Research article

Assessment of Sustainable Energy Potential of Non-Plantation Biomass Resources in Sameakki Meanchey District in Kampong Chhnang Province, Cambodia

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Abstract Biomass has always been a major source of energy for mankind, and accounts for about 14% of the world's total energy supply. Biomass is a clean energy resource, considered neutral on CO_2 emissions, that has a high potential for meeting increasing energy demands as a substitute for fossil fuels. Biomass energy sources are abundant in Cambodia. We assess the energy potential of the following non-plantation biomass resources: (1) agricultural residues, (2) animal manure. The production of agricultural residues and animal manure was based on the production of crops obtained from the National Census 2008 and one study site. This information was categorized into: (i) primary residues (paddy straw, sugarcane tops, maize stalks, empty coconut bunches and fronds, palm oil fronds and male bunches etc.) and, (ii) secondary residues (paddy husks, bagasse, maize cobs, coconut shells, coconut husks, coir dust, saw dust, palm oil shells, fiber and empty bunches, etc.), and (iii) animal manure. The estimation of residue generated can be calculated from the residue to product ratio (RPR). To estimate the potential for deriving additional energy from a residue, it is important to establish the present utilization pattern of the residue. The results of energy potential analysis indicate that agricultural residues could have produced 212.11 GJ in 2010. The total annual potential of biogas from animal manure in 2006, 2007 and 2008 was 1357.96 thousand m^3, 1432.89 thousand m^3 and 1452.66 thousand m^3, respectively, and the corresponding energy potential was 29.87 GJ, 31.52 GJ and 31.96 GJ, respectively. If this energy potential can be developed in order to meet the demand for energy, it can reduce the pressure on natural forests, the impact on human health, especially of women and children, and the amount of greenhouse gas emissions.

Keywords biomass, conservation, energy potential, residues, sustainable energy

INTRODUCTION

Biomass has always been a major source of energy for mankind, and accounts for about 14% of the world's total energy supply. The term biomass refers to all organic materials that originate from living organisms e.g. wood, agricultural residues, animal manure etc. Biomass sources are therefore diverse(Bhattacharya et al. 2005). Biomass is a clean energy resource that shows high potential as a substitute for fossil fuels and to meet the world's increasing energy demand.

Biomass energy sources are abundant in Cambodia. Fuelwood is the most common source of energy for the majority of the population in the Kingdom. Firewood and charcoal are often referred to as traditional fuels, yet they remain the dominant source of energy for cooking within the domestic sector, and are used extensively by industry and the service sector. The Statistical Yearbook 2008 published by the National Institute of Statistics reported that fuelwood was by far the most commonly used fuel for cooking purposes; 85.0% of Cambodian households in 2007. Around 98.2 percent of rural households used fuelwood and charcoal.

In Sameakki Meanchey district in Kampong Chhnang province, fuelwood is the main energy source for cooking, boiling water, preparing animal feed and protecting cattle against insects. Approximately 96% of the households in the district depend on fuelwood as a primary energy source for cooking along with other energy types such as charcoal, animal dung, crop residues, LPG, kerosene, and biogas(San et al. 2012a). Kerosene was the main energy source used by local people (60.5%) for lighting (San et al. 2012b). Other energy sources used for lighting among the 767 households interviewed were rechargeable batteries, 57.9%, and electricity, 5.1%.

Although wood biomass is important for people in Sameakki Meanchey district, non-plantation biomass is an alternative energy source that could reduce pressure on natural forests by reducing fuelwood dependency for cooking and boiling water and reduce greenhouse gas (GHG) emissions.

OBJECTIVE

The objective of this study is to assess the sustainable energy potential of the following biomass resources in Sameakki Meanchey district, Kampong Chhnang province, Cambodia: (i) agricultural residues, (ii) animal manure, and (iii) fuelwood saving potential through improved efficiency.

METHODOLOGY

Site description

Sameakki Meanchey District located in the south western Kampong Chhnang Province was selected as the study area. The district lies in the south of the province and shares a border with Kandal and Kampong Speu Provinces to the south. The district is subdivided into 9 communes (*Khum)* and 85 villages *(Phum)*. The total number of households in 2010 was 15,516 households of which the total population was 73,303 people (NCDD, 2010). The average household size was 5.37 (Mode = 5) (San et al. 2012a).

Non-plantation energy potential assessment

This section presents the methodologies used to assess the potential of the different non-plantation resources considered in this study. These can be categorized into: (i) primary residues (paddy straw, sugarcane tops, maize stalks, coconut stalks and fronds, palm oil fronds and male bunches etc.) and, (ii) secondary residues (paddy husk, bagasse , maize cobs, coconut shells, coconut husks, coir dust, saw dust, etc.), (iii) animal manure, and (iv) fuelwood released through efficient improvement. The production data of each non-plantation biomass resource was obtained from the homepage of the National Committee of Sub-National Democratic Development (NCDD, 2010).

Primary and secondary residues: The term agricultural residue is used to describe all the organic materials which are produced as by-products from harvesting and processing of agricultural crops. Agricultural residues, which are generated in the field at the time of harvest are defined as primary or field based residues (e.g. rice straw, sugar cane tops), whereas those co-produced during processing are called secondary or processing based residues (e.g. rice husk, bagasse). The availability of primary residues for energy applications is usually low since collection is difficult and they have other uses as fertilizer, animal feed etc. However secondary residues are usually available in relatively large quantities at the processing site and may be used as captive energy sources for the same processing plant involving little or no transportation and handling cost. The energy potential of various primary and secondary residues was estimated.

Energy potential of the residues: The estimation of residue generated was calculated on the basis of the residue to product ratio (RPR). To estimate the potential of deriving additional energy from a residue, it is important to establish the present utilization pattern of the residue (Bhattacharya et al.

1999).

$$ARG = \sum (RPR \times AH),$$

$$EP_{residue} = ARG \times (SAF + EUF) \times LHV_{residue}$$

Where ARG is the amount of a residue generated annually (t yr^{-1}), RPR is the residue production ratio, AH is the annual harvest of the crop or product (t), $EP_{residue}$ is the total energy potential of residue (J t^{-1}), SAF is surplus availability factor (dimensionless), EUF is the energy use factor (dimensionless), and $LHV_{residue}$ is the lower heating value of residue (J t^{-1}).

Fuel characteristics: Moisture content of residues normally varies widely at different stages of harvesting and storage. The moisture content of a residue influences its fired heating value and should be known. A review of RPR values at different moisture content and lower heating values (LHVs) for different residues was carried out by Bhattacharya et al. 1996. The RPR values reported by them can be used for estimating the energy potential of agricultural residues; however, country-specific RPR and LHV values should be used wherever possible.

Animal manure: Animal manure is principally composed of organic material, moisture and ash. Decomposition of animal manure can occur either in an aerobic or anaerobic environment. Under aerobic conditions, CO_2 and stabilized organic materials (SOM) are produced. Under anaerobic conditions, CH_4, CO_2, and SOM are produced. Since the quantity of animal manure produced annually can be substantial, the potential for CH_4 production and hence energy potential of animal manure is significant. Energy potential of recoverable animal manure is estimated by Bhattacharya et al. 1997. A preliminary estimation of energy potential of animal manure was reported by Bhattacharya et al. 1997. The amount of dry matter from an animal, recoverable fraction of animal manure, volatile solid fraction, and biogas yield values reported by them, could be used for estimating the energy potential of animal manure.

Fuelwood released through efficiency improvement: In the household sector, large amounts of fuelwood are consumed, normally in inefficient traditional stoves, for cooking and water boiling purposes. Energy saving through improved cooking stoves is discussed in this paper. A methodology for estimation of fuelwood released through efficient improvement was reported by Bhattacharya et al. 1999.

RESULTS AND DISCUSSION

The potential for energy production from crop residues

The main occupation of households in the study is farming. Rice paddy is the main crop in the study area. The other major crops grown in the study area are corn, peanuts, and cassava. During the dry season, farmers in the research area could not grow rice because they lacked a water source for irrigation. Rice production per ha in 2008 ranged from 1ton to 2.5 ton. It is necessary to note that total production of corn, peanuts and cassava increased in 2007 but declined in the following year because production demand decreased.

Table 1 Types of crop residues, RPR and calorific value for agricultural residue

Crop	Residue	Moisture (%)	RPR	Energy use Factor	Surplus availability factor	LHV (MJ kg^{-1}) (as received)
Rice	Straw,	8.17	0.447	0.000	0.684	8.83
	Rice husks	8.83	0.230	0.531	0.469	12.85
Corn	Stover, cobs	8.65	0.250	0.193	0.670	16.63
Peanut	Straw, leaves, shell	--	2.663	0.007	0.760	18.00
Cassava	Stalks	--	0.088	0.000	0.407	16.99

Source:(Sajjakulnukit et al. 2005)

The crops grown in the study area produce various types of crop residues. These residues arise from the harvesting of these crops and their subsequent processing into various products. The data in Table 1 shows the types of crop residues found at the study site. The estimated energy potential is performed based on residue product ratio (RPR) and as received calorific values as shown in Table 1.

Greater rice production in comparison to other crops in the study area contributed to high availability of rice residues such as rice husk and rice straw. Rice husk, also called rice hull, is the outermost layer of the paddy grain. It is separated from brown rice during the first step in the milling process. The unutilized rice husk mainly causes waste disposal problems and breathing problems because of its low density but could be an option for biomass energy systems. The use of rice husk as a solid fuel may be a promising way to avoid these problems and provide considerable amounts of useful energy (Chungsanguit et al. 2010). Rice straw is another by-product of rice and a great bio-resource since it is one of the richest materials in terms of its lignocelluloses (Yoswathana et al. 2010). However, it is important to note that rice straw is also an import fodder for animals in Cambodia. Table 2 shows the estimated energy potential from agricultural residues in 2008. The production of agricultural residue is calculated based on the production of crops obtained from the National Committee for Democratic Development in 2010. Total of estimated energy potential from crop residues is approximately 212.11 GJ in 2008.

Table 2 Energy potential of agricultural residues in 2008

Product	Residue	Production (tonne)	Residue available for energy (tonne)	Energy potential (GJ)
Rice	Straw,	31,537	14,097.00	85.14
	Rice husks		7,254.00	93.21
Corn	Stover, cobs	35	8.75	0.13
Peanut	Straw, leaves, shell	913	2,431.32	33.57
Cassava	Stalks	95	8.36	0.06
			Total	212.11

The potential for energy production from animal manure

In the study area the most important animals are cattle/buffalo, pigs, chickens and ducks. Other livestock includes goats, sheep and horses, but the numbers are comparatively small. Livestock farms produce polluting wastes. Traditionally their disposal has been by direct use as fertilizers or in some instances as landfill. These methods cause severe environmental problems such as odour, contamination of water, methane emission etc. The present study focused only on cattle/buffalo, pigs, chickens and ducks. Livestock populations over three years were obtained from the National Committee for Democratic Development 2010 (NCDD 2010).

Table 3 Dry matter, recoverable fraction, and volatile solid of animal waste

Animal	Number (head)			Fresh Waste* (kg head^{-1} d^{-1})	Recoverable fraction*	Dry mater* (DM) (%)	Volatile solid* (%)
	2006	2007	2008				
Buffalo/cattle	37,922	40,773	40,960	12.40	0.50	17.77	13.64
Pig	15,319	13,900	15,190	1.50	0.80	35.22	24.84
Chicken	42,402	43,368	46,282	0.03	0.80	33.99	22.34
Duck	2,462	2,780	2,151	0.03	0.40	26.82	17.44

**Source: (Sajjakulnukit et al. 2005)*

Values for different characteristics of animal manures considered in the present study, such as dry mater, fraction recoverable as well as physical and chemical properties are given in Table 3. The heating value of biogas is taken as 22 MJ m^{-3} (IPCC, 2006). The estimated amount of animal manure recoverable, the potential of biogas production and the total potential of energy from animal manure are presented in Tables 4 and 5. The total annual potential of biogas from animal manure in 2006, 2007 and 2008 is 1357.96 thousand m^3, 1432.89 thousand m^3 and 1452.66

thousand m^3, respectively, and the corresponding energy potential is 29.87 GJ, 31.52 GJ and 31.96 GJ, respectively.

Table 4 Biogas yield and recoverable DM of animal manure

Animal	Number (head)			Recoverable DM (tonne DM yr^{-1})			Biogas yield (m^{-3} kg^{-1} VS)
	2006	2007	2008	2006	2007	2008	
Buffalo/cattle	37,922	40,773	40,960	30499.53	32792.51	32942.91	0.286
Pig	15,319	13,900	15,190	2953.53	2680.33	2929.08	0.217
Chicken	42,402	43,368	46,282	157.82	161.41	172.26	0.242
Duck	2,462	2,780	2,151	7.23	8.16	6.32	0.310

Table 5 Energy potential from animal manure

Animal	Number (head)			Amount of biogas (Tm^{-3} yr^{-1})			Energy potential (GJ)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Buffalo/cattle	37,922	40,773	40,960	1189.80	1279.25	1285.12	26.18	28.14	28.27
Pig	15,319	13,900	15,190	159.23	144.48	157.89	3.50	3.18	3.47
Chicken	42,402	43,368	46,282	8.53	8.73	9.31	0.19	0.19	0.20
Duck	2,462	2,780	2,151	0.39	0.44	0.34	0.01	0.01	0.01
			Total	1357.96	1432.89	1452.66	29.87	31.52	31.96

Fuelwood saving through efficiency improvement

The New Lao stove, known as the Cambodian improved stove, is the most frequently used stove type in the study area (33%), followed by the Three Stone stove (18%), the Siam and Lao Kompong Chhnang stove (13%), the Traditional Lao stove (10%), the Korng Rey stove (9%), the self-made or clay stove (2%) and the Samaki stove (2%) (San et al. 2012a). The study conducted by San et al. (2012) reports that more than 50% and 35% of households in the study area owns 2 stoves or 1 stove, respectively. Some households use two different types of stove in their household. Therefore, we assumed that households were using the same type of traditional stove in their household in order to calculate fuelwood saving by switching from inefficient traditional cooking stoves to improved cooking stoves (Table 6). We also assume that all traditional cooking stoves are replaced by New Lao Stove, which is a more energy-efficient cooking stove. The average fuelwood consumption rate per family per year for cooking and boiling drinking water in study area is 1.87 and 1.02 tonne (San et al. 2012a).

Table 6 Biomass saving potential in residential cooking and boiling drinking water

Type of stove	Fuelwood consumption (tonne family^{-1} year^{-1})	Efficiency (%)		Saving potential	
		Traditional stove	Improved stove	(t)	(GJ)
Three Stone	2.89	10	25	0.61	27.74
Siam	2.89	15	25	0.40	18.50
Loa Kampong Chhnang	2.89	16	25	0.36	16.65
Traditional Loa	2.89	11	25	0.57	25.89

CONCLUSION

All biomass residues including primary and secondary residues have the potential to provide 244 GJ in 2008. Rice straw and rice husks have higher energy potential compared to other crop residues because of their ready availability in large quantities. Animal manure, which produces 31.96 GJ in 2008, is considered to be the main resource for biogas production. Improving the efficiency of biomass use for cooking and boiling drinking water through improved cooking stoves can save huge amounts of fuelwood per family per year. More than 16 GJ per family per year were saved when local households in the study area switched from inefficient traditional to energy-efficient cooking stoves.

The results of the study clearly indicate that non-plantation biomass residues provide a promising potential energy source for local people in the study area. If this potential energy source can be developed to meet their energy demands, it could reduce; the pressure on natural forest, the impact on human health, especially women and children, and greenhouse gas emissions.

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