CHAPTER III

RESULTS

3.1 Household energy utilization in communities at different levels of urbanization in Northeast Thailand

3.1.1 Study sites

The three study villages, Ladna Piang, Nongbua Deemee, and Srijan, are located in Maung district of Khon Kaen province (Figure 3.1). Their characteristics are given in Tables 3.1 and 3.2. Ladna Piang, the rural village, is 32 km from Khon Kaen city, and is 15 km from the main highway but connected to it by a paved road. It has the largest land area (832.5 ha), but the lowest population density (2 persons/ha) among the three villages. Most of the area (97 %) is agricultural land used to grow rice, cassava, sugarcane and vegetables (Table 3.1). Most (93.8 %) of the household heads are farmers, the rest are laborers (4.6 %) and government or private enterprise employees (1.5%) (Table 3.2), thus, the community has low occupational diversity. The village has a day-care facility for pre-school children, primary school and junior high school, but has no health service center. All households have access to electricity, mobile telephone service, and tap water provided through the community managed system. Most of the houses are typical rural Thai wooden houses built on stilts, but there are also a few modern style masonry houses in the village. Most houses have an adjoining rice storage barn, also built on stilts, around which firewood is stored. The life style in this community is typically rural; women still engage in making handicrafts, such as silk weaving, when they are free from farm work.

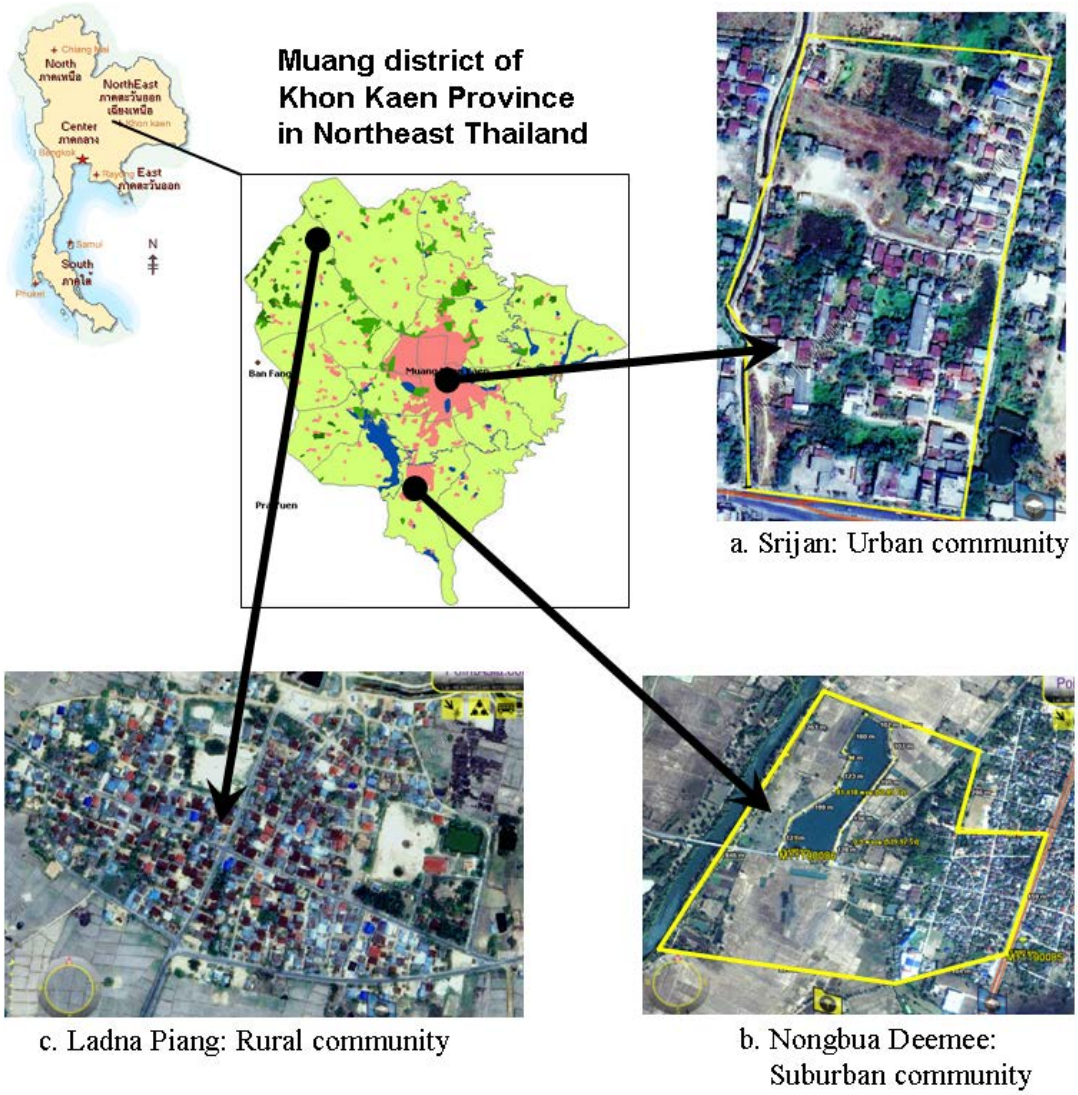

Figure 3.1 Aerial photographs of the three study communities.

Table 3.1 Characteristics of the three study communities.

Characteristics	Rural: Ladna Piang	Suburban: Nongbua Deemee	Urban: Srijan
Distance from Khon Kean city (km.)	32	12.5	0
Total households (no.)	343	240	118
Total population (person)	1620	1624	895
Total community area (ha)	832.5	75.2	6.8
Population density (persons/ha)	2	22	132
Proportion of agriculture land	high = 0.97	medium = 0.72	very low
Occupation diversity	low	medium	high
Infra-structure	low	medium	high

Sources: Khon Kaen geo-database, Anonymous, 2006; RDIC, 2008.

Table 3.2 Percentages of households types for the individual classifications in the three study communities.

Household type	Rural: Ladna Piang (130 hh)	Suburban: Nongbua Deemee (93 hh)	Urban: Srijan (65 hh)
Occupation*			
Regular income	1.5	10.8	49.2
Having own business	0.0	4.3	26.2
Irregular income	4.6	36.6	24.6
Agriculture	93.8	48.4	0.0
Household size			
Small (< 3 persons)	13.8	18.3	33.8
Medium (3-5 persons)	63.8	68.8	49.2
Large (> 5 persons)	22.3	12.9	16.9
Average household size (person)	4.2	3.8	3.5
Household income**			
Below poverty line (< 439 US$/yr)	7.7	16.1	3.1
Medium (439-3,864 US$/yr)	65.4	60.2	40.0
Well-off (> 3,864 US$/yr)	26.9	23.7	56.9
Average household income (US$/yr)	3,584.4	3,821.5	7,265.3
Land operating			
Very small (0-1 ha.)	16.9	75.3	100.0
Small (1-2 ha.)	15.4	15.1	0.0
Medium (2-4 ha.)	36.2	8.6	0.0
Large (>4 ha.)	31.5	1.1	0.0
Average land operating (ha.)	3.6	0.7	0.02

*Regular income = household with monthly income from public or private organization; Irregular income = daily-paid worker.

**1 US$ =33.64 Thai Baht.

At the opposite end of the rural-urban continuum is the village of Srijan inside Khon Kaen city. It has the smallest land area (6.8 ha), but the densest population (132 persons/ha) of the three communities (Table 3.1). There is no agricultural land in this village, but there are few unused vacant plots, belonging to rich investors, that are used by some villagers to raise cattle and collect firewood. The community has easy access to all the facilities and infrastructure available in Khon Kaen city, e.g., transportation, electricity, telephone, tap water, public and private schools from primary to university level, public and private hospitals, supermarkets, shopping centers, public services, etc. Houses are of modern style, made from concrete, in the form of detached houses, townhouses and apartments. Almost half of the households (49.2 %) have members who are employees of public organizations or private enterprises with regular income; the rest are more or less equally divided between business owners (26.2 %) and daily-paid workers (24.6 %); no households have agriculture as their main occupation (Table 3.2). The life style is typical of residents of provincial cities in Thailand.

Nongbua Deemee, the suburban village, has characteristics that are intermediate between Ladna Piang and Srijan with regard to urbanization. It is 12.5 km from Khon Kaen city, to which it is connected by a good all weather road. The villagers, thus, can have access to all the facilities and infrastructure available in Khon Kaen city although using these services is less convenient for them than it is for households in Srijan village. Total land area (75.2 ha) and population density (22 persons/ha) is intermediate among the three communities (Table 3.1). Agricultural land accounts for 72 % of the total community area, but many plots are not used because their owners either have other occupations or are rich people living outside the community. There are fewer agricultural households (48.4 %) but more households with daily wage workers (36.6 %), government and private employees with regular salaries (10.8 %) and business owners (4.3 %) in this village than in Ladna Piang (Table 3.2), so that occupational diversity was considered as medium. There are also more houses of modern-style than in Ladna Piang, and more people follow an urban life style.

The mean size of households tended to decrease with urbanization from 4.2 persons in the rural community to 3.9 persons in the suburban one to 3.3 persons in the urban community. The distribution of households of different sizes differed to some extent among the three communities. While households of medium size (3-5 persons) were the most numerous class in all of the communities (63.8 % for the rural community, 68.8 % for the suburban community, and 49.2 % for the urban community), the rural community had a greater share of large size (>5 persons) households (22.3 %), followed by the suburban community (18.3 %) and the urban community (16.9 %). The share of small size (<3 persons) households was greatest in the urban community (33.8 %) compared to 13.8 % in the rural community and 12.9 % in the suburban community (Table 3.2). Income increased with urbanization with average household incomes for the rural, suburban and urban communities being 3,611, 3,384 and 6,279 US$/year, respectively. The distribution of households with different income levels was similar for the rural and suburban communities, with the majority (> 60 %) being in the medium income class and around 25 % classified as well-off. Poor households were more numerous (16.1%) in the suburban community than in the rural one, where they made up only 7.7% of the households. More than half (56.9 %) of the households in the urban community were well-off, while 40 % had medium income, and only 3.1 % were poor (Table 3.2). Differences in the area of land cultivated per household among the three communities were quite clear, with the area decreasing with urbanization. Not surprisingly, over 90 % of the households in the urban community had only small or very small plots of land (Table 3.2). The average areas were 3.62, 0.63 and 0.02 ha per household for the rural, suburban and urban communities, respectively. In the rural village, the majority of the households cultivated large and medium sized areas of land (31.5 and 36.2 %, respectively), but most of the households in the suburban community cultivated small (15.1 %) or very small (75.3 %) areas of land.

Percentages of households that used firewood were quite high for the rural (94 %) and suburban (80 %) communities, but much lower (46 %) for the urban community (Table 3.3). The percentages of households that used charcoal also declined with urbanization but more gradually, being 88, 83 and 74 % of households in the rural, suburban and urban communities, respectively. Conversely, use of LPG

increased with urbanization, with the percentages of households that used LPG being 48, 69 and 71 %, for the rural, suburban and urban communities, respectively. All households in the three communities used electricity for their living activities. Most of the households had motorcycles, but the percentage declined with urbanization, being 91, 88 and 71 % for the rural, suburban and urban communities, respectively, while the share of households owning cars or trucks increased with urbanization, being 22, 25, and 42 % for the rural suburban and urban communities, respectively.

Table 3.3 Percentages of sampled households that used different sources of energy in the three study communities.

Characteristic	Rural: Ladna Piang (130 hh)	Suburban: Nongbua Deemee (93 hh)	Urban: Srijan (65 hh)
Using firewood	94	80	46
Using charcoal	88	83	74
Using LPG	48	69	71
Using electricity	100	100	100
Using gasoline for Agriculture	88	43	0
Using gasoline by motorcycle	91	88	71
Using gasoline by car	22	24	42

3.1.2 Differences in energy consumption among communities

Total average energy consumption per household increased with urbanization, from 46,042 MJ/hh/yr in the rural community to 52,465 MJ/hh/yr in the suburban community to 55,076 MJ/hh/yr in the urban community (Table 3.4). The share provided by biomass energy markedly decreased with urbanization, from 47.1 % of the total energy consumed by households in the rural community, to 35.4 % in the suburban community, to only 9.9 % in the urban community. The amounts of biomass energy used also decreased from 21,691 to 18,557 to 5,433 MJ/hh/yr for the rural, suburban and urban communities, respectively. At the same time, the amount of non-biomass energy used progressively increased from 24,351 MJ/hh/yr for the rural

community to 33,907 MJ/hh/yr for the suburban community to 49,643 MJ/hh/yr for the urban community (Table 3.4).

Similar patterns were observed for quantities and shares of different types of energy consumed on a per capita basis (Table 3.4). The urban villagers used more energy per capita (19,396 MJ/person/yr) than those in the suburban and rural communities (16,219 and 11,952 MJ/person/yr, respectively), although the difference between the urban and suburban communities was not statistically significant. The average per capita share of biomass energy consumed declined from 46.2 % in the rural community, to 37.4 % in the suburban community to only 10.2 % in the urban one. The amount used, however, was slightly more for the suburban community (6,064 MJ/person/yr) than for the rural community (5,521 MJ/person/yr), and both were significantly higher than the average amount consumed in the urban community (1,977 MJ/person/yr).

In all of the communities, total energy consumption varied greatly among different households, ranging from 10,602 to 167,278 MJ/hh/yr for the rural community, from 11,289 to 217,354 MJ/hh/yr for the suburban community, and from 19,339 to 191,942 MJ/hh/yr for the urban community (Figure 3.2). Overall, 62.5 % of all sample households used less than 50,000 MJ/hh/yr, while 94 % used less than 100,000 MJ/hh/yr, and only 6 % used more than 100,000 MJ/hh/yr (Table 3.5). The percentage of households using less than 50,000 MJ/hh/yr was roughly similar in all three communities whereas the percentage using more than 100,000 MJ/hh/yr increased with urbanization.

Table 3.4 Absolute quantity (± standard error) and relative share of biomass and non-biomass energy consumption per household and per person in communities with different levels of urbanization.

Community	No. of sampled households	Biomass		Non-biomass		Total	
		Quantity* ± SE	%	Quantity* ± SE	%	Quantity* ± SE	%
Average energy consumption per household (MJ/household/yr)							
Rural	130	21,691 [a] ± 1,570	47.1	24,351 [c] ± 1,510	52.9	46,042 [a] ± 2,187	100
Suburban	93	18,557 [a] ± 1,996	35.4	33,907 [b] ± 3,307	64.6	52,465 [a] ± 3,842	100
Urban	65	5,433 [b] ± 990	9.9	49,643 [a] ± 4,662	90.1	55,076 [a] ± 5,769	100
Overall average	288	17,010 ± 1,051	33.9	33,145 ± 1,739	66.1	50,155 ± 1,913	100
Average energy consumption per person (MJ/person/yr)							
Rural	130	5,521 [a] ± 355	46.2	6,432 [c] ± 513	53.8	11,952 [b] ± 651	100
Suburban	93	6,064 [a] ± 1,164	37.4	10,155 [b] ± 1,118	62.6	16,219 [a] ± 1,734	100
Urban	65	1,977 [b] ± 359	10.2	17,419 [a] ± 1,869	89.8	19,396 [a] ± 1,884	100
Overall average	288	4,896 ± 425	32.6	10,114 ± 650	67.4	15,010 ± 779	100

*Different letters in the same column indicate statistical difference at P = 0.05 by DMRT.

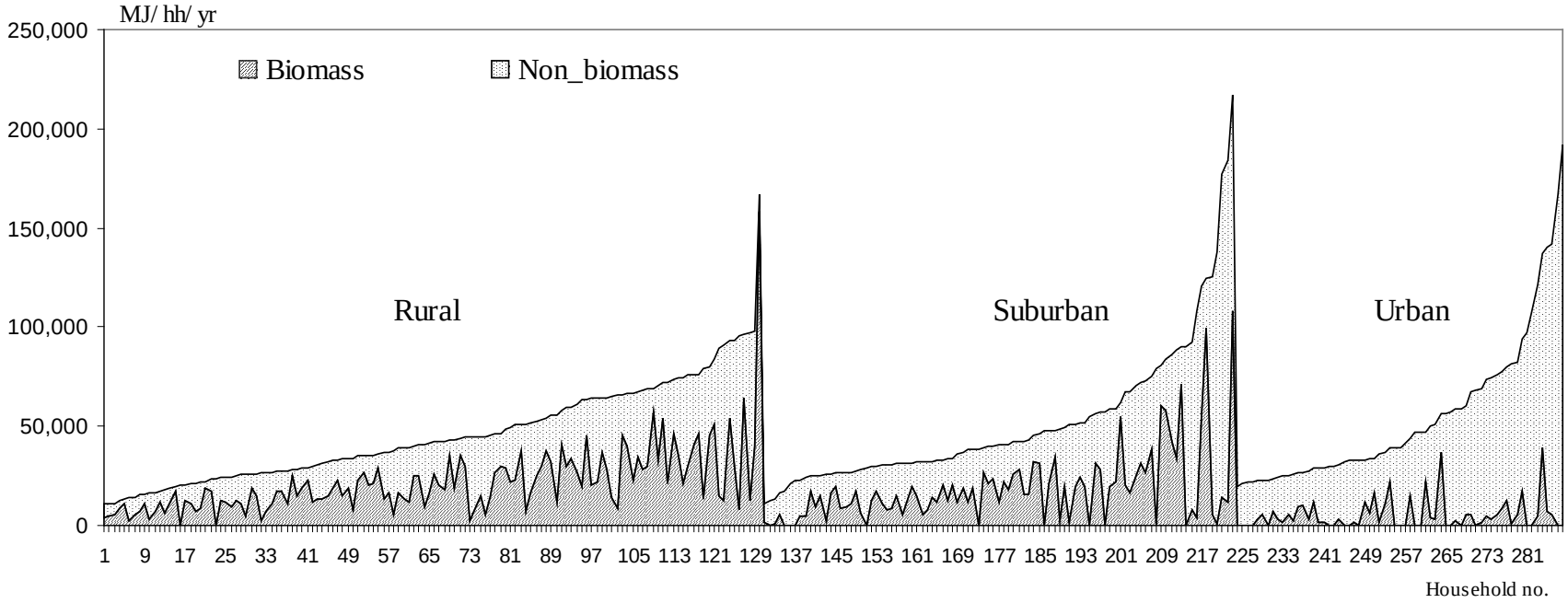

Figure 3.2 Distribution of biomass and non-biomass energy consumption of households in rural, suburban and urban communities.

3.1.3 The roles of different types of energy

Household activities that use energy were divided into living (cooking, lighting, cooling and entertainment), transportation (motorcycles, cars and trucks), agriculture and home industry (silk production, blacksmithing, and mushroom production). Averaging over all households in the three study communities, energy use for living amounted to 55.5 % of total household energy consumption, while transportation accounted for 39.2 %, agriculture for 4.0 % and home industry only 1.2 % (Table 3.6). Living activities used all types of energy except gasoline, while transportation and agriculture used only gasoline and home industry used only biomass.

The results in Table 3.6 clearly show that different types of energy are utilized for different roles. Both firewood and charcoal were used primarily for living, i.e., cooking, with a small amount used for home industry. The amounts of firewood and charcoal used for living were 9,066 and 7,344 MJ/hh/yr respectively, compared to 94 and 506 MJ/hh/yr, respectively, used in home industry. LPG and electricity were used entirely for living. Gasoline was mostly used for transportation (19,674 MJ/hh/yr) while a much smaller amount (2,020 MJ/hh/yr) was used for agriculture. Overall, biomass accounted for 34.0 %, gasoline 43.3 %, electricity 15 %, and LPG only 7.8 % of total household energy consumption.

Table 3.5 Frequency distribution of households at different levels of energy consumption in the three study communities.

Type of community	HH (no.)	<50,000 MJ/hh/yr		50,000- 100,000 MJ/hh/yr		100,000-150,000 MJ/hh/yr		>150,000 MJ/hh/yr	
		HH (no.)	%	HH (no.)	%	HH (no.)	%	HH (no.)	%
Rural	130	81	62.3	48	36.9	0	0.0	1	0.8
Suburban	93	60	64.5	25	26.9	5	5.4	3	3.2
Urban	65	39	60.0	19	29.2	5	7.7	2	3.1
Total	288	180	62.5	92	31.9	10	3.5	6	2.1

Table 3.6 Average energy consumption (± standard error) (MJ./hh/yr) by activity over the three study communities.

Activity	Biomass (MJ./hh/yr)		Non-Biomass (MJ./hh/yr)			Total	
	Firewood	Charcoal	LPG	Electricity	Gasoline	MJ/hh/yr	%
Living	9,066 ± 582	7,344 ± 536	3,909 ± 360	7,542 ± 320	0	27,860 ± 967	55.5
Transportation	0	0	0	0	19,674 ± 1,547	19,674 ± 1,547	39.2
-Motorcycle	*0*	*0*	*0*	*0*	*8,721 ± 464*	*8,721 ± 464*	*17.4*
-Car	*0*	*0*	*0*	*0*	*10,952 ± 1,487*	*10,952 ± 1,487*	*21.8*
Agriculture	0	0	0	0	2,020 ± 191	2,020 ± 191	4.0
Home industry	94 ± 39	506	0	0	0	601 ± 508	1.2
Total - amount	9,160 ± 586	7,850 ± 723	3,909 ± 360	7,542 ± 320	21,694 ± 1,547	50,155 ± 1,913	100
- percent	18.3	15.7	7.8	15.0	43.3	100	

The roles of different types of energy were the same in the three communities, but their relative shares of total energy used varied among the three communities. For the rural community, energy used for living accounted for 55.8 % of total household energy consumption; most of this (44.4 %) was provided by biomass, with 24.4 % of firewood and 20 % charcoal providing (Table 3.7). The shares provided by LPG and electricity were only 5.2 and 6.3 %, respectively. A slightly greater share of energy (59.0 %) was used for living in the suburban community, but the share provided by biomass was slightly less (35.2 %), and more firewood was used than charcoal. More LPG and electricity were used than in the rural community, and their shares increased to 9.5 and 14.4 %, respectively. For the urban community, energy for living was about half (50.3 %) of total energy use, with electricity providing the largest share (30.6 %) while biomass provided only 9.9 %

These results clearly show that as communities become more urbanized people tend to change the types of energy they use for living activities from biomass to cleaner sources (LPG and electricity). However, the changes were relatively slight when moving from rural to suburban, but were quite pronounced when moving from suburban to urban. The use of gasoline for transportation also increased in both absolute amount and relative share with urbanization, with the share being 33.1, 39.1 and 49.7 % for the rural, the suburban and the urban communities, respectively. In the rural community, gasoline was used for motorcycles more than for cars and trucks (20.7 % for motorcycles vs. 12.4 % for cars and trucks), whereas in the suburban community 18.3 % was used for motorcycles vs. 20.8 % for cars and trucks. In the urban community, much more gasoline was used for cars and trucks (39.1 %) than for motorcycles (10.6 %). The amount and share of energy used for agriculture and home industry both rapidly declined in the course of urbanization (Table 3.7).

3.1.4 Factors influencing household energy consumption

Apart from the type of community (rural, suburban and urban) in which they reside, household energy consumption may also be influenced by occupation, size of household, area of land cultivated and level of income of different households.

For purposes of our analysis, all of the households in our sample were assigned to four occupational categories.[1] These categories are: regular income, own business, irregular income and agriculture. On average, the households with regular income and the agricultural households used more or less the same amount of energy (47,233 vs. 46,662 MJ/hh/yr). The business owner households used slightly less energy (41,883 MJ/hh/yr), and the irregular income households used the lowest amount (36,620 MJ/hh/yr) (Table 3.8). The shares of different types of energy used by households varied considerably according to their main occupations. The regular income households and the business owners used much less biomass than the irregular income and the agricultural households, with the shares of biomass being 14.9 and 5.6 % for the regular income households and the business owners, respectively, as compared to 38.1 and 43.7 % for the irregular income and the agricultural households, respectively.

[1] In the three study communities together, there were 16 households (6 % of the total sample of households) that used exceptionally high quantities of energy (>100,000 MJ/hh/yr). Detailed examination revealed that each of these households engaged in income generation activities that used exceptionally high amounts of energy, e.g., doing blacksmithing, cooking ready-to-eat foods for sale, operating a truck for hire. As it was not possible to separate energy used for these activities from energy used for living, we excluded this group of households from the analysis of factors influencing household energy use. However, these households do clearly show that occupation has a major influence on household energy consumption.

Table 3.7 Average energy consumption (± standard error) (MJ/hh/yr) and relative share by activity and source in rural, suburban and urban communities.

Activity	Rural community			Sub-urban community			Urban community		
	Amount*	SE	%	Amount*	SE	%	Amount*	SE	%
Total living	25,714	± 1,219	55.8	30,956	± 2,239	59.0	27,722	± 1,392	50.3
-Living-Biomass	*20,434*	*± 1,156*	*44.4*	*18,454*	*± 1,999*	*35.2*	*5,433*	*± 990*	*9.9*
-Firewood	*11,243*	*± 739*	*24.4*	*10,760*	*± 1,269*	*20.5*	*2,287*	*± 544*	*4.2*
-Charcoal	*9,191*	*± 761*	*20.0*	*7,695*	*± 1,086*	*14.7*	*3,146*	*± 748*	*5.7*
-Living-LPG	*2,393*	*± 313*	*5.2*	*4,962*	*± 800*	*9.5*	*5,436*	*± 852*	*9.9*
-Living-Electricity	*2,888*	*± 52*	*6.3*	*7,540*	*± 351*	*14.4*	*16,853*	*± 1,188*	*30.6*
Transportation-Gasoline	15,241	± 1,345	33.1	20,502	± 3,053	39.1	27,354	± 4,416	49.7
-Motorcycle	*9,544*	*± 699*	*20.7*	*9,599*	*± 832*	*18.3*	*5,820*	*± 847*	*10.6*
-Car	*5,697*	*± 1,116*	*12.4*	*10,902*	*± 2,855*	*20.8*	*21,534*	*± 4,417*	*39.1*
Agriculture- Diesel	3,829	± 340	8.3	904	± 176	1.7	0	± -	0.0
Home industry	1,257	± 1,122	2.7	103	± 103	0.2	0	± -	0.0
-Firewood	*135*	*± 44*	*0.3*	*103*	*± 103*	*0.2*	*0*	*± -*	*0.0*
-Charcoal	*1,122*	*± 1,122*	*2.4*	*0*	*± -*	*0.0*	*0*	*± -*	*0.0*
Total	46,042	± 2,187	100.0	52,465	± 3,842	100.0	55,076	± 4,691	100.0

*Unit = MJ/hh/yr.

Households cultivating larger areas of land tended to use more energy than those farming smaller land areas. Means for total energy uses were 53,373, 46,174, 40,216 and 41,966 MJ/hh/yr for the households cultivating large, medium, small and very small areas of land, respectively (Table 3.9). Although energy used for living accounted for the major share of household energy for all the groups, its share of total energy use was slightly less for households with medium and large land areas (54.1 and 56.1 %, respectively) than for households with small and very small areas of land (63.2 and 63.7 %, respectively). However, the patterns of energy use for living were similar for households having small, medium and large areas of land, in that for these households biomass, mostly firewood, constituted the major share of the energy they used for living. In contrast, households having only very small areas of land used slightly more non-biomass energy for living than biomass energy (34.2 vs. 29.5 %), with electricity being the predominant type of non-biomass energy. In all four household types, more gasoline was used for motorcycles than for cars and trucks, but the difference declined among households with larger areas of land. Households with smaller areas of land used less energy for agriculture than those with larger areas. The effect of household size on energy consumption was clearly shown by the increase in total energy consumption as the household size increased. Means for energy consumption were 33,532, 45,269 and 53,503 MJ/hh/yr for the small (<3 persons), medium (3-5 persons) and large (>5 persons) households, respectively. Energy for living accounted for more than 60 % of total consumption for the small and large households, but slightly less (58.0 %) for the medium households. Use of biomass energy increased with increasing household size, while electricity use decreased with increasing household size (Table 3.10). The medium and large households used more gasoline for transportation than the small households, and used more gasoline for motorcycles than for cars and trucks. The small households, however, used more gasoline for cars and trucks than for motorcycles. The use of energy for agriculture also increased with increasing household size, reflecting the fact that on average agricultural households are larger than non-agricultural households.

Income levels also have a significant influence on household energy consumption. Households with higher income used more energy than households with

lower income, as shown by the average energy consumptions of 32,058, 43,020 and 50,593 MJ/hh/yr for the low income, medium income and well-off households, respectively (Table 3.11). The share of energy for living, however, declined with the increasing level of income; the share was quite high (80.7 %) for the low income households, and declined to 64.3 % for the medium income and to 49.7 % for the well-off households. Although the share of biomass decreased with increasing income level, the actual amount used did not differ between the low income and the medium income households (16,990 and 17,993 MJ/hh/yr, respectively) but was somewhat lower for the well-off households (11,907 MJ/hh/yr). Richer households used more gasoline for transportation than poorer households, while the amounts of energy used for agriculture and home industry were small and did not differ very much among households with different income levels.

Table 3.8 Average energy consumption (MJ/hh/yr) and relative share (%) by source for the different occupations of the sampled households in the three study communities.

Source of energy	Regular income (38 hh)		Own business (18 hh)		Irregular income (55 hh)		Agriculture (161 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	25,159	53.3	22,084	52.8	27,573	75.3	27,331	58.6
-Living-Biomass	*7,015*	*14.9*	*2,337*	*5.6*	*13,968*	*38.1*	*20,385*	*43.7*
-Firewood	*2,953*	*6.3*	*1,232*	*2.9*	*8,123*	*22.2*	*11,410*	*24.5*
-Charcoal	*4,062*	*8.6*	*1,105*	*2.6*	*5,845*	*16.0*	*8,975*	*19.2*
-Living-LPG	*3,986*	*8.4*	*4,963*	*11.9*	*3,864*	*10.6*	*2,902*	*6.2*
-Living-Electricity	*14,157*	*30.0*	*14,784*	*35.3*	*9,742*	*26.6*	*4,044*	*8.7*
Transportation-Gasoline	22,075	46.7	19,750	47.2	8,967	24.5	15,616	33.5
-Motorcycle	*6,274*	*13.3*	*8,978*	*21.5*	*6,465*	*17.7*	*9,757*	*20.9*
-Car	*15,800*	*33.5*	*10,771*	*25.7*	*2,502*	*6.8*	*5,859*	*12.6*
Agriculture-Diesel	0	0.0	0	0.0	79	0.2	3,546	7.6
Home industry-Biomass	0	0.0	0	0.0	0	0.0	169	0.4
Total	47,233	100.0	41,833	100.0	36,620	100.0	46,662	100.0

Table 3.9 Average energy consumption (MJ/hh/yr) and relative share (%) by source for the households with different size of operating land in the three study communities.

Source of energy	Very small* (146 hh)		Small*(29 hh)		Medium* (55 hh)		Large* (42 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	26,736	63.7	25,405	63.2	24,973	54.1	29,919	56.1
-Living-Biomass	*12,390*	*29.5*	*18,079*	*45.0*	*18,281*	*39.6*	*24,292*	*45.5*
-Firewood	*6,646*	*15.8*	*11,133*	*27.7*	*9,967*	*21.6*	*13,735*	*25.7*
-Charcoal	*5,744*	*13.7*	*6,946*	*17.3*	*8,313*	*18.0*	*10,557*	*19.8*
-Living-LPG	*3,808*	*9.1*	*2,834*	*7.0*	*3,128*	*6.8*	*2,628*	*4.9*
-Living-Electricity	*10,539*	*25.1*	*4,492*	*11.2*	*3,565*	*7.7*	*2,999*	*5.6*
Transportation-Gasoline	15,019	35.8	13,086	32.5	17,798	38.5	15,489	29.0
-Motorcycle	*7,728*	*18.4*	*7,008*	*17.4*	*10,531*	*22.8*	*9,901*	*18.6*
-Car	*7,291*	*17.4*	*6,078*	*15.1*	*7,268*	*15.7*	*5,588*	*10.5*
Agriculture-Diesel	145	0.3	1,659	4.1	3,327	7.2	7,691	14.4
Home industry-Biomass	66	0.2	66	0.2	76	0.2	274	0.5
Total	41,966	100.0	40,216	100.0	46,174	100.0	53,373	100.0

*Very small = 0-1 ha, small = 1-2 ha, medium = 2-4 ha, large = >4 ha.

Table 3.10 Average energy consumption (MJ/hh/yr) and relative share (%) by source for households of different sizes in the three study communities.

Source of energy	< 3 persons (54 hh)		3-5 person (170 hh)		> 5 persons (48 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	21,886	65.3	26,251	58.0	33,870	63.3
-Living-Biomass	*9,607*	*28.7*	*16,149*	*35.7*	*22,808*	*42.6*
-Firewood	*4,683*	*14.0*	*8,837*	*19.5*	*13,813*	*25.8*
-Charcoal	*4,924*	*14.7*	*7,312*	*16.2*	*8,995*	*16.8*
-Living-LPG	*2,667*	*8.0*	*3,245*	*7.2*	*4,684*	*8.8*
-Living-Electricity	*9,611*	*28.7*	*6,857*	*15.1*	*6,378*	*11.9*
Transportation-Gasoline	10,295	30.7	16,872	37.3	16,200	30.3
-Motorcycle	*4,040*	*12.0*	*9,712*	*21.5*	*9,527*	*17.8*
-Car	*6,255*	*18.7*	*7,159*	*15.8*	*6,673*	*12.5*
Agriculture-Diesel	1,239	3.7	2,067	4.6	3,273	6.1
Home industry-Biomass	113	0.3	79	0.2	160	0.3
Total	33,532	100.0	45,269	100.0	53,503	100.0

Table 3.11 Average energy consumption (MJ/hh/yr) and relative share (%) by source for households with different levels of income in the three study communities.

Source of energy	Low* (24 hh)		Moderate* (164 hh)		Well -off * (84 hh)	
	MJ/hh/yr	%	MJ/hh/yr	%	MJ/hh/yr	%
Total living	25,879	80.7	27,670	64.3	25,135	49.7
-Living-Biomass	*16,990*	*53.0*	*17,993*	*41.8*	*11,907*	*23.5*
-Firewood	*7,610*	*23.7*	*10,517*	*24.4*	*6,081*	*12.0*
-Charcoal	*9,380*	*29.3*	*7,477*	*17.4*	*5,826*	*11.5*
-Living-LPG	*2,318*	*7.2*	*3,128*	*7.3*	*4,189*	*8.3*
-Living-Electricity	*6,571*	*20.5*	*6,548*	*15.2*	*9,039*	*17.9*
Transportation-Gasoline	4,920	15.3	13,218	30.7	22,807	45.1
-Motorcycle	*4,920*	*15.3*	*8,661*	*20.1*	*9,382*	*18.5*
-Car	*0*	*0.0*	*4,558*	*10.6*	*13,425*	*26.5*
Agriculture-Diesel	1,179	3.7	2,025	4.7	2,559	5.1
Home industry-Biomass	80	0.2	107	0.2	91	0.2
Total	32,058	100.0	43,021	100.0	50,593	100.0

* Low = below poverty line = <439 US$/yr, Medium = 439-3,864 US$/yr, Well-off = > 3,864 US$/yr.

3.2 Biomass energy acquisition of households in communities at different levels of urbanization in Northeast Thailand and possible strategies or sustainable management of household sources of fuelwood

3.2.1 Shares of biomass energy for the individual households in the three communities

In all the three study communities, total energy consumption varied greatly among households, ranging from 10,602 to 167,278 MJ/hh/yr with an average of 158,018 MJ/hh/yr for the rural community, from 11,289 to 217,354 MJ/hh/yr with an average of 107,891MJ/hh/yr for the suburban community, and from 19,339 to 191,942 MJ/hh/yr with an average of 38,814 MJ/hh/yr for the urban community. The share of biomass energy in the total household energy mix also differed greatly, ranging from 6% to 90 %, with an average of 47 % for the rural community, from 1% to 88 %, with an average of 37 %, for the suburban community, and from 0.2% to 66 %, with an average of 13 %, for the urban community (Figure 3.3). Clearly, the share represented by biomass energy out of the total amount of energy consumed by households declined as the communities become more urbanized. However, the share of biomass declined only slightly when going from the rural to suburban community but the decline was much more substantial when going from the suburban to the urban community. It was also found that biomass energy was highly correlated with total energy consumption for households in the rural and suburban communities but not for the urban community, with the correlation coefficients being 0.65**, 0.57** and 0.29 for the rural, suburban and urban communities, respectively.

The shares of biomass energy in household energy consumption of all the sampled households showed a more or less normal distribution, with the highest percentage (36 %) being in the class of households getting 26-50% of their total energy from biomass and declining towards both the higher and lower share levels. Of the 272 households in the whole sample, more than 90 % used biomass as a source of household energy, while only 9.2 % did not use biomass at all for their household energy (Table 3.12).

Households with different occupations show considerable differences in the extent of their reliance on biomass energy. The majority of the agricultural households were concentrated in the 26-50 % and 51-75 % biomass share classes, with the frequencies being 42.9 % and 36 %, respectively. The majority of the irregular income households were concentrated in three biomass share classes; the highest percentage (30.9 %) was in the 26-50 % share class, followed by 23.6 % in the 51-75 % share class and 21.8 % in the 1-25 % share class. On the contrary, most households of business owners (61.1 %) were in the low share class of biomass (1-25 %), and a considerable proportion (33.3 %) did not use biomass at all. Similarly, for all households with regular income the share of biomass energy was less than 50% of their total household energy consumption, with 26.3 % being in the 26-50% biomass share class, 47.4 % in the 1-25 % share class, while 26.3 % did not use biomass at all (Table 3.12). Apparently, agricultural households and irregular income households used more biomass energy than households with business owners and employees of government offices and private enterprises with regular incomes.

These patterns of frequency distribution of biomass shares for households with different occupations were reflected in the each of the individual communities (Table

3.12). For each community, the frequency distribution of households in different levels of biomass share of total energy use closely reflected the relative proportions of the occupations of households in the respective community. Thus, the rural and suburban communities had high percentages of households with high shares of biomass in total household energy use because these two communities had high proportions of agricultural and irregular income households, while the urban community had low share of biomass energy because most of the households were business owners and regular income households.

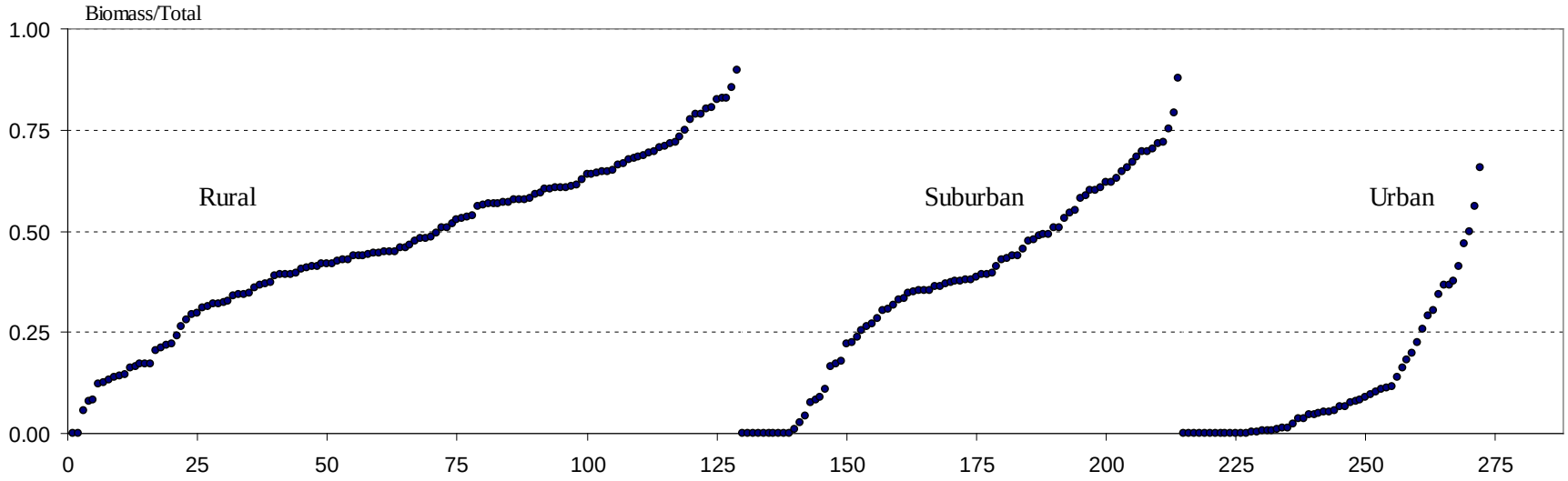

Figure 3.3 The share of biomass energy in the total household energy of households in the rural, suburban and urban communities.

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Table 3.12 Numbers and percentages of households at different levels of biomass energy share (% of total household energy consumption) for different occupations in the rural, suburban and urban communities.

Community/Occupation	Not use (0 %)		1- 25 %		26 – 50 %		51 – 75 %		>75 %		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Rural	**2**	**1.6**	**19**	**14.7**	**50**	**38.8**	**48**	**37.2**	**10**	**7.8**	**129**	**100**
Regular income	*0*	*0.0*	*1*	*50.0*	*1*	*50.0*	*0*	*0.0*	*0*	*0.0*	*2*	*100*
Business owner	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*
Irregular income	*0*	*0.0*	*1*	*16.7*	*1*	*16.7*	*0*	*0.0*	*4*	*66.7*	*6*	*100*
Agriculture	*2*	*1.7*	*17*	*14.0*	*48*	*39.7*	*48*	*39.7*	*6*	*5.0*	*121*	*100*
Suburban	**10**	**11.8**	**13**	**15.3**	**37**	**43.5**	**22**	**25.9**	**3**	**3.5**	**85**	**100**
Regular income	*3*	*37.5*	*1*	*12.5*	*4*	*50.0*	*0*	*0.0*	*0*	*0.0*	*8*	*100*
Business owner	*2*	*50.0*	*2*	*50.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*4*	*100*
Irregular income	*4*	*12.1*	*3*	*9.1*	*12*	*36.4*	*12*	*36.4*	*2*	*6.1*	*33*	*100*
Agriculture	*1*	*2.5*	*7*	*17.5*	*21*	*52.5*	*10*	*25.0*	*1*	*2.5*	*40*	*100*
Urban	**13**	**22.4**	**33**	**56.9**	**10**	**17.2**	**2**	**3.4**	**0**	**0.0**	**58**	**100**
Regular income	*6*	*21.4*	*16*	*57.1*	*5*	*17.9*	*1*	*3.6*	*0*	*0.0*	*28*	*100*
Business owner	*4*	*28.6*	*9*	*64.3*	*1*	*7.1*	*0*	*0.0*	*0*	*0.0*	*14*	*100*
Irregular income	*3*	*18.8*	*8*	*50.0*	*4*	*25.0*	*1*	*6.3*	*0*	*0.0*	*16*	*100*
Agriculture	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*
Total-regular income	***9***	***23.7***	***18***	***47.4***	***10***	***26.3***	***1***	***2.6***	***0***	***0.0***	***38***	***100***
Total-business owner	***6***	***33.3***	***11***	***61.1***	***1***	***5.6***	***0***	***0.0***	***0***	***0.0***	***18***	***100***
Total-irregular income	***7***	***12.7***	***12***	***21.8***	***17***	***30.9***	***13***	***23.6***	***6***	***10.9***	***55***	***100***
Total-agriculture	***3***	***1.9***	***24***	***14.9***	***69***	***42.9***	***58***	***36.0***	***7***	***4.3***	***161***	***100***
Total-all households	**25**	**9.2**	**65**	**23.9**	**97**	**35.7**	**72**	**26.5**	**13**	**4.8**	**272**	**100**

3.2.2 Acquisition of biomass by the individual households

In this section, the various ways in which households acquired biomass fuel are examined and factors influencing their choice of sources are analyzed. There are three ways by which households obtained biomass fuel: 1) by collecting it, either from their own land, neighbors' land or public land, 2) by purchasing it, and 3) by both collecting and purchasing it. The percentage of households relying on collecting tends to decrease as communities became more urbanized whereas the percentage of households relying on purchasing increases. In the rural and suburban communities, the vast majority of households (89.0 % and 81.3 % respectively) obtained all their biomass fuel by collecting it, where as in the urban community only about half (53.3 %) of households collected some or all of their fuel whereas 42.0 % purchased all that they use (Table 3.13).

The share of biomass energy in the total amount of energy used by households did not show any clear relationship to ways in which it was obtained (Table 3.13). However, occupation appeared to strongly influence the choice of ways to obtain biomass fuel. Table 3.14 shows that, in all communities, the majority (58.3 %) of households that own businesses purchased all of their biomass energy and more than one-third (37.9 %) of households with regular income also purchased all of their supply, whereas most agricultural households (89.9 %) and those with irregular income (70.8 %) relied on collecting to obtain their biomass energy supplies. This suggests that these latter two groups should be the focus of future efforts to promote additional biomass energy use.

Most (62.7 %) of the agricultural households collected biomass fuel only from their own land whereas households with irregular incomes obtained firewood from several different sources, including public land (27.1 %), their own land (16.7 %) or both public land and their own land (16.7 %). A much smaller number of households of both types also got fuel from land belonging to neighbors (Table 3.15). Table 3.16 shows the specific sources from which households in the different communities obtained biomass fuel. Rural households who collected their own biomass energy mostly obtained fuel from trees in their paddy fields (85.0 %) and from public forest land (22.0 %), most suburban households got biomass fuel either from public forest land (44.0 %) or their own paddy fields (40.0 %) and only 9.3 % got it from neighbors' land, while urban households collected fuel from public forest land (20.0 %), their own house plots (8.6 %), and land of their neighbors (6.7 %).

On average, rural households consumed 20,434 MJ/yr of biomass energy (11,243 MJ from 703 kg of wood, 9,191 MJ from 318 kg of charcoal) while suburban ones used 18,454 MJ/yr (10,760 MJ from 673 kg of wood, 7,695 MJ from 266 kg of charcoal). Using a wood to charcoal conversion rate of 19.2% for Eucalyptus, which is typical of the crude kilns most commonly employed in Northeastern Thailand, this represents the energy value of 2,362 kg of wood for rural households and 2,062 kg of wood for suburban households. Since mature Eucalyptus trees have an average annual growth increment of 35 kg, the annual fuelwood consumption of a rural household could be sustainably met by 68 trees while a suburban household would need only 59 trees At the typical planting density for Eucalyptus in Northeast Thailand of 3,750 trees/ha, the area required to meet a typical household's current annual fuelwood requirement would be only 180 m^2 per rural household and 160 m^2 per suburban

household. As is shown by Figure 3.4, the majority of households in the rural village own much more land than this and should have no difficulty in reserving this small area for biomass fuel production. Moreover, if, as is already common local practice, the trees were planted in a line on the paddy bunds or property boundary lines with a spacing of 1.5 m between trees, instead of in a single block, only 102 m of bund or boundary line would need to be planted with eucalyptus trees to meet the needs of a rural household and 89 m of bund or boundary line would supply a suburban household for a year. Planting trees in this fashion does not take much land away from cultivation of food and cash crops. Therefore, it does not appear that availability of land to grow fuelwood is likely to be an important limiting factor on the ability of most rural and suburban villagers to sustainably meet their biomass energy needs in the long-term.

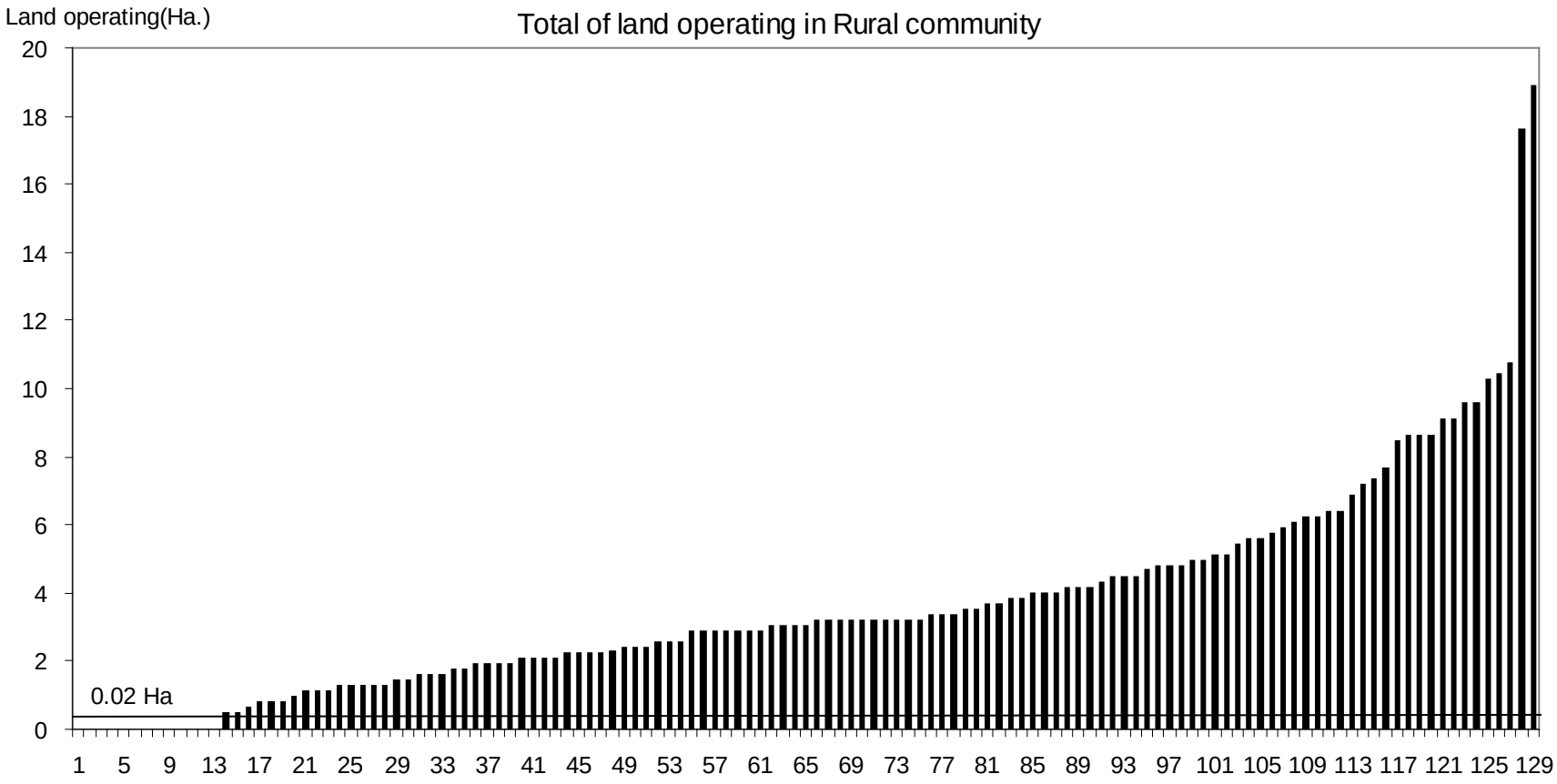

Figure 3.4 Potential of households in the rural village that own much more land than the needs

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Table 3.13 Numbers and percentages of households that acquired biomass in different ways for the individual levels of the share of biomass energy (% of total household energy consumption) in the rural, suburban and urban communities.

Community/Share of	Collecting		Purchased		Collecting + Purchased		Total	
biomass energy (%)	No.	%	No.	%	No.	%	No.	%
Rural	**113**	**89.0**	**10**	**7.9**	**4**	**3.1**	**127**	**100**
1-25 %	*15*	*78.9*	*4*	*21.1*		*0.0*	*19*	*100*
26-50 %	*45*	*90.0*	*3*	*6.0*	*2*	*4.0*	*50*	*100*
51-75 %	*44*	*91.7*	*2*	*4.2*	*2*	*4.2*	*48*	*100*
>75 %	*9*	*90.0*	*1*	*10.0*		*0.0*	*10*	*100*
Suburban	**61**	**81.3**	**11**	**14.7**	**3**	**4.0**	**75**	**100**
1-25 %	*9*	*69.2*	*4*	*30.8*		*0.0*	*13*	*100*
26-50 %	*32*	*86.5*	*3*	*8.1*	*2*	*5.4*	*37*	*100*
51-75 %	*17*	*77.3*	*4*	*18.2*	*1*	*4.5*	*22*	*100*
>75 %	*3*	*100.0*		*0.0*		*0.0*	*3*	*100*
Urban	**24**	**53.3**	**19**	**42.2**	**2**	**4.4**	**45**	**100**
1-25 %	*14*	*42.4*	*18*	*54.5*	*1*	*3.0*	*33*	*100*
26-50 %	*8*	*80.0*	*1*	*10.0*	*1*	*10.0*	*10*	*100*
51-75 %	*2*	*100.0*		*0.0*		*0.0*	*2*	*100*
>75 %	*0*	*0.0*		*0.0*		*0.0*	*0*	*100*
Total: 1-25 %	***38***	***58.5***	***26***	***40.0***	***1***	***1.5***	***65***	***100***
Total: 26-50 %	***85***	***87.6***	***7***	***7.2***	***5***	***5.2***	***97***	***100***
Total: 51-75 %	***63***	***87.5***	***6***	***8.3***	***3***	***4.2***	***72***	***100***
Total: >75 %	***12***	***92.3***	***1***	***7.7***	***0***	***0.0***	***13***	***100***
Total-all households	**198**	**80.2**	**40**	**16.2**	**9**	**3.6**	**247**	**100**

Table 3.14 Numbers and percentages of households that acquired biomass in different ways for the individual occupations in the rural, suburban and urban communities.

Community/Share of biomass energy (%)	Collecting		Purchased		Collecting + Purchased		Total	
	No.	%	No.	%	No.	%	No.	%
Rural	**113**	**89.0**	**10**	**7.9**	**4**	**3.1**	**127**	**100**
Regular income	*1*	*50.0*	*1*	*50.0*		*0.0*	*2*	*100*
Business owner		*0.0*		*0.0*		*0.0*	*0*	
Irregular income	*4*	*66.7*	*2*	*33.3*		*0.0*	*6*	*100*
Agriculture	*108*	*90.8*	*7*	*5.9*	*4*	*3.4*	*119*	*100*
Suburban	**61**	**81.3**	**11**	**14.7**	**3**	**4.0**	**75**	**100**
Regular income	*4*	*80.0*	*1*	*20.0*		*0.0*	*5*	*100*
Business owner	*1*	*50.0*	*1*	*50.0*		*0.0*	*2*	*100*
Irregular income	*22*	*75.9*	*5*	*17.2*	*2*	*6.9*	*29*	*100*
Agriculture	*34*	*87.2*	*4*	*10.3*	*1*	*2.6*	*39*	*100*
Urban	**24**	**53.3**	**19**	**42.2**	**2**	**4.4**	**45**	**100**
Regular income	*12*	*54.5*	*9*	*40.9*	*1*	*4.5*	*22*	*100*
Business owner	*4*	*40.0*	*6*	*60.0*		*0.0*	*10*	*100*
Irregular income	*8*	*61.5*	*4*	*30.8*	*1*	*7.7*	*13*	*100*
Agriculture	*0*	*0.0*		*0.0*		*0.0*	*0*	
Total-regular income	***17***	***58.6***	***11***	***37.9***	***1***	***3.4***	***29***	***100***
Total-business owner	***5***	***41.7***	***7***	***58.3***	***0***	***0.0***	***12***	***100***
Total-irregular income	***34***	***70.8***	***11***	***22.9***	***3***	***6.3***	***48***	***100***
Total-agriculture	***142***	***89.9***	***11***	***7.0***	***5***	***3.2***	***158***	***100***
Total-all households	**198**	**80.2**	**40**	**16.2**	**9**	**3.6**	**247**	**100**

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Table 3.15 Numbers and percentages of households that acquired biomass in different ways for Agriculture and Irregular income.

Acquiring biomass	Agriculture		Irregular Income		Total	
	No.	%	No.	%	No.	%
Collecting *(for free)*	**142**	**89.9**	**34**	**70.8**	**176**	**85.4**
Own land (paddy, upland, residential)	*99*	*62.7*	*8*	*16.7*	*107*	*51.9*
Neighbor	*1*	*0.6*	*1*	*2.1*	*2*	*1.0*
Public land	*7*	*4.4*	*13*	*27.1*	*20*	*9.7*
Own land+Neighbor	*1*	*0.6*	*2*	*4.2*	*3*	*1.5*
Own land+Publicland	*33*	*20.9*	*8*	*16.7*	*41*	*19.9*
Neighbor+Publicland		*0.0*	*1*	*2.1*	*1*	*0.5*
Own land+Neighbor+publicland	*1*	*0.6*	*1*	*2.1*	*2*	*1.0*
Buying	**11**	**7.0**	**11**	**22.9**	**22**	**10.7**
Collecting+buying	**5**	**3.2**	**3**	**6.3**	**8**	**3.9**
Own land+Buying	*3*	*1.9*	*1*	*2.1*	*4*	*1.9*
Neighbor+Buying	*1*	*0.6*		*0.0*	*1*	*0.5*
Publicland+buying		*0.0*	*1*	*2.1*	*1*	*0.5*
All combinations	*1*	*0.6*	*1*	*2.1*	*2*	*1.0*
Total	**158**	**100.0**	**48**	**100.0**	**206**	**100.0**

Table 3.16 Numbers and percentages of households that acquired biomass from different sources for three communities.

	Own land								**Neighbor**		**Public land**						**Purchased**		**Total**	
	Paddy		Upland		House Plot		**Total**				Forest		River forest		***Total***					
	No.	%	No.	%	No.	%	***No.***	***%***	***No.***	***%***	No.	%	No.	%	***No.***	***%***	***No.***	***%***	No.	%
rural	108	85.0	67	9.4	11	1.5	***108***	***85***	***5***	***3.9***	28	22.0	2	1.6	***28***	***22.0***	***13***	***10.2***	127	100
suburban	30	40.0	11	2.7	15	3.6	***30***	***40***	***7***	***9.3***	33	44.0	16	21.3	***33***	***44.0***	***13***	***17.3***	75	100
urban	0	0.0	0	0.0	21	8.6	***21***	***47***	***3***	***6.7***	9	20.0	1	2.2	***9***	***20.0***	***19***	***42.2***	45	100
Total	138	55.9	78	5.7	47	3.4	***159***	***64***	***15***	***6.1***	70	28.3	19	7.7	***89***	***36.0***	***45***	***18.2***	247	100

3.2.3 Case studies of selected households that are self-sufficient in producing all their own biomass energy

This section presents some short case studies of households that are able to get all of the biomass that they need throughout the year from their own land. These cases show the different sources of biomass on their land and describe the different approaches they use for management of these resources. They also suggest that it is possible to promote the use of biomass without forest destruction.

Case 1:

There are 4 members in this three generation household. They are 63, 56, 33 and 6 years old. The main occupation of this household is farming but the daughter works for daily wages in a factory.

They cultivate 2 plots of land with a, total land area of 2.7 ha including a paddy field of 1.6 ha and an upland field of 1.1 ha that is planted with sugarcane. Their fields are located about 1 km from the community. They go to their fields by motorcycle or in a cart pulled by an iron buffalo. On their land, they have kept a lot of the forest trees [*Plerocarpus macrocarpus* 30 trees, *Barringtonia acutanguls* (L.) *Gaertn*. 10 trees, one of *Xylia xylocarpab* (iron wood), three of *Tectona grandis L.f.* (Teak), and one of *Acacia auriculaeformis*]. They have also planted fruit trees such as *Mangifera indica* (mango) 35 trees, and tree producing edible leaves and flowers -- *Cassia siamea* 6 trees, and one sweet Tamarind. They prune the mango branches for use as fuelwood and also collect some wood from dead branches of their forest trees. These forest trees are not cut down for firewood because they want to retain them in their fields. Whenever they collect a large enough quantity of wood, they convert it

into charcoal at their field, after then it is packed in a big bag and transported it to store at home.

They have enough fuelwood to meet their own needs and some surplus to share with their relatives. This household still consumes firewood and charcoal because it can be easily collected from their farm, and they can manage firewood production without much difficulty. They use about 1,200 kg per year so they are one of the highest usage households. They have no LPG stove. In the future, if wood becomes difficult to collect and acquire they will buy it for household consumption, since they believe that even if they pay for firewood or charcoal, it will still be cheaper than LPG. Anyhow, they manage their farm to ensure that they will have firewood and charcoal to use in future years.

Case 2:

This interesting case features a small agricultural household with three members: the head of household is a 60-year old man, 55-year old wife and an young boy, age 14 (student). The head of household had an operation on his back and has been bedridden for 4 months. This year, they may not be growing rice because they have no labor. At present time, the wife's daily wages comprise the main income for the household.

They own one plot of land, 1.76 ha of paddy land. The paddy field is located about 1 km to the north of the village. A small natural river runs through their land. The family works their land with an iron buffalo. There are no forest trees, but they have grown 200 Eucalyptus trees around a farm pond, along with 2 mangoes.

This household still consumes only firewood and charcoal for cooking. They have no LPG stove, both because they are afraid of the LPG explosion risk and because the initial cost of the stove and ongoing fuel costs for LPG are too high. The teenage boy prepares fires from wood that he can easily collect from their farm. This household can also ask for assistance from relatives, since there is strong cooperation between relatives and neighbors in this community. They use about 1,080 kg of wood per year, placing them in the high ratio of biomass by total. Wood management is not too complex, and fuelwood is generally collected by the last woman or boy who goes to the field. Usage is limited by the fact that they can only collect and store 2-3 weeks worth of wood at a time. They said that in the near future, the Eucalyptus trees will be enough for their household energy.

At the present time they can find wood and manage trees for household energy, and while it is not easy as in the past, trees are abundant. When wood is lacking, relatives provide assistance. In the future, if they must buy it, they will do so grudgingly, since collection of firewood has always been simple in the past. The head of household explained that even though his nephew was from a new generation, he preferred to use firewood.

Case 3:

This household has three generations. There are 5 persons, 90, 87, 50, 50 and 26. The main occupation is farming and their main income comes from agricultural and daily labor. The nephew is studying in university and has not yet graduated.

They have one plot of land of 4.9 ha comprised of 1.5 ha for paddy, 2.5 ha for sugarcane, 0.8 ha for cassava, and 0.1 ha for a farm pond in the paddy area. At the paddy area, there were formerly 12 large *Barringtonia acutanguls (L.) Gaertn*. trees which grow naturally but 10 of these trees were cut and used to build a new house. They have also planted fruit trees around pond, including 10 *Mangifera indica* (mango) trees, five *Artocarpus heterophyllus* trees, 2 coconut trees, and one each of Tamarind and *Zizyphus mauritiana Lamk*. There are ten Eucalyptus trees on the paddy bund. These trees supply sufficient biomass energy for this household. Some of the wood is shared with other adult children now living in separate households.

They use a mix of firewood and charcoal for cooking. Sometimes, when they are rushed for time, they use LPG. Almost all of the wood comes from trees in their paddy field. They consumed about 720 and 480 kg per year, of firewood and charcoal, respectively, which indicates a very high ratio of biomass by total.

The grandfather and grandmother said that they still prefer firewood consumption because it is free and is a part of their daily routine. They can easily collect and manage consumption on their own land. When enough wood is collected, they will make charcoal, normally at their paddy. He said that one of *Barringtonia acutanguls (L.) Gaertn* has supplied 5 years' worth of firewood for household energy use. They use small, residual pieces of wood to build a house right now. If their grandchildren want to change to another choice of energy, it is their decision, but for them, the first choice is firewood.

Case 4:

The head of this household is a 51 year old man who is a community leader. His wife (age 55) is a housewife, and his daughter and son-in-law are 30 year old farmers. Two granddaughters, who are students, are 12 and 5 years old. The main household income is from the paddy field, vegetables (tomato seeding production) and sugarcane.

They own 2 plots of cultivated land, with a total area of 7.6 ha, 2.8 for paddy, 4.8 ha for upland crops, and 0.5 ha for intensive tomato production (in the dry season that after rice harvesting). The total amount of firewood and charcoal consumed in this household is about 730 and 720 kg per year, respectively, but the ratio of biomass energy usage is not too high, only about 51%. Household members are quite busy, with many activities already described as well as silk production, cooking 2 meals of food for the temple every day, and travel to take good care of the villagers. All these activities consumed more energy than is typical for other households. Despite having little free time, they still mostly use firewood and charcoal for cooking, which the daughter or son-in-law collects from their own land. It is not complicated to collect and manage. The wife usually uses firewood for boiling silkworms, but sometimes uses charcoal. She makes silk every 2 weeks.

Their choice is biomass because of it is not difficult to find and it is sufficient. Sometimes they buy charcoal for silkworm boiling, depending on the time limit.

Case 5:

There are 6 members in this household, a cluster type of household characteristic of Thailand, with aged 84, 76, 55, 45, 23, and 17 years old. The main occupations of this household are the agricultural work and daily wage labor provided by the husband and wife. Her older son is a recent college graduate and is looking for work.

This household owns one plot of land with a total area of 5.6 ha: 4 ha for paddy and the remainder including 0.16 ha of tomato and 1.6 for upland crops (rotating between sugarcane and cassava). It is about 4 km to the north of the community. There are two trees of *Artocarpus heterophyllus Lam*, and one of *Schleichera trijuga*. However, wood is collected from the upland field area, where there are 8 *Pterocarpus macrocarpus*, 2 *Mangifera indica*, and one Tamarind. There is one farm pond in the upland area and about 10 Eucalyptus trees around edge of the pond. They consume about 1,200 kg of firewood and 500 kg of charcoal per year. A big stack of firewood is stored at their house, including mango, rain tree and Eucalyptus wood. The wood came from their upland fields, public lands, land of relatives and neighbors, or was purchased. A small amount came from their paddy field. They make charcoal by themselves, yielding about 200 kg. per time. This house has no LPG stove, and they cook outdoors on a firewood stove. Their lives are not rushed, and everyone in this household can collect wood for fuel. However, this year the wife bought firewood because she and her husband had no time to collect it while she was caring for her ailing father. However, buying wood is not prohibitively expensive.

They consume firewood and charcoal because they are accustomed to using low-cost, naturally occurring items. They believe that LPG is too expensive, and that is reason they do not want to use it. Firewood is still easy to collect, and although it is less abundant than it was five years ago, it is still available and there is good cooperation in the village. The wife said that some households shift to use LPG and then do not go back to using firewood because it is more convenient. For her case, the switch to LPG may not happen within the next 5 years because of its high price.

Case 6:

This is a large household with 6 people. There are 80, 67, 45, 45, 23, and 18 years old. The grandparents are aged, but still make fishnets. The main household income comes from agricultural and wage labor by the daughter and her husband. His niece has graduated from university and is looking for job. The nephew is a student.

Grandfather has 3 children and has divided his land among them. The youngest daughter who lives with him received 3.2 ha. It is the upland area with not enough water, leading them to decide to grow cassava and sugarcane, along with small amount of paddy for household consumption. There is one irrigation pond.

There are 6 tamarind trees, 2 of which are very big and old, on their land. They use tamarind wood for household fuel by cutting the branches, collected and brought to the house by the son-in-law. They consumed high ratio of biomass (85%), roughly 672 kg. per year. Wood management by cutting Tamarind branches is not difficult and is sufficient for household use.

They have previously used LPG but stopped using it because of the high price and shifted back to firewood. Although the grandchildren use firewood, in the future they may change to electricity. Still, at the present time for his household, firewood is easily acquired from their land. If it is difficult to find, they may grow 4-5 Eucalyptus trees around the farm pond or along the paddy bund. The grandfather had talked with other households who followed this practice, and he believed it would not be difficult to follow.

Case 7:

This big household is comprised of 7 people. Old generation (75 and 76 years old), wife and husband are 50 and 55 years old, and new generation are three people (29, 24, and 18 years old). Household occupations are agriculture and daily wage labor.

They have one plot of land 2.56 ha. in size and located 1 km south of their house. The land is planted with rice in the rainy season after which they plant tomatoes. There are no more trees in paddy field. They consumed large amounts of firewood and charcoal, 1,008 kg and 672 kg per year, respectively. The ratio of biomass to total energy is 83%. The son-in-law collects wood from relatives' land, transporting it by iron buffalo. They make charcoal at their land, where it is packed into bags and shared among relatives. The main reason of using wood is because it saves money and they are accustomed to using it. As long as firewood is less expensive than LPG, then their choice is wood.

Nowadays, wood is not scarce. Though it is not abundant as in the past, there is enough to use for the next 10 years. He may buy wood or plant Eucalyptus trees in order to sell or use small branches for household fuel.

Case 8:

This household has 5 members, with aged 55, 53, 30, 12 and 6 years old. The father is a farmer, and the mother stays at home. Their daughter works as an administrative officer. Their main income is from agriculture.

They have only 1.8 Ha.: 0.8 ha. for paddy, 0.16 ha. for pond and the rest for sugarcane. They have grown 100 Eucalyptus trees around a pond. The wood can be sold during the next year; the small branches will be the firewood used in their household. They did not consume much firewood (about 400 kg per year), and it is for cooking, along with LPG. They use small pieces of Eucalyptus wood obtained from the brother in law who works as a middle man collecting Eucalyptus for sale. They use LPG during the rush time, based on guidance from her daughter, because of cleanliness and convenience.

She said that for the next year, she would sell Eucalyptus trees and the small pieces will be the firewood.

Case 9:

This household has 6 people. There are, the first generation (74 and 64 years old), the second is 37 and 35 years old which works in college as a teacher, and the third are two small children.

They own one plot of paddy, 3.16 ha. in size. There are 30 Eucalyptus trees growing along a small natural river, as well as one rain tree. Around one pond, they grow vegetables. They consumed a large amount of firewood and charcoal, measuring 2,016 and 864 kg per year, respectively. The ratio of biomass is 83%. They collect wood from forested land that belongs to his older daughter. Some of the wood comes from dead trees which the son collects along the road and then takes home for storage.

They have used LPG, but stopped using it because of the cost. In the last few years, wood has been plentiful and easy to obtain. They may continue to use firewood or charcoal for the next 5 years.

3.2.4 Comparison of the case study households

Table 3.17 summarizes key characteristics of the nine case study households. Although the sample is too small to permit detailed analysis, a number of general relationships are evident. Consumption of fuelwood per capita ranges from 80 to 1,087 kg,yr, with the majority of households using a moderate quantity of between 300 and 744 kg/capita/yr. Even so, less than half of the households are currently able to produce sufficient wood on their own land to meet their consumption needs but all but two households expect to increase wood production in order to achieve self-sufficiency within the near future and have already taken steps to do so by planting Eucalyptus trees. No clear relationship between area of land per capita and self-sufficiency is evident although households that are presently self-sufficient mostly have larger per capita land areas than households that fail to produce enough wood to meet their own needs. Most households that are self-sufficient now or expect to be self-sufficient soon already have an area of trees of 0,2 ha or larger, which is the

minimum area that is estimated to be necessary to sustainably produce an adequate supply of wood to meet average consumption requirements. The ratio of area covered by trees to total land area is mostly quite low, except in the case of households that have planted large numbers of Eucalyptus as a cash crop. Therefore, if households want to achieve complete self-sufficiency it appears that they have enough land available to meet their goal. The fact that several households are still able to meet their fuelwood needs by acquiring surplus wood from relatives or neighbors may reduce the urgency they feel in trying to achieve self-sufficiency.

Table 3.17 Summary of characteristics of case study households.

Case	Size of hh	Biomass consumed (wood equivalent) (kg./yr)		Area of land cultivated (ha)		No. of trees		Type of trees			Estimated area occupied by trees (ha)	Ratio of area of tree to total area	Self-sufficiency in fuelwood production	
		per hh	per capita	per hh	per capita	per hh	per capita	Timber	Multi-purpose	Fast-growing			Now	Future
1	4	1,200	300	2.70	0.68	90	23	47	43	-	0.41	0.15	yes	yes
2	3	1,080	360	1.76	0.59	202	67	-	2	200	0.40	0.23	no	yes
3	5	3,222	644	4.90	0.98	39	8	12	17	10	0.20	0.04	yes	yes
4	6	4,483	747	7.60	1.27	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	na.	yes	yes
5	6	3,807	634	5.60	0.93	24	4	9	5	10	0.11	0.02	no	no
6	6	2,694	449	3.20	0.53	6	1	-	6	-	0.19	0.06	yes	yes
7	7	4,511	644	2.56	0.37	2	0.3	-	2	-	0.02	0.01	no	no
8	5	400	80	1.80	0.36	120	24	-	-	120	0.24	0.13	no	yes
9	6	6,520	1,087	3.10	0.52	31	5	1	-	30	0.09	0.02	no	yes