BIO-ECONOMIC PERSPECTIVE TO FUELWOOD POLICY OPTIONS IN UGANDA: A DEMAND-SUPPLY NEXUS

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ABSTRACT

This study examines the benefits and costs of selected policy options for increasing fuelwood supplies or decreasing fuelwood demand in Hoima district, Uganda. On the supply side, a benefit-cost analysis is done on a government sponsored tree farming project. In order to reduce the demand for fuelwood, two demand-side options are considered, namely, introduction of an improved energy-efficient woodstove, and the substitution of a kerosene stove for a traditional woodstove. Greater understanding of the linkages among these factors requires a systems approach. We have proposed such an approach using a non-linear dynamic programming model to explore the system behaviour of forest degradation. Our results show that tree-farming is one of the possible approaches to increase the supply of fuelwood (energy), while the woodstoves and kerosene substitution are policies that reduce the demand for fuelwood. This helps to alleviate the rural energy shortage and take some pressure off existing protected forest areas. The tree cover in the forest areas declined by 6% in the BASE scenario, 4.8 % in POPG scenario and 4.7% in TECH scenario, indicating an overall trend of forest degradation in the Hoima district under each of these scenarios. Reductions in the population growth rate, introduction of improved agricultural technology and increase in the prices of major agricultural crops can help slow down the rates of forest decline. This study does not attempt to analyse the wider energy planning program that would be needed to understand accurately the various alternatives available in Uganda.

Keywords: Fuelwood, woodstoves, tree-farming, kerosene, Uganda

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INTRODUCTION

Fuelwood occupies an enviable place for providing many people, especially the poor and rural households, with a primary source of energy (Shackleton 1998). Fuelwood is used for both domestic and industrial purposes in rural and urban areas of most economies of the developing world (Tietema 1993). Wood consumed annually for fuel energy in sub-Saharan Africa increased from 1,500 million m^3 to 3,500 million m^3 between 1950 and 2002 (Moyini and Muramira, 2002).

The energy sector is characterised by a heavy dependence on biomass resources, and studies have demonstrated that woodfuel (firewood and charcoal) account for more than 90% of energy used in Uganda (MoEMD, 2002). Traditionally, the majority of Ugandans depend on fuelwood for their domestic heating, cooking and lighting purposes. Total wood production (monetary and non-monetary) has registered a steady increase over the period between 1995-2000. The importance of fuelwood becomes clearer when for example kerosene is substituted for charcoal in urban households, which would result in an increase in the national import bill by US$180 million (Ushs. 324 billion) annually (Falkenberg & Sepp, 1999). Such strategy will in fact lead to loss of jobs by poor people who are involved in fuelwood income generating activities.

It has been argued that in southern Africa, there is a fuelwood 'crisis' in many areas (Dovie *et al.* 2004). The 'crisis' refers to a shortage in fuelwood supplies to meet households' requirements and is manifested as an ever increasing distance covered by rural households to obtain and harvest wood suitable for fuel energy. With increasing deforestation, the distance travelled to collect firewood increases. This affects the productivity of households, when the time spent on collecting firewood would have been used for productive activities. The average distance travelled by households to collect firewood has increased dramatically between 1992 and 2000 from 0.06 km to 0.73 km (MoEMD 2002). Fuelwood is one of the commodities that households sell to raise income especially in areas where free access to forestry resources is declining. Unfortunately, the income from sale of fuelwood not clearly recorded in the national accounting system as part of the forestry contribution to household income. Hence forestry remains just recognised as being of extremely high economic importance, but mainly in the informal sector (MWLE 2002b).

Conceptual framework

Factors affecting the pressure on fuelwood use have been oversimplified as type and quality of wood, stove technology, population growth and availability of substitutes (Kalumian & Kisakye 2001; Jacovelli & Caevalho 1999). However, their link to supply-side approach to providing fuelwood through tree-farming projects, and demand-side options aimed at reducing firewood demand by either introducing more efficient woodstoves and use of kerosene as a substitute fuel are still unclear and with little empirical justification. The objective of this paper is therefore to examine, using revealed preference technique, the various policy options for meeting the demand for fuelwood and rural energy supplies in Hoima district, Uganda.

Traditionally, the major land-use types in Hoima district are dichotomized into agriculture for food production, and forestry for production of wood and fiber. Also included in the latter land-use type is the protection forestry for stabilizing fragile upland systems and water catchment areas. However, the two-faced aims of forestry development also call for attention to the provision of the human needs which are: to increase rural people's self-sufficiency in producing food, fodder, fuel, timber on their cultivated lands; on addition to conserve the forest resource and land resources by reducing the current pressure on them to supply these commodities. The growing population demands a sustainable supply annual food, fodder, fuel, and timber.

The gradual but steady population growth in Hoima district has inevitably caused a gap between the demand for fuelwood and sustainable supplies. The exponential growth in demand with population growth and growing burden placed on users of having to search ever further a field for fuelwood and of having to divert crop and animal residues needed for soil working or as livestock feed to fuel use has given rise to further rural problems.

Secondly, the existing wood stock has been widely mined to meet the food, fodder, fuelwood, and timber demand, that there remains no other feasible alternative to wood fuel other than other bio-mass such as crop residues and dung and that the principal means of averting growing shortages, and the attendant deforestation and human suffering, was to initiate widespread planting of additional trees. As a consequence, a very large part of the initial investment in community forest management was in form of afforestation projects to increase fuelwood

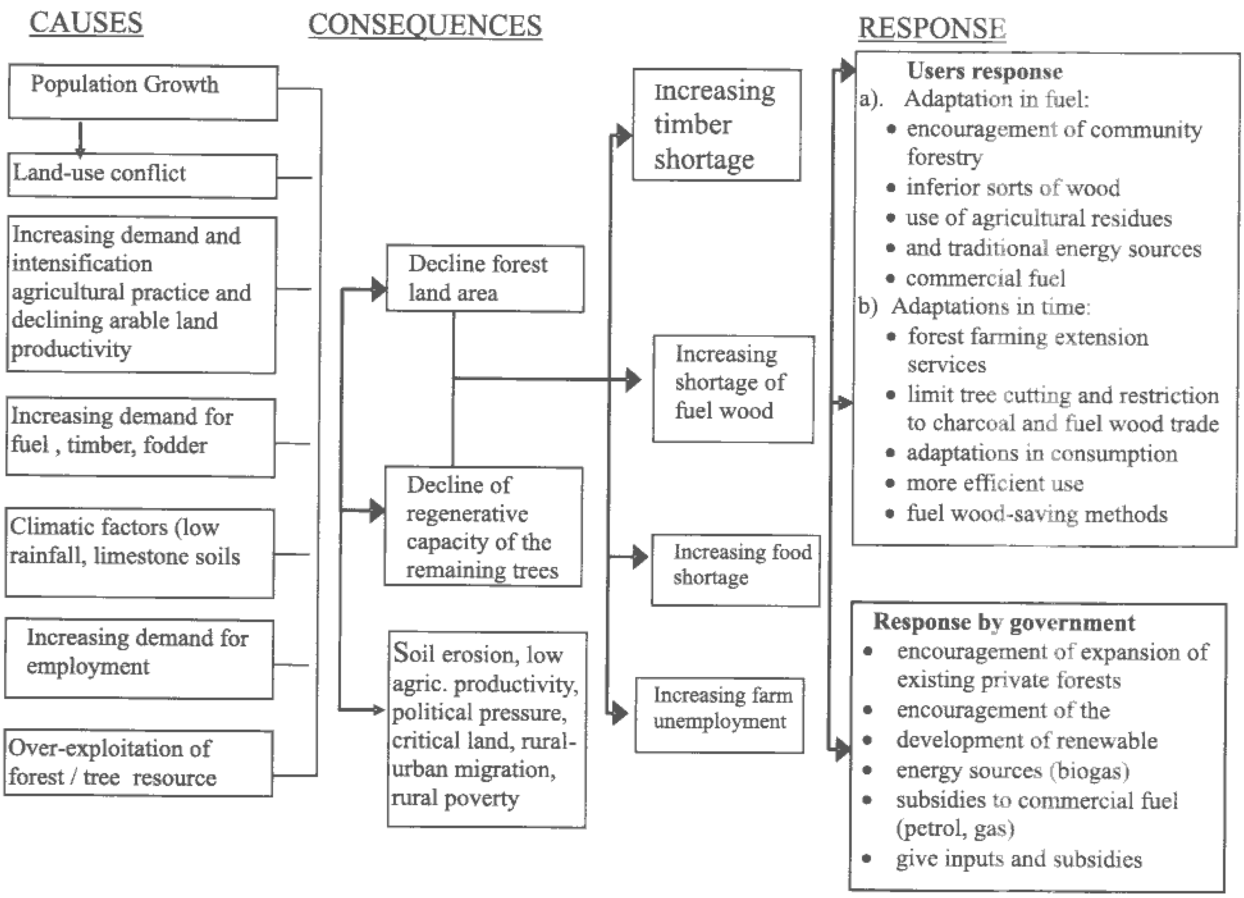

Figure 1. Diagnosis of the causes, consequences, and response to forest product shortages

supplies. The causes of fuelwood shortages, consequences and possible responses are given in Figure 1.

MATERIALS AND METHODS

Description of study area

The study site was Kigorobya sub-county, Hoima district (1°00'- 2°00'N; 30°30'- 31°45'E). The district covers an area of 59,327 km^2 of which 22,686 km^2 is occupied by Lake Albert. Forests constitute a relatively smaller portion of about 12% (7123 sq. km) of the total area. The district generally has a pleasant climate with small variations in temperature, humidity and winds through out the year. Rainfall ranges from 700-1000mm per annum and mean annual temperature is 28°C with a range of 15-32°C.

Vegetation is very varied ranging from medium altitude moist forests through forest/savannah mosaic, swamp to post cultivation communities. Grass savannah is derived from forests, wooded savannah and thicket by repeated cultivation, grazing and burning. They occur in sub-counties of Buseruka and Kigorobya on off-shore tips of Lake Albert. The soils are mainly weathered basement, yellowish-red clay loams on sedimentary beds. There are also complex formations of the pre-cambrian age, which consist mainly of metamorphic and igneous rocks, largely composed of gneisses and granites.

Hoima district has a total human population of 340,000, with a high population density (300 persons/km^2 in the west and approximately 200 in the east) (UBOS, 2002). Subsistence agriculture has remained the major economic activity contributing

48 percent on districts gross production. Approximately 83 percent of the population depend on agriculture for their livelihood with a small landholding size (0.48 ha per family). Given the limited opportunities for rural employment and low agricultural production, a few households have migrated to other adjoining districts.

According to the land-use pattern, the study area has permanent crops cover (24%), savanna and pasture cover (11%), woodland and forest (28%) and others (43%) (MWLE, 2001b). Susceptible to accelerated soil erosion and declining soil fertility, the sources of livelihood of the rural people have been threatened. Fuelwood is an important form of rural energy in Hoima district, nearly 97 percent of all household cook with fuelwood at least part of the time. The average household fuelwood consumption is 65 kg/week/family; in addition, rural households burn small amounts of charcoal and agricultural residues (Jacovelli & Caevalho 1999; Kalumian & Kisakye 2001).

Data collection and analysis

The field work was conducted during September – December, 2004, and three data collection methods were employed, namely surveys, open-ended interviews and review of project records and other published literature. The interviews were combined with simple Participatory Rural Appraisal (PRA) tools in order to ease the acquisition of information (Dove *et al*, 2004). Data collection emphasised household approaches rather than community level enumeration because fuelwood use takes place at the household level. The survey included 120 rural and urban households (63% sampling intensity). Another sample consisted of 20 cottage industry firms including bricks burners, tobacco curers, bakeries, restaurants, producers of sugarcane molasses, ceramics and pottery.

The study was based on data from a large survey of the demand for fuelwood and an analysis of options for meeting that demand. This use of large-scale survey was intended to determine the magnitude of fuelwood demand and the various factors that affect this demand. The demand survey investigated consumption and uses of wood and charcoal fuels. These questionnaires elicited data on time spent in collecting firewood; proportion and source of firewood collected; and proportion grown for own use. All the amounts of fuelwood were converted into actual weights because of lack of standardization of commonly used units.

Special emphasis was placed on preferences for the types of woodstoves and attitudes toward tree growing in order to develop policies directed at solving the wood fuels shortage. Some questions in the consumption survey also were directed toward consumption of other biomass fuels such as bamboo, rice husks, molasses, and animal dung, as well as conventional such as kerosene, gas, and electricity, to determine the extent to which these currently serve as substitutes for fuelwood.

Another survey dealt with staff in National Forestry Authority (NFA), fuelwood sellers, charcoal burners, and tree farmers. The questionnaires for the fuelwood tree farmers covered background information of the tree farmer; size and quality of the tree farm site; tree spacing, planting and harvesting period; labour requirements for clearing land, planting, tending, and harvesting trees; tree growth and mortality; economic returns; use of co-products such as leaves, fruits, and nuts; market for the output; extension of tree farming beyond the project area; tree farmers' evaluation of the program and participating institutions; prospects and challenges of the project.

Some fuelwood was collected by household members and some was bought in the market. Thus, market prices were available for valuing purchased fuelwood, although there was considerable variation in prices. However, a shadow price was estimated for collected, own-consumption fuelwood. The shadow price of fuelwood was derived using on *revealed preferences* method. We assumed that the value people place on wood fuel was at least equal their costs in collecting it as a free good, including travel time to collection sites and related transportation costs. Thus, transport time was valued at its opportunity cost in terms of foregone labor. Based on relative productivity and opportunity cost factors, a child's labor time was valued at one-half of the adult wage rate. In cases where there was extensive surplus labor due to underemployment or unemployment, the opportunity cost of labor time for collecting fuelwood was low. Transport costs were very low because family members travelled on foot to collect fuelwood unless there were relatively affluent and grow fuelwood on lands their own.

Conceptual framework

Fuelwood use statistics often greatly underestimate true consumption because most wood is gathered directly by users rather than being purchased. The shortage of fuelwood leads to economic welfare loses, as well as environmental degradation from over-cutting of trees.

Fuelwood was measured by weight (in kilograms). Villagers would normally harvest and collect fuelwood in head loads, pick-up vehicles and wheelbarrows. Households provided their wood

Table 1. Farm inputs of tree farming (*Pinus caribaea Var. hondurensis*) enterprise in Hoima district, Uganda (ha^{-1}).

	Operation or Activity	Year	Labor Requirement (man-days equivalent)	Input Cost (Ushs)
1.	land clearing and preparation	1	35	
2.	Seedlings (5,000/ha, spacing: 1x2 m)	1	-	86/seedling
3.	Linging, digging, and planting seedlings	1	35	
4.	Seedling replacement in yera 2 based on 20% mortality in year 1			86/seedling
5.	Replanting seedlings	2	5	
6.	Fertilizer purchase	1		18,500
		2		267,000
7.	Fertilizer aplication	1	7	
		2	3	
8.	Weeding and brush removal	1	10	
		2	13	
9.	Maintenance	3 to 8	4	
10.	weeding and single coppice tending	5	4	
11.	Harvesting	5 to 9	1.6/solid m^3	
12.	Cost of loan administration	1		48,000
13.	Cost of nursery establishment	1		3,200,000
		2		65,000
14.	Cost of collecting loan payment	5,6,7,8		2,700

Labor requirements

Year	2	3	4	5	6	7	8	9
Man-days	21	4	4	156	4	4	4	148

Note: Exchange rate at survey time (2004) US$1 = Ushs 1980 consumption data their records and observations. The mass of a wheelbarrow load (standard measure of pricing) of fuelwood was approximately 45 kg.

Based on the survey results and other secondary sources, the following data and assumptions were used:

- Discount rate is set at 15 percent per annum.
- Pure stands yielded about 123 m^3 per hectare annually.
- Rural adult wage rate is Ushs. 3,700 per day (US$ 1.87) (8 work hours / day; child labor is rated half the adult wage; proxy market values were estimated in case of wages in-kind).
- Kerosene stoves cost Ushs. 17,000 (US$ 8.6); improved woodstoves cost Ushs. 20,000 (US$ 10); domestic kerosene costs Ushs. 1,200 (US$ 0.6) (these prices exclude periodical taxes and subsidies).

Tree-farming inputs and costs based on survey data are presented in Table 1.

Costs are incurred in form of purchase of purchase of factor inputs such as seedlings, servicing loans, wages for labour, rent for land, and other payments made to the different factors of production that are employed by the tree farming enterprise.

The tree farming practice

The structural model (Figure 2) shows that fuelwood consumption is related to food consumption, in that for each unit of consumed food, a certain amount of energy is needed for preparation. The income and availability of fuel determine the actual wood use. The abundance of fuel increases fuel consumption while at the other hand a shortage

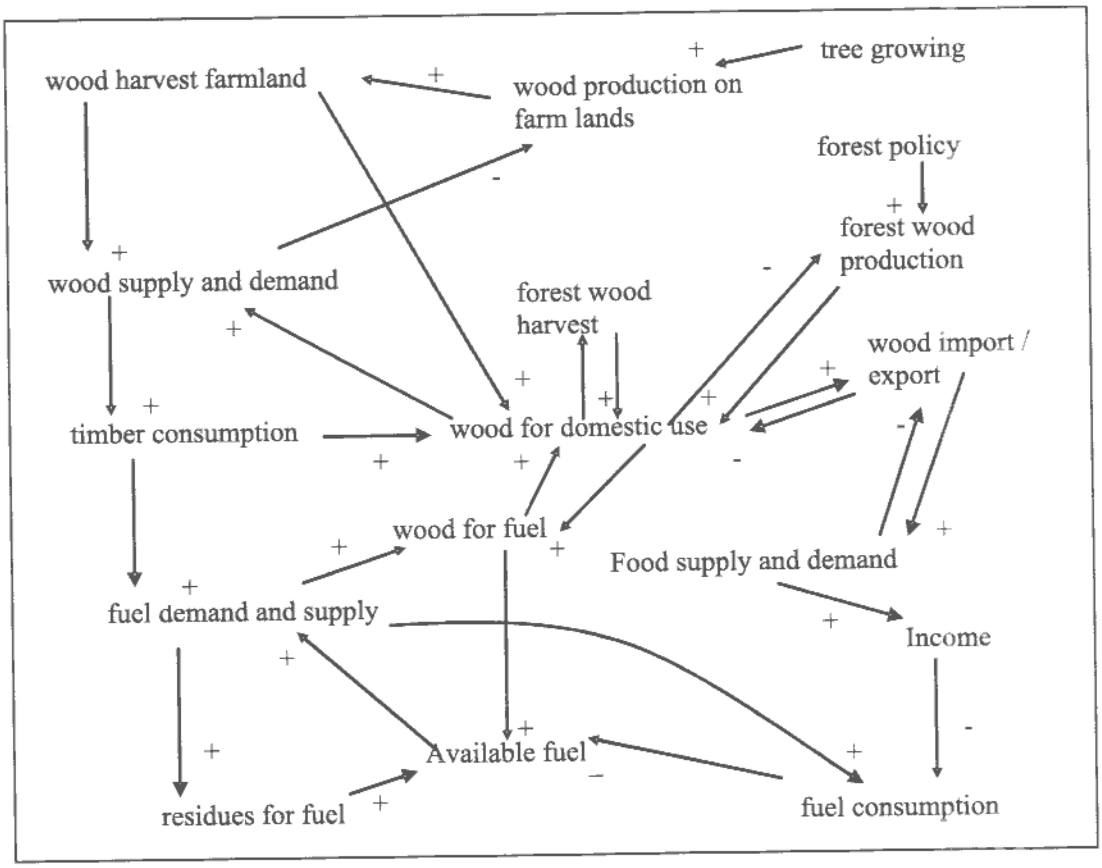

Figure 2. Structural model of the fuel production and consumption

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will be compensated through a rational use or a decrease of use. The high incomes result in more consumption pattern of food, which needs more energy for food preparation, in cases where households have substantial incomes the wood energy is substituted by commercial fuel sources.

The private tree farming has helped to generate additional employment and income in the rural areas. The local wood production areas take many forms: roadside plantings, trees planted along the borders of agricultural fields, cultivated areas with a mixture of agricultural and tree crops, and tree crop plantations of commercial species. These wood production areas are often of prime importance for the local population, as they enable the private collection of fuel and construction wood, thus obtaining wood products without cash outlays. In many statistics this subsistence wood collection has often been unrecorded.

The objectives of intensification in forestry is to maximize the forest functions for meeting the people's demand and maintain the environmental quality, it should be developed based on both forest ecosystem and human social ecosystem. Unless, the created forest management regimes will not relevant to the existing condition and requirement, and hence it will fail to achieve its objectives. The components of forest ecological system are climate, soil, water, plants, and animals, meanwhile the components of the human social ecosystem are population, technology, socials structure, and ideology. Before the intensified forest management is developed, the roles of each of the components and their dynamics interactions should be understood.

The other interlinked problem is that a part from the wood for the fuel, wood is also used as timber construction and for several agricultural uses. The fuelwood is gathered from the own lands and the forest lands but it is assumed that the most important source of fuelwood are the agricultural. The production figures of wood on the agricultural lands vary but are substantial. For the regions where state forests are scarce, more fuelwood is produced on the own agricultural fields.

The fuel consumption is related to food consumption, in that for each unit of consumed food, a certain amount of energy is needed for preparation. The income and availability of fuel determine the actual wood use. The abundance of fuel increases fuel consumption while at the other hand a shortage will be compensated through a rational use or a decrease of use. The high incomes result in more consumption pattern of food, which needs more energy for food preparation, in cases where households have substantial incomes the wood energy is substituted by commercial fuel sources.

The shortage of energy (fuel) is an incentive tree growing on the agricultural fields, the prices and time to gather the wood, increases so much that the production of wood can compete with the production of food. The production of wood will decrease as a result of over-cutting. As explained in the other parts of this paper, there are other motivations to plant to maintain the trees on the agricultural lands. In fact it would be more meaningful if a comprehensive evaluation of the performance of the on-farm forestry practices in the region could be completed, however, such a deeper evaluation would require land resource auditing, planning, and environmental impact assessment, and yet this study was constrained by the limited time and research funding, therefore several important aspects of the social-cultural and ecological nature could not be studied exhaustively.

Description of dynamic bio-economic model

This study makes use of a dynamic non-linear mathematical programming bio-economic model developed by Sankhayan *et al.* (2003) and suitably modified to adequately account for the conditions characteristic of Hoima district, Uganda. The actual yields and prices for different crops, growth rates of vegetative biomass, population growth rate both for human beings and animals, consumption rates of crops and forest products, etc., specific for Hoima district were used. Model calibration was performed to test the ability of the model to produce results in respect of area under different crops and density of vegetative biomass, reasonably close to those estimated on the basis of field surveys for the base year 2004. The model maximizes an aggregate utility objective function consisting of the following main components at village level:

(i). net cash income from various production activities,

(ii). leisure time for family labor, and

(iii). food grains, cash, fuel wood and fodder requiems for human and animal population.

These components, assumed to be exogenous and progressively increasing constraints with population growth, enter the objective function indirectly through their hierarchical attainment. By using a positive wage rate as the opportunity cost of unused family labor, households have been assumed to have a reserve wage below which leisure is preferred over work. Due to lack of appropriate data to account for risk, it could not be incorporated in the model. The description of the model is as follows:

If the aggregate total net return (U) at time t is expressed as follows:

The objective function considered in the model is to:

$$Maximize \sum_{t=1}^{T} 1/(1+\tau))^{t} U_t$$

where

$$U_t = \sum_{1}^{u} \sum_{j=1}^{s} (a_{ijt}\, y_{ijt}^{ca}) + \sum_{i=u+1}^{v} (a_{it}\, y_{yit}^{la}) + \sum_{i=v+1}^{w} (a_{it}\, y_{yit}^{fa}) + \sum_{i=w+1}^{n} (a_{it}\, y_{it}^{lsa})$$

$$t = 1,2,\ldots, T$$

and;

$$a_{ijt} = (p_{it}\, q_{ijt}) - \sum_{r=1}^{m} (c_{rjit} x_{jit}),\ a_{it} = (p_{it}\, q_{it}) - \sum_{r=1}^{m} (c_{rit}\, x_{it})$$

The abbreviations used in the above relations are as follows:

y_{ijt}^{ca} = level of ith crop activity grown in jth type of land unit during the tth year.

y_{it}^{la} = level of ith livestock and livestock product activity during tth year.

y_{it}^{fa} = level of ith forest activity.

y_{it}^{lsa} = level of ith leisure activity.

q_{ijt} = yield of the ith *crop from jth land category and tth year.*

q_{it} = *yield of the ith non-crop activity during the tth year.*

x_{ijt} *is the quantity of rth resource per unit of the associated activity.*

a_{ijt} and a_{it} are the per unit net returns from ith crop activity from jth land, and ith activity other than crop activity during the tth year.

p_{it} and c_{rjit} are the per unit prices of products and inputs.

τ = annual percent discount rate, taken as 5% per annum in this study.

Model assumptions and constraints

Households are assumed to make decisions under a number of constraints. Some of these constraints are:

- Annual land availability constraints were used according to relatively homogenous land units since annual crop rotations were considered as the major crop activities.

- Manpower and laborforce constraints (man equivalent days) are considered according to months, which increase with growth of population over the run of the model.
- It was assumed that the production function refers to "production + purchase – consumption - sale" and must be equal to zero during each production period.
- The tree growing enterprise is profit motivated whereby cost minimisation and profit maximization is the main goal.
- Enterprise operational capital during the current period is assumed to be a fixed percent of the cash proceeds of the previous year that can be supplemented through borrowing at the current rate of interest (taken to be 12%).
- Constraints are incorporated for important fertilizer types requiring that their use should not exceed the amount purchased.
- Some calculating equations for variables such as crop area, land area cleared/abandoned, loss of vegetative biomass due to grazing, extraction of forest products and forest fires[1], and tree biomass in the uncultivated and cropland in each land category are also provided.
- Some of the other important constraints used in the model related to livestock carrying capacity, remaining stock of tree biomass in each land category at the end of the model period.

Some important relations, such as, stock of vegetative biomass and human and animal populations will, however, be described in some detail.

Loss due to forest fires was treated as a fixed proportion of the stock of vegetative biomass during the previous year.

Activities used in the model

- Production, consumption,sale and purchase activities: A number of activities for production, consumption, sale and purchase are used for the crop, animal, forest and miscellaneous products. The level of consumption activity is assumed to be equal to annual average requirement per head times the population.
- Land clearing/abandoning activities: To enable addition of new land for cultivation from the uncultivated area, land clearing activities have been incorporated separately for each category of land. Abandoning of cultivated land activities are also allowed to get activated if needed. Of land clearing and abandoning activities, only one can enter into the model at a time.

* Labor-hiring activities: The model provides for labor hiring for all production activities for each of the 12 months when profitable. Depending upon the availability of employment opportunities, limited hiring out activities of labor during certain months is also incorporated.

Growth of vegetation

The biological growth function used for biomass of trees is as follows:

$$BM_{t+1,j} = BM_{tj}(1+g_j)$$

Where: $BM_{(t,\ i,\ j)}$ stands for tones of tree woody biomass per hectare during the t^{th} year in j^{th} land category. It represented the biomass density and was used as the measure of vegetative degradation/ regeneration in this study. g_j is an exogenously determined parameter for growth rate of vegetation per annum.

The accounting function for total woody biomass during t^{th} time period in j^{th} land category,

[1] Loss due to forest fires was treated as a fixed proportion of the stock of vegetative biomass during the previous year.

representing net of the losses due to animal grazing, fuel and timber wood extraction, and forest fires, for each of the land categories is given by:

$$TBM_{tj} = BM_{tj} * LAND_{tj} - (BMUA_{tj} + XFPT_{tj} + LFIRE_{t,j}).$$

Where: TBM, LAND, BMUA, XFPT and LFIRE, respectively, stand for total woody biomass, land area, biomass used by animals (both for grazing and stall feeding), biomass loss due to collection of wood (for fuel and timber) and vegetative biomass lost due to fire.

Human population, its growth and migration

The population during time period *t*, (*P (t)*), is given by the equation:

$$P_t = P_0 . (1+ d)^t + IM_t - EM_t ,$$

Where: d = average annual percent growth rate, IM = immigration and EM = emigration.

In this study, IM_t was taken to be "0". EM_t was 18 per cent of the active labor force. Given the ratio of workers to total population (RWP) and average working days per month (WDM) as exogenous variables, labor availability during t^{th} year and m_{th} month is found out as follows: $LABOR_{t,m} = RWP . WDM_m . P_t$.

Animal population, its growth and migration

The accounting functions for livestock population can be written as:

$$LIVPOP_{t+1,a} = LIVPOP_{t,a} + LIVBR_{t,a} + LIVPUR_{t,a} - LIVSOLD_{t,a} - LIVSLT_{t,a} + LIMP_{t,a} - LEMP_{t,a};$$

Where: LIVPOP = Number of livestock during the beginning of the next period

t = Time periods

a = Livestock type (cattle, buffaloes, goat and sheep).

LIVBR = Livestock borne (net of livestock died)

LIVPUR = Livestock purchased

LIVSOLD = Livestock sold

LIVSLT = Livestock slaughtered, with a fixed value of zero for cattle

LIMP = Livestock immigration into the area

LEMP = Livestock emigration out of the area

Study sample and model data collection

The input for the bio-economic model comprising of socio-economic, ecological and vegetative biomass data were collected for the Hoima district by using appropriate sampling methods. Both primary and secondary data (on prices, growth rates, human and animal population, vegetative biomass, past soil erosion rates.) were collected from published records and through a socio-economic survey, using both participatory and interview methods. Detailed input-output data on crops, livestock and livestock products and forest activities (fuel wood collection and timber harvesting) were collected for the modelling exercise. It should, however, be mentioned that these data were obtained from only the sample households in the village.

Bio-economic model was calibrated and run for a period of 20 years (2000 to 2024) under four alternate scenarios, namely, (1) base scenario (BASE) run with the existing data, (2) introduction of improved agricultural technology (TECH) where yields of major crops, namely, paddy, maize and wheat were assumed to increase by 5% per year, (3) reduction in population growth (POPG), where population growth rate is halved to 0.67% per annum, and, (4) increase in the prices of major agricultural crops

(PP), where prices for paddy, maize, wheat were assumed to increase by 5% per year.

Increasing population reduce the size of landholdings and the landless out-migrate in search of off-farm employment in the urban areas. The other positive loop shows that population density reduces the size of landownership which consequently leads to farm unemployment and incites families to out-migrate to urban areas. The negative loops show that the community forestry system is a goal-seeking system trying to find an equilibrium. The unemployment will be countered by out-migration, secondly the unemployed labourforce will be absorb in the urban employment until such a time of saturation. The unemployment implies that many will shift to the urban areas for employment to earn incomes which they bring back to develop and buy land in Hoima district and as such regional incomes increase.

In relation to these population-caused problems, the population sub-system has got connections with other parts of the rural system through:

a. Fuel consumption is directly related with food consumption, for a certain amount of food a related amount of fuel is needed for preparation of the food;
b. Food consumption is, in a subsistence production system, directly related with production. Higher rates of production will induce a higher consumption rate and export of "surpluses".

The fuel consumption is related to food consumption, in that for each unit of consumed food, a certain amount of energy is needed for preparation. The income and availability of fuel determine the actual wood use. The abundance of fuel increases fuel consumption while at the other hand a shortage will be compensated through a rational use or a decrease of use. The high incomes result in more consumption pattern of food, which need more energy for food preparation, in cases where households have substantial incomes the wood energy is substituted by commercial fuel sources.

The shortage of energy (fuel) is an incentive to plant trees on the agricultural fields, the prices and time to gather the wood, increases so much that the production of wood can compete with the production of food. The production of wood will decrease as a result of over-cutting. As explained in the other parts of this dissertation, there are other motivations to plant to maintain the trees on the agricultural lands.

RESULTS AND DISCUSSION

We estimated the value of fuelwood based on the labor time used to collect it. This was probably a minimum value as it did not include any scarcity value of fuelwood nor was it related to the cost of the next best alternative fuel source. The average family surveyed collected 65 kg per week of fuelwood and used both adult and child labor. Valuing the time spent in fuelwood collection by the appropriate wage was equivalent to Ushs 2,750 which is approximately Ushs. 42 per kilogram. In terms of solid, air-dried fuelwood, this is equivalent to Ushs. 32,340 per m^3 (770 x Ushs. 42). We assumed that there were alternative productive opportunities available for adults and children at the specified wage rate. If such opportunities were not available or the true opportunity costs were higher or lower than assumed, the shadow price of fuelwood changed.

The mean annual consumption of fuelwood was estimated at 4,400 kg which implies that per capita fuelwood consumption in the study area was approximately 330 kg/user household, or 53 kg / capita per annum. The mean fuelwood consumption rate of 692 kg/capita of wood per annum in this study compares satisfactorily with figures elsewhere, for example, in South Africa as summarized by Shackleton (1993), who reported a mean fuelwood consumption of 687 (49 kg/capita annum) across 12 studies. Kalumian and Kisakye (2004) reported a lower consumption figure 485 kg per capita. On a household basis, the amount of 4,400 kg/household per annum for Hoima is comparable to 4,300 kg in parts of South Africa (Dovie *et al.* 2004). This similarity in figures represents a source of vital information for comparing analyses of the fuelwood crisis and comparing adaptive management strategies towards sustainable management of forests and allied natural resources.

Fuelwood farming option

Tree farming was evaluated using a net present value (NPV) approach. The costs of tree-farming were derived from the data given in Table 1. The various activities occurred in different years which resulted into different labor requirement and consequently varied costs and benefits for each year. For each activity, the labor requirements were converted to Uganda shillings and input costs (seedling, fertilizer) were also calculated.

The operational costs were calculated from activities 12, 13, and 14 in Table 1. Similarly, input (material) costs were only seedling and fertilizer and all these costs occurred in years 1 and 2. Labor occurred in all years. In year 1, labor is required for land clearing and preparation (35 man-days), seedling planting (35 man-days), fertilizer application (7 man-days), and weeding and brush removal (10 man-days). This adds to 87 man-days valued at Ushs. 321,900 (87 x Ushs. 3,700). In the succeeding years amount of labour required is as presented in Table 2

The fuelwood was harvested in years 5 and 9 and it was discovered that pure stands yielded about 123 m^3 per hectare; but, even with replanting, there was some mortality (approximately 25 percent). Therefore, the fuelwood harvest total was estimated at 92.25 m^3 (123 x 0.75). Harvesting required 1.6 man-days of labour per m^3; total labor required was thus 147.6 man-days (92.25 x 1.6). The man-days were then converted to Uganda Shillings at the stipulated wage rate, Ushs. 3,700 per day. We, however, recognize that no costs were assigned to tools used for harvesting or fieldwork.

Recent public surveys (MWLE, 2002b) indicate that it is common practice for schools in the rural areas to request pupils to carry firewood to school. How often this is done varies from one school to

Table 2. Direct costs and benefits from tree farming (Ushs/ha)

Year	Operating Costs			Fuelwood		
	Labour	Materials	Operational Cost	Benefits	Net Benefits	NPV (15% disc. rate)
1	321.900	442,700	208,00	0	-764,600	-114,690
2	77,700	102,000	36,300	0	-216,000	-32,400
3	14,800	0	0	0	-14,800	-2220
4	14,800	0	0	0	-14,800	-2220
5	577,200	0	14,800	3,030,0000	2,438,000	365,700
6	14,800	0	14,800	0	9,600	4440
7	14,800	0	14,800	0	29,600	4440
8	14,800	0	14,800	0	29,600	4440
9	547,600	0	0	03,030,000	2,482,400	372,360
Total	1,598,400	544,700	95,500	60,600,000	3,999,000	599,850

another. It could be daily, weekly or monthly depending on the demand. There are also cases of where pupils pay for firewood as part of their school fees (MoFPED 2003). In the urban areas, and in some boarding schools, the situation is different. Most of the schools buy firewood (ranging between Ushs 50,000 – 800,000/= per term of schooling) depending on the firewood demands of the school. Many poor communities derive their incomes from charcoal burning and trade.

Although, the present national resource basis for fuelwood is known imprecisely and the few existing studies about the local fuelwood situation mainly have been consumption surveys rather than supply-and- demand studies, there are several reasons why the future fuelwood production capacity of the district is in doubt (Kalumian & Kisakye 2001). First, the production capacity of most public forest lands is threatened by conversion to non-forest land uses. Second, the future demand for fuelwood will rise in response to population growth and increases in tobacco production. Third, there exist several plans in Hoima district for the establishment of large-scale projects such as charcoal-using iron blast furnaces, which will increase the demand for fuelwood tremendously (MWLE 2002b). As planned, these projects are assumed to provide their own wood energy resources from associated plantations. Because the slow progress in planting and high rates of mortality, however, it seems reasonable to expect that commercialisation will result in at least some degree of substitution of fuelwood from the existing traditional fuelwood sector to this new modern fuelwood sector (Jacovelli & Caevalho 1990).

The benefits of fuelwood farming are the value of wood produced (direct benefits) and environmental quality benefits of maintaining land under forest cover or reforesting land. Such benefits may include reduced erosion or increased forest production from "protected" forest lands previously used for fuelwood collection. The direct benefits occur in years 5 and 9. Each, year, 92.25 m^3 of fuelwood are harvested. Converted to kilograms and valued at fuel wood's shadow price, the value per hectare in each year is Ushs. 3,030,000.

When net benefit in each year are discounted at 15% and summed, the NPV is found. In this case, it is Ushs. 599,850 per hectare (Table 2). If the environmental quality benefits are included, the positive NPV becomes even larger. The environmental quality benefits consist solely of effects on land quality, valued at Ushs. 65,700 per hectare. These benefits begin in year 2 and continue for each succeeding year. Discounted, these benefits increase the NPV by Ushs. 256,000 for a total NPV of Ushs. 3,999,000.

If only direct costs and benefits are included (Table 2), the NPV at a 5 percent discount rate is Ushs. 2,302,000 per hectare of tree farms. With a 20 percent discount rate, it is Ushs. 460,000 per hectare. At higher discount rates, the NPV will turn negative since the large initial expenses involved in tree stand establishment outweigh future benefits. The inclusion of other environmental benefits not quantified in this study would increase the NPV. Since most of the costs are incurred in planting: additional coppice rotations (10 years) would increase the NPV because the harvest benefits are much larger than the costs of harvesting and weeding.

Fuelwood is collected by the people and used directly to meet their energy requirements. Fuelwood collection is an activity that is largely informal, and the economic value associated with it is not easy to capture. However, it is generally agreed that households consume a lot more fuelwood than what is actually recorded in the formal sector. Falkensberg and Sepp (1999) estimated fuelwood production in the informal sector to be about eight times higher than in the formal sector. Given that over 85% of Uganda's population is rural (UBOS, 2002), fuelwood contributes to the livelihoods of the majority of Ugandans. Moreover, the poorest 35% of the population who live below the poverty line cannot afford buying fuelwood, and hence rely heavily on collecting from the natural forests and trees to meet their energy requirements. The use of fuelwood depends more on the locality than on the level of household income, as the households in urban and peri-urban communities tend to prefer charcoal for cooking. This is because urban consumers find charcoal to be a cheaper source of fuel. In 2000 for example, the cost of cooking with electricity was roughly double that of cooking with charcoal, and paraffin was about 3 - 4 times higher than that charcoal (MWLE, 2002a).

Improved woodstove option

A new woodstove design could improve fuel efficiency from 8 percent to 20 percent (MoEMD, 2002). Fuelwood consumption would therefore decrease since now 0.4 as much wood would supply the energy required to cook a given amount of food. The wood fuel savings is Ushs. 40 kg (0.6 x 65 kg). At a price of Ushs. 43 per kg, this is a saving of Ushs. 1,700 per week (Ushs. 89,900 /year). Over a 9-year period the annual benefits of the new stove are Ushs. 89,960. The costs are the Ushs. 21,000 purchase price and Ushs. 25,000 for administrative costs. Both costs occur in year 1. The NPV over nine years at a 15% discount rate is about Ushs. 390,000. The introduction of improved stoves appears to be very attractive based on fuel savings alone. If the new stove's fuel efficiency were only 10 percent, the annual fuel saving falls to Ushs. 36,000 and the first-year cash flow is negative. The NPV over nine years falls to Ushs. 8,800 which is one third of the previously calculated amount.

We assumed that the decreased fuelwood demand reduces the cutting of forests for fuelwood production, we therefore used the previously assigned values these benefits (Ushs. 65,700 per ha) and determine what part of a hectare would not be cut if the new tree farming areas ($25m^3$ x 770 kg/m^3 = 19,250 kg/ha), the annual wood fuel benefits of about 2,111 kg are equal to 0.11 of an hectare or about Ushs. 7,400 in annual environmental benefits per improved woodstove. Other studies (Moyini & Muramira 2002; Tumuhimise & Kutesakwe 2003), have, however, proved that natural forest yields are substantially lower than managed tree farms and therefore the environmental benefits from each kilogram of wood saved are greater. In addition, there are other benefits from each kilogram of wood increased production of other forest products when fuelwood needs are reduced. If the natural forest's annual increment were only $5.75m^3$/ha, the environmental benefit would be Ushs. 31,000 per year. At a 15% discount rate, the total NPV for year 2 to 9 amounts to Ushs. 121,000.

Kerosene stove option

The kerosene stove is assumed to eliminate the need for fuelwood; 65 kg valued at Ushs. 300 per year. Annual fuel costs are Ushs. 134,900 (2.25 litres x 1153.5 x 52 weeks). In addition, the stoves costs Ushs. 17,200 and there is a one time administrative cost to the government of Ushs. 24,700 per stove adopted. The direct benefits and costs are very close. In the first year, net benefits are negative Ushs. -32,350. In subsequent years, the net benefits are marginally positive (Ushs. 8,800). If environmental benefits are included, however, this option becomes more attractive. Reasoning as before for the woodstove example, the annual land quality benefits

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would be Ushs. 11,360 per ha which increased the NPV by Ushs. 44,400.

We faced problems associated with the option to use commercial fuels such as kerosene. This is because Uganda imports most of its kerosene using scarce foreign exchange. The price of kerosene has greatly increased therefore, making the fuelwood the most feasible alternative for the rural poor households. A new stove may last longer than nine year hence increasing the NPV or it may require repairs and replacement parts whereby lowers the NPV.

Model simulation results

The tree cover in the forest areas declined by 6% in the BASE scenario, 4.8 % in POPG scenario and 4.7% in TECH scenario, indicating an overall trend of forest degradation in the Hoima district under each of these scenarios (Figure 3). Reduction in the population growth rate (represented by POPN model scenario) and introduction of improved farming methods (TECH model scenario) did, however, to a somewhat reduced forest degradation rate. Reduction in the population growth rate would reduce demand for wood fuel and timber. Increase in crop yields due to introduction of technology would increase the household income, and hence, activities such as the sale of fuel wood and timber will decrease. In both cases, the rate of tree removal will be lower than in the base scenario.

The price increases for the major crops (PP scenario) reversed the degradation process and actually indicated regeneration within the study area during the latter part of the simulation period. This option seems to be more effective in mitigating forest degradation rate by enabling an increase in income from crops, and thereby reducing pressure on sales of fuel wood and timber, to meet the household requirements. Furthermore, enhanced income form existing farm production would mean that less land would need to be brought into cultivation, hence less deforestation.

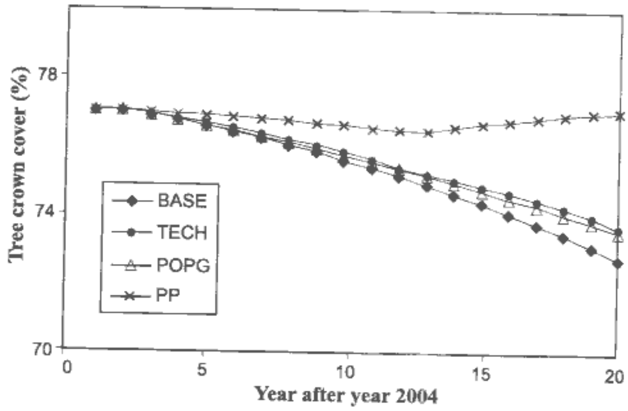

Figure 3. Projected tree crown cover (%) under alternate scenario in Hoima district, Uganda

Scarcity of fuelwood is one of the key factors that motivate farmers in adopting rotational woodlot technology (Jacovelli & Caevalho, 1999). As long as fuel wood could be collected without paying for it, farmers always have little incentive to plant fuelwood producing trees. Shackleton (1998), however, reported that high fuel wood demand stimulate tree production that this is only the case when there is a fuel wood crisis. Thus, the high cost of fuel wood may motivate farmers to establish woodlots (Tumuhimise and Kuteesakwe 2003).

The results of this study have shown the importance of trees in supplying domestic fuelwood. Wood and charcoal remains the predominant cooking fuels for households in rural areas with growing population, less innovative energy utilization technologies, increasing price for agricultural produce, During the period of 2004 to 2020 the fuelwood consumption is predicted to increase by 2.2% annually, which is about the same percentage as the increase in average amount of 0.5 - 0.6 m^3 fuelwood consumption per household each year (MWLE, 2002a).

CONCLUSION

Environmental degradation, rural poverty, food shortages, wood scarcities and heightened concern for energy supplies have all contributed to an increased awareness of the importance of forests and trees for the well-being of rural people. With the growing impact of deforestation and land deterioration, new approaches are called for. This study has shown that tree-farming is one of the possible approaches to increase the supply of fuelwood (energy), while the woodstoves and kerosene substitution are policies that reduce the demand for fuelwood. This helps to alleviate the rural energy shortage and take some pressure off existing protected forest areas. The tree-farming illustrates one of the possible approaches to how the supply of fuelwood (energy) can be changed, while the woodstoves and kerosene substitution examples are policies that would reduce the demand for fuelwood. The amounts of Fuelwood sold depend on the uses, the location, and the sources.

Based on these findings we can not claim that tree-farming is definitely better than introducing new woodstoves. Both options would appear to be attractive and, if implemented, would both increase fuel supply and decrease demand. This could help to alleviate the rural energy shortage and take some pressure off existing protected forest areas. In practice, both types of options have been hindered by implementation problems in many areas.

Our results are very sensitive to the imputed shadow price of fuelwood. If this shadow prices were greatly different from the Ushs. 44 per kg calculated, the different options might appear more or less attractive. The only other option discussed in this study that appears unattractive is the use of kerosene stoves. High fuel costs make this option economically unattractive although some people will opt for kerosene stoves because of convenience and availability.

Given the complicated interactions between humans, forest lands, land-use practices, and fuelwood collection, it was difficult to state precisely that a given percentage decrease in fuelwood collection resulted in a proportionate improvement in forest land cover or decrease in deforestation. Regardless of the exact environmental consequences of deforestation, there is general agreement on several facts: there is a rural energy shortage; fuelwood is the most common rural fuel, and its use will increase for both continued household use and for new commercial purposes; deforestation has decreased the production capacity of fuelwood; and reforestation of denuded lands may assist to ensure a future resource base for fuelwood production, as well as to control environmental degradation.

The price of kerosene has greatly increased therefore, making the fuelwood the most feasible alternative for the rural poor households. A new stove may last longer than nine year hence increasing the net present value or it may require repairs and replacement parts whereby lowers the total benefit to the poor farmers.

The necessity to plant trees on private fields probably will become more important in the future in satisfying the needs of the fast growing population, therefore, an understanding of the factors that determine the decisions about tree growing of the farmer will prove important. The social problems emerging from population development and traditional agricultural expansion seem to remain unsolved constraints for rehabilitation and community forest development is in relation with land status and property rights on its resources.

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