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Wood Energy Production and Consumption in Rural and Farming Systems Context: A Case of Family-Household and Local Industry Northern Thailand

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Abstract

Due to the fact that a non-sustainable use of wood energy from the forests, in terms of sustainable production and utilisation, occurs in northern Thailand, understanding the complexity of availability and use of wood energy resources is required as a basis to finding a solution. Therefore, monitoring as well as analysing the present situation of energy consumption and production are essential. This paper aims to examine wood energy production and consumption in the rural and farming systems context. The survey was done in Phayao province, Northern Thailand in crop year 1992/93.

The results showed that wood is still the main energy source for rural families in Northern Thailand. Income was the main factor determining the energy type and quantity consumed. Therefore, any measurement of increasing income will result in decreasing the quantity of wood energy consumed by substituting modern energy sources e.g. LPG. The forest is the main source of wood energy production in the study area with wood from cultivated fields and around home still playing a minor role. The ever increasing distance to the collection places was reported by most wood collectors as the main problems of wood gathering and led to the longer time spent in acquiring wood as a source of energy. It implied that increasing the opportunity cost of labour (the families earning potential against their costs in gathering wood) would contribute to reducing wood energy collection. Finally, it was found that the sustainable wood energy supply constitutes less than 50 percent of total actual consumption of Phayao province in 1992/93. With the present wood energy consumption and production as well as respondents‘ attitudes, the pressure on the forest is likely to continue. In conclusion, enhancing local job opportunities to enhance family income would help to dampen the present problem of wood energy.

Introduction

Rural northern Thai society depends primarily on traditional fuels such as firewood and charcoal which are derived mainly from the forest biomass (Department of Energy Affairs, 1992). Unfortunately, the energy biomass from forests is in decline. The combination of commercial felling, agricultural expansion, effects of urbanisation and fuelwood collection has reduced the country’s forest areas. Northern forest areas, the largest forest areas of Thailand, have especially been reduced form 102,327 km^2 in 1976 to 77,143 km^2 in 1991, a reduction of 25% (Royal Forestry Department, 1991). Consequently, the severe fuelwood shortage in northern Thailand was reported (Center of Community Forest in Asia and Pacific Region, 1992). Therefore, careful consideration of the sustainable production and utilisation

of this biomass is required. If they are not balanced, environmental problems such as deforestation, loss of soil fertility and impacts on water resources are likely to arise (PARIKH, 1988). In addition, DOPPLER (1993) regarded energy, in relation to the forest, as an important resource in the Tropics and Subtropics. So, to understand the complexity of the energy subsystem and to monitor the present situation, an analysis of energy production and consumption is essential. This paper aims to analyse the energy consumption and production of family-household and local industry in Phayao province, Northern Thailand.

Methodology

The farming system approach of DOPPLER (1994) was applied throughout the study. It began from collection of information at the family-household, village and regional levels. All relevant information was included. Problems were investigated. A data bank was established for analysis. Finally, a conclusion was drawn. Three family groups were classified based on their location: (1) Rural forest families are the families located in or nearby the mountain forests and work in some agricultural activity. (2) Rural agricultural families are the families who live in the plains area, and are mainly agriculturist. (3) Urban families are the families who live in the town and comprise of few farmers. Then, a formal survey of the family-household and an informal survey of local industries was done in Phayao province, Northern Thailand in 1993. Sixty samples per family group were randomly selected, in total 180.

Results and Discussions

Energy consumption

Various energy consumption combinations often indicate the level of development within the country, region and family-household and their change from traditional fuel to modern energy differs depending on their existing resource base (KAMALA 1986, p.52). The consumption of various energies by urban, rural agricultural and rural forest families in the study area are, therefore, analysed in the following section.

Energy consumption of family-household

Family-household energy consumption by sector

The structure of energy consumption of a family can be categorized several ways. One of these is based on four main items of a family-household system: (1) families personal items; (2) household; (3) farm; and (4) off-farm (Figure 1). However, due to an interlinkage among families, household, farm and off-farm as a system (such as energy consumption for a trip to the market is often for the sake of farm, family, household and/or off-farm at once), it is difficult to quantify the exact amount of energy use in each sector. They are, therefore, grouped into four main activities namely agriculture, cooking, transportation and household facilities for lighting and providing the convenient lifestyle in order to show a clearer picture of wood energy consumption.

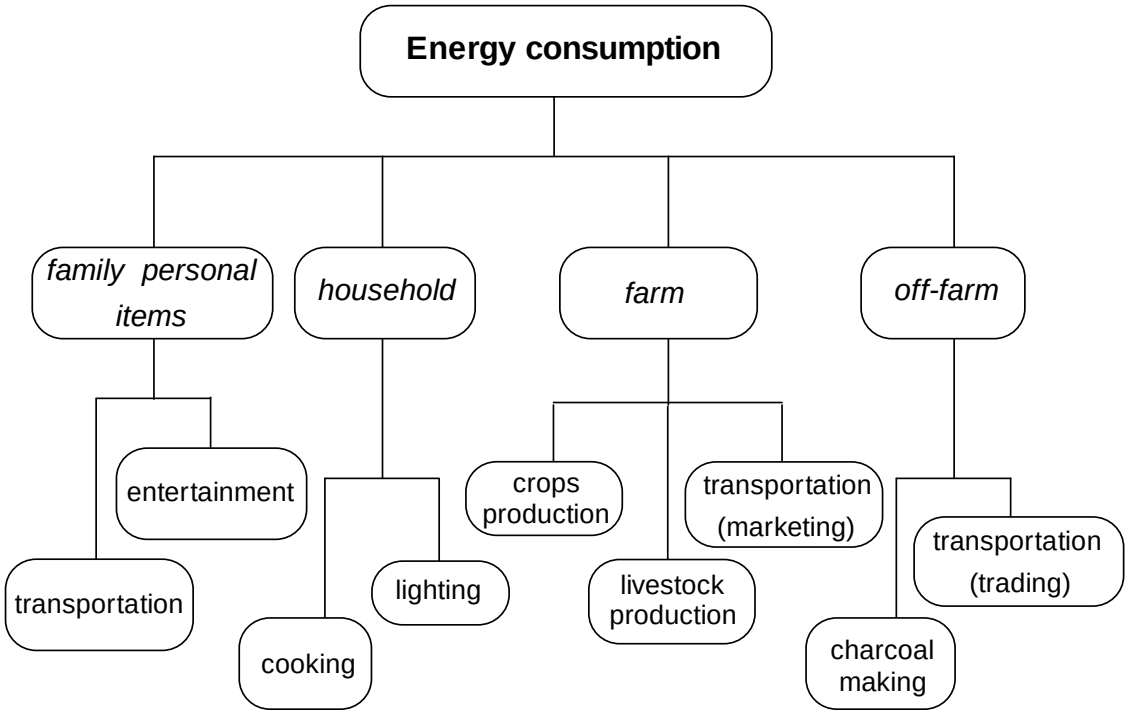

Figure 1. Structure of energy consumption of a family-household system

In terms of total energy consumption, the urban families were significantly different from the rural agricultural and forest families. The urban families consumed the highest amount at 56,066 Megajouls (MJ) with the rural agricultural families second at 40,150 MJ and the rural forest families the lowest (39,934 MJ) (Figure 2). There was no significant difference in terms of energy consumption between the rural agricultural and forest families. Four sectors of families energy consumption (transportation, household facilities, agriculture and cooking) are separately discussed as follows.

Transportation. The urban families consumed high levels of energy in the transportation sector which accounted for 60% of total energy consumption. Those energy sources are such as superbenzene, benzene and diesel which are used for driving their own car daily to the work place and to recreation places on the weekend. On the contrary, rural agricultural and forest families consumed energy for the transportation sector lower than urban families accounting for 29% and 20% respectively. Those energy sources were mainly benzene utilised for motorcycles. The energy use for transportation of the rural agricultural and forest families is not as high because most of the transportation activities were mostly performed on foot or by bicycle.

Household facilities. Energy use for household facilities comprises of usage for lighting, heating and appliances (televisions, radios, videos, fans, air conditioners, refrigerators etc.). The urban families consumed the highest amount of energy for household facility (8,701 MJ) with the rural agricultural families second (4,830 MJ) and the rural forest families the least

(2,861 MJ). The energy use for household facilities of rural forest families was not as high because they mainly use firewood for body heating during winter and scarcely use electricity for lighting and other appliances. Statistically, there was a significant difference in energy consumption for household facilities between the urban and rural agricultural families but there was no significant difference between that of the rural forest and agricultural families.

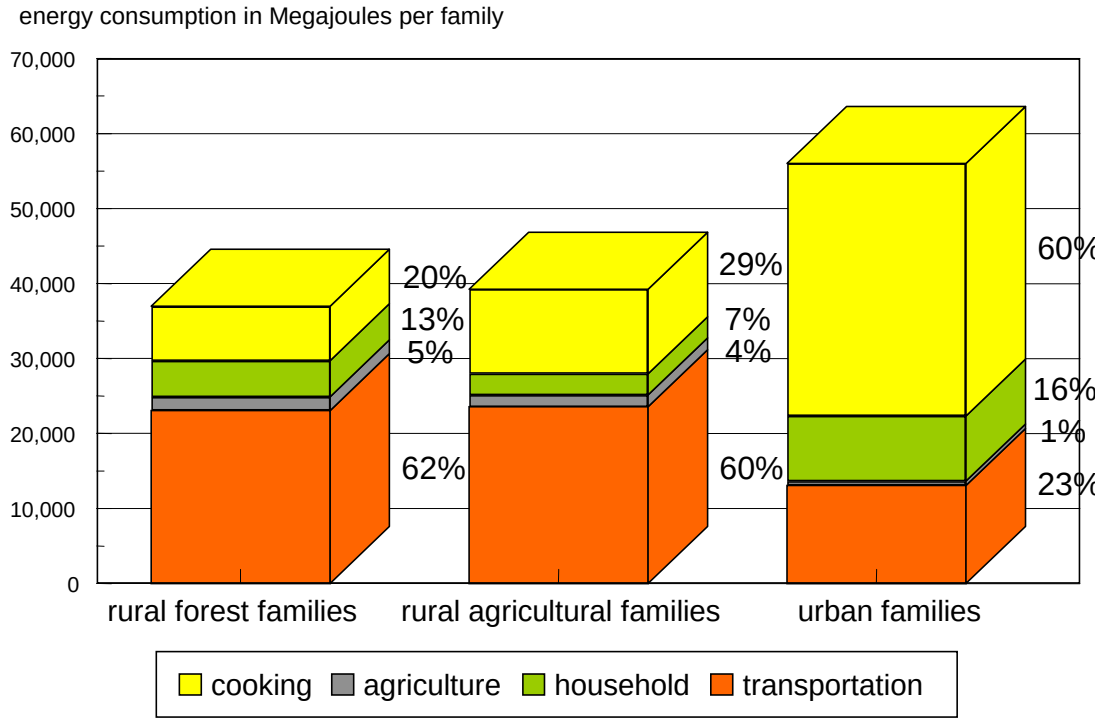

Figure 2. Energy consumption by sector of the three family groups in Phayao province, Northern Thailand, 1992/93

Agriculture. Energy use in the agricultural sector is mainly achieved by solar energy which is not measured in this study. The energy consumption of this sector was, therefore, proportionately low compared to other sectors of the household energy consumption. Since the study involved only the direct use of energy, the conversion of solar energy as well as of seeds and fertilizers as indirect energies for agricultural products are not included in this study. The main direct energy use for agricultural activities was diesel for the two-wheel hand tractor used for ploughing the rice fields by all families. Firewood was used by the rural forest families to repel insects from cattle standing under the house. The energy use in agricultural activities was not significantly different between the rural agricultural and forest families.

Cooking. Energy used for cooking was the most important household energy consumption of rural forest and rural agricultural families. For the rural forest families energy used for cooking accounted for 62% of total household energy, for rural agricultural families second with 60% and the urban families the lowest with 23%. The cooking sector plays an important role in terms of energy consumption of all families, especially for the rural forest and rural agricultural families as they use fewer pre-processed ingredients. So, a detailed analysis of the cooking sector is done in the following section.

Per capita energy consumption of family-household by type

Using a per capita basis, in many aspects, provides a clearer picture than using a total basis. This also applies to the energy consumption aspect. Per capita energy consumption can be different from total household consumption because the size of the household of urban and rural families can be different, particularly in developing countries. Although, the average household size of all families in the study area are relatively similar, per capita energy consumption is still meaningful to examine. Wood energy (firewood and charcoal) was the main energy consumed per person per year by rural forest (68%) and agricultural families (60%). By contrast, in the urban families it was only 17% (Figure 3). Non-wood (LPG, electricity, gasoline and diesel) was the main source of energy consumption for urban families (83%) but was low in the case of rural forest and rural agricultural families.

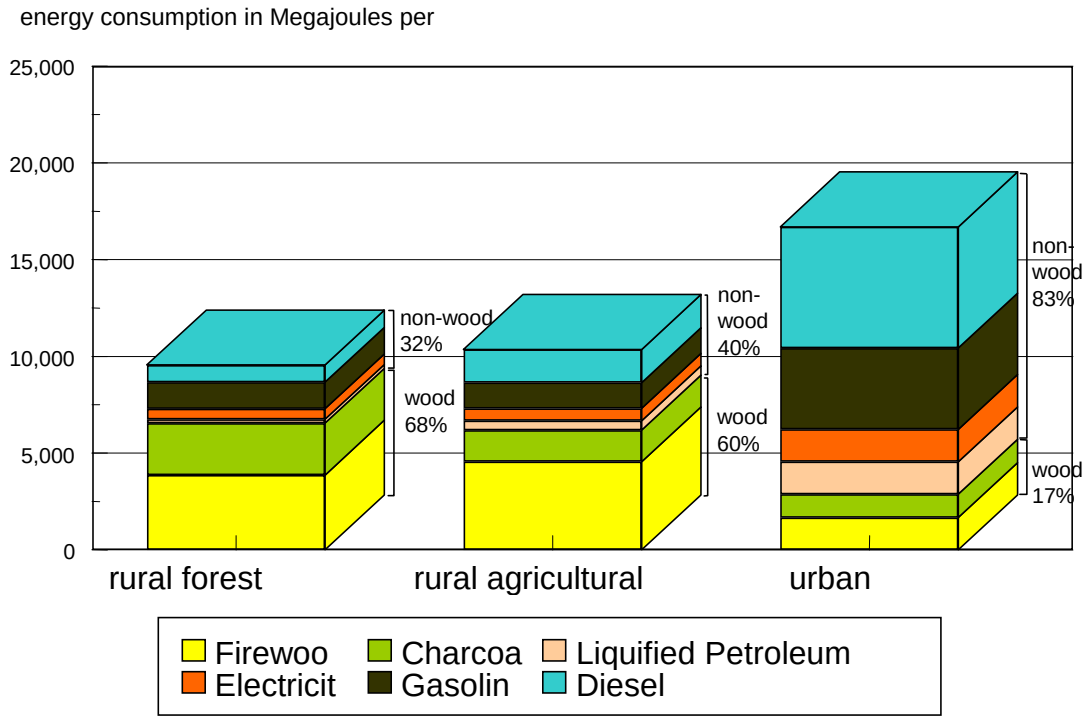

Figure 3. Per capita energy consumption by energy type, the three family groups in Phayao province, Northern Thailand, 1992/93

It is clearly pointed out, that wood is the most important energy source of families in rural area. Agricultural residues were not utilised as energy by families in the study area. This was due to the following reasons. Firstly, wood produces higher quality energy for cooking than agricultural residues. Secondly, the use of agricultural residues, for instance rice straw, corn straw and cow dung, as fuel have negative side effects. These fuels usually require more time during cooking, often produce higher smoke and higher amounts of ash, and induce less healthy conditions in the kitchen. In addition, residues could be better utilised as organic fertilizer and soil conditioner in the field. Thirdly, wood is available in forests which surround the study area, as well as most parts of northern Thailand. Based on respondents' opinions, wood is and will remain the major source of energy for rural families in the study area.

Quantity of wood energy consumed per person (family-household sector)

On a per capita basis, the rural forest families consumed the highest amount of wood energy among families in the study area at 706 kg, the rural agricultural families second at 570 kg and the urban families the least at 314 kg. Per capita consumption of wood energy was not significantly different between rural forest and agricultural families. On the other hand, the per capita consumption was significantly different between the urban and rural forest families and between the urban and rural agricultural families. Based on an average of all families, 210 kg of firewood and 64 kg of charcoal were consumed. When comparing this analysed data to the study[42] of Department of Energy Affair (1992), an average per capita energy consumption of northern Thailand in 1990 was 192 kg for firewood[43] and 109 kg for charcoal, it indicated that the amount of charcoal consumption apparently decreased whereas firewood slightly increased. This might be due to several reasons, for instance a) an increase in scarcity of wood for charcoal making, as mentioned by many respondents in the study area; b) the policies of banning charcoal making in forests. These policies, however, hurt mainly poor rural families in terms of reducing a source of their family incomes and reducing the basic energy consumption for those who can not afford to shift to modern energy (such as reducing to two cooked meals instead of three cooked meals a day). c) some families having substituted wood for modern energy. Nevertheless, BARNES and QIAN (1991, p. 16) contended that wood energy does not disappear completely as incomes rises and many high income households still use wood. As a result, wood is still an important source of energy.

Factors affecting the quantity of energy consumed by family-household

Explanatory power of regression. The multiple regression function of several energies were analysed to find out the factors affecting the quantity of energy consumed by family-household. Suitable equations were selected based on the goodness of fit and the magnitude of the coefficient of multiple determination (R^2), the signs of the regression coefficients, the significance of the t-values of the regression coefficients and the general significance of the regression equation.

The coefficients of multiple determination (R^2) of energy were rather low ranging from 23% and 52% (Table 1) implying that there must be some additional factors explaining the level of those energies consumed. However, other important indicators of this hypothesis testing were obtained i.e. the signs of coefficients, the significance of the t-values of the independent variables and F-value showing the general significance of the regression equation. For instance, the F-value of all presented regressions were significant at the 1 percent level indicating that the independent variables successfully explained the variations in the quantities of energy consumed.

[42] Although, this data was examined at the regional level whereas this study data was calculated on a family-household basis of a selected area, it provided an idea of the situation.

[43] Data of wood was originally available on cubic metre basis and a conversion factor of 1 cubic metre = 600 kilogram of wood (Department of Energy Affair, 1991) was utilised.

Table 1. Determinants of household energy consumption of rural and urban families in Phayao province, Northern Thailand, 1992/93

Families	Functio-nal form	Dependent variable	Sample size	Constant	Coefficients of independent variables			Adjusted R square	F-value
					Y	N	E		
All families	Double Log	Total energy	180	6.040	0.343^{++} (5.820)	0.937^{++} (6.878)	-0.003 (0.563)	0.27	22.83*
Rural families	Double Log	Total energy	120	5.518	0.435^{++} (5.771)	0.768^{++} (5.660)	-0.001 (0.167)	0.35	21.97*
Urban families	Double Log	Total energy	60	0.419	0.840^{++} (4.066)	1.476^{++} (4.888)	-0.104 (0.586)	0.31	9.64*
All families	Double Log	Electricity	180	-0.330	0.793^{++} (13.686)	0.574^{++} (4.200)	-0.007 (1.195)	0.52	64.38*
Rural families	Double Log	Electricity	120	0.628	0.713^{++} (6.877)	0.342^{+} (1.837)	-0.008 (1.435)	0.29	17.25*
Urban families	Double Log	Electricity	60	-0.133	0.746^{++} (5.625)	0.850^{++} (4.381)	-0.004 (0.031)	0.40	14.14*
All families	Double Log	Liquified Petroleum Gas	180	-143.378	13.307^{++} (9.361)	7.976^{+} (2.423)	0.111 (0.825)	0.34	32.24*
All families	Double Log	Firewood	180	116.640	-12.856^{++} (9.236)	-0.739 (0.229)	-0.089 (0.673)	0.34	32.06*
All families	Double Log	Wood energy	180	11.651	-0.348^{+} (2.075)	1.048^{++} (3.471)	0.025^{++} (2.909)	0.23	6.84*

Figures in parentheses are t-values. Y: income; N: number of household members; E: education of household head
*: F-value significant at the 1 percent level; ++: t-value significant at the 1 percent level; +: t-value significant at the 5 percent level;

Income. Based on a two-tailed t-test of the regression coefficients, the impact of income was the strongest determinant of energy consumption in the rural and urban families. The positive impact of income on the quantity of electricity consumed occurred on both the rural (0.71) and urban (0.75) families indicating that with a rise of family income, electricity consumption by rural families and by urban families will increase. As well, the positive impact of income on the quantity of LPG (13.31) consumed occurred for all families proposing that increasing the family income, the LPG consumption will rise. By contrast, the negative impact of income appeared on the quantity of firewood (-12.86) and wood energy (-0.35) consumed pointing out that as income raises, firewood consumption will reduces and wood energy consumption also reduces through switching to modern energies.

Household size. Household size was the second significant explanation of electricity, LPG and wood energy consumption of the rural and urban families. The positive impact of household size of all families occurred on the electricity (0.57), LPG (7.98) and wood energy (1.05) consumption indicating that as household size expands, there is an increase of electricity, LPG and wood energy consumption. Firewood was an exception, a negative impact of household size for firewood consumption occurred. It might be due to a high homogeneity of household size among the firewood consumers. Nonetheless, the impact was not significant.

Educational attainment. The educational level of the household leader did not play a significant role in terms of the quantity of consumed energy, indicated by the non-significant two-tailed t-test of the coefficient. However, education of the household head had an indirect influence on energy consumption through enhancing the prospects of income generation which was a strong indicator of the quantity of energy consumed as mention above.

Conclusion. Income played the central role in determining the level of energy consumed. It implied that various development efforts to increase income of rural families would reduce the level of wood energy consumed by switching them to modern energy sources such as LPG or electricity. Nonetheless, although income improved, wood energy remained as a main type of energy consumption and was increasingly consumed with increasing household size, particularly in rural families where there were obstacles of availability to modern energy and accessibility to it. Therefore, improvement of the physical conversion efficiency of the wood energy stove is also required in parallel. In addition, despite a non-significant impact of educational achievement of the household head, enhancing the education of the household head is a useful role in wood energy demand because it can lead to an enhancement of income generation.

Wood energy consumption of local industries

Rural industries of Phayao province are mostly small scale agro-based industries such as tobacco rolling, sugar processing, rice milling, etc. All of them have common characteristics of being simple technologies, dispersed and often dependent on local materials and local inputs. The fact is that many of them require intensive heating, make traditional fuels more appropriate in meeting their energy requirements without spending much on high quality modern fuels (MICHAEL, 1993, p.40). A survey on fuelwood consumption of industries in Thailand during 1991-1992 showed that the northern region consumed the highest amount of wood energy, about 4.7 million cubic meters per year, where tobacco rolling industries were

the highest consumers of fuelwood. (BENJACHAI, 1994). In addition, local industry plays an important role in employment for the people in the rural area. Accordingly, the firewood consumption of rural industries is essential to consider.

Among the local industries of Phayao province, tobacco rolling industries play the most important role in the region, though ranked as the second largest industry groups. Tobacco curling industries are the highest consumers of firewood whereas the others consume wood energy in small amounts, including rice mills. Based on the above facts, the calculation of industry consumption was done mainly on tobacco rolling industries. Their consumption was measured using both survey and secondary data. This estimation, however, did not include those firewood sent to other tobacco rolling industries outside Phayao province. The preferable size of firewood for tobacco rolling is about 20-30 diameter and 1 meter in length.

The results show that about 114,633 cubic meters or 68,780,022 kg of wood energy were consumed by tobacco rolling industries in Phayao province in 1992/93. According to interview results of some employees of a tobacco rolling industry in Phayao province, most of firewood production came from the public forests, not as claimed by forestry officers and owners who said that most came from private lands. This wood energy consumption of local industries was then combined with the household wood energy consumption to show the entire fuelwood consumption of the region.

Energy Production

Energy production of a family can be derived from several sources such as forest products, farm residues, other on-farm products and external marketed supplies (Figure 4). Firstly, forest products we comprise of firewood and wood for charcoal production. Secondly, farm residues are wood from farm trees, animal manure, and crop residues such as rice and corn straw. Thirdly, other on-farm products are biogas and wood from agroforestry. Fourthly, external marketed energy supplies included electricity, Liquified Petroleum Gas, benzene, diesel and other petroleum fuels.

Situation and stage of wood energy production

Viewing the situation of and stage on wood energy production in the study area provides a clearer picture of the wood energy problem. The world fuelwood situation was done by SOUSSAN, O'KEEFE and MERCER (1992) using topological approach which is summarised in Appendix 4.1. Based on this approach, the study area could be considered as a high in woody biomass with a medium to high population density area. Wood energy problems in such an area are a common feature i.e. communal areas are under stress since woodlands are cleared, for instance, for agricultural purposes. The traditional rights and obligations on land resources management have been changed. This could be further explained by SUBHADHIRA et al (1988, p. 34). The stage of wood energy situation of the rural forest families would be defined as stage 2 (increased scarcity), whereas that of the rural agricultural families would be described as stage 3 (serious shortage). In stage 2, villagers already feel the pressure of increasing wood energy scarcity. Most nearby forested areas have been converted into other forms of land use or are no longer freely open to villagers. The amount of wood used for fuel has decreased. Villagers also use many more types of wood, with less regard to preferences or to taboos upon certain types. Charcoal is made for domestic use, especially for use during the rainy season, but not by most households for commercial

purposes. Trading in charcoal does exist, however, especially among friends and relatives. In stage 3, fuelwood shortages have become acute. All nearby forests have been converted into agricultural land and few trees are left in the fields. Villagers normally have to either hire a truck to obtain fuelwood from distant sources or make long trips with pushcarts. Villagers are highly dependent on fuelwood sources outside or far away from their own villages. Fuelwood collection in large quantities is normally done during the dry season when agricultural activities are less demanding. They gather whatever shapes, sizes and species they can find. Some families have adopted substitutes such as Liquified Petroleum Gas and electricity. Stage 1 (abundance) and 4 (recovery) are not applicable in the study area.

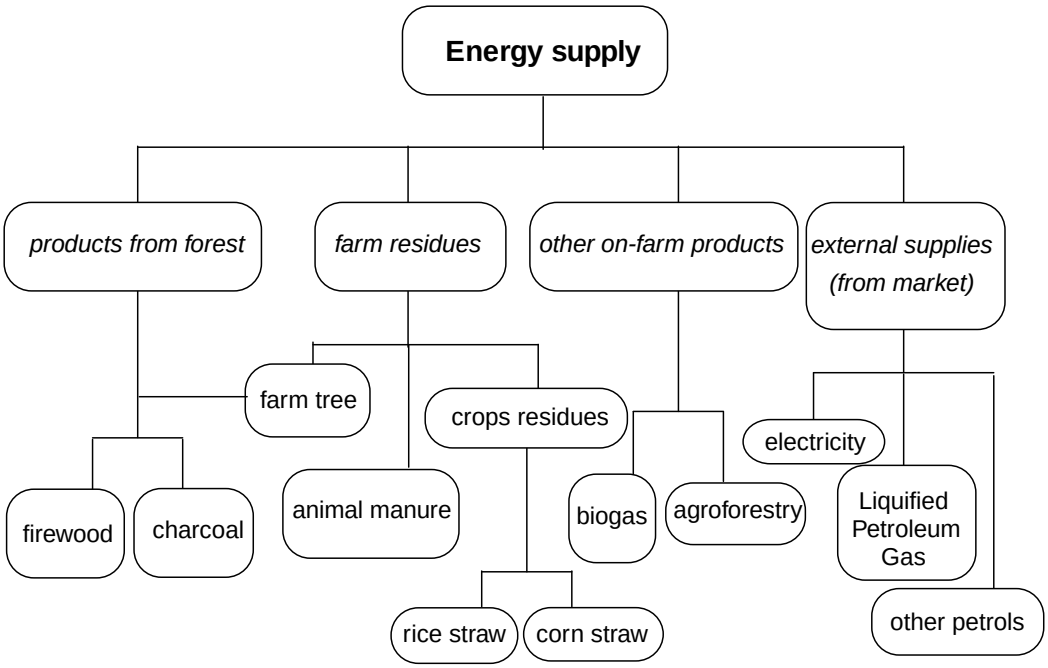

Figure 4. Structure of the energy supply of a family-household

Wood energy gathering and producing by family-household

Wood energy gathering was perceived during the mid-eighties as a major cause of deforestation in several developing countries (FAO, 1993, p.3), which led to several studies and activities to improve the wood energy situation: by reducing fuelwood consumption through more efficient energy production systems and higher efficiency cooking devices as well as substitution by modern fuels and by increasing the supply of wood through planting. In spite of these activities, people continue gathering wood fuels. Today, wood gathering is still an important activity to fulfil domestic energy requirements for people in several countries of Asia (KUMAR and HOTCHKISS, 1988, OUERGHI, 1993, KOOPMANS, 1993). Therefore, the study of wood energy gathering is an important issue contributing to solving the wood energy problem.

Firewood gathering by family-household

Firewood was gathered for cooking and for heating in the winter as well as for repelling mosquitoes and other insects from cattle through its smoke. However, the main quantity of firewood gathering was for the purpose of cooking. Firewood gathering for other activities were not as important and they were used only by the rural forest families who are located near forests.

Considering the location of firewood gathering, the forest was determined as the main gathering place, more than 85% of all families gathered firewood from forests (Table 2). Wood around their home and in cultivated fields played a minor role in terms of firewood production for all families in the study area. This might be because firewood from forests was considered as a public good while wood around the home and in cultivated fields is an individual asset. Some places where forests are almost depleted, firewood around the home and in cultivated fields has begun to play an important role.

In terms of rural forest families transporting firewood back home, the major means was on foot since they live near the forests, at an average of 2 kilometres from the wood collection point. Rural agricultural families transported firewood mostly by cattle drawn carts, because of the greater distance from the house, at an average of 7 kilometres from the wood collection location. Urban families (few firewood consumers) rented pickup trucks to transport the firewood back home, since the distance of the firewood gathering locations is on average 13 kilometres. The average amount of labour required for firewood gathering and travelling by rural forest families was 36 mandays per family per year (md/family/y) with that of rural agricultural families 37 md/family/y and that of urban families 10 md/family/y. The difference was due to the means of transportation as mentioned above.

Unlike many countries in Africa, where women are the main collectors of firewood (LEACH and MEARNS, 1988), for more than half of all families in the study area firewood was collected by men, mainly household heads. The activity of firewood collection by men was particularly high in the case of rural forest families. Since firewood was gathered primarily from the forest, it is preferable for men to do the gathering due to several reasons. Firstly, it is less dangerous than for women (for example, for women there is the problem of rape which has sometimes occurred). Secondly, men could easily gather firewood as a side-job from other main activities in forests, for instance hunting, bamboo shoot gathering or collecting other forest products. This facilitates participation in a tree planting programme because the men involved in firewood gathering are also the decision makers in farm planning. Nevertheless, women also play an increasing role in firewood gathering.

The average amount of firewood gathering by rural forest families was slightly lower than that by rural agricultural families but higher than that by urban families (Figure 5). But the wood gathered for charcoal production by the rural forest families was much higher than that by rural agricultural families. The urban families were the lowest producers of both firewood and charcoal. Charcoal production is discussed later.

Table 2. Firewood gathering activities of the three family groups in Phayao province, Northern Thailand, 1992/93

Items	Rural forest families n=51	Rural agricultural families n=49	Urban families n=7	All families n=107
Location of firewood gathering (% of families)				
- forest	88.2	87.8	85.7	87.9
- cultivated field	0	4.1	0	1.9
- around home	11.8	8.2	14.3	10.3
Firewood transporting (% of families)				
- on foot	60.8	22.4	14.3	40.2
- bicycle	2.0	2.0	0	1.9
- motorcycle	5.9	0	14.3	3.7
- pick up	0	4.1	42.9	4.7
- traditional truck (E-tan)	11.8	2.0	28.6	8.4
- cattle drawn cart	19.6	69.4	0	0
Family member who gathered firewood (% of families)				
- household head	68.0	41.7	40.0	54.4
- wife	6.0	10.4	0	7.8
- son or/and daughter	20.0	16.7	20.0	18.4
- father or/and mother	0	2.1	40.0	2.9
- other relatives	6.0	29.2	0	16.5

When asking firewood collectors about the problems of firewood gathering, most of them talked about the ever increasing distance to the collection places and hence the longer time spent in acquiring firewood. In addition, they reported a rapidly decreasing trend in the amount of firewood available for gathering, mainly due to the overexploitation of forests. The scarcity of wood energy resulted in the longer time spent in fuelwood gathering which affects agricultural labour and productivity, and in the worst case even the diet of the people (FAO, 1993a). Some respondents said that there was less dry wood to collect and they had to cut the small easily felled young trees. This can be a signal of the approaching problem of deforestation as well as the degrading environmental effects as mentioned by EL-HINNAWI and BISWAS (1981) who stated that excessive pruning of the branches would reduce the tree‘s capacity for growth and removal of the more easily felled younger trees would reduce the regenerative ability of the forests.

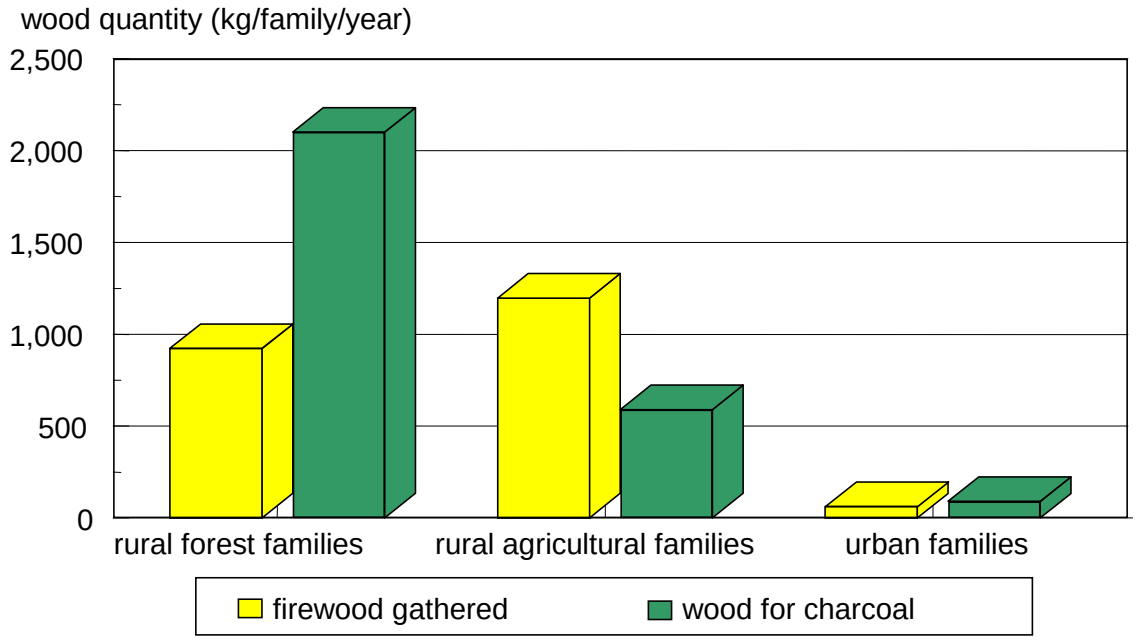

Figure 5. Amount of firewood gathered and wood collection for charcoal production of the three family groups in Phayao province, Northern Thailand,1992/93

Charcoal producion by the family-household

About half of rural forest families and only some rural agricultural families (23%) produced charcoal while very few urban families (3%) produced charcoal. Similar to firewood gathering, the men were the main family members who gathered wood for charcoal production. The forest was the main source of wood collection for charcoal making and charcoal production. Charcoal was produced mainly for home consumption with the excess being sold. About half of charcoal makers used temporary clay kilns when they making charcoal in the forests. Some of them used temporary rice husk kilns when making charcoal near villages. A few of them used permanent brick kilns. The material used as fuel for making charcoal was mainly wood for the clay kiln and rice husks for the rice husk kiln.

Rural forest families were the main producers of charcoal for all families in the study area with some rural agricultural families also producing charcoal for sale. Urban families were mainly purchasers of charcoal, though some rural forest and agricultural families also purchased charcoal (26-28%). The wife was the person who normally bought charcoal. A simple flowchart of the charcoal marketing channels of families in the study area is presented in Figure 5. Forest families mainly purchased charcoal from the same villagers who had some charcoal left over after fulfilling their own requirements. Most rural agricultural families purchased charcoal from the producers who came from the villages near forests (rural forest families) by ordering it. These producers took orders before making charcoal which was then sent to the customers when ready. Urban families bought charcoal mainly from small shops near their homes. When asking about the problems with charcoal, most respondents claimed the problems of the increasing price of charcoal.

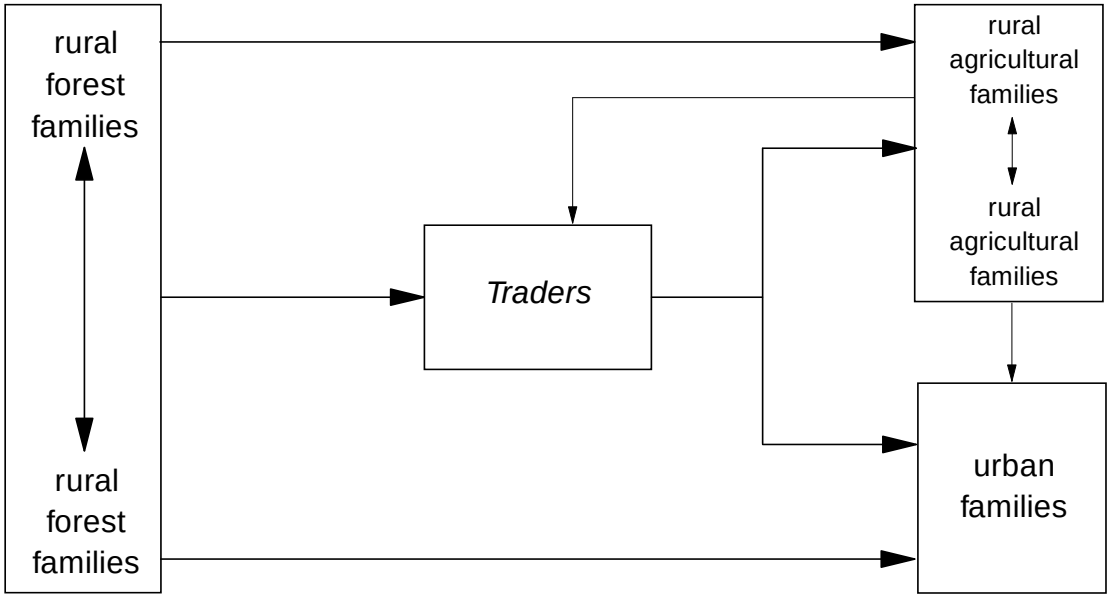

Figure 5. A simple flowchart of the charcoal marketing channels of families, Phayao province, Northern Thailand, 1992/93

Gap between Wood Energy Consumption and Sustainable Supply

To monitor the present situation of wood energy, gap analysis between sustainable supply and consumption were estimated.

Sustainable wood energy supply. To measure the long run impact of the taking of wood from forests on the development of forests on one side, and the energy supply on the other, it has to be estimated what the maximum take-off of wood energy would be under the condition that forests potentiality would not be reduced. The amount of wood energy which can be taken out of the forests under this condition is defined as the sustainable wood energy supply. The sustainable wood energy supply was estimated by using two sources of data:

1. using fuel wood productivity and its accessibility from northern Thailand data from the Center of Community Forest in Asia and Pacific Region (1992); and
2. using the sustainable supply[44] of wood from forests at 64 kg/rai (0.4 tons/hectare) from OUERGHI (1993, p. 72).

From the survey, there were no families who reported wood energy used from manufacture or industrial wastes. Therefore, wood energy from forests, degraded forests, range/shrub land, tree crop lands, paddy/field crop lands and idle/open lands were mainly taken into consideration. The sustainable supply from the first data source was estimated by using the stock areas of wood multiplied by wood energy productivity and multiplied by the access of wood energy and resulted in 152 million kilograms (Table 3).

[44] The sustainable productivity defined as an estimated production of biomass per unit area of forest calculated by modelling the growth of each tree using models of relative growth rates dependent on total tree biomass, species, extent of crown damage and agro-ecological zone (OUERGHI, 1993, p.72).

Table 3. An estimation of wood energy sustainable supply in Phayao province, Northern Thailand in 1993 (using wood energy productivity and accessibility)

Item	Stock areas (rai) (a)	Fuelwood productivity (kg/rai) (b)	Access of wood energy (%) ©	wood energy supply (kg) (a)x(b)x(c)/100
Forest	1,171,766	480	10	56,244,768
Degraded forest	255,385	320	45	36,775,440
Range/shrubland	75,113	320	47	11,296,995
Tree crop	65,472	320	100	20,951,040
Paddy/field crop	842,148	30	100	25,264,440
Idle/open land	15,258	80	100	1,220,640
Total				151,753,323

Sources: a : Own Calculated data of forest, degraded forest and range/shrubland area was based on a regression function.
b: Data on fuelwood productivity and accessibility were taken from the Center of Community Forest in Asia and Pacific Region (1992).
c: Data on tree crop, paddy/field crop, idle/open land and other land areas in 1991 were obtained from the Office of Agricultural Economics (Office of Agricultural Economics, 1993, pp. 216-217).

The second data source was used to estimate the sustainable wood energy supply by using the sustainable productivity of 64 kg/rai multiplied by forests, degraded forests, range and shrubland areas plus the wood energy supply from tree crops, paddy and field crops lands; and idle lands. It equalled 144 million kilograms (Table 4).

Table 4. An estimation of wood energy sustainable supply of Phayao province, Northern Thailand in 1993 (using sustainable productivity of forests)

Item	Stock areas of wood (rai) (a)	wood productivity (kg/rai) (b)	sustainable wood energy supply (kg) (a)x(b)
Forest	1,171,766	64*	74,993,024
Degraded forest	255,385	64*	16,344,640
Range/shrubland	75,113	64*	4,807,232
Tree crop	65,472	320	20,951,040
Paddy/field crop	842,148	30	25,264,440
Idle/open land	15,258	80	1,220,640
Total			143,581,016

Sources: the same as Table 4.7;
* is the sustainable productivity of biomass from the forests using data from OUERGHI (1993)

Actual wood energy consumption. The consumption of wood energy of all families and local industries in the study area were aggregated. Wood energy of all families was calculated by multiplying the total number of rural forest, agricultural and urban families with the average amount of wood consumption of each family at about 246 million kilograms. That of local industries was estimated by using the survey data of the wood requirement per unit of tobacco production multiplied by total tobacco production in 1992/93 from the Office of Phayao Industry (Office of Phayao Industry, 1993) at about 69 million kilograms. The total wood consumption of Phayao province was about 314 million kilogram in 1992/93.

Gap analysis. Figure 6 shows the actual consumption and sustainable supply of wood energy of Phayao province. Both sources of data in deriving sustainable supply, pointed out that the supply of wood energy constituted less than 50% of the actual consumption indicating a non-sustainable situation of wood energy supply since the main source of wood energy came from the forests as mention by the respondents. However, several studies indicated that the calculation of demand and supply of wood resources in the past led to narrow policy implications, for instance high taxes imposed on charcoal producers and banning small-scale charcoal entrepreneurial activities (PANYA, 1993), or too-broad policies established from the aggregated demand and supply which did not help to solve the locally specific targets of the wood energy problem (LEACH and MEARNS, 1988). By contrast, the author would like to state clearly that the purpose of this gap estimation is only to point out the existing problem of wood energy in the study area. Consuming wood in a sustainable way contributes to the reduction of the world energy crisis for the following reasons: wood is a self-sufficient energy produced within the region, consequently, this helps by not increasing the requirement of modern energy sources on the one hand and the steps of transporting, packaging and processing (which certainly requires much energies) of those modern energy sources on the other. The gap occurred because of the rapid degradation of forest resources due to several combined and complex causes. In addition, although several innovations, successes and failures, have slightly dampened wood energy consumption, the problem of wood energy is not yet solved.

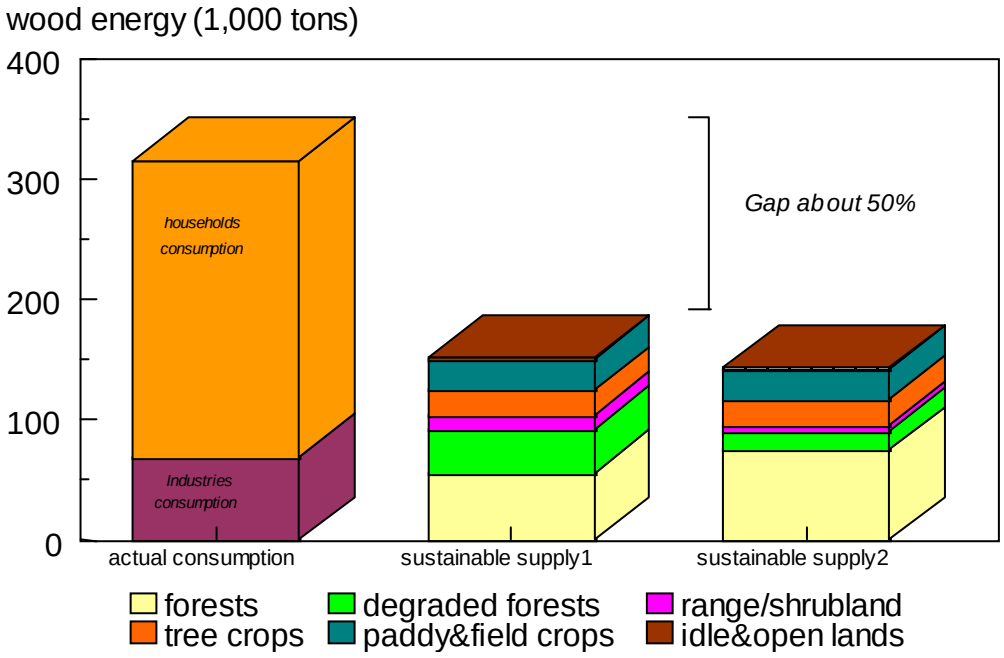

Figure 6. Actual consumption and sustainable supply of wood energy, aggregated at Phayao province, Northern Thailand, 1992/93

Conclusion

Energy Consumption. Wood energy still plays an important role as the main energy source of families in the study area, mainly for cooking purpose, especially for rural forest and agricultural families. In terms of wood energy consumption, there was no significant difference between the rural forest and agricultural families. However, there were significant differences between the urban and rural agricultural families as well as between the urban and rural forest families. Income was the main factor determining the type and quantity consumed. Increasing resulted in decreasing the quantity of wood energy consumed by substituting modern energy sources e.g. LPG.

Energy Production. The forest was the main source of wood energy production in the study area with wood from cultivated fields and around the home still playing a minor role. The ever increasing distance to the collection places was reported by most wood collectors as the main problems of wood gathering and hence the longer time spent in acquiring wood energy. It implied that increasing the opportunity cost of labour (the families earning potential compared to their costs in gathering wood) through enhancing local job opportunities would contribute to reducing wood energy collection.

Gap between actual consumption and sustainable supply of wood energy. It was found that the sustainable wood energy supply constitutes less than 50 percent of total actual consumption of Phayao province in 1992/93. With the present level of wood energy consumption and production as well as respondents‘ attitudes, the pressure to the forest is likely to continue.

In summary, wood energy is and will remain the main resource in rural areas of the study area as well as in Thailand for at least the next two decade (SABHASRI and WIBULSWAS, 1992, p. 526). The concern of environmental and economic consequences arising from a non-sustainable use of wood energy is, therefore, very important.

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