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A SAMPLE STUDY OF BIOMASS FUEL CONSUMPTION IN SRI LANKA HOUSEHOLDS

by

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ABSTRACT

Biomass, as a household fuel, is vital to the energy economy of Sri Lanka, but estimates of consumption have hitherto been only speculative because of the absence of reliable data. In the present study, the population of the country was stratified, and the biomass fuel consumption measured and other related data collected in a dispersed sample of 518 households.

The current consumption of biomass fuel by the household sector in the country was estimated at 7.5 million tonnes/year and the per caput consumption at 1.36 kg/day. The biomass fuel mix comprised rubber wood 18.0%, crop wastes (mainly from coconut) 28.8%, and other fuelwood 53.2%.

Of the rural households studied 81% obtained their biomass fuel entirely by gathering, generally within a distance of 1.6 km (1 mile).

The mud stove and the 3-stone open fireplace were by far the predominant cooking devices used.

Key words: household energy, biomass fuel, Sri Lanka.

BACKGROUND INFORMATION

Geographical features

Sri Lanka is a tropical island, 65 610 km^2 in area, lying in the Indian ocean between longitudes E 79° 39' and 81°53' and latitudes N 5°54' and 9°52'. Although the altitude of the land varies from sea level to 2524 m, three-fourths of the island consists of a lowland peneplain with an average elevation of 75 m above sea level. The mean annual temperature of the lowlands ranges from 27°C in the wet southwest area to 30°C in the dry northern and eastern regions, and there is little variation in the mean monthly temperatures during the year. In the hill country which is situated in the south-central part of the island, the temperature is appreciably lower than in the lowlands, and ground frost occasionally occurs at night in places at an altitude of around 2000 m and more. The high altitude region, however, represents only a very small fraction of the area of the country. Precipitation varies from a well distributed rainfall of 1900 to 5000 mm/ year in the southwest sector of the island to a rainfall of less than 1900 mm, occuring seasonally, in the rest of the island.

Forest cover

Sri Lanka's forest area was 28 996 km^2 in 1956,[1] but by 1981 it had dropped to 16 318 km^2, indicating a loss of as much as 44 % of the forest cover within the space of two and a half decades.[2] The forest cover consists of natural forests (nearly all of which are state-owned) which have been exploited to varying degrees. Forest plantations, about 1000 km^2 in area in 1981, were not included in the later survey.

Plantation crops

The main plantation crops in Sri Lanka are tea, rubber and coconut. The tea plantations (2449 km^2 in area) are situated in the high and middle altitudes in the south-central part of the island, and the rubber plantations (2305 km^2) are at lower elevations, mainly in the southwest. The coconut plantations (4515 km^2) are situated in a coastal belt in the southwest and in a region in the west bounded by the lines joining Colombo, Kurunegala and Chilaw - the so called "Coconut Triangle".

Population and gross national product

At the census of population carried out by the Department of Census and Statistics in 1981 the population of Sri Lanka was found to be 14.85 million, of which 72.2 % have been classified as rural.[3] The current rate of growth of population (net increase) is reckoned at 1.7%.

The country has a very low gross national product per caput; it was US $ 284 at current prices in the year 1982.[4]

The energy scene

The primary energy consumed in Sri Lanka consists of electricity (mainly hydro-power), oil and biomass fuel.* The relative proportions of these have been estimated at hydro-electricity 13.3 %, petroleum products 26.7 % and biomass 60 %.[5] Sri Lanka has no known fossil fuel resources, and the only indigenous sources of energy are hydro-power and biomass. The expenditure on the import of petroleum products accounted for 57 % of the total export earnings of the country in 1982.[4]

Electricity is used mainly in industry and lighting, and oil is used in industry, transport, electricity production to supplement hydro-power, and lighting. Biomass fuel is used for household cooking and as a source of heat in small industries. It is of vital importance to the energy economy of Sri Lanka since it is used by the vast majority (94%) of households for cooking.[6] Heating of houses is not of general importance as it is required only in the cool up-country region which is relatively small in area.

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* The term biomass here refers to wood and other lignocellulose material. The more accurate term is phytomass, but "biomass" is the one that is generally used. Many writers use terms such as "fuelwood", "firewood", "forest produce", etc. while the context indicates that they refer to a biomass fuel mix.

Biomass fuel has been growing in importance in Sri Lanka since the fuel crisis of 1973, but despite this, the data available on the consumption pattern and on the sources of supply remain very meagre. Sankar and Fernando estimated the biomass fuel consumption in the domestic sector indirectly by first estimating the useful energy consumed in the households and deducting from it what was considered to be the contribution of fuels other than biomass.[7] On this basis it was estimated that the biomass fuel consumption in the household sector in 1975 was 4.2 million tonnes. Later, Fernando et al have given a figure of 5.2 million tonnes as the estimated 1980 consumption.[5]

Bialy measured, over a period of 10 days, the fuelwood consumption of six families in a Sri Lankan village 12 km from Anuradhapura.[8] On the basis of his study he estimated that the average fuelwood consumption of a family of six members would be about 50 kg/ week.

The Sri Lanka State Timber Corporation which is the agency that markets produce from the state forests supplied 314 931 m^3 of stacked billets (or 220 452 tonnes, assuming that one m^3 of stacked billets = 700 kg) of fuelwood in 1980.[9] A good part of the Corporation's supplies goes to feed industries that use fuelwood (e.g. baking of bread, brick and tile manufacture, tea drying etc.) However, even if it is assumed that all of it is used as household fuel, the Corporation's share in supplying the estimated household sector consumption of 5.2 million tonnes in 1980 was still a bare 4%. The huge balance is said to come from agricultural residues, rubber wood, saw mill wastes, home garden trees and unrecorded collections from the state forests,[10,11] but the proportionate contribution of each of these sources to the biomass fuel mix has remained obscure.

OBJECTIVES

Although biomass plays a vitally important role in the energy economy of Sri Lanka being the domestic cooking fuel of the vast majority of the population, there is no reliable information on the consumption pattern of this fuel. The objectives of the present study were to :

(a) estimate the amount of biomass fuel consumed by the household sector in Sri Lanka.

(b) obtain information on the composition of the biomass fuel mix and on the method of procurement, and

(c) obtain information on the types of biomass fuel cookers in use.

METHODOLOGY

The oil crisis of 1973 gave rise to a spate of investigations on the energy situation in the rural areas of the Third World. Many of these investigations were based on questionnaires and were confined to one or a few villages. In the present study the writer decided to actually measure the biomass fuel consumed (avoiding the questionnaire approach as far as possible) and to disperse the sample households throughout the country so as to get a total picture of the household consumption in Sri Lanka.

Sampling design and procedure

In stratifying the population it was decided initially to divide the island into different zones on the basis of predictable regional variations in the biomass fuel consumption pattern. Taking this factor into account and treating the administrative districts as units as far as was considered reasonable, four zones were recognized. They (numbered 1 to 4) are as follows:

1. Dry Lowlands; Administrative districts: Hambantota, Amparai, Anuradhapura, Polonnaruwa, Moneragala, Trincomalee, Badulla (1/4), Puttalam(1/4), Mannar, Vavuniya, Jaffna, Batticaloa, Mullativu;

2. Upcountry Tea; Administrative districts: Kandy, Matale, Nuwara-Eliya, Badulla (3/4);
3. Coconut; Administrative districts: Colombo, Kurunegala, Gampaha, Galle, Matara, Puttalam (3/4);
4. Rubber; Administrative districts: Kalutara, Ratnapura, Kegalle.

Two of the 24 districts (Badulla and Puttalam) were each divided between two zones, the fraction given against their names denoting the proportion of the households assigned to each zone. It must be noted that since the district boundaries were used to define the boundaries of the zones (except in the two cases mentioned) each zone does not represent a completely homogeneous unit. A certain amount of overlap was unavoidable; for example, although Zone 4 is predominantly a rubber growing area, there are some tea plantations within it. The zonation is shown in Fig.1.

In the 1981 national census, the population was classified into three sectors, urban, rural and estate in each of the 24 administrative districts of the island. The urban population comprised those living within the limits of municipal councils, urban councils and town councils. The rural population consisted of those residing in village council areas but excluded those that fell into the estate sector. The estate sector included crop plantation estates of 8.1 ha (20 acres) or more in area and with 10 or more resident labourers. The populations of these three sectors were 3.195 million (21.5 %), 10.722 million (72.2 %) and 0.933 million (6.3 %) respectively.[3] The distribution of households by district and by sector has not been published, but the information was available in the Department of Census and Statistics.[12]

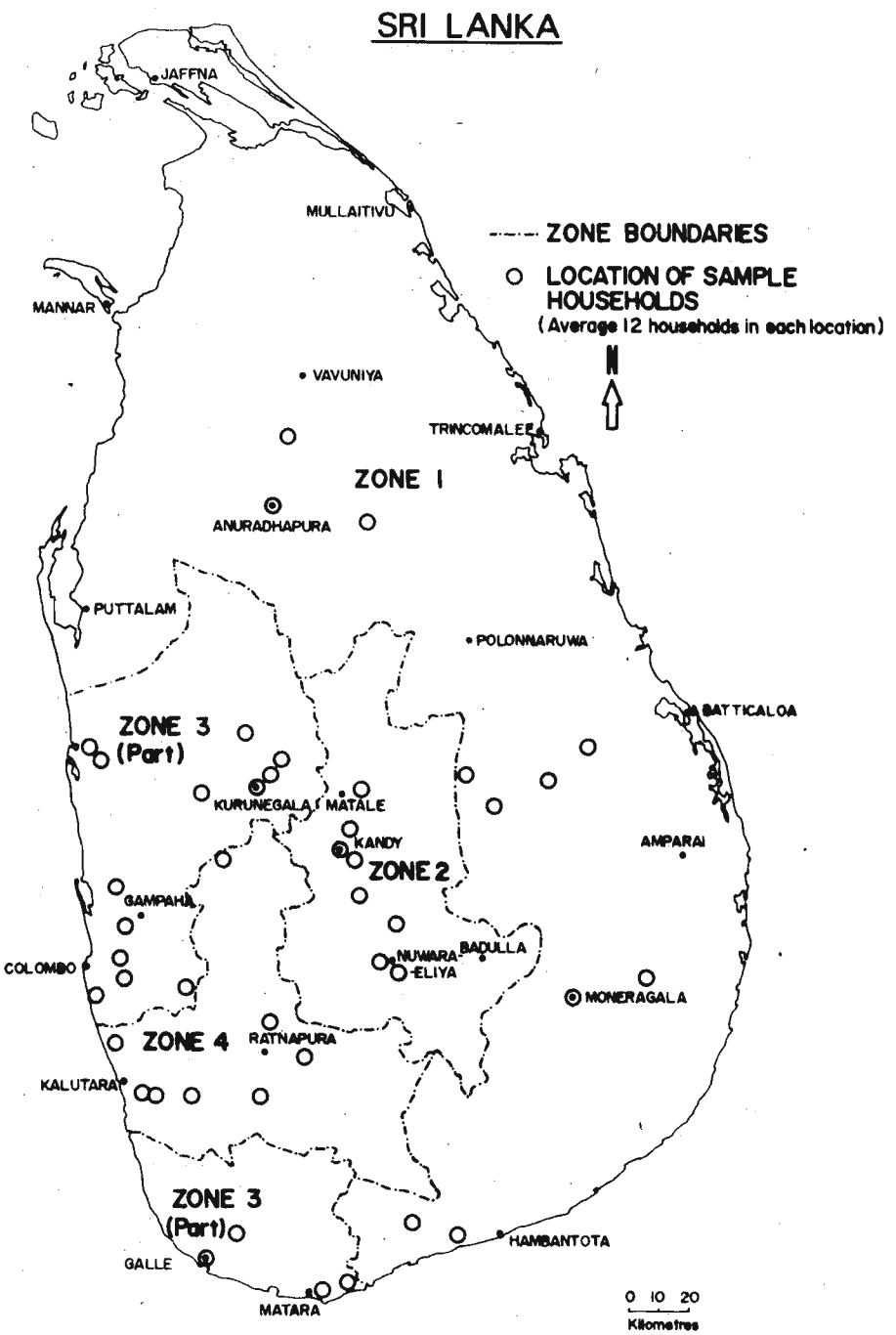

Fig.1. Map showing the zonation and the locations of sample households

The population (and the households) in each zone were further stratified on the basis of sector (i.e. urban, rural or estate). Since the estate sector populations (as defined in the census report) in the Dry lowland and Coconut Zones are relatively small, and moreover, as the domestic fuel consumption patterns in these two strata were not expected to be different from those in the corresponding rural sector strata, the estate sector population in each of these zones was aggregated with that of the corresponding rural population. The sample size was set at around 500 households and the allocation of the sample among the strata was done in proportion to the number of households. However, to keep the sampling error within reasonable limits the minimum sample size for a stratum was set at 10 households. Such a departure from the proportional allocation system adopted was not expected to adversely affect the estimates since the estimates were to be based on the per caput consumption within each stratum and the corresponding population. Table 1 gives for each stratum the population and the total number of households (based on the 1981 census), and the number of households that constituted the sample. The sample finally consisted of 518 households.

Although town council areas have been assigned to the urban sector, the majority of houses in these areas are not provided with the amenities normally associated with urban development like electricity, pipe-borne water and sewerage, and these houses are in fact more akin to rural dwellings than to urban ones in the generally accepted sense. Hence "urban and semiurban" may more appropriately describe this sector; but the term "urban" as used in the census report is retained in this paper.

Within each stratum the district and the location within the district where the sampling was to be done were chosen randomly. Having decided on a location the team went to the spot and adopted a random procedure to select the households e.g. the team would proceed along a randomly selected road or pathway and in one case select every third housing unit on the right side and in another pick every fifth dwelling on the left and so on, thereby simulating a "circular sampling system".In any one location the survey team selected sufficient households to cover a day's study, the average being about 12. The map in Fig. 1 gives the location of sample households.

TABLE I

Population, total number of households, and the number of households constituting the sample in each stratum

		Urban (U)	Rural (R)	Estate (E)	All sectors
Zone: 1 (Dry lowlands)	Population	665 425	3 260 999	-	3 926 424
	No. of households	119 065	654 580	-	773 645
	No. of households studied	20	114	-	134
Zone: 2 (Upcountry, Tea)	Population	261 818	1 631 664	594 643	2 488 125
	No. of households	38 478	301 413	140 868	480 759
	No. of households studied	10	52	24	86
Zone: 3 (Coconut)	Population	1 977 950	4 151 434	-	6 129 384
	No. of households	316 997	882 464	-	1 199 461
	No. of households studied	54	151	-	205
Zone: 4 (Rubber)	Population	289 686	1 802 080	214 302	2 306 068
	No. of households	46 638	378 334	45 494	470 466
	No. of households studied	13	68	12	93
All Zones	Population	3 194 879	10 846 177	808 945	14 850 001
	No. of households	521 178	2 216 791	186 362	2 924 331
	No. of households studied	97	385	36	518

The lack of uniformity in the distribution of the sample locations in Zone 1 as seen in the map is the result of the following factors. (1) Though this zone has a population that is comparable with the others it's area is very much larger. (2) Large sections of it consist of Forest Reserves and Wild Life Parks with few or no resident people, and these areas were therefore left out when selecting sampling locations. (3) The selection of sample households in the Jaffna district had to be abandoned because of the conditions of civil unrest prevailing there, and that part of the sample was relocated elsewhere within the zone.

Data collection

The basic data required for the study were obtained by measuring the actual quantities of biomass fuel used by each of the sample households over a 24-hour period. The possibility of measuring the consumption over a longer period (say, 72 hours) was considered since this might be expected to give a better figure for average consumption. However, this was rejected chiefly for two reasons. (1) It became evident in a pilot study that the biomass fuel required for three days or even for two is very often not available in stock at one time; the householder will therefore have to obtain fuel from outside if the study period is longer than 24 hours. (2) Even in the few homes where biomass fuel for three days was available, some of the material had to be dried further before being used as fuel, and this is accomplished by placing the material in the sun or by stacking it over the kitchen fireplace; weighing such material will result in the reduction in weight caused by drying being accounted for as fuel consumed. This problem could have been overcome by making daily weighings over a three-day period, but such a procedure would have been time consuming and costly. Even in adopting a 24-hour period there were still some households, though very small in number, where sufficient fuel was not available to last the day. In such a case, if the shortage was of material that was normally obtained by gathering, the team assisted in collecting it to build up a day's stock or, if the shortage was of fuel that was to be purchased, precise instructions were given on how a record should be kept of the purchased material.

Each selected household was visited twice by the investigating team which comprised two Staff Assistants (both physical science graduates) and a labourer. The writer accompanied the team in the early stages, and occasionally afterwards. At the first visit to a household the purpose of the study was explained to the senior householder present (who was generally the wife, the mother-in-law or the mother of the chief occupant), and almost without exception she agreed to co-operate. The householder was asked to set aside all the biomass fuel that she would require during the following 24 hours, and some extra was added to ensure that there would be no shortfall. If cooking was in progress the partially burnt fuel was removed from the fireplace, the flame doused, and the material added to the pile. The fuel was disaggregated into the three categories, (a) rubber wood, (b) crop wastes* and (c) other fuelwood. The different categories of fuel were then weighed to the nearest 10 g using a round dial spring scale. After weighing, the fuel was placed in a single pile in a convenient place (in some cases a large polythene garbage bag was spread on the floor of the kitchen and the fuel heaped on it). The householders were requested to use fuel only from this heap until the investigators called over the following day, and they were specially instructed not to deviate from their normal cooking practices.

A second visit was made 24 hours later. The biomass fuel remaining in the pile was disaggregated as done earlier and weighed. The data now gave the quantity of biomass fuel used by the household during the preceeding 24 hours.

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* Lignocellulose material (including wood) from crop trees like coconut, tea, etc.,but excluding rubber wood, was placed in this category.

The following data were also collected by observation or by questioning the householder:

(a) Whether the household purchased or gathered the biomass fuel used during the 24-hour study period and, if gathered, the distance travelled;
(b) The type of cooking device used during the study period;
(c) The number of persons in the household;
(d) Any other relevant information.

In a few cases, on the first visit, samples of biomass fuel were collected (before weighing) from the material that was to be used during the day and placed in moisture proof containers. The moisture contents of 12 samples were determined in the Wood and Cellulose laboratory of the Ceylon Institute of Scientific and Industrial Research.

The field work commenced in February and was completed in September, 1983.

RESULTS

Biomass fuel consumption

The most recent population figures available for the different strata are those that could be derived from the 1981 census report, and since it could reasonably be assumed that there has been no major change in the household biomass fuel consumption pattern in the two years that has elapsed since the census, the consumption data obtained from the present study were applied to the 1981 population.

The mean per caput consumption of biomass fuel and the proportions of the three categories of fuel, rubber wood, crop wastes and other fuelwood in the 10 strata were calculated from the sample data. Based on these values and on the 1981 population the biomass fuel consumption for the year was estimated. The results of these calculations are given in Table 2. The biomass fuel mix in the four zones and in the whole island are shown diagramatically in Fig. 2.

Biomass

(1) Stratum	(2) Mean per caput consumption of biomass fuel/day (all types) in g	(3) Standard error	(4) % Rubber Wood	(5) % Crop Wastes	(6) % Other Fuelwood	(7) Estimated annual consumption of biomass fuel (all types) in tonnes **
1 U*	1036.9	90.5	-	11.51	88.49	251 842
1 R	1452.3	81.2	-	4.73	95.27	1 728 621
2 U	804.3	213.7	-	0.60	99.40	76 862
2 R	1649.6	100.3	1.76	21.37	76.87	982 431
2 E	1873.9	188.0	-	5.35	94.65	406 720
3 U	857.2	71.3	31.41	41.04	27.55	618 857
3 R	1370.5	44.2	11.34	63.15	25.51	2 076 682
4 U	1020.5	147.3	37.45	35.19	27.36	107 903
4 R	1399.4	67.6	83.70	12.35	3.95	920 468
4 E	1391.4	221.7	48.81	31.55	19.64	108 836
						7 279 222

* For identification of strata see Table 1

BLE 2

l consumption

(8) Estimated annual consumption of rubber wood in tonnes**	(9) Estimated annual consumption of crop wastes in tonnes **	(10) Estimated annual consumption of other fuelwood in tonnes	(11) Percentage and the number (in parenthesis) of sample households that used biomass fuel exclusively	(12) Mean per caput consumption of biomass fuel/day(in g) taking only those households that used biomass fuel exclusively	(13) Standard error
-	28 987	222 855	55 (11)	952.1	109.5
-	81 764	1 646 857	99(113)	1460.6	81.4
-	461	76 401	50 (5)	1021.4	395.1
17 291	209 945	755 195	100 (52)	1649.6	100.3
-	21 760	384 960	100 (24)	1873.9	188.0
194 383	253 979	170 495	65 (35)	1097.3	74.2
235 496	1 311 425	529 761	99(150)	1379.7	43.5
40 410	37 971	29 522	77 (10)	1041.2	169.9
770 432	113 678	36 358	100 (68)	1399.4	67.6
53 123	34 338	21 375	100 (12)	1391.4	221.7
1 311 135	2 094 308	3 873 779			

** Based on the 1981 population

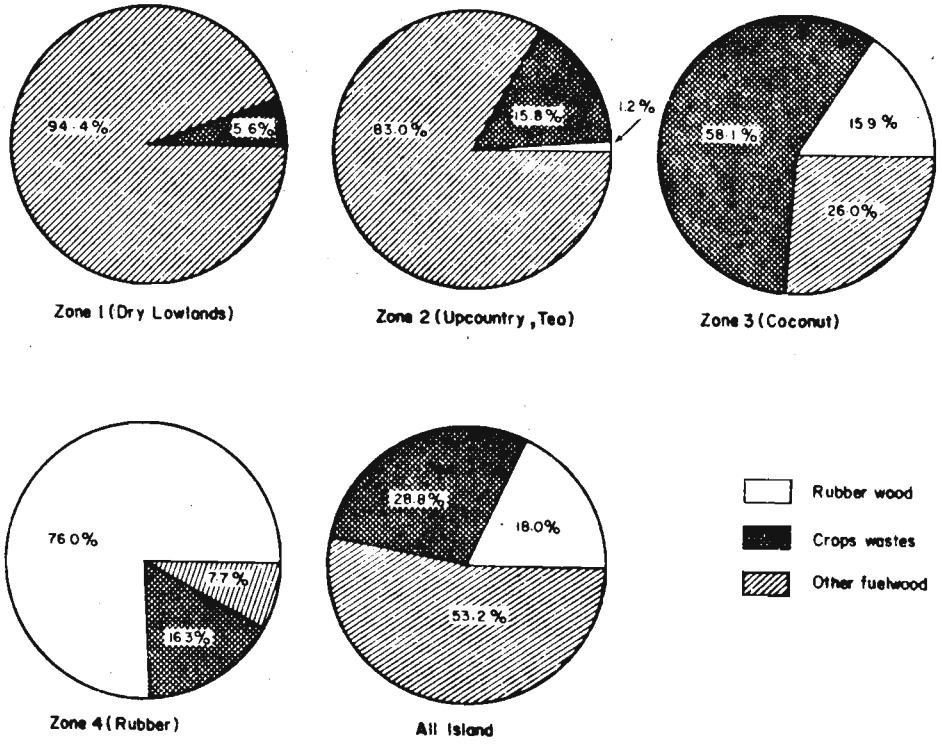

Fig. 2. Diagrammatic representation of the estimated % composition of the biomass fuel mix

As indicated in Table 2 the total biomass fuel consumption of the household sector in 1981 was estimated at 7.3 million tonnes. Assuming that the generally accepted annual net increase of population (1.7%) applied equally to all the strata, the estimated biomass fuel consumption for 1983 would be 7.5 million tonnes comprising rubber wood 1.36 million tonnes (18.0%), crop wastes 2.17 million tonnes (28.8%), and other fuelwood 4.01 million tonnes (53.2%). The mean *per caput* consumption of biomass fuel for the whole island as calculated from the sample data was 1.36 $\pm$ 0.06 kg/day (496.4 kg/year).

The crop wastes were predominantly products of the coconut tree - the leaf (particularly the woody petiole and rachis), husk, spathe, spadix, shell, trunk and root. Cinnamon and manioc (cassava) sticks, arecanut (*Areca catechu*) trunk, material from uprooted tea bushes, and biomass from other crop trees (except rubber) when identified as such were also placed in this category; but these together formed only a small proportion of the crop wastes used as fuel.Fuelwood from scrub and forest trees and from home garden and estate trees which were not categorized as crop waste (e.g. *Glyricidia* sp.), saw-dust, and off-cuts from saw mills were all aggregrated together as 'other fuelwood'. Rubber wood formed a separate category.

Biomass fuel was used by the households for cooking food, boiling water for tea, and occasionally for other household purposes such as boiling medicinal herbs for treating a sick person and heating water for bathing infants or invalids. When paddy was par-boiled in bulk for sale, the biomass fuel used for the purpose was not taken into account. In the cool up-country areas no special devices for heating the houses were observed, but the fireplace was sometimes replenished with fuelwood and the fire kept going after cooking was completed so as to provide warmth to the occupants at night. This may well account for the high *per caput* consumption values in the rural and estate sectors in Zone 2 compared to the corresponding sectors in the other zones.

The mean *per caput* consumption in each of the rural sector strata was significantly higher (as indicated by the t test) than the corresponding mean in the urban sector. This was an expected result since more urban households use alternative fuels (kerosene, electricity, gas) for cooking, generally as a partial substitute for biomass fuel, than rural

households. But, more interesting, taking only those households that used biomass fuel exclusively during the 24-hour study period (column 12 in Table 2) the rural sector mean consumption *per caput* was still, in every case, higher than the corresponding urban sector mean, suggesting that the urban householder uses his biomass fuel more economically. It must be noted, however, that the difference proved to be highly significant [$t_{(183)} = 2.90$] only between strata 3U and 3R. This was probably because, considering the high degree of variation in the *per caput* consumption within a stratum, the number of samples in the other cases was inadequate to yield a positive result in the significance test (t test).

The average moisture content of the biomass fuel samples that were collected was 17.3% (on an oven dry weight basis) which is within the range of moisture contents of air-seasoned wood in Sri Lanka.[13] It may therefore be assumed that the biomass fuel measured in this study was air-dry or nearly so.

Procurement of biomass fuel

There were 385 rural sector households in the sample, and of these 311 (81%) obtained their biomass fuel gathering it themselves, while 24 (6%) obtained a part (crop wastes) by gathering and the balance by purchasing. A large majority (84%) of the rural sector households gathered their biomass fuel from within a distance of 1.6 km (1 mile) of their abode, but collection distances of up to 10 km (6 miles) were recorded. The collection distances were lowest in Zone 3 (Coconut).

The sample in each stratum was taken and the percentage of households that used each of the three types of biomass fuel calculated; and a further breakdown was made into households that purchased the fuel and those that obtained it by gathering. The results are given in Table 3. The values in columns 1, 4 and 7 in the majority of cases add up to more than 100 because many households used two or all three types of biomass fuel and were therefore included in each of the appropriate categories. Households that obtained their fuel by gathering collected it from their own gardens, from estates and gardens in the vicinity, or from waste land and forests.

TABLE 3

Methods of procuring the different categories of biomass fuel in the sample households

Stratum	(1) Households that used rubber wood	(2)	(3)	(4) Households that used crop wastes	(5)	(6)	(7) Households that used other fuelwood	(8)	(9)
	Expressed as a % of the stratum sample	% that purchased	% that gathered	Expressed as a % of the stratum sample	% that purchased	% that gathered	Expressed as a % of the stratum sample	% that purchased	% that gathered
1 U	-	-	-	50	20	80	100	80	20
1 R	-	-	-	15.8	27.8	72.2	98.2	9.8	90.2
2 U	-	-	-	10.0	-	100	90.0	100	-
2 R	1.9	-	100	63.5	3.0	97.0	96.2	28.0	72.0
2 E	-	-	-	4.2	-	100	95.8	-	100
3 U	38.9	95.2	4.8	63.0	11.8	88.2	42.6	56.5	43.5
3 R	16.6	56.0	44.0	80.8	16.4	83.6	45.7	18.8	81.2
4 U	53.8	100	-	76.9	30.0	70.0	38.5	60.0	40.0
4 R	89.7	14.8	85.2	47.1	-	100	7.4	20.0	80.0
4 E	58.3	-	100	41.7	-	100	8.3	-	100

Considering the two categories, rubber wood and other fuelwood, the percentage of households that purchased the fuel was greater in the urban sector than in the corresponding strata in the rural and estate sectors, and the converse was true of the percentage of households that obtained their fuel by gathering. This pattern was not seen in the case of crop wastes. This type of biomass fuel is obtained mostly by gathering, and many urban households are able to collect the fuel from their own land holdings; hence the high percentage of urban households which obtained their crop waste fuel by gathering.

Cooking devices

In Table 4 the households are categorised according to the cooking devices used by them. Many households in the urban sector possessed more than one type of cooker, but only those cookers that were used during the 24-hour study period were recorded. The category "other" (column 7) includes the households not listed in any of the previous columns e.g. where a household used both a kerosene cooker and an electrical cooking appliance.

The commonest biomass fuel cooking device was the mud stove, built out of brick and mud on the hearth which is elevated to varying heights up to about 1 m from floor level (Fig.3). This cooker has no chimney. It is open on one side for inserting fuel, and the cooking vessel is placed on top. The three-stone open fireplace (Fig.4) was the next most common type of cooking device. Here, three bricks or stones are placed in a triangular arrangement on the hearth to support the cooking vessel while leaving room below the vessel for placing the fuel. Of the 518 households in the sample, 266 (51%) used only the mud stove and 197 (38%) only the 3-stone open fireplace, while 6 (1%) used both.

Saw dust cookers (together with other cooking devices) were used in 13 households. These houses were situated in proximity to saw mills from where the saw dust could be readily purchased. The saw dust is packed tight into a metal can (of about 6 litre capacity) leaving a vertical passage in the middle linking with a horizontal passage from an opening on a side towards the bottom of the can. The passage provides the air draft required for burning.

TABLE 4

Data on cookers used by the sample households

(1) Stratum	(2) % Using mud stove exclusively	(3) % Using 3-stone exclusively	(4) % Using mud stove and 3-stone only	(5) % Using saw dust cooker & mud stove and/or 3-stone	(6) % Using any form of biomass fuel cooker and kerosene cooker	(7) % Using mud stove or 3-stone and an electrical cooking appliance	(8) % Others
1 U	35.0	20.0	-	-	5.0	40.0	-
1 R	39.4	58.8	0.9	-	-	0.9	-
2 U	50.0	-	-	-	-	40.0	10.0
2 R	88.4	5.8	-	5.8	-	-	-
2 E	100.0	-	-	-	-	-	-
3 U	14.8	38.9	1.9	9.3	3.7	16.7	14.7
3 R	45.7	51.0	1.3	1.3	-	-	0.7
4 U	7.7	69.2	-	7.7	15.4	-	-
4 R	72.1	23.5	2.9	1.5	-	-	-
4 E	100.0	-	-	-	-	-	-

Fig.3. Mud stove

Fig.4. 3-stone open fireplace

Fig.5. Fuelwood stacked over kitchen fireplace

Kerosene cookers (together with other cooking devices) were used in 10 households and they were of the two or three burner wick type. Liquified petroleum gas (LPG) was used in five households, but only in one household was it the sole cooking fuel used. The few electrical appliances observed in the study were electric kettles, hot plates and rice cookers.

DISCUSSION

Earlier estimates of biomass fuel consumption in the household sector in Sri Lanka have been largely speculative since there were no data on which a reliable estimate could be made. The estimate of Fernando et al of 5.2 million tonnes for 1980 was the one that was generally accepted.[5] However, it is evident that this figure, with any reasonable upward adjustment for 1981, would still fall well short of the estimate for the same year computed in this study (7.3 million tonnes). Hence the present study indicates that the consumption of biomass fuel in the household sector is considerably higher than what has generally been assumed.

In 1979 Bialy estimated that an average family of six members consumed 50kg/week of biomass fuel, and assuming that there were two million households that used biomass fuel, he arrived at a figure of five million tonnes/year for the whole island.[8] However, the 1981 census of population and housing has revealed that a much higher percentage (94.1%) of households use biomass fuel for cooking than was earlier assumed by Bialy; and this would suggest that Bialy had underestimated, perhaps by an appreciable amount, the 1979 total consumption.

Regarding the biomass fuel mix, Sankar and Fernando reckoned that, on a "conservative" estimate, the coconut plantations may produce 1.2 million tonnes of material suitable as fuel, but assumed that only a third of it was actually used as such. Their estimate of the rubber wood component of the mix was 1.0 million tonnes.[7] Vivekanandan computed the maximum amount of fuelwood that could come out of estates cleared for replanting under the rubber rehabilitation programme and obtained a lower figure (0.85 million tonnes).[11]

The present study gives the contribution of crop wastes (for 1981) as 2.1 million tonnes and of rubber wood as 1.3 million tonnes which are substantially higher than what have been suggested by the authors quoted above. The crop wastes included material from crop species other than coconut, but the total contribution of these species, though not recorded separately, was noted to be very small in relation to coconut. In regard to rubber wood it was noted that many of the users in the rural sector obtained their fuel from sporadic fellings that had no connection with the rubber rehabilitation programme, while the supplies from areas falling under the programme went to the towns. This might explain why the earlier workers had underestimated the quantity of rubber wood used as fuel.

Taken as a percentage of the whole, the present study puts the contribution of crop wastes and rubber wood together as 46.8%. Interestingly, Arnold and Jongma, reviewing the charcoal and fuelwood position in developing countries, have stated that in Sri Lanka over half the biomass fuel needs are met from coconut wastes and rubber wood,[14] a conclusion that accords fairly well with the results of the present study.

CONCLUSIONS

1. This investigation which is the first island-wide study of household biomass fuel consumption in Sri Lanka based on actual measurements indicates that the consumption and the contribution of crop wastes and rubber wood to the biomass fuel mix are appreciably higher than what have generally been suspected.
2. A great majority of the rural households obtain their biomass fuel by collecting it themselves, generally within easy walking distance ($\leq$1.6 km) of the home, though distances of up to 10 km (6 miles) were recorded.
3. The vast majority of households use the primitive mud stove (without a chimney) and 3-stone open fireplace to cook their food.

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REFERENCES

1. Andrew, J.R.T. (1961). A forest inventory of Ceylon. Forest Department, Colombo.

2. Geiser, Urs & Sommer, Martin (1982). Up-to-date information on Sri Lanka's forest cover. Loris XVI, 66-69

3. Director of Census and Statistics (1981). Census of population and housing, Sri Lanka, Preliminary release no. 1. Department of Census and Statistics, Colombo 7.

4. Central Bank of Ceylon (1983). Annual Report of the Monetary Board for the year 1982, Part I. Central Bank of Ceylon.

5. Fernando, G.B.A., Chandrasekera, D., Jayasekera, D.M. & Sepalage, B.P. (1981). Sri Lanka energy sector study-Asian Development Bank regional energy survery (mimeo). Ministry of Finance & Planning, Colombo 1.

6. Director of Census & Statistics (1982). Housing tables, Preliminary release no.3. Department of Census & Statistics, Colombo 7.

7. Sankar, T.L. & Fernando, G.B.A. (1978). Towards an energy policy in Sri Lanka (mimeo). Ministry of Finance & Planning, Colombo 1.

8. Bialy, Jan (1979). Firewood use in a Sri Lankan village - a preliminary survey. Occasional papers on appropriate technology, University of Edinburgh, School of Engineering Sciences.

9. State Timber Corporation (1982). Annual Report of the State Timber Corporation for 1980. State Timber Corporation, Colombo 5.

10. Wijesinghe, L.C.A. de S. (1981). Sri Lanka country report to an expert group meeting on fuelwood and charcoal (mimeo). ESCAP, Bangkok.

11. Vivekanandan, K. (1980). Energy plantations - Paper read at a seminar on energy in Sri Lanka (mimeo). Forest Department, Colombo 2.

12. Director of Census & Statistics (1983). Unpublished data. Department of Census & Statistics, Colombo 7.

13. Tisseverasinghe, A.E.K. (1971). A Manual of Timber Utilization for Ceylon. Forest Department, Colombo.

14. Arnold, J.E.M. & Jongma, Jules (1978). Fuelwood and charcoal in developing countries. Unasylva, 29, 2-9.