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A STUDY OF TERENGGANU'S BIOMASS ENERGY POTENTIAL FROM FORESTRY WASTES VIA MATERIAL FLOW ANALYSIS (MFA) APPROACH

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Abstract: This paper discusses the potential for producing biomass energy of forestry and sawmill residues located in the Terengganu region, Peninsular Malaysia by considering the inventory data from 2005 to 2010. In this study, the Material Flow Analysis (MFA) approaches were used to investigate the energy accumulation and the flux of forestry production system. The results depicted that the input of biomass energy from sawlogs residue was found to be the highest in forest production system. The results further exhibited that the total recycled and reused wood residue was the poorest in the region among other regions in Malaysia. This study also revealed the long run relationship between the trade import-export demand and explanatory variables in forest products. This study provided important information on the implementation of sustainable management of forest system viable biofuel production systems.

KEYWORDS: Material Flow Analysis (MFA), forestry, biomass energy, Terengganu.

Introduction

The Material Flow Analysis is an environmental management tool used especially to support environmental policy decision making (Fischer-Kowalski *et al*., 2011; Graham *et al*., 2011 and Chu-Long *et al*., 2012). Feasibility MFA methods in analysing the forest resources flow represent the scientific basic data, reveal the hidden emissions, and provide the signal warning of environmental problems (Bouman *et al*., 2000). Several studies on the relationship between material and energy flow in a forest system measured using MFA tools had been undertaken (Korhonen and Niutanen, 2003; Antikainen *et al*., 2003; Marko *et al*., 2000; and Monika *et al*., 2011). Some studies presented the determination of biomass energy in wood residue using MFA techniques (Radoslava *et al*., 2011). For developing countries, MFA is applied successfully to describe the "physical economy" and to solve the considerable data scarcity and uncertainty problems (Krausmann *et al*., 2004). Nevertheless, MFA approach has not been commonly applied specifically to the forestry sector in Malaysia region. Therefore, the objective of the present study is to determine the biomass energy flow in wood waste of forestry production system using the MFA approach in developing a decision support model to support the identification of suitable policy for regional sustainability development regarding forest utilisation.

Methods and Data Sources

Methodology

In order to identify the pattern of biomass energy flow in a particular area, the distribution of forest residue that best fits the data has to be considered. In this study, five categories of waste streams namely sawn timber, plywood, veneer, sawlogs, and moulding were used to model the distribution of energy flow along with the MFA techniques. The MFA modelling framework for the Terengganu region was constructed using the following steps, which were introduced by (Baccini and Brunner, 1991):

(1) A system analysis comprising of goods, processes and system boundary.
(2) The measurement of all goods per unit time.
(3) The calculation of the element fluxes.

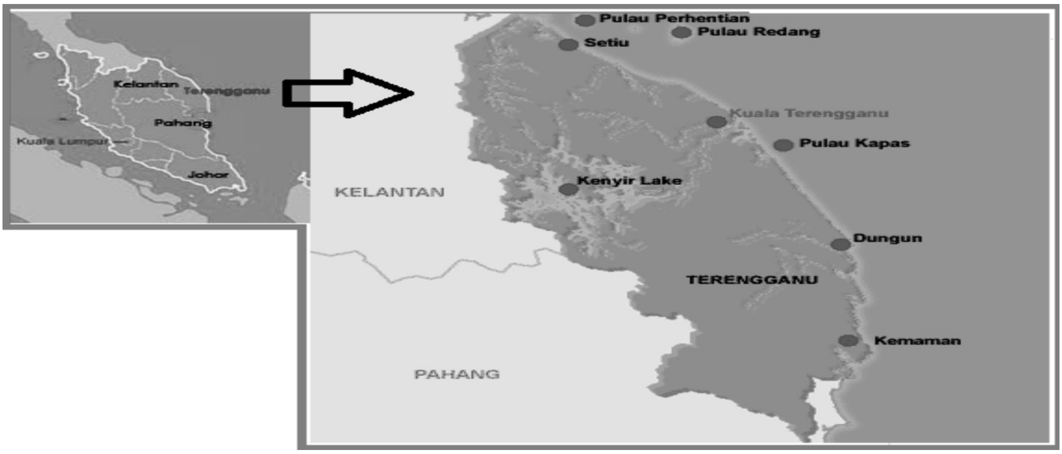


Figure 1: Location of the Region of Terengganu.

(4) Interpretation and presentation of the results.

About the Data

Forest and wood processing residue data starting from year 2005 until 2010 in the present study were obtained from Forest Department of Peninsular Malaysia and Department of Statistics Terengganu (DSM, 2012; FDPM, 2011; and MTC 2011). The data concerning clearing of forest lands, collecting deadwoods, cutting and lopping trees, and trees growing for private land, agricultural lands and communal lands were not considered in this study. The unit of energy used in this study was in Giga Joules per year and the amount of wood residue was defined as solid cubic meters.

Mathematical Formula

In order to calculate the obtained data, the MFA mathematical formula was applied at different goods and process to determine the amount of biomass energy input and output follows a particular probability uncertainty involves. The formula is given by (Bhattacharya *et al*., 2005):

$$RV = MPV \times RPR/(100 - RPR) \quad (1)$$

$$EP = RV \times LHV \quad (2)$$

where:
RV = Residue volume (m^3)
MPV = Main product volume (m^3)
RPR = Residue production ratio (%)
EP = Energy potential (toe)
LHV = Lower heating value (toe/m^3)

Case Study Setting

Terengganu is a green state located in the northeastern Peninsular and comprises an area of 12,955 km² (see Figure 1). It has a population of 1.05 million inhabitants, mainly 94% of the ethnic are Malay. The average temperature ranges from 23 ºC in February to 32 ºC iin October. Forest is the most important domestic natural resource of Terengganu today. In year 2010, the Gross Domestic Product (GDP) from forestry and agriculture sector was 9.5% (RM 1447 million) with the manpower used in this forestry sector was around 8.45 thousand employees (EPU, 2011). The land used for forest reserve is 544,000 hectares while the area opened for logging is 2,800 hectares. In year 2005, for forestry industry, Terengganu's main forest products were dominated by sawlogs production (711,400 m^3) followed by plywood and veneer (124,200 m^3) (FDTS, 2006). In year 2007, Terengganu was identified as an excellent region for bioenergy plant development due to its relatively high potential of production of biomass residues from wood residues forest residues. According to Poh and Alexander (2005), Terengganu region is abundant with biomass residue as it is one of the most reserved places in Peninsular Malaysia.

Table 1: Summary of the Profiles of Forestry Land in Terengganu in Year 2010.

Type of land	Areas (hectares)
Peat swamp forest	13,757
Dry inland forest	525,206
Forest plantation	544,118
Mangrove forest	1,295
Gazetted protected area:	
(a) Taman Negara Terengganu	103,082
(b) Santuari Penyu Rantau Abang	-
(c) Rezab Tuntung Bukit Palong	1.0
Permanent reserved forest (PRF)	544,118
The area opened for harvesting	11,920
Forested area	654,625

Source: (FDPM, 2010)

	2005	2006	2007	2008	2009	2010
Blackboard	0	0	0	0	0	0
Logs	522738	493859	403786	388262	304389	560138
Sawn timber	414927	389558	368439	358308	295529	339548
Plywood	23697	18448	24382	10473	2731	5044
Veneer	10074	4616	1095	0	0	0
Moulding	35260	31258	30452	25499	24007	23959

Figure 2: The Various Forest Production of Logging and Timber Processing in Terengganu from 2005 to 2010.

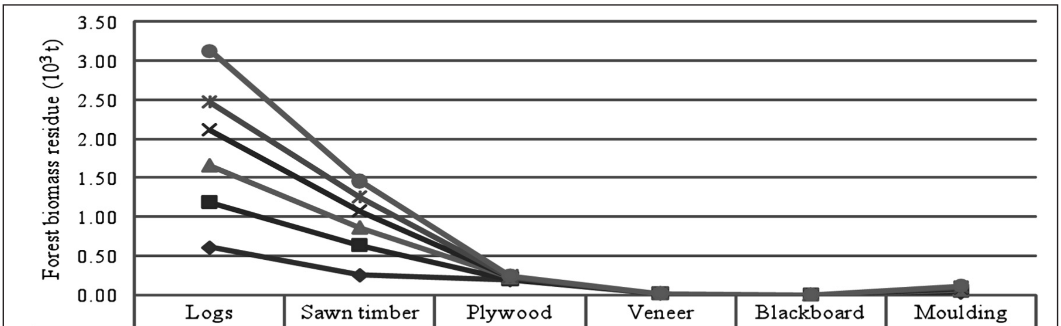
Results and Discussion

Forestry Profiles in Terengganu

The total forest land area in Terengganu was about 12,956 km^2 in year 2010. As shown in Table 1, the forested areas mostly consist of dry inland forest, peat swamp forest and mangrove forest which are sparsely populated with a variety of species, the dominant genera being Balau, Kapur, Kelat, Kempas, Keruing, Medang, Meranti Tembaga, and Nyatoh. Structurally there are 384 mills in Terengganu mostly consists of 215 furniture mills, 85 sawmills, 64 charcoal mills, 16 moulding mills, and 4 plywood mills. In year 2010, Terengganu was the second largest state in Peninsular Malaysia after Pahang in the wood-based industry with a total of 100 sawmills, 4 veneer/plywood mills, and 15 moulding mills.

Forest Production

The results of the forest production of particular types of forest and wood processing in Terengganu are presented in Figure 2. The types



	Logs	Sawn timber	Plywood	Veneer	Blackboard	Moulding
2010	0.66	0.20	0.00	0.00	0.00	0.02
2009	0.36	0.18	0.00	0.00	0.00	0.02
2008	0.45	0.22	0.01	0.00	0.00	0.02
2007	0.47	0.22	0.02	0.00	0.00	0.02
2006	0.58	0.39	0.02	0.01	0.00	0.02
2005	0.61	0.25	0.19	0.01	0.00	0.02

Figure 3: Annual Forest Biomass Residue Production in Terengganu.

of timber products including logs, sawn timber, plywood, veneer, moulding, and blackboard represent the total average of the six year period is 2,555,238 m^3. As calculated, nearly one-sixth of wood products by means of 445.5×10^3 t/yr belong to sawlogs products. In year 2010, Terengganu was the fourth largest producer of logs in Malaysia is 560,138 m^3 (13.5%). The results clearly demonstrate the highest of logs harvested represent the excess growth of forest resources in Terengganu which provides a potential woody biomass feedstock for energy production and other forest products. Moreover, previous study done by FRIM (FDPM, 2011) signified that saw logs production from Permanent Reserve Forest (PRF) and outside of PRF in Terengganu between 2006 to 2010 accounted for about 2,150,439 m^3 or in an average of 430,087.8 m^3 per year. Out of this amount, about 57% of total log production was contributed from big logs with diameters > of more than 45 cm (Poh and Alexander, 2005).

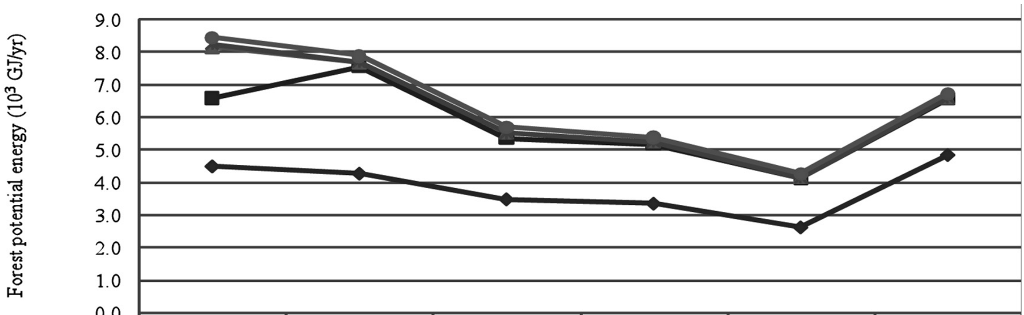
Forest Biomass Residue

Figure 3 shows the annual potential of forest biomass residue in the study. The recovery rate of forest biomass residue was taken from related literature (IEA, 2007 and Kuboyama, 2005), varying between 0.65 and 1.0. As can be seen, the sawlogs and sawn timber residue distribution increased gradually to 2006 and after reaching a certain changes in year 2010 and both average values were 0.52 × 10^3 t (sawlogs) and 0.24 × 10^3 t (sawntimber). The recovery rate in the form of bark is 12 % in the form of slabs, edgings, and trimmings are 34 %; and in the form of sawdust is 12 % of the log input. Moreover, the average generated residue of wood in five years is 0.83 × 103 m^3 assuming that 0.5 m^3 wood residues generated in the sawmill is capable of generating about 120 kWh of electricity and the electricity production from wood residue is 198 MWh/yr (Suzuki and Yoshida, 2009).

Energy Flow in Forest Production System

Comparison of Forest Biomass Energy from 2005 to 2010

Figure 4 shows the results of the estimated forest biomass energy flow in Terengganu based on the MFA method for indices over the period from 2005 to 2010. The results show that the total average of forest energy potential is 6.4 GJ E/yr. On the other hand, the results quantify for 6 groups wood biomass energy are 60% for logs, 31% for sawntimber, 5% for plywood, 3% for moulding and 1% for veneer. As this



	2005	2006	2007	2008	2009	2010
Moulding	0.2	0.2	0.2	0.1	0.1	0.1
Blackboard	0.0	0.0	0.0	0.0	0.0	0.0
Veneer	0.1	0.0	0.0	0.0	0.0	0.0
Plywood	1.6	0.1	0.2	0.1	0.0	0.0
Sawn timber	2.1	3.3	1.9	1.8	1.5	1.7
Logs	4.5	4.3	3.5	3.4	2.6	4.8

Figure 4: Estimated Forest Biomass Energy Flow in Terengganu.

Figure shows, the highest forest biomass energy accumulated was accounted in the year 2005 with the average sum of 8447 GJ E /yr, followed in year 2006 (7889 GJ E/yr), in the year 2010 (6729 GJ E/yr), in the year 2007 (5693 GJ E/yr), in the year 2008 (5393 GJ E/yr) and in year 2009 (4281 GJ E/yr). Based on the results reported in Figure 4, the main conclusion is the significant contributor to the highest potential energy of all wood products in this region is sawlogs with total average of 3852 GJ E/yr.

MFA Schematic Diagram for Forest Production System

Once through the experiment using a single of the MFA methodology of section 2, it is known which number of goods and processes gave energy balance. The MFA layouts for biomass energy flow (or was known as aggregate model) are presented in Figure 5. The following groupings have been identified in the MFA energy model and can be explained in the following ways:

a) by logging residues component (for e.g: bark, stumps, branches, broken logs, defective and injured standing trees),
b) by saw milling residues (for e.g: sawdust, offcuts, bark, slabs, and shaving),
c) by plywood and veneer residues (for e.g: veneer cores, defective ends and irregular pieces of veneer sheets),
d) by moulding residues (for e.g: sawdust, plane shavings, small pieces of lumber trimming, edging, bark and fragments),
e) by untreated wood (the wood residue generated from PRF and SLF).

Additional factors taken into account by the model are as follows:

- The theoretical lower heating content (LHV) for logging residue is 7.4 GJ/m^3, and 8.4 GJ/m^3 for mill residues and plywood residues (Suzuki and Yoshida, 2009).
- In Terengganu, the volume of forest was estimated at an average of 281 m^3/ha for eight squares of tree growth and more than 400 m^3/ha for natural forest volume, which is equal to 42.31 m^3/ha of net timber output from 135,731.80 m^3 of annual timber production between 1986 and 2003 (FDTS, 2009).

Figure 5 shows that the total input of energy flow for 2010 from woody biomass was 11.85 × 10^3 GJ E/yr. The figure also shows that the highest energy distribution was accounted for roundwood product (35%), indicating that these

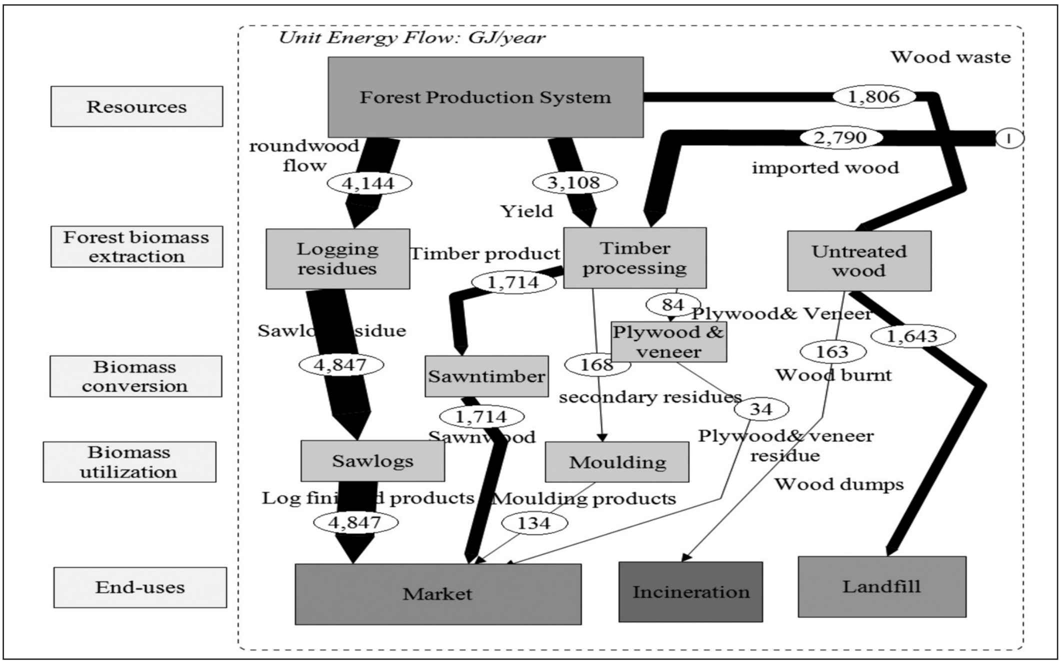


Figure 5: MFA Schematic Diagram for Biomass Energy Flow in Forest System in Terengganu in 2010.

goods were significant for energy uitilisation. This was followed by sawn timber products (26%). Goods of saw logs and sawn timber are the key element for evaluating the energy distribution in this region due to the existence of strong correlation during direct transformation of sawlogs. According to Andersen (1999a), approximately 64% of the volume of logs was recovered as sawn timber. However, about 15% of the total tree harvested was lifted at site as tree branches and leaves (equivalent to 1 cubic meter of sawlogs = 0.176 m^3 unwanted branches and leaves) (Lim *et al*., 2000). Further study done in Terengganu, also highlighted that two-thirds of logging residues generated from tree were damaged or destroyed during road construction, logging, and extraction. Therefore, only a small energy flow was used directly in the energy production in this region from the forest.

In total, about 2.79 × 10^3 GJ E/yr from energy flow in round-wood is imported from Pahang and Kelantan to be used in the industry because the annual cuttings of forests in Terengganu are less than the annual growth of the trees. However, the export of wood product is low compared to the import. According the terms of untreated woody biomass, natural forests from Permanent Reserved Forest (PRF) and State Land Forest (SLF) produce, an average of 0.22 million m^3 residues with the total energy flow was estimated at 1.81 × 10^3 GJ E/yr (16%). About 87% of the energy flow was annually transported to landfills. The rest for 13% of energy annually is released to the air from the burning of wood based fuels. In other words, the total output of energy bound annually into the domestic market use is about 6.72 × 10^3 GJ E/yr. The cutting waste, energy flow from sawlogs residue was 4.85 × 10^3 GJ E/yr about corresponding to 72% of energy release from forest biomass. Hence, the forest ecosystem served as an energy sink of 8.54 × 10^3 GJ E in 2010. Summing up, the significant energy stocks in the forest cycle inventory come from the value of 75% of the biomass energy was accumulated within the region in which they originated from.

Conclusion

Generally, MFA is the best decision support tool for estimating the flow of biomass energy input, conversion and outputs and determining the sustainability balance of the present forest production system as a bioenergy source in the region. So it is necessary MFA inventory be written for all forest biomass database as well as encourage related parties to be used in planning for biomass energy production and use. Large potential would be economic and it is possible to improve the level of recycling of wood residue and avoid this residue from burnt or left to rot on site. Of occurs depends on fossil fuel for energy supply. It is important to say that if population growth is not correspond with energy capacity demand, biomass energy source should function as exchange in future.

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