the number of cases correctly or incorrectly predicted. The percentages of correct predictions can be calculated from those values.

Specific models from tables 4.8 through 4.16 are listed in column 1. Column 2 shows the values of the dependent variable that were actually 0 (non-adopters) and were also predicted by the model as 0. Column 3 shows the cases where the dependent the dependent variable was actually zero but was incorrectly predicted as 1 (Adopter). Column 4 shows the number of cases where the dependent variable was actually 1 but was incorrectly predicted as a zero. Finally, column 5 shows the situations where the model correctly predicted the number of adopters. This provides a helpful presentation of predictive capability.

Model KCJ1 illustrates that 76 out of 82 non-adopters were correctly predicted as non-adopters. Similarly, 60 out of 63 adopters were correctly predicted. Model KCJ2 did well in predicting non-adopters but only 3 out of 7 adopters were correctly predicted. Model KUM1 predicted 121 out of

Table 4.23 Predictive capability of the models

Model[a]	Actual 0		Actual 1	
	Predicted 0	Predicted 1	Predicted 0	Predicted 1
KCJ1	67	15	13	50
KCJ2	153	1	4	3
KUM1	121	3	18	3
KUM2	117	3	31	10
KES1	130	3	12	0
KES2	114	4	36	7
TPH1	58	22	27	38
TPH2	126	3	27	5
KCJC	222	14	22	48
KUMC	239	5	54	8
KESC	243	8	49	6
TPHC	182	26	64	34

[a] Model KCJC, KUMC, KESC, and TPHC are based on the combined data for the two villages (n=306) and reflect adoption of KCJU, KUMU, KESU, and TPHS10 respectively.

124 non-adopters correctly and 3 out of 21 adopters correctly. Model KUM2 shows that 117 out of 120 non-adopters were correctly predicted as non-adopters while 10 out of 41 adopters correctly predicted. Model KES1 predicted 130 out 133 non-adopters correctly. The 12 adopters were incorrectly predicted as non-adopters. Model KES2 illustrates that 114 out of 118 non adopters were predicted correctly as non-adopters while 7 out of 43 adopters were correctly predicted. In model TPH1, 58 out of 90 non-adopters were predicted correctly while 38 out of 65 adopters were predicted correctly as adopters. Finally, Model TPH2 illustrates that 126 out of 129 non-adopters were predicted as non-adopters and 5 out of 32 adopters were predicted as adopters.

The percentage of correctly predicted values is obtained by adding the actual number of correctly predicted zeros (non-adopters) to the actual number of correctly predicted ones (adopters), dividing that value by the total (sample size), and then multiplying it by one hundred. These values were calculated for the twelve models and are shown in Table 4.24.

The combined data models do better in predicting non-adopters than single village models. There were a lot more non-adopters than adopters of the technologies in the two villages and that is the main reason why non-adopter based percentages are more robust. The percentages for adopters

Table 4.24 Percentages correctly predicted for all models

Model[a]	Adopters and non-adopters	Non-adopters	Adopters
KCJ1	80.7	81.7	79.4
KCJ2	95.6	99.4	42.9
KUM1	85.5	97.6	14.3
KUM2	78.9	97.5	24.4
KES1	96.6	97.7	0
KES2	75.2	96.6	16.3
TPH1	66.2	72.5	58.5
TPH2	81.4	97.7	15.6
KCJC	88.2	94.1	68.6
KUMC	80.7	98.0	12.9
KESC	81.4	96.8	10.9
TPHC	70.6	87.5	34.7

[a] The model acronyms are for Kenya Ceramic Jiko (KCJ1, KCJ2, KCJC), "Kuni Mbili" stove/fireplace (KUM1, KUM2, KUMC), kerosene stoves (KES1, KES2, KESC), and tree planting (TPH1, TPH2, TPHC) for Village 1, Village 2, and combined data respectively.

only were generally low. From a policy perspective, being able to correctly predict a non-adopter is also as good as being able to predict an adopter. Once the two groups are properly identified, relevant policies can be put in place.

Overall Model Performance

Table 4.25 presents a summary of the overall performance of the models in terms of the expected and observed signs on the probit coefficients for the independent variables. The possible reason for differences between signs were explained under separate models in this chapter. Some of the variables expected to be significant were not. This summary and the predictive power of the models summary (Table 4.23 above) provide useful evaluation criteria. Extension visits and household size had positive coefficients in most models. Other variables produced mixed results. An evaluation of each model shows where the opportunity for improving adoption for each technology lies.

Summary

This chapter has presented results of the parametric and non-parametric tests and the probit analyses. The mean difference tests suggested that the two villages were significantly different in a number of important variables. The primary emphasis was therefore placed on analyzing the

Table 4.25 Summary of coefficient signs

Variable[b]	A Priori Sign	Observed coefficient signs for models[a]					
		KCJ1	KCJ2	KCJC	KUM1	KUM2	KUMC
AGE	-	-		-			
EVPY	+	+				+	
THHX	+ or -	+	+	+			
MEMFEOF	+	NS[c]	NS	NS	NS	NS	
HSZ	+		NS				
KELM	+ or -	+	+	+			
AREA	+		+	-	+		
CRHM	+				-	+	+
LEAD	+				+	NS	+
SH10	+				+		NS
TREV	+				-	NS	
EDH	+						
TIC	+			+			
RHPD	+						
TN1	+						
TN2	+ or -						
TN3	+ or -						
FWHM	+						
DUMMY	+ or-			+			NS
CGAM	+ or -						NS

[a] Model column headings represent technology specific model results for Village 1, Village 2, and combined data respectively.
[b] Variable descriptions appear in Appendix 1.
[c] Not significant (NS) at $\alpha = 0.05$.

Table 4.25 (continued)

Variable[a]	A Priori Sign	Observed coefficient signs for models[c]					
		KES1	KES2	KESC	TPH1	TPH2	TPHC
AGE	-	-	NS[b]	-			
EVPY	+	+	+	+		NS	NS
THHX	+ or -					-	
MEMFEOF	+	NS					
HSZ	+				+	NS	+
KELM	+ or -						
AREA	+				-		-
CRHM	+						
LEAD	+	NS	NS				
SH10	+				NS		NS
TREV	+	NS	NS		+		NS
EDH	+	-		-			
TIC	+		NS				
RHPD	+		NS	+		NS	NS
TN1	+				NS	NS	
TN2	+ or -				NS	NS	
TN3	+ or -						
FWHM	+					+	
DUMMY	+ or -			-			+
CGAM	+ or -						

[a] Model column headings represent technology specific results for Village 1, Village 2, and combined data respectively.
[b] Variable descriptions appear in Appendix 1.
[c] Not significant (NS) at $\alpha = 0.05$.

villages as two separate entities in the central Kenya region. To examine whether more general statements could be made for the two villages, four more probit models (KCJC, KUMC, KESC, TPHC) were run with combined data using a village dummy variable. Electricity use was excluded since it was not available in Village 1 and also because of its very limited use for cooking and heating in Village 2. There were only two electricity users. It was therefore difficult to examine the factors that influenced its adoption and discussion was based on the mean characteristics of electricity-using households compared to the overall village means.

A comparison of mean differences between adopters of at least one technology and non-adopters indicated that the two groups had different characteristics. In Village 1, they differed in parameters such as area under cultivation (AC91), crop revenues (CREV), household expenditures (THHX), age (AGE) and education (EDH) among others. For Village 2, differences included farm input costs (FIC), household size (HSZ), extension visit per year (EVPY) and headloads of fuelwood used per month (FWHM). Those differences are useful indications of where policy interventions may be made.

The probit results indicated that some of the important factors influencing adoption of wood-energy production and consumption strategies included age (AGE), crop revenue

(CREV), time spent in fuelwood collection (TIC), extension visits per year (EVPY), education level of head of household (EDH), area of farm land owned (AREA), and access to different sources of information (NPPM, SH10, TVHPD, RHPD) among others. These variables were examined and evaluated with regard to how they affected the adoption of different policy-supported strategies. The elasticities presented serve a useful function in that regard.

V. SUMMARY AND CONCLUSIONS

The specific objectives of this study were (1) to determine how households have responded to specific wood-energy policies which were put in place or strengthened during the 1980s, and (2) to identify the factors associated with household adoption or non-adoption of the strategies. The intended end-use of these results is to make recommendations on suitable implementation approaches for wood-energy policies.

A review of literature in this area indicated that important data were lacking in Kenya and other countries faced with similar fuelwood problems. As a result, some policy decisions have been based on experiences in other sectors or regions that may sometimes be significantly different. For example, quantitative analysis including information on response elasticities has been lacking. The models estimated in this study provide adoption-related information for the two villages studied.

The more efficient wood- and charcoal-burning technologies showed highly variable adoption rates in the two villages. The Kenya Ceramic Jiko, for example, had been adopted by 43 percent of the households in Village 1 and only 4 percent in Village 2. Kerosene stoves had been adopted by 8 and 27 percent, respectively, in Villages 1 and 2. This study has shed some light on the adoption process and the different factors associated with adoption or non-adoption of these technologies. Table 4.25 summarizes the important variables in the adoption process for the two villages. Households have generally responded positively to the wood-saving and supply-enhancing technologies.

The technologies that appear to have a good potential in two the villages and for the central Kenya region in general are the Kenya Ceramic Jiko and the "Kuni Mbili" stove/fireplace. The two technologies are improved adaptations of widely used technologies and are therefore easily appreciated. Their costs relative to other improved technologies are also low. The Kenya Ceramic Jiko had an adoption rate of 43 percent in Village 1 where average household charcoal use per month (CCBM) was twice that of Village 2. Although charcoal prices were low in Village 1 relative to prices faced by Village 2 households, the cost of charcoal may have provided an incentive towards using charcoal-efficient stoves. On the other hand, Village 2 had an adoption rate of 27 percent for the "Kuni Mbili" stove/fireplace compared to 15 percent in Village 1. Households tended to respond by adopting technologies that saved frequently-used fuels that were relatively expensive or scarce. The adoption rates are encouraging considering that the average adoption period is rather short. The Kenya Ceramic Jiko had been in use for an average of 3.3 and 1.4 years for Villages 1 and 2, respectively. Similarly, the "Kuni Mbili" stove/fireplace had been in use for an average of 3.3 and 3.8 years in Villages 1 and 2, respectively.

Electricity does not appear to hold a great promise in substituting fuelwood for cooking and heating. Distribution and use costs are likely to be major limitations to its adoption. In the development of rural infrastructure, the government policy of accelerated rural electrification may still have a positive contribution. Industries and institutions wishing to locate in rural areas often need electricity. Such facilities positively contribute to rural income and development. The adoption of new technologies is likely to improve as household resource endowments increase.

Kerosene was used for cooking and heating by 27 percent of the households in Village 2 and 8 percent of the households in Village 1. Existing and proposed subsidies may therefore benefit some households. It is necessary to understand how regularly kerosene is used for cooking and heating before it can be justified as a valuable alternative. As indicated elsewhere in this study, kerosene subsidies pose serious equity questions. Forest depletion, soil degradation and watershed destruction due to excessive cutting for fuelwood and other forest products are nevertheless serious problems for Kenya. It is therefore important to explore all possibilities.

Policy Implications

The technologies discussed in this study have been supported through different government policies with varying degrees of success. Research results indicate that important policy variables include: extension services, income growth, improved access to different energy alternatives, area of farm-land owned, leadership role, household size, years of formal education received by head of household, and locational characteristics. Policy choices include: improving information flows for new technologies, improving linkages between private and public sector efforts, improving the efficiency of supply- and demand-side interventions, developing better feed-back systems, and encouraging household to change energy consumption patterns.

The probit models evaluated indicate that the availability of technology information through various channels is crucial. This means that extension services, meetings, agricultural shows, and mass media information flows need to be improved. Local meetings and radio are good avenues for conveying information on efficient wood-energy strategies since they appear to be accessible to most small-scale farmers. Agricultural shows and field visits to farmers' training centers are likely to have greater potential if they were accessible to more farmers. These two information sources can directly address the wood-energy question and provide demonstrations of more efficient wood-energy technologies. Subsidized field trips and lower gate fees for small-scale farmers may improve awareness of these technologies. Efforts can also be made to ensure that extension agents are well prepared with this knowledge so that they can disseminate it.

Though not examined quantitatively in this study, another helpful intervention would be for the Ministry of Energy and private producers of efficient stoves to work together in supporting and training stove producers and retailers in rural retail outlets. Such producers and traders can easily advise fellow village residents on the merits of these technologies and also sell them. This would complement the work of extension agents. The on-going program of training artisans from rural village polytechnics (vocational schools) should also be intensified. The stove prices can be lowered if they are produced locally thereby reducing transport costs considerably. As more artisans become available, more of these technologies would be produced and disseminated. The costs of the Kenya Ceramic Jiko and the "Kuni Mbili" stove/fireplace do not appear prohibitive.

Demand- and supply-side policies need to be pursued concurrently in addressing wood-energy problems in the rural areas of Kenya. Literature indicates that much effort has been invested in increasing wood-energy supplies. With adequate public and private sector investment levels, new fuelwood and charcoal saving or substituting technologies can make significant contributions in the future. As the country develops, more energy alternatives will become available. Large-scale adoption of efficient technologies can save forests and delay certain environmental degradation.

Agroforestry approaches to land use are important in increasing fuelwood supply. Small-scale farmers can conveniently adopt agroforestry. Farmers faced with serious wood shortages tend to be more interested in tree planting. Agroforestry enables them to enjoy the benefits derived from multi-purpose tree crops grown in association with other agricultural products. In this study, results indicate there is good agroforestry potential among small-scale farmers. Well-funded tree nurseries and extension agents are likely to play an important role in the adoption of agroforestry practices.

The Ministry of Energy or another agency should develop an appropriate system of collecting feedback from new technology users. Such a system would provide useful information for future planning and improvements in new technology designs. An interesting observation made by some Kenya Ceramic Jiko users in Village 1, for example, was that the stove tended to lead to quick deterioration of the bottom part of aluminum cooking pots due to the intense and focused heat that pots are exposed to during cooking. Better information flow between researchers, stove manufacturers and users would be very helpful in design and use of such stoves. In that process, problems which may hinder adoption can be detected and rectified in the early stages.

Changing the energy use patterns of households can be improved through better public awareness programs. Better marketing programs for new technologies is very important. In Village 2, some households reported that stoves such as the Kenya Ceramic Jiko were not available locally. A better distribution network may significantly improve adoption.

In general, low-cost strategies that directly address household needs in specific regions of the country are likely to be more widely adopted than more expensive ones. Programs directed towards economic development and the reduction of population growth rates in the country are also useful in facilitating adoption. Higher incomes increase the ability of households to purchase new technologies.

The population growth rate in Kenya during the last three decades has averaged 3.3-4.1 percent. This high population growth rate has continuously reduced the impact of gains in economic growth. A higher population puts a strain on the nation's resources and also exerts greater pressure on the land. Increasing rural energy needs under these circumstances can lead to rapid cutting of woody vegetation. The end result is environmental degradation, reduced productivity and poverty. Effective wood-energy production and consumption strategies can alleviate the pressure on the natural resources of Kenya while a search for long-term solutions continues. The different policy variables discussed can be manipulated to improve wood-energy use, supply, and availability of substitutes.

Recommendations for Future Research

A lot of research work is still needed to effectively deal with the wood-energy shortages in Kenya. Policies have to be examined within the context of rapidly changing socio-economic situations. Land parcels will continue to decrease as population grows. There is need for a broader study linking the use of different technologies to supply and demand situations in different regions of the country. Other research needs include: regular studies to capture the temporal dimensions of adoption, developing effective extension techniques, better definition of research variables, evaluating energy needs and adoption strategies of poorer villages, and evaluating potential adoption of improved charcoal conversion kilns.

Comprehensive studies of selected villages at regular time intervals would provide useful longitudinal information which would be very helpful in understanding the diffusion process for the strategies discussed. The average duration of use for wood-saving technologies was low. Regular follow-up over time would therefore supply new and useful information on adoption profiles and trends.

A focus group type of study dealing with opinion leaders in different villages in Kenya would be useful in evaluating the technology knowledge base for larger parts of central Kenya or similar regions in other parts of the country. Such a study can show what the general production and consumption trends are. A comparison of such studies with village specific results can provide additional insights on the wood-energy problem and relevant technology for rural households in Kenya

Providing better extension services emerged as an efficient way of increasing the likelihood of adoption for many of the technologies. Extension agents in the field tend to focus their efforts on revenue generating activities. It is necessary to ensure that the most effective communication techniques are developed and used. Farmers can adapt to wood-energy shortages more effectively if they know all their options.

The level of education among the heads of households in the study areas is low and extension information must be simplified to capture their attention. Posters and other literature should be written in local languages or Swahili to enable as many farmers as possible to acquire information about these technologies. Research on how to effectively do this would be very helpful.

In examining attributes of different strategies (e.g. costs, perceived safety), information was found to be inadequate for comparative analyses. Different technologies were sometimes preferred for reasons such as tradition. In other cases, farmers did not give any indication as to why they used certain technologies. After discarding samples without adequate data, not enough cases were left for comparative analyses. A future study can incorporate these information concerns in the objectives and in the related questionnaire. To address model specification problems, additional variables such as perceived affordability and relative advantages of specific regions need to be examined.

A relatively high proportion of the households surveyed reported that they were still using (at least some of the time) the same old strategies (e.g., the traditional metal stove and the three-stone fireplace that were supposed to be replaced). An evaluation of the extent of use for various technologies is important. It was apparent in many cases that new strategies were replacing older ones. It is needed to establish whether new wood-energy technologies completely replace older technologies or whether older ones are retained for occasional use. For example, the traditional metal stove may be retained for warming the house during cold days while the Kenya Ceramic Jiko is used for cooking most of the time. This information may help bring about improving designs.

Local geographic and economic differences exist in the study areas and they should be given due consideration in applying results of this analysis. The two villages studied generally represent the more productive parts of the high agricultural potential region of central Kenya. At least one village in the less productive parts of the region needs to be studied. The less productive areas tend to have fewer trees and are therefore likely to have unique wood-energy adoption profiles. Many post-independence settlement schemes for previously land-less households were established in such areas.

An extension of the current study may look at the factors associated with the adoption of different combinations of technologies. A number of households had adopted more than one technology. A study could be carried out to establish whether the relative use rates for technologies in use at any one time. The relative merits of different technologies can then be better understood.

A study of the factors associated with the of adoption of more efficient charcoal-making technology would also complement the current study. Significant energy losses occur in the charcoal-making process. The diffusion of efficient charcoal-making kilns would complement the diffusion of strategies discussed in this study.

In addition to filling some important information gaps, this study has provided information that can be used to improve adoption rates for desirable wood-energy production and consumption strategies in high agricultural potential areas of Kenya. The full potential of new technologies, however efficient, will never be realized if adoption rates remain low. A good understanding of the factors associated with the adoption of these technologies is useful for Kenya, and also for governments in Africa and elsewhere which are interested in developing and implementing workable wood-energy policies.

APPENDICES

Appendix 1. Variable Description

AC91	Area under cultivation in 1991 in acres
AGE	Age of the head of household in years
AREA	Area of land owned and managed by the household
CCBM	Charcoal bags used by household per month
CGAM	Cylinders of gas used by household per month
CREV	Crop revenue per year in Kenya Shillings
CRHM	Headloads of crop residues used by household per month
DSHH	Dwelling structure occupied by household (1=Permanent stone or brick house, 2=Timber house with tin roof, 3=Mud walls with tin roof, 4=Mud walls and grass thatched)
DUMMY	Dummy variable for village effect (1 or 0)
EDH	Education level of the head of household in years
ELEU	Use of electricity in the household for cooking and heating (1=Yes, 0=No)
EVPY	Extension agent visits per year
FIC	Farm input costs per year in Kenya Shillings
FUCC	Use of charcoal for cooking and heating (1=Yes, 0=No)
FUCR	Use of crop residues for cooking and heating (1=Yes, 0=No)
FUEL	Use of electricity for cooking and heating (1=Yes, 0=No)

FUFW	Use of firewood for cooking and heating (1=Yes, 0=No)
FUGA	Use of gas for cooking and heating (1=Yes, 0=No)
FUKE	Use of kerosene for cooking and heating (1=Yes, 0=No)
FUOT	Use of other fuel for cooking and heating (1=Yes, 0=No)
FWHM	Headloads of fuelwood used by household per month
GNDH	Gender of the head of household (1=Male, 0=Female)
HSZ	Household size (Includes persons generally bound by ties of kinship who normally reside together under a single roof or under several roofs within a single compound and who share the community of life in that they are answerable to the same head and share a common source of food (CBS, 1981 p.22))
KCJU	Use of the Kenya Ceramic Jiko (KCJ) (1=Yes, 0=No)
KELM	Liters of kerosene used per month
KESU	Use of kerosene stove (1=Yes, 0=No)
KUMU	Use of Kuni mbili fire place (1=Yes)
LEAD	Leadership position in the village (1=Yes, 0=No)
LBAV	Labor availability measured in hours
MTATT	Attendance to at least one public meeting during the previous year (1=Yes, 0=No)
MEMFEOF	Member of household employed off-farm (1=Yes, 0=No)

NPPM	Number of issues of newspapers read per month
OTHM	Amount per month of other fuel used in specified units
OTHU	Other method used for cooking and heating (1=Yes, 0=No)
RHPD	Hours per day spent by head of household listening to the radio
SAVINGS	Difference between total revenue and total expenditure
SDSU	Use of sawdust stove for cooking and heating (1=Yes, 0=No)
SH10	Number of visits to agricultural shows during the last ten years
TEXP	Total expenditure in Kenya shillings
THHX	Total household expenditure in Kenya shillings
TIC	Time spent collecting one headload (or other specified unit) of fuelwood in hours
TIM	Time the household has settled on the land in years
TMSU	Use of the traditional metal stove for cooking and heating (1=Yes, 0=No)
TN1	Land bought and privately owned (1=Yes, 0=No)
TN2	Land inherited but shared (1=Yes, 0=No)
TN3	Land inherited but not shared (1=Yes, 0=No)
TN4	Coded categories of land tenure structure (1=TN1, 2=TN2, 3=TN3)

TNP	Existence of tenure problems (land disputes) (1=Yes, 0=No)
TPHS10	Household has planted trees on their farm during the last ten years (1=Yes, 0=No)
TREV	Total revenue for the household in Kenya shillings
TSFU	Use of three stone fireplace for cooking and heating (1=Yes, 0=No)

App

Appendix 2. UCRHS Approval Letter

MICHIGAN STATE UNIVERSITY

OFFICE OF VICE PRESIDENT FOR RESEARCH
AND DEAN OF THE GRADUATE SCHOOL

EAST LANSING • MICHIGAN • 48824-1046

July 8, 1991

Albert M. Mwangi
1647 J Spartan Village
East Lansing, MI 48823

RE: ANALYSIS OF WOOD ENERGY PRODUCTION AND CONSUMPTION STRATEGIES AMONG SMALL SCALE FARMERS IN CENTRAL KENYA, IRB #91-328

Dear Mr. Mwangi:

The above project is exempt from full UCRIHS review. The proposed research protocol has been reviewed by another committee member. The rights and welfare of human subjects appear to be protected and you have approval to conduct the research.

You are reminded that UCRIHS approval is valid for one calendar year. If you plan to continue this project beyond one year, please make provisions for obtaining appropriate UCRIHS approval one month prior to July 2, 1992.

Any changes in procedures involving human subjects must be reviewed by UCRIHS prior to initiation of the change. UCRIHS must also be notifed promptly of any problems (unexpected side effects, complaints, etc.) involving human subjects during the course of the work.

Thank you for bringing this project to my attention. If I can be of any future help, please do not hesitate to let me know.

Sincerely,

David E. Wright

David E. Wright, Ph.D., Chair
University Committee on Research Involving
Human Subjects (UCRIHS)

DEW/deo

cc: Dr. Larry Leefers

Appendix 3. Domestic Energy Production and Consumption Strategies Survey

Interview No. : ....

Village : ....

Interview date : ....

Interviewer's Name: ....

Checked by PI On : ....

SOCIOECONOMIC DATA:

1. a. How many people live in this household? ....

No. of children : ....

Ages of the children: ....

No. of adult males : ....

Ages of the adult males: ....

No. of adult females: ....

Ages of the adult females: ....

b. How many other independent households are represented on your farm? ....

2. a. Is the person answering this question male or female? ......

[Enter 1 if Male, and 0 if Female]

b. What is the relationship of the person interviewed to the head of the household? ....(e.g. wife)

c. Does the head of household live on the farm most of the year?............. [Enter 1 if Yes, and 0 if No]

d. What type of dwelling structure is occupied by the head of household? ....
[Enter 1 if Permanent (i.e. stone or brick house), 2 if Semi-permanent (i.e. timber with tin roof), 3 if Temporary1 (i.e. mud walls with tin roof, and 4 if Temporary2 (i.e. mud walls and grass thatched)]

3. a. How many years of education do you have? ....
   b. How many years of education does your spouse have? ....

4. What is your age? ......Years

5. Does anyone in your household have any leadership position in the village (e.g. a cooperative official, a school committee member, women group leader, etc.)? .... [Enter 1 if Yes, and 0 if No]

6. How much total land do you own? ...... acres or ...... hectares
(note: 1 ha = 2.47 ac.)

7. a. Is farming land split into smaller tracts for other members of the family? ....
[Enter 1 if Yes, and 0 if No]
   b. How much land do they farm? ....acres / hectares

8. a. How many acres/hectares do you farm? .... acres/ha.
   b. How many acres/hectares are under cultivation this year?...

Food crops = ... ac./ha.

Cash crops = ... ac./ha.

c. If food crops also serve as cash crops, what percentage of the crops produced is sold?........

d. How many acres/hectares are under

Pastures? .... ac./ha.

Woodlots? .... ac./ha.

(Be certain to circle acres or hectares)

9. How long has your household lived on this land? ..... Years

10. How did you gain access to your land?

(Enter 1 if Yes, and 0 if No)

Bought and privately owned : .....

Inherited but still shared : .....

Inherited but not shared : .....

Other : .....

Specify other : ....

11. Have you had any disputes over your right to use the land recently? ....

[Enter 1 if Yes, and 0 if No]

12. Could you please give an estimate of your cash crop and/or livestock yields and revenues since this time last year(or for the most recent production year for your crops and/or livestock)?

PRODUCT	YIELDS	REVENUES (Regular)	REVENUE Bonuses)
....	....	....	....
....	....	....	....
....	....	....	....

13. How much money (Kenya shillings) did you spend on these farm

inputs since this time last year?

Agricultural labor : ....

Agricultural seeds : ....

Fertilizers : ....

Pesticides : ....

Animal feed : ....

Tree seedlings : ....

Others : ....

14. How much money (KShs.) does your household spend on the following items in a month (or year) ?

Food : ....

School fees for your children : ....

(specify whether per month,

term, or year)

Other educational costs : ....

(e.g. uniforms, books, etc.)

Medical expenses : ....

Transportation : ....

Others : ....

Specify important others: ....

15. Do your children help you work on the farm? ....

[Enter 1 if Yes, and 0 if No]

b. How many? ....

c. How much time (hours per day) during the school term? ....

d. How much time (hours per day) during school holidays? ....

e. How many paid workers did you use on your farm last year? ....

f. For how long did each of the laborers work on your farm?

(i) .... days per week/month/year

(ii) ...... "

(iii)...... "

etc.

16. a. Do you sometimes work outside your farm for pay? ....

[Enter 1 if Yes, and 0 if No]

b. If yes, how often?

Days per week : .... or

Days per month: ....

17. What are the current wage rates for farm labor in your area? Ksh/per day: ....

18. a. Are any family members employed off-farm? ....

[Enter 1 if Yes, and 0 if No]

b. If yes, how many? ....

c. What kind of professions are they engaged in?

....

....

d. How long have they been engaged in their professions?

....

....

19. a. Are any family members involved in a trade other than agriculture e.g. backyard carpentry, basket weaving, shopkeeping etc.? ....

[Enter 1 if Yes, and 0 if No]

b. What is the name of their trade: ....

c. What is their monthly income from the trade? Shs........

DOMESTIC ENERGY PRODUCTION AND CONSUMPTION DATA:

20. What fuel do you usually use for daily cooking?

[Place a 1 in the appropriate spaces, Enter 0 for all others]

	Always	Sometimes	Never
Fuelwood	....	....	....
Kerosene	....	....	....
Charcoal	....	....	....

Electricity	....	....	....
Gas (LPG)	....	....	....
Crop residues	....	....	....
Others	....	....	....

21. Was the fuelwood availability better or worse for your household

one year ago? ....

five years ago? ....

ten years ago? ....

[Enter 1 if Better, and 0 if Worse]

22. What quantities of the following fuels are used in your household per month?

Fuelwood ....headloads/stacks/other unit

Kerosene .... litres

Charcoal .... bags

Gas .... cylinders

Crop residues............. headloads

Electricity .... kilowatt hrs/last months bill

Others ....

23. a. Do you use any of the following for cooking or heating?

[Interviewer- Enter a 1 if Yes, or a 0 if No in the appropriate spaces below]

	Currently	Duration of use in years.	Used in other household
Three stone fireplace :	....	....	....
Traditional metal stove:	....	....	....
Improved Jiko e.g.KCJ :	....	....	....
Electricity :	....	....	....
Kerosene stove :	....	....	....
"Kuni Mbili" Fireplace :	....	....	....
Saw-dust stove :	....	....	....
Other :	....	....	....

b. If there are other independent households on your farm, please indicate whether they use any of the above cooking and heating methods to the best of your knowledge.

[Enter 1 if Yes, and 0 if No in column 3 above]

24. The following are possible reasons for choosing a particular energy consumption strategy:

(1) it would be an improvement over my current practice,

(2) it is easy to use,

(3) it is an acceptable method in the village,

(4) it can be easily tried and dropped if found unsuitable, and

(5) I have seen it being used and believe it would serve me well.

Are any of the above reasons important to you in deciding whether or not to use any of the following? [Interviewer- Circle the appropriate reason code(s) next to the alternative methods]

Kuni Mbili Fireplace	:	.1.	.2.	.3.	.4.	.5.	.6.
Improved stove (KCJ)	:	.1.	.2.	.3.	.4.	.5.	.6.
Kerosene stove	:	.1.	.2.	.3.	.4.	.5.	.6.
Electric cookers	:	.1.	.2.	.3.	.4.	.5.	.6.
Three-Stone Fireplace	:	.1.	.2.	.3.	.4.	.5.	.6.
Traditional metal stove	:	.1.	.2.	.3.	.4.	.5.	.6.

Please specify any other reason(s) that are important to you. [Interviewer- Please note down the reasons in the space below]:

....

....

....

25. To the best of your knowledge, what are the current costs in KShs. of:

[Interviewer- Please indicate "Don't Know" for situations where respondents can not make reasonable guesses]

Traditional metal stoves: ....

Improved Jiko e.g. KCJ : ....

Kerosene stoves : ....

Charcoal (e.g. per bag): ....

Electric cooker (1 plate) : .....

Electricity (e.g. accesories plus average monthly bill):

[Basic accesories: ....; Last month's bill:.......]

Kerosene (per litre) : ......

[Secondary data sources will be used to corroborate the answers given here]

26. How much fuelwood do you use per

Week? : ....

Other specified period? : ....

e.g. per month

(Interviewer-specify the units of measure e.g. headloads, stacks, etc)

27. Who collects the fuelwood needed in the household?

[Interviewer-note down 1 if yes, and 0 if no]

	Always	Sometimes	Never	Don't Know
Wife:	......	......	.....	......
Husband :	......	......	.....	......
Children:	......	......	.....	......
Other :	......	......	.....	......

28. Where do you collect your fuelwood?

[Interviewer- note down 1 if yes, and 0 if no]

	Always	Sometimes	Never
Own land :	......	......	......
Neighbor's land:	......	......	......
Market :	......	......	......
Public land : (Govt. Owned)	......	......	......
Others :	......	......	......

29. What are the current prices (in K.Shs.) for the fuelwood you use?

[Interviewer-Please indicate the sources and units on which cost is based?]

Fuelwood from own land : ....

Fuelwood from neighbor's land: ....

Fuelwood from government land: ....

Fuelwood from the market : ....

Fuelwood from other sources : ....

30. How satisfied are you with the fuelwood supply from your current sources?

[Interviewer- note (1) for Very Satisfied, (2) for Satisfied, and (3) for Not Satisfied]

Own Land : ....

Neighbor's land: ....

Market : ....

Other Sources : ....

31. a. How much time do you use to gather and bring home a headload (or other specified unit) of fuelwood?

....

b. If a cart, truck, etc. is used, how much time does it take to

collect, load, and deliver the fuelwood? : ....

32. Do you have more or fewer trees on your farm than you had

[Interviewer- note down (1) if more, and (0) if fewer]

1 year ago? : ....

5 years ago? : ....

10 years ago? : ....

33. a. What species of trees have you planted on your land during the last 10 years?

[Interviewer- Please note down the species mentioned. Local tree names are acceptable]

....

....

b. Where do you do most of your tree planting?

....

Enter 1 if in woodlots, 2 if along borders/hedges, 3 if among crops, and 4 if others.

34. a. If you have planted trees during the last ten years, how important were the following needs to your decision to plant?

[Interviewer- please note (1) for Very Important, (2) for Important, and (3) for Not Important]

Fuelwood : ....

Poles : ....

Posts : ....

Charcoal : ....

Rafters : ....

Timber : ....

Soil conservation : ....

Fodder : ....

Others : ....

b. Please rank the above uses of trees from the most important one first to the least important one last.

....

....

35. If you have not planted trees during the last ten years, were any of the following reasons important in that decision?

[Interviewer- note down (1) if yes, and (0) if no]

Already have enough trees : ....

Seedlings are not available : ....

Tree nurseries too far away : ....

Dont know where to get seedlings: ....

Suitable species not available : ....

Not enough land : ....

Not enough labor : ....

Other (Please specify) : ....

....

36. a. Is it necessary to consult other members of your household before you can decide where to plant trees? ....

[Please note down (1) if YES, and (0) if NO]

b. If the above answer is YES, which members of the household are consulted? ....

[Please note down (1) if Male, and (0) if Female]

c. Do you do the same consultations for tree cutting decisions?.....

[Please note down (1) if Yes, and (0) if No]

37. Are you required to seek permission from public officials before you can cut your trees? ......

[Please note down (1) if Yes, and (0) if No]

38. From around this time last year, have you attended a chief's (or any other) meeting in which tree planting activities were discussed? ......

[Please note down (1) if Yes, and (0) if No]

39. How many agricultural shows (fairs) have you attended during

The last 1 year : ....

The last 5 years : ....

The last 10 years: ....

40. Do you have access to any of the following sources of information?

[Please note down (1) if Yes, and (0) if No]

Radio : ....

Television : ....

Newspapers : ....

Extension agents: ....

41. How often do you listen, watch, read or come into contact with the following?

Radio (e.g. hours per day) : ....

Television (e.g. hours per day) : ....

Newspapers(e.g. Issues per week or month) : ....

Extension agents (e.g. visits per month) : ....

42. a. If you have planted trees recently, have any of the following sources of information positively influenced your decision?

[Please note down (1) if Yes, and (0) if No]

Fellow Farmers : ......

Extension workers : ......

Agricultural shows, meetings, field days etc: ......

Radio : ......

Television : ......

Newspapers : ......

b. Have any of the above sources of information negatively influenced your decision to plant trees? ....

[Enter 1 if Yes, and 0 if No]

c. If the answer to (b) above is yes, please state which one(s).

....

43. How do you think economic well being in this village will change in the next ten years? ....

[Enter 1, 2, or 3 for the answers below]

1. Things will remain the same.
2. Things will be better.
3. Things will be worse.

Appendix 4. Variables with High Correlation Coefficients in Village 1.

Variables[a]	Correlation Coefficient
CREV, SAVINGS	0.758
CREV, THHX	0.559
TREV, CREV	0.975
TREV, THHX	0.562
TREV, SAVINGS	0.792
TREV, CCBM	0.669
CREV, CCBM	0.711

Appendix 5. Variables with High Correlation Coefficients in Village 2.

Variables[a]	Correlation coefficient
FIC, CREV	0.739
FUGA, CREV	-0.740
KELM, CREV	0.686
SAVINGS, CREV	0.756
TEXP, CREV	0.724
THHX, CREV	0.547
TREV, CREV	0.973
FUCR, CRHM	-0.602
NPPM, EDH	0.536
TEXP, FIC	0.876
TIC, FIC	0.561
TREV, FIC	0.742
TREV, FIC	-0.679
TREV, KELM	0.707
SH10, KELM	0.642
TVHPD, NPPM	0.607
TREV, SAVINGS	0.792
THHX, TEXP	0.891
TREV, TEXP	0.728
TVHPD, SH10	0.510
TREV, THHX	0.551
TN1, TIM	0.681
TN2, TIM	-0.537
TN3, TN1	-0.902
TN3, TIM	-0.627

[a]Variables with relatively high correlation (above + or - 0.50). These variable combinations were not used together as independent variables in a single probit model.

Appendix 6. Coefficients for Model KCJC

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-2.3195	0.5356	-4.331	
AGE	-0.0345	0.010	-3.630*	-0.006
THHX	0.5E-04	0.9E-05	-3.630*	0.8E-05
MEMFEOF	-0.0812	0.2458	5.668*	-0.013
KELM	0.0854	0.0187	4.555*	0.014
AREA	-0.0309	0.0130	-2.372*	-0.005
TIC	0.2065	0.518	3.985*	0.033
DUMMY	2.1023	0.2981	7.052*	0.335

Log-likelihood = 84.419
*Significant at α = 0.05
-2LLR (CHI SQ 7 DF) =160.28
CHI-SQ TAB = 16.013
[a] See appendix 1 for definitions of variables
[b] Elasticity computed at mean value of independent variable.

Appendix 7. Coefficients for Model KUMC

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-1.1744	0.1796	-6.54	
CRHM	0.0274	0.009	3.051*	0.007
LEAD	0.4034	0.1735	2.325*	0.108
SH10	0.0393	0.0252	1.562	0.011
CGAM	-0.3882	0.4334	-0.896	-0.104
DUMMY	-0.2181	0.1986	-1.098	-0.058

Log-likelihood = 142.23
*Significant at $\alpha = 0.05$
-2LLR (CHI SQ 5DF) = 23.984
CHI-SQ TAB = 12.833
[a] See appendix 1 for definitions of variables
[b] Elasticity computed at mean value of independent variable.

Appendix 8. Coefficients for Model KESC

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	0.0741	0.008	0.159	
AGE	-0.0200	0.008	-2.581*	-0.005
EVPY	0.0227	0.465	2.694*	0.005
EDH	-0.0578	0.026	-2.226*	-0.013
RHPD	0.0828	0.040	2.059*	0.019
DUMMY	-0.5230	0.200	-2.623*	-0.119

Log-likelihood = 123.17
*Significant at $\alpha = 0.05$
-2LLR (CHI SQ 5 DF) = 41.917
CHI-SQ TAB = 12.833
[a] See appendix 1 for definitions of variables
[b] Elasticity computed at mean value of independent variable.

Appendix 9. Coefficients for Model TPHC

Variable[a]	Coefficient	Std error	t-value	Elasticity[b]
CONSTANT	-1.672	0.2803	-5.966	
EVPY	0.0112	0.0081	1.388	0.003
HSZ	0.1091	0.0328	3.322*	0.132
AREA	0.0333	0.0150	-2.215*	-0.017
SH10	-0.0353	0.0261	-1.350	-0.006
TREV	0.3E-05	0.3E-05	1.136	0.112
RHPD	0.0364	0.0376	0.969	0.006
DUMMY	1.0845	0.1854	5.850*	0.212

Log-likelihood = 168.90
*Significant at $\alpha = 0.05$
-2LLR (CHI SQ 7 DF) = 45.958
CHI-SQ TAB = 16.013
[a] See appendix 1 for definitions of variables
[b] Elasticity computed at mean value of independent variable.

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