ASSESSMENT OF SIERRA LEONE'S ENERGY POTENTIAL FROM AGRICULTURAL WASTES

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ABSTRACT

A survey has been conducted to estimate the energy potential of agricultural and forestry wastes available in Sierra Leone, to provide the necessary information base for policy makers. The preliminary results which covered nine types of crop wastes, three different animal wastes and two types of forestry wastes are presented. Examples are discussed of how the different agricultural wastes can be used to supply the energy required in most of the post-harvest operations that are carried out at village level.

INTRODUCTION

Sierra Leone does not have a large pool of conventional energy resources. To become energy self-sufficient, non-conventional sources of energy must be developed, including biomass. At present in Sierra Leone, most of the biomass used for energy is in the form of wood or charcoal. There is potential to exploit a much broader range of biomass resources. However, it is necessary first to assess the amount available nationally.

The project described in this paper has been carried out to determine the national energy potential from agricultural and forestry wastes.

BACKGROUND ON AGRICULTURE AND FORESTRY

Agriculture (crops)

Agriculture plays a major role in the economy of Sierra Leone, contributing about 28.6% of the total export earning and 32% of the gross domestic product. Rice is the staple crop and is produced all over the country. Other food crops include cassava, maize and millet. Among the cash crops are: coffee, cocoa and palm kernel which are produced mainly in the southern and eastern region; groundnut and sugar cane which are produced in the north; and citrus fruits which are produced all over the country on a very small scale. Of these, coffee and cocoa rank high with 16.1% and 13.4% of the total annual export earnings respectively. Together, these crops represent only 10% of the GDP.

Agriculture (Livestock)

In Sierra Leone, the main source of meat is beef. But cattle rearing is not very organised and most farms average only 10-50 head of cattle. Most of the cattle are in the northern province. Goats and sheep are reared in large numbers all over the country. The combined population of sheep and goats is greater than that of cattle. Goats, sheep and cattle are seldom housed or confined. Piggeries exist only in the urban centres and their adjacent rural communities. The average size is about thirty (half of which may be piglets). There are several poultry farms in the country, with from 500-50,000 chickens.

Forestry

About five percent of the total area of the country (mainly south-eastern region) is covered with high tropical forest. There are several forestry plantations whose total area is approximately 10,000 ha.

METHODOLOGY

Following an initial identification of the different wastes produced in the various farming operations, two parallel investigations were undertaken to characterise the wastes and to determine the total resources using data from field tests and statistical records.

Identification of agricultural and forestry wastes

Wastes have been classified into five groups: crop wastes produced in farming operations such as harvesting and milling; firewood produced as a result of the bush fallow farming system; animal wastes; wastes from forestry operations; and wastes from agro-industries.

Three criteria were identified for selecting a particular plant crop waste as a possible source of energy. Firstly, the crop should have an annual production in excess of 10,000 tons. Second, the moisture content of wastes is less than 20% making them good candidates for thermochemical conversion. However, wet wastes are suitable for bacteriological conversion. Third, the ratio of waste to crop should be high. For instance, cassava stems were not considered because of the low ratio of stem to root.

As far as animal wastes are concerned only confined animals and larger animals were selected. Goat and sheep wastes were not considered suitable. Although cattle are not confined in most cases, the size of their droppings and the limited distances over which they roam makes the collection of cowdung a potentially economic exercise. Poultry and piggery wastes were also considered in this study.

In the case of agro-industrial wastes only solid wastes were considered since most liquid wastes tend to be very dilute. Two forestry wastes were considered; sawdust and wood cut-offs.

It is widely believed that deforestation is caused by clearing of forest for firewood. However in most developing countries like Sierra Leone, forests are not cleared for firewood. Firewood is a waste product of the land preparation in the bush fallow farming system. Thus the quantity of firewood available depends on the extent of the food crop farming operations. In this study, firewood is considered as a waste from the farming work.

Laboratory experiments

Laboratory tests were carried out to determine some of the relevant physical characteristics of the wastes. The properties measured were: moisture content; calorific value; bulk density and ash content. The energy content, the thermo-chemical conversion prospects, and problems involved in transporting large quantities away from the point of production were determined.

Determination of waste factors

Total production of various crops was obtained from statistical records. The proportion it was to crop produced was estimated in field experiments. The method for the collection of field data varied from crop to crop. Below the methods used to determine the waste factor which is defined as the ratio of the waste to the primary products are described. Two broad categories of wastes have been defined: those produced on farms and those produced during processing off the farms.

Wastes left on farm land

Only rice straw and the natual vegetation removed during land preparation for farming, can be considered as a farm waste.

a. Determination of waste factor for rice straw: In Sierra Leone during harvesting most of the straw is left on the farm and only the stems containing the seeds are cut-off. Straw from a measured area was collected and weighed and the ratio of straw to paddy produced, thus calculated. The waste factor thus obtained was estimated at various locations and for both upland rice farms and boliland swamps.

b. Natural vegetation: During land preparation for farming the natural vegetation is cleared. Most is burnt and serves as a soil fertiliser. The larger trees are traditionally used for firewood. Available statistics on the volume of wood per acre of forest land in Sierra Leone (Alanta 1979) and on the total acreage of upland rice farm developed annually, was used to calculate the tonnage of firewood available annually from rice farming.

Wastes produced off-farm

This group includes all the wastes in the post-harvest operations such as milling and threshing, as well as those generated by agro-industries.

a. Rice husk, peanut shells and coffee husk: All these wastes are generated during the milling (or shelling) of the primary product. A measured quantity of the uncleaned product (i.e. paddy rice, unshelled peanut etc) was milled (or shelled) and the weight of the waste and the primary product recorded separately. The ratio of the waste to the primary product is the waste factor.

b. Cocoa pods: Cocoa-bean production statistics are normally quoted for dried beans. The waste factor was therefore based on dried beans. A weighed sample of the podded cocoa was taken and processed by the traditional method. The dried beans and the dried pods were weighed and the waste factor computed.

c. Palm fruit fibres: This type of waste is produced on a large scale in three main oil mills processing palm fruits. A known quantity of palm fruit was processed. The ratio of palm fruit fibres to the quantity of palm oil produced gave the waste factor.

d. Woody remains of palm fruit bunches: The palm fruits are loosely attached to a thorny mass which is disintegrated during processing for palm oil. The woody remains are a useful source of energy. The waste

factors for this waste was estimated from a mass balance taken over the total crop.

e. Palm kernel shells: To determine the quantity of shell generated per unit weight of palm kernel produced, a known quantity of the unshelled units was cracked and the weight distribution between the kernel and the shell recorded.

f. Bagasse: There is only one sugar mill in the country. The factory provided information on the quantity of bagasse to sugar produced.

g. Livestock (poultry, piggery and cattle waste): Animal compounds (eg a poultry, a piggery) were visited once a day (early in the morning) to collect all wastes of the previous day. The total waste was divided by the number of animals present to give the waste per animal. The average weight of the animals involved in the experiment was also recorded.

Forestry wastes

Two types of wastes are generated by the forest industry: sawdust and wood cut-off. Some of the latter is usually left on the forest floor by the logging team. The quantity of wood cut-off produced depends on company practice and hence the waste factor will vary with the company. These industries were visited and interviewed on the quantity of waste they produced. An average of the estimates was used as waste factor for the industry.

Data on primary products

To gain regional and national estimates for waste products information on the annual production of the primary products was obtained. Three main sources of information were used: published reports or data, communications with industries and government departments, and visits to industries. The Agricultural Statistical Bulletin (PEMSU 1983) proved the most useful source of published data. Published by the Planning, Evaluation, Monitoring, and Services Unit (PEMSU) of the Sierra Leone Government's Ministry of Agriculture and Forestry, it has information on the annual production of nearly all major crops produced in the country. It also has information on the nature and size of both natural and plantation forests.

RESULTS AND DISCUSSION

Physical characteristics of the wastes

The results of the experiments to determine the bulk density, moisture content, ash content and calorific value of the wastes are given in Table 1. With the exception of palm kernel shells, all waste products are very bulky (bulk density less than that of water). This has very unfavourable implications for the transportation, particularly of rice husts. Thus these wastes will have to be used locally.

The moisture content of most of the crop wastes (with the exception of bagasse) ranged from 11-20%. Hence they can readily be converted to other forms of energy through any of the thermo-chemical routes such as combustion, pyrolysis and gasification. Biological conversion will require the addition of a lot of water, and bacteria, and will have a long retention time. The moisture content

of animal wastes was fairly high - varying betwen 16% and 86%. The lower figure represents cowdung which was usually dropped in open fields where they dried before collection. The average moisture of forestry wastes was 30%, which corresponds to that of wet wood.

The ash content of most of the wastes is faily low. The only exceptions are rice husk and straw which have very high ash content (approximately 20%). The ash contents of palm fruit fibres, palm kernel shells, sawdust and other forestry wastes are negligible.

Gross energy values are inversely correlated with ash content, as would be expected, since ash represents weight contributing zero energy.

Waste factors

Tables 2-4 give the waste factors for all the crop wastes considered in this work. Table 5 summarises the daily droppings of animals. Table 6 contains information on the percentage of logs that is wasted in sawmills.

These data are similar to published work especially in the case of rice husk (Pitakarnnop et al 1983). Rice straw to grain ratio is very high because of the low grain yield per hectare. Paddy production is 1.3 tonne per hectare compared with 3-5 tonnes per hectare reported in some literature (Dunn et al 1983). The larger yield corresponds with improved farming methods.

Daily droppings per animal are also very much lower than those reported in the literature because of the lower average weight of the animals. In the case of cattle, the dung was dry when collected and explains the low value for the daily droppings.

Total energy from agricultural and forestry wastes

Tables 7-9 give the total wastes associated with each of the major crops. Wastes associated with rice are the most abundant. Rice straw tops the list in quantity, followed by wastes from clearing for rice farming and then rice husk. Among the forestry wastes, wood cut-off is the most abundant and in the livestock cowdung dominates.

The total energy available nationally from all major agricultural and forestry wastes is given in Table 10. By far, the most important waste is dry wood collected during clearing of natural vegetation in the bush fallow farming system. Some of this waste, especially that generated on farms close to urban areas, is already being used as firewood.

Other major potential energy sources are rice straw and husk. However because of their high ash content and low bulk density, these fuels will have a very short radius of economic usefulness. The largest energy potential from agro-industries is bagasse produced by the sugar mills. This and other wastes like palm fruit fibres and palm kernel shells are currently being used by the industries that produce them. In addition, a small number of farmers who process oil palm by traditional methods also use palm fruit fibres as energy sources in some parts of the country.

The estimated total energy available annually from wastes produced on farms and in agro-industries is about 1.5 million tonnes oil equivalent. This is very

significant since the annual import of crude oil to Sierra Leone is approximately 300,000 tonnes.

Mode of utilisation of wastes

Most of the wastes produced by industries are used in those factories as a source of energy. Palm oil mills use the palm fruit fibres and the nut shells to fire their boilers, and bagasse produced by sugar mills is similarly used. Recently, the forest industries corporation of Kenema in the eastern region started using their wastes to generate electricity to run all their machines. Sawdust can also be used for cooking or baking in specially designed stoves and ovens (Massaquoi 1985; Bassey 1983).

Other wastes evaluated here have not yet been recognised by farmers as potential energy sources. In order to promote the utilisation of these waste, notice must be made of the fact that their low bulk density requires them to be used at or near the point where they are generated. Promotional efforts, should aim at augmenting existing energy sources for farm activities and providing energy for other work currently been undertaken by human labour.

Thus, efforts to utilise rice husk or straw should concentrate on using them in some form in drying, milling or parboiling. The use of rice husk in stoves to parboil paddy are currently underway. Similar efforts should be made in converting rice husk to gas which could be used to run rice mills.

Farm wastes should be considered individually. All the processing and farming operations associated with a particular waste should be examined to identify those steps that could be energised.

CONCLUSION

A survey of Sierra Leone's energy potential from agricultural and forestry wastes has been carried out. From the results of the survey the following conclusions can be drawn.

i. The total energy from plant wastes, which is estimated at 1.5 million tonnes of oil equivalent per annum, is about five times the total annual crude oil import.

ii. The total energy from crop wastes alone is more than double that of the annual crude oil import.

iii. The total energy from the dead remains of the natural vegetation which is cleared in the bush fallow system, is estimated at 23,852 TJ/annum or 542,000 T.O.E.

iv. The total energy from crops associated with rice farming is about 700,000 tonnes oil equivalent.

v. The low bulk density of the wastes means that they are best used in the communities in which they are produced.

vi. It is possible to use the energy available from some crop wastes to energise the operations leading to the production of the waste. An example is the use of rice husk stoves to parboil rice.

vii. The energy available from forestry wastes is not substantial but exist in large quantities in a few locations.

viii. Among the livestock wastes, cowdung has the largest energy potential but since most of the cattle are not housed it is difficult to use this waste.

ix. All waste from agro-industries are currently been used by the producers to run their boilers.

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TABLE 1: Physical characteristics of major agricultural and forestry waste

Waste	Bulk density (kg/m^3)	Moisture content (% wet basis)	Ash content (%)	Calorific value (MJ/Kg)
CROP				
Rice husk	107	11.87	20.3	12.75
Rice straw	320	17.91	17.9	13.5
Firewood (average)	650	17.5	Neg.	16.5*
Cocoa pods	-	19.27	10.2	14.2
Coffee husks	575.5	17.35	9.4	15.35
Peanut shells	429	16.35	14.2	15.46
Palm kernel shells	1315.56	12.02	1.31	16.4
Palm fruit fibres	826	11.48	Neg.	23.21
Woody remains of palm fruit bunches	-	10.2	Neg.	18.2
Bagasse	-	50	11.3	9.3+
FORESTRY				
Sawdust	200-220	50	Neg.	10.5
Wood cut-offs (Green)	690	50	10.5	
ANIMAL				
Piggery	-	90	-	1.8
Poultry	-	85	-	4.4
Cowdung	-	16.8	-	14.5

* Menyonga (1983); + National Academy of Science

TABLE 2: Waste factor of some crops wastes

Waste (primary product)	Average weight of sample (Kg)	Average weight of primary (Kg)	Average weight of waste (Kg)	Waste factor = wt of wst / wt of pri	
Rice husk (rice paddy)	20	20	6.5	0.325	
Rice husk (cleaned rice)	20	13.5	6.5	0.482	
Dry cocoa pods (beans)	11	1.5	1.5	1	*
Coffee husks (coffee seeds)	5.5	1.25	1.25	1	*
Peanut shells (peanut)	28.0	14.0	14.0	1	
Palm kernel shells (kernel)	16.0	5.6	10.4	1.85	
Palm fruit fibres (oil)	24	3.6	3.5	0.97	
Woody remains of palm fruit bunches (oil)	-	-	-	1.48	**
Bagasse (sugar)	60,000	6,000	20,000	3.3	***

* In the case of cocoa pods and coffee husk, the difference between the sample weight and the sum of that of the primary and waste is due to moisture which was removed after drying the waste and the primary product.

** Estimated by this work.

*** Magbass Sugar Factory (personal communication).

TABLE 3: Computation of waste factor for rice straw

	Swamp rice	Upland rice	
Area of farms brushed (3.85 x 3.45)	13.30 m^2	13.30 m^2	
Quantity of rice straw gathered (Kg)	10	6	
Straw/hectare (kg/ha)	7520.0	4511	
Paddy/hectare (kg/ha)	1500	1340	(PEMSU 1982)
Waste factor = $\frac{\text{wt of straw}}{\text{wt of paddy}}$	5.013	3.37	

N.B. The ratio of upland rice to swamp rice is 3.254/1.263. Hence the average waste factor for straw is given by

$$\frac{1}{4.5} \quad (3.254 \times 3.37) + (1.263 \times 5.013) = 3.78$$

TABLE 4: Weight of dead wood generated from bush fallow farming system

Average volume of wood/hectare	5.48	m^3/ha	PEMSU (1982)
Quantity of paddy/hectare	1.35	tone/ha	
Volume of wood/tonne paddy	4.06	m^3/tonne	
Approximate density	0.650	tonne/m^3	
Weight of wood/tonne of paddy	2.6	tonnes/tone of paddy	

TABLE 5

No of animals		Total daily droppings (kg/day)	Average droppings per animal per day kg/animal/day	Annual droppings tonnes/ animal/year	Average weight of animal (kg)	Daily dropping % of live wt
Poultry	1000	60	0.06	0.0216	1	6
Piggery (Unit waste)	49	90	1.83	0.66	60	3.05
Cowdung (air dried)	23	80.5	3.5	1.26	200	1.75

TABLE 6: Statistics on forestry wastes

Industry	Percentage of logs wasted as		
	sawdust	wood cut-off	Total
Panguma Sawmills	4	36	40
Forest Industries Corporation	3	30	33
SILETI	Not applicable	50	50
Average	3.5	38.7	41

TABLE 7: Computation of total wastes generated annually (crops)

Wastes (primary product)	Waste factors (tonne/tonnes)	Total annual primary production (tonnes)	Total waste (tonnes)
Rice husk (paddy rice)	0.325	556,000	180,700
Rice straw (paddy rice)	3.78	556,000	2,101,680
Dead natural vegetation (paddy rice)	2.6	556,000	1,445,600
Cocoa pods (cocoa beans)	1.0	8,600	8,600
Coffee husks (coffee seeds)	1.0	30,500	30,500
Peanut shells (peanut)	1.0	10,100	10,100
Palm kernel shells (palm kernel)	1.85	41,000	75,850
Palm fruit fibres (palm oil)	0.97	49,000	47,530
Woody remains of palm fruit (oil) bunches	1.48	49,000	72,520
Bagasses (sugar)	3.3	6,000	20,000

TABLE 8: Computation of total wastes (forestry)

Waste	Waste as % of log	Annual quantity of logs handled		Total waste (tonnes)
		(m^3)	tonnes	
Sawdust	3.5	71,000	46,150	1615.75
Wood cut-offs	38.7	71,000	46,150	17,860
Total Forestry Wastes				19475.3

TABLE 9: Computation of total wastes (animals)

Waste	Waste per animal per year tonnes/animal year	Total animal population	Total annual waste (tonnes)
Cowdung	1.26	333,181	420,000
Poultry	0.0216	3973,000	85,817
Piggery	0.66	15,000	9,900
Total Animal Waste			515,717

TABLE 10: Total energy potential from wastes

Type of waste	Total waste produced annually (tonnes)	Calorific value GJ/tonne	Total energy potential (GJ)	Total energy in tonnes oil equivalent*
Rice husk	180,700	12.75	2,303,925	52,362
Rice straw	2,101,680	13.5	28,372,680	644,833
Cocoa pods	8600	14.2	122,120	2775
Coffee husk	30,500	15.35	468,175	10,640
Peanut shells	10,100	15.46	156,146	3548
Palm kernel shells	75,850	16.4	1,243,940	28,271
Palm fruit fibres	47,530	23.2	1,102,696	25,061
Woody remains of palm fruit bunches	72,520	18.2	1,319,864	29,996
Bagasse	20,000	9.4	188,000	4272
A. Total Crop Waste			35,277,352	801,758
B. Clearing of natural vegetation for farming	1,445,600	16.5	23,852,400	542,100
Sawdust	1615	10.5	16,957	385
Wood cut-offs	17,860	10.5	187,530	4262
C. Total Forestry Waste			204,497	4647
Cowdung	420,000	14.5	6,090,000	138,409
Poultry	85,817	4.4	377,594	8581
Piggery	9900	1.8	17,820	405
D. Total Animal Waste			6,485,414	147,385
Grand Total (A+B+C+D)		**65,819,160**		**1,495,890**

* tonne of oil = 44 GJ