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Potential of biomass from selected cropping systems as source of feed / food and energy

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Abstract

Surveys were carried out to determine the biomass yield of selected tree crops in order to estimate the potential gross income from cogeneration of energy and feed / food. The coconut crop was studied on farms in Takeo and Kompot provinces; cassava was studied on farms in Takeo and Kompong Cham provinces; and mulberry and the ornamental tree *Cassia stamea* were evaluated in CelAgrid, Kandal province.

The potential for generation of electricity was estimated to be in the range of 4665 to 14156 kwh/ha/yr for coconuts managed for sale of green nuts for drinking; 6141 to 13936 kwh/ha/yr for mulberry managed to produce leaves as a protein source for livestock; 16970 kwh/ha for cassava managed for leaf and starch production from the roots in the high yield region and 1221 kwh/ha managed for leaf and human food from the roots in the low yield region; and 4120 kwh/ha/yr for *Cassia stamea* managed as a shade tree.

The preliminary data derived from the analysis presented in this paper indicate that there is considerable scope for adding value to selected tree crops when the fibrous residues are used as feedstock for a gasifier producing combustible gas for an internal combustion engine driving an electric generator. Apart from the direct economic advantages there will be associated social and environmental benefits as the technology is "carbon-neutral" (there are no net emissions of carbon dioxide) and will provide increased employment in rural areas.

Key words: Biomass, coconuts, cassava, mulberry, Cassia stamea, tree crops

1. Introduction

The tropical climate is suitable for a wide range of biomass resources such as forages and forest trees and shrubs. However, many parts of these regions seem to be facing many constraints such as wars, human activities, increasing population and natural disasters.

In ancient time the efficient use of biomass was not of much concern because of low density of population but today the population has increased dramatically, made possible through the discovery and utilization of energy from fossil fuels, especially oil. The US Department of Energy has reported that increases in population and energy consumption, accompanied by growing concerns about global change and atmospheric pollution, will create a major opportunity for fibrous biomass to play a greater role in energy production (Skog and Rosen, 1997).

In Cambodia, it was reported that biomass represented 96.3% of national fuel consumption (NIS, 1999). Similar data were recorded by Sovanndara (2004) who calculated that most of the energy in Cambodia was derived biomass (wood 82 %, charcoal 1.2 %, other forms of biomass 1.7 %), with imported petroleum products providing the remainder.

The major thrust of this thesis is to demonstrate ways to utilize biomass as a replacement for fossil fuel (Paper I), in view of the imminent decline in oil production, and the negative effects on the environment from burning of fossil fuels. The challenge is to manage the biomass, not just for energy but in an integrated system which also takes account of the need for production of human food and live stock feed, without negative effects on the environment.

The purpose of this study was to evaluate the overall yields from certain crops which are considered as potential candidates for this integrated approach. The selected crops are: coconuts, cassava, mulberry and an ornamental / shade tree (*Cassia stamea*) widely found in urban and peri-urban area.

2. Materials and Methods

2.1 Location

Surveys were carried out at different places according to the selected resources:

- Coconut: Takeo and Kompot provinces
- Cassava: Takeo and Kompong Chham provinces
- Mulberry: CelAgrid Research Centre
- *Cassia stamea*: CelAgrid Research Centre

2.2 Procedure

Coconuts (Cocoa nucifera)

Farmers (n=12) who were able to sell nuts each year were interviewed in 2 different locations (Trunk district, Takeo province and Angkorchey district, Kompot province). Village leaders were contacted to get the names of suitable farmers. The overall aim was to find out how many nuts were sold at any one time, how many times per year they were sold, what was the price of the nuts, and the planting density of the trees (distance from one palm to another). Four green nuts in each study area were selected to evaluate the yield of the two components: the juice used for human consumption and the residue (husk and shell). The areas of the survey were mostly located on sandy soils. The criteria used to obtain the data were:

- Location (availability of coconut trees and possibly to sell the nuts
- Farmers owned at least 5 coconut palms..
- The nuts were sold green, and not kept for ripening.
- Target villages had a tradition of selling nuts to middle-men
- RRA tools were used to get information and make sure the data were accurate by using SSI (semi-structured interview) and the "triangular technique-direct observations", to corroborate the information through interviews with middle-men and neighbors.

Cassava (Manihot esculenta)

The survey was done in two different locations with 6 plots in different places in the same farm. One location was in a high yield region (Kampong Cham province) and the other in a low yield region (Takeo province) depending on the soil property. The cassava plants were sampled at the traditional stage for root harvest. The high yield cassava (Imported variety) was planted at the early stage of the rainy season in May 2003. Harvest time was 11 months after planting. The low yield cassava (local variety) was planted in November 2003 and harvested in July 2004. The cassava in both locations was not fertilized or irrigated. Plant density was 15625 stalks/ha (high yield region) and 12500 stalks/ha (low yield region). Each plant was separated into leaves (including the tender green stems), the woody stems and root.

Mulberry (Morus alba)

The estimation of mulberry yield was carried out in CelAgrid UTA Cambodia as part of an experiment on the effect of different levels of biodigester effluent on yield and composition. There were 6 treatments, according to levels of nitrogen application (0, 100, 250, 400, 550 and 700 kg N/ha) from effluent from a biodigester charged with pig manure. Plot size was 38.25 m^2. The first harvest was taken after a 12 month establishment period and subsequent harvests at intervals of 2 months. The data were taken from the second harvest, and converted to an annual basis on the assumption there would be 6 harvests per year. The stems were cut at 0.5 m from the ground and the biomass divided into leaves and stems. The density was 40000 plants/ha (distance 0.5 m from one plant to another).

Cassia stamea

These trees had been planted in CelAgrid in October 2003. Seedlings were transplanted after 1 month germination in plastic bags. The trees were planted along the canals and paths in the center. Plant density was estimated at 1600 trees/ha (6.25 m^2/tree). The trees were not given any fertilizer or irrigation. The harvest was one year after planting (October 2004). Harvesting was done in 2 ways: cutting the whole tree or just the lateral branches. Ten trees were harvested; 5 for all the biomass (30 cm height from the ground) and the other 5 trees only the lateral branches. The biomass was separated into leaves (including petioles) and branches. For biomass estimation only the system of harvesting the whole tree was analysed.

2.3 Measurements

The components were weighed fresh and samples taken for dry matter (DM) determination by micro-wave radiation (Undersander et al 1993).

2.4 Statistical model and calculations

The data were presented as averages and ranges for each parameter that was measured.

3. Results and discussion

3.1 Coconut:

Twelve families in two target villages were interviewed. The palms were planted at various densities, from 25 m^2 to 49 m^2/palm with an average of 37 m^2/palm, which is a range from about 204 to 400 palms/ha (average 302 palms/ha) (Table 1). The yield of nuts varied from 42 to 65 nuts/palm/yr (average 54 nuts), which is about 8568 to 26000 nuts/ha/yr (average 17284). The farmers sold the nuts to middle-men at an average of 0.08 $/nut. The middle-men sold the nuts to retailers at about the average of 0.16 $/nut and the retailers sold the nuts at higher prices (0.25 $/nut) for use as a source of food/ drink. The average return to the farmer was estimated to be from 1383 to 4321 $/ha (average of 2852 $/ha).

Table 1: Data from the survey used to calculate the added value to coconut production by producing electricity from the fibrous waste discarded when the nuts are used as source of drink

	Range	**Average**
Plantation density, m2/palm	25 – 49	37
Palms/ha	204 – 400	302
Nuts/palm/yr	42 – 65	54
Nuts/ha/year	8568 – 26000	17284
Selling cost, $/nut	0.08 - 0.25	0.16
Whole nut sales, $/ha/yr	1383 - 4321	2852
Husk & shell, kg DM/ha*	4198 - 12740	8469
Energy from coconut, kwh/ha/yr**	4665 - 14156	9410
Gross income from husk & shell, $/ha/year***	1166 - 3539	2352
Total gross income from food & energy, $/ha/yr		5204

** Husk & shell 0.49 kg DM/nut*

*** Efficiency, 0.9 kwh/kg husk-shell DM (paper I)*

**** Electricity price 0.25 $/kwh*

The green nuts were only partly used by the customers, usually only the coconut water was drunk and the other part (shell and husk) was discarded. Based on the husk+shell yield (Table 1), the potential of husk+shell (DM)/year was from 4198 to 12740 kg/ha/yr (average 8469 kg DM/ha). This amount of husk+shell when used in the gasifier (Paper I) can produce 4665 to 14156 kwh of electricity (average 9410 kwh), that can generate a gross income of 1166 to 3539 $/ha/yr (average 2352 $/ha). The total gross income from the system was estimated to be 5204 $/ha/yr, of which 45% corresponds to the energy from the fibrous residue from the nuts.

3.2 Mulberry

The production of stem DM at the second harvest (after 56 days of regrowth) was in the range 7.2 to 16.4 tonnes/ha/yr (Table 2). The yields increased linearly in response to nitrogen application (0 to 700 kg N/ha). These amounts of stem were estimated to produce from 6141 to 13936 kwh of electricity annually, assuming an efficiency of 0.85 kwh of electricity/kg biomass DM (Paper I). The gross income from mulberry stems/ha/yr was thus 1535 to 3484 US $ by way of gasification, based on the electricity price of US $ 0.25/kwh (range in Cambodia is from 0.13 to 0.5 US $/kwh).

Mulberry leaf is widely used as a protein source for many kinds of livestock. The leaf yield ranged from 2.7 to 8.4 tonnes DM/ha, equivalent to a crude protein yield of from 0.2 to 1.6 tonnes/ha/yr (Table 3). It was assumed the value of the protein was the same as that in dried fish (US $ 0.91/kg protein). The estimated values of the protein were thus from 219 to 1486 US $/ha.

Table 2: Data used to calculate the added value to mulberry trees when the stems are used as feedstock for a gasifier unit producing electricity (biomass data from Chiev Phiny, personal communication)

N, kg/ha	Stem, kg/plot*	DM %	DM tonnes/ha/yr	Electricity kwh/ha/yr**	Electricity US$/ha/yr***
0	10.0	46.1	7.2	6141	1535
100	12.9	44.2	8.9	7606	1901
250	20.0	40.3	12.6	10733	2683
400	19.0	41.2	12.3	10430	2607
550	29.2	37.8	17.3	14721	3680
700	32.9	31.8	16.4	13936	3484

** Plot area 38.25 m²; period of re-growth 56 days*
*** Gasifier efficiency, kwh/kg biomass DM is 0.85 (Paper I)*
**** Electricity is 0.25 US $/kw*

The combined value of energy and feed from the mulberry foliage was in the range of 1754 to 4970 US $/ha/yr, according to the level of N fertilization (Table 4). The proportion of the gross income derived from the energy component was from 70.1 to 87.5 % of the total gross income.

Table 3: Data used to calculate the added value to mulberry trees when the leaves are used as protein (CP) source for live stock (biomass data from Chiev Phiny, personal communication)

N kg/ha	Leaves * kg/plot	DM %	Leaf DM, tonnes/ha/yr	CP, %DM	CP tonnes/ha/yr	Value** US $/ha
0	27.4	37.8	2.7	8.9	0.2	219
100	33.9	33.3	3.0	12.2	0.4	327
250	42	32.5	3.6	15.2	0.5	493
400	47.6	39.9	5.0	16.2	0.8	731
550	63.9	31.7	5.3	18.1	1.0	869
700	74.1	43.1	8.4	19.6	1.6	1486

** Plot area 38.25 m²; period of re-growth 56 days*
*** Protein valued at 0.91 US $/kg*

3.3 Cassava

The yield of cassava in Kompong Cham province (high yield region) was very high (Table 5), with average leaf production of 9438 kg/ha (2934 kg DM/ha) and root yield of 104688 kg/ha (45627 kg DM/ha). The yield of stems was 60313 kg/ha (fresh basis) and 23494 kg DM/ha. In the low yield region, the production was much lower.

Table 5: Cassava production (high and low yield regions) in terms of food/feed and energy

Components	Yield, kg/ha (fresh)	Yield, kg/ha (DM)	Value (USD/ha)
High yield region			
Leaves	9438	2934	558[a]
Root	104688	45627	5234[b]
Stem (gasifier)	60313	23494	6910[c]
Total			**12702**
Low yield region			
Leaves	1552	399	76[a]
Root	5539	1957	692[b]
Stem	4886	1436	422[c]
Total			**1191**

[a] CP of leaves 20.9 % in DM and 0.91 USD/kg protein

[b] Fresh root 0.05 USD/kg in high yield region and 0.125 $/kg in low yield region;

[c] Electricity (0.85 kwh/kg DM [Paper I]) at 0.25 USD/kwh

In the high yield region, the roots are used for starch production (Figures 1 to 4) but in the low yield region they have a higher sale value as they are used as human food. The amounts of electricity produced from the stems, using the conversion factor of 0.85kwh/kg stem DM (Paper I), was estimated to be 16970 kwh/ha in the high yield region and 1221 kwh/ha in the low yield region.

Figure 1: Cassava high yield

Figure 2: Stems were burnt to clear up the farm

Figure 3: Leaves not used **Figure 4:** Slight use of stems

3.4 Cassia stamea

One year after planting on the poor soils in CelAgrid (Figures 5 and 6), the total biomass production from *Cassia stamea* was 4.82 tonnes/ha in DM (Table 6). After gasification (Paper I), this would yield 4120 kwh/ha/yr with a value of $ 1030/ha. The leaves and petioles have potential value as sources of mulch or compost or as substrates for earthworms. However, there are no data available on which to base the potential income from this source. If the branches had been sold for firewood ($ 0.041/kg dry wood) the income would have been $ 197.

Table 6. Potential of *Cassia stamae* for production of electricity through gasification of the fibrous trunk and branches

Components	**Yield tonnes DM/ha/yr**	**Electricity kwh/ha/yr**	**Electricity $/ha/yr**
Leaves & petioles	2.83		
Tree/twig/branch	4.82	4120	1030[a]

[a] The comparable value as firewood is 197 USD.

Figure 5: *Cassia stamea* growing in dry season

Figure 6: Planting *Cassia stamea* along the canal and fence

The data presented in Table 7 indicate the potential for adding value to three tree crops (coconut, mulberry and cassava) by processing the non-edible fibrous biomass into electricity by gasification. This assessment could not be made with *Cassia stamea* as the tree has no food / feed value. The likely impact in a practical situation will depend on many factors, such as plant population, soil fertility and harvest frequency. Thus Saddul et al., (2004) showed that the DM yield of mulberry stems increased from 1.0 to 7.2 tonnes/ha/year, with almost no change in the leaf DM yield (5.0 – 5.9 tonnes/ha/year), when the harvest interval was increased from 3 to 9 weeks. The implication is that new management practices may be needed when the aim is to derive both energy and feed from a given cropping system.

Table 7: Estimates of added gross income from conversion of the non-edible fibrous biomass into electricity through gasification

	Coconut	**Mulberry**	**Cassava High yield**	**Cassava Low yield**	***Cassia stamea***
Food / feed	2852	1486	5792	768	0
Energy (electricity)	2352	3484	6910	422	1030
Total	5204	4970	12702	1190	1030
Added value from the energy component, %	82	234	104	55	