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Biomass energy flow screening for good governance in agricultural system: A case study in Terengganu state

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Abstract

A good and sustainable governance in agricultural waste management is considered effective by maximising the economic profit, and at the same time minimising the effect of environmental pollution. This paper presents the findings of the flow of biomass energy in the agricultural productivity system in Terengganu by using Material Flow Analysis (MFA) technique with the aid of SubsTance Flow Analysis (STAN) 2.5 software. Simultaneously, a combined focus was also given by studying the governance system of the relevant parties in organising the agricultural waste management. The findings show that the biomass energy flow centred on the crop subsystem with the total energy input of 509 Peta Joule (PJ) per year from which 68 percent was contributed by the pasture community, which was equivalent to 344 PJ per year. Other than that, the livestock subsystem that was dominated by cattle species contributed the highest biomass energy flow of 54 percent which is equivalent to 202 PJ per year. In addition, it was also found that the involvement of governance, especially from the agropreneur, was still unclear and inadequate which indirectly contributes to the zero bioenergy development in this region. It is hoped that the developing of MFA technique with social field performed in this research would be able to highlight several important issues such as current flow and reservoir level in other area.

Keywords: agricultural biomass, agriculture waste, biomass energy, governance, Material Flow Analysis (MFA), Terengganu

Introduction

Agricultural biomass is special in terms of the unlimited ability of recycling based on the basic carbon cycle in photosynthesis. Other benefits of agricultural biomass are renewable, can be stored and replaced, and readily available in abundance (Tinia et al., 2017; Munir et al., 2017). Based on OECD (2007), the applications of agricultural biomass include food, chemicals, fertilisers, animal feed, fibres, raw materials, forestry materials, and fuels. Globally, the issues related to agricultural biomass resources have been long debated. Since 1993, the World Energy Council has stipulated a clear need on the utilisation of renewable resources towards 2020. In line with the aim to stabilise the global release of the greenhouse gases. The prediction by EREC (2006) determined that half of the global energy resources will be contributed by renewable energy resources by 2040. The global potential of biomass energy generation is expected to increase from the current value of 42 EJ (Exajoule equals to one quintillion (10^{18}) joules) to 350 EJ in 2100 (WBGU, 2010).

Malaysia has tabled a number of policies and targets in accelerating the development of biomass energy from agricultural sector that the reliance on fossil fuel resource can be overcome in the future. A strong support and resolution from the Malaysian government in the implementation of biomass-related activities can be seen in the Five-Fuel (2001-2005) Diversification Policy under the Eighth and Ninth Malaysia Plans (2006-2010). Meanwhile, the examples of the project involved are Small Renewable Energy Power (SREP), UNDP-GEF Biomass Power Generation and Demonstration (Ahmad et al., 2009; Lee et al., 2009; Mustapa et al., 2010; MEC, 2016).

In addition, in 2009, 16 biomass companies were established with a total energy generation capacity of 137 Megawatt (MW). In 2011, the amount of biomass-based electricity generation in Malaysia was 2.47 percent (671.32 MW) placed at the fifth spot after gas, coal, hydro and diesel (MEC, 2016). According to SEDA (2016), approximately 16 percent of biomass fuel successfully contributed to the national energy utilisation. It is followed by 51 percent of oil palm biomass residue, 27 percent of wood residue and 22 percent of the combination of agricultural, livestock and domestic wastes.

Terengganu, as other states in Malaysia, also involves in the exploration of renewable energy resources. However, the activity of development and growth of bioenergy is still at its infancy stage compared to the states in the West Coast Malaysia including Sabah and Sarawak. For example, there are five bioenergy plants in Sabah only that have been operated since 2003 (MGTC, 2005). Generally, there were four reasons for choosing Terengganu as the selected region namely the abundant agricultural resources, zero development for bioenergy plant, lack of biomass-based study and unstudied biomass database (Latifah et al., 2013; Latifah et al., 2014).

Nowadays, more focus is given to the practice of governance system for agricultural biomass and it is studied based on various perspectives. In line with that, the approach of MFA method was selected as the support tool for decision-making process in various fields such as waste management, nutrient management, resource management and urban metabolism analysis. Brunner and Rechberger (2003) defined MFA as the method to study input, storage, and output of a particular material or a material within the system boundary fixed for a certain period. This differs from the other management tools such as Life Cycle Assessment (LCA), Environmental Impact Assessment (EIA), Cost-Benefit Analysis (CBA), Risk Assessment (RI), Environmental Management Plan (EMP) and others. MFA is capable to act as a diagnostic procedure during the environmental problems management. In addition, MFA supports the planning of policy management steps and evaluates different policies scenario. A mass balance concept in MFA can forms a rigid foundation for evaluation beyond a single issue such as environmental protection or resource conservation. The outcome of MFA can be used for such diverse purpose as conceptual decisions for the design of resources, nutrients, waste and others management systems, improvements of particular treatment processes, cost benefit optimizations and so on.

Therefore, this article reports the potential of biomass energy in terms of the quantity and its availability as well as defines the energy flow in a proposed MFA system. The main objective of this study was to utilise the basic advantage of MFA in developing an agricultural wastes management model framework, and subsequently highlighting the MFA output to answer the particular issues stated above.

Literature review of the stream of MFA

> "Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time."
> (Brunner & Rechberger, 2004)

Material Flow Analysis (MFA) is one of the tools to support decision making. According to Ayres (1989), MFA is an initial concept which builds and balances the energy and materials. MFA can be defined as a tool that provides initial recognition for the development of rules and policies for issues such as resource depletion and environmental quality. The most valuable MFA ability is its analytical feature. It is able to handle a large system and it is also flexible to be used at varying scales (Bouman et al., 2000).

MFA is widely used in various fields including environment and finance, locally and globally. In Malaysia, MFA is used in a smaller scope restricted to only certain fields such as solid waste management, land use pattern analysis, and nutrient flow analysis (Agamuthu, 2011; Latifah & Noor Zalina, 2013; Nora'aini, Latifah & Noor Zalina, 2013; Siti Aisyah, 2014). However, MFA has not yet been implemented in biomass and agricultural waste management in Malaysia. The situation is different in other countries such as Austria, Australia, Netherlands, Japan, and Thailand, where MFA technique has been applied in certain policies and standard procedures (Frank, 2004; Frederick et al., 2009; Bernhard et al., 2010). As stated by Fischer-Kowalski (2011), MFA technique is becoming more useful and now it has become a very convincing tool among researchers and decision makers, especially in industrial economy, social, and industrial ecology. Four key aspects of MFA research are as follows: 1) Industrial Ecology, 2) Environmental Management and Engineering, 3) Resource and Waste Management, and 4) Human Metabolism (Brunner & Rechberger, 2003). Looking at the global scenario, the effort to expand the MFA application locally is also increasing through continuous initiative from the federal government of Malaysia such as Ministry of Science, Technology and Innovation (MOSTI), Ministry of Agriculture (MOA), Sustainable Energy Development Authority of Malaysia (SEDA) and the state government.

The real remarkable feature of MFA technique is related to its data analysis and model presentation that allow further integration with other supplementary assessment tools. MFA integration for environmental assessment has been studied by researchers worldwide, especially in Australia. Some of the studies conducted in Australia are related to integration in Stormwater Runoff Management (McLaughlan et al., 2007) and Sustainable Management of Biomass Resources (Napat, 2007). According to Natthira (2005), every tool developed to support decision making has its own knowledge gap. Locally, the integrity of MFA family tool is also being developed as Material Flow Cost Accounting (MFCA) by researchers such as Chong et al. (2009).

Therefore, this study tried to make MFA as the 'dominant inventory key' that has the functions of producing the input data, generating additional information, producing integrated model, and replicating statistical records to be oriented in varying alternative selections.

Methods

This study used qualitative method with descriptive for raw data collection and quantitative method for MFA data analysis. According to Arikunto (2010), descriptive research does not necessarily test the hypothesis of the study, but attempts to explain and describe the phenomenon of the situation to be studied. Therefore, the selection of informants by purposive sampling technique was carried out in this study. Primary data were collected through semi-structured interview from individuals and organisations as main respondents, who are the stakeholders of the agricultural system management. Secondary data from interviews, formal reports, articles, policies and legal documents that are related to the organic solid waste management were reviewed. The research aspects of the agricultural waste governance system include the current evaluation of the governance structure for the agricultural waste management in the studied region.

In this study, MFA method was used to investigate the potential of biomass energy in agricultural system in Terengganu. Permanent biomass (stock) and biomass decomposition (constant) were ignored in this study because a complete finding for the permanent biomass is capable to explain a good outcome for an MFA system. The application of MFA procedure was based on the biomass equilibrium principle as explained in the study by Voet et al. (1995), Udo de Haes et al. (1997) and, Brunner and Rechberger (2003). Four main steps involve in MFA are (1) system analysis, (2) mathematical model, (3) data acquisition and model calibration, and (4) simulation and sensitivity analysis.

System analysis

The studied boundary system was Terengganu and the assigned time frame was one year in 2017. In this case, the agricultural system consisted of two main subsystems namely crop production and livestock production. The energy unit displayed was petajoule per year (PJ/year). A part of the findings for the framework of the livestock production system was obtained from the study by Latifah et al. (2013).

Mathematical model

Table 1 shows a set of simple formulas used in this study and two examples involved with calculation are:

a) The total agricultural biomass energy production was estimated using the agricultural statistics of Terengganu and multiplied by the ratio of waste generation. The subsequent product was multiplied by the energy conversion coefficient.
b) The total livestock waste generation was estimated by determining the livestock population and multiplied by the ratio of the generated manure for each livestock and subsequently multiplied by the energy conversion coefficient.

Data acquisition and model calibration

The purpose of the MFA technique in this analysis was to establish a pattern of material flow and integrated energy element in certain areas. Therefore, a sturdy database is needed in building a complete model. According to Kandelaars and Van (1997), the basic MFA is the database related to stock and physical flow of material and product via the economic process. Therefore, in this study, the biomass resources for the crop residue were categorised as straws, stalks, pruning, and litter. Meanwhile, the livestock wastes were referred to as the waste from feedlots and slaughterhouses, livestock wastes, carcass, and the waste from slaughtering processes. The information was obtained from literature studies (scientific publications, official statistics and documents), measurement field (sampling and laboratory analysis), field research (surveys, interviews with the stakeholders), or mass balance calculation on the process.

Simulation and sensitivity analysis

The analysis results at the final stage was presented in the form of a complete framework system. The quantity of movement of energy flow from one process to another was labelled and the outcomes were interpreted.

Table 1. Agriculture waste energy calculation for crop production in Terengganu

Districts	Crop	Production (thousand)	Crop energy value(GJ/t)	Annual crop energy potential (10^3 GJ)	Waste factor	average annual waste (10^3t)	Residue energy value (MJ/kg)	Residue annual energy potential (10^3 GJ)
Besut	Paddy	1780	16	28474	0.22-0.40 [2]	552	14.93-15.85 [6]	8495
	Rubber	12	19	230	0.42-2.0 [9]	15	19.40-24.41 [5]	329
	Palm Oil	247	18	4441	0.56-2.60 [2]	390	18.73-39.36 [7]	11328
	Sugarcane	2	18	32	0.32 [2]	1	16.64-17.88 [6]	17
	Maize	73	17	1234	0.25-2.0 [3]	82	12.6-17.7 [4]	1242
	others crop	692	15	10386	0.5-1.89 [1]	827	12.6-25.0 [4]	15548
	Fruits	1597	15	23474	0.45-2.4[1]	2276	13.1-17.8 [8]	35164
	Vegetables	373	14	5218	0.9-1.8 [1]	503	12.0-17.0[4]	7294
Setiu	Paddy	3956	16	63296	0.22-0.40 [2]	1226	14.93-15.85 [6]	18868
	Rubber	13	19	251	0.42-2.0 [9]	16	19.40-24.41 [5]	351
	Palm Oil	660	18	11880	0.56-2.60 [2]	1043	18.73-39.36 [7]	30299
	Sugarcane	2	18	41	0.32 [2]	1	16.64-17.88 [6]	17
	Maize	32	17	532	0.25-2.0 [3]	36	12.6-17.7 [4]	545
	others crop	1195	15	17931	0.5-1.89 [1]	1429	12.6-25.0 [4]	26865
	Fruits	4878	15	71707	0.45-2.4[1]	6951	13.1-17.8 [8]	107393
	Vegetables	282	14	3945	0.9-1.8 [1]	380	12.0-17.0[4]	5510
Kuala Terengganu	Paddy	2520	16	40314	0.22-0.40 [2]	781	14.93-15.85 [6]	12020
	Rubber	8	19	156	0.42-2.0 [9]	10	19.40-24.41 [5]	219
	Palm Oil	147	18	2646	0.56-2.60 [2]	232	18.73-39.36 [7]	6740
	Sugarcane	9	18	162	0.32 [2]	3	16.64-17.88 [6]	52
	Maize	57	17	970	0.25-2.0 [3]	65	12.6-17.7 [4]	985
	others crop	106	15	1583	0.5-1.89 [1]	126	12.6-25.0 [4]	2369
	Fruits	5233	15	76919	0.45-2.4[1]	7456	13.1-17.8 [8]	115195
	Vegetables	1601	14	22407	0.9-1.8 [1]	2161	12.0-17.0[4]	31335
Hulu Terengganu	Paddy	783	16	12534	0.22-0.40 [2]	243	14.93-15.85 [6]	3740
	Rubber	12	19	219	0.42-2.0 [9]	14	19.40-24.41 [5]	307
	Palm Oil	744	18	13396	0.56-2.60 [2]	1176	18.73-39.36 [7]	34163
	Sugarcane	2	18	30	0.32 [2]	1	16.64-17.88 [6]	17
	Maize	250	17	4225	0.25-2.0 [3]	281	12.6-17.7 [4]	4257
	others crop	316	15	4734	0.5-1.89 [1]	377	12.6-25.0 [4]	7088
	Fruits	2980	15	43799	0.45-2.4[1]	4246	13.1-17.8 [8]	65601
	Vegetables	490	14	6854	0.9-1.8 [1]	661	12.0-17.0[4]	9585
Marang	Paddy	82	16	1309	0.22-0.40 [2]	25	14.93-15.85 [6]	385
	Rubber	7	19	135	0.42-2.0 [9]	9	19.40-24.41 [5]	197
	Palm Oil	253	18	4549	0.56-2.60 [2]	399	18.73-39.36 [7]	11591
	Sugarcane	60	18	1068	0.32 [2]	19	16.64-17.88 [6]	328
	Maize	327	17	5528	0.25-2.0 [3]	368	12.6-17.7 [4]	5575
	others crop	511	15	7658	0.5-1.89 [1]	610	12.6-25.0 [4]	11468
	Fruits	2610	15	38360	0.45-2.4[1]	3719	13.1-17.8 [8]	57459
	Vegetables	833	14	11666	0.9-1.8 [1]	1125	12.0-17.0[4]	16313
Dungun	Paddy	79	16	1259	0.22-0.40 [2]	24	14.93-15.85 [6]	369
	Rubber	5	19	87	0.42-2.0 [9]	6	19.40-24.41 [5]	131
	Palm Oil	1065	18	19163	0.56-2.60 [2]	1682	18.73-39.36 [7]	48862
	Sugarcane	9	18	164	0.32 [2]	3	16.64-17.88 [6]	52
	Maize	84	17	1411	0.25-2.0 [3]	94	12.6-17.7 [4]	1424
	others crop	206	15	3086	0.5-1.89 [1]	246	12.6-25.0 [4]	4625
	Fruits	560	15	8235	0.45-2.4[1]	798	13.1-17.8 [8]	12329
	Vegetables	665	14	9303	0.9-1.8 [1]	897	12.0-17.0[4]	13007
Kemaman	Paddy	468	16	7482	0.22-0.40 [2]	145	14.93-15.85 [6]	2232
	Rubber	8	19	144	0.42-2.0 [9]	9	19.40-24.41 [5]	197
	Palm Oil	2363	18	42530	0.56-2.60 [2]	3733	18.73-39.36 [7]	108444
	Sugarcane	5	18	94	0.32 [2]	2	16.64-17.88 [6]	35
	Maize	81	17	1364	0.25-2.0 [3]	91	12.6-17.7 [4]	1379
	others crop	164	15	2456	0.5-1.89 [1]	196	12.6-25.0 [4]	3685
	Fruits	3586	15	52710	0.45-2.4[1]	5110	13.1-17.8 [8]	78950
	Vegetables	269	14	3767	0.9-1.8 [1]	363	12.0-17.0[4]	5264

Sources: Lim, 1986; Shamsuddin, 1989; Koopmans and Koppejan, 1997; Lim et al., 2000; Daniela and Stefan, 2005; Shinya and Matsumura, 2008; Keat et al., 2010

Data analysis and results

Crop residue

The data from the calculation of the potential biomass energy for the selected crops in Terengganu in 2017 are given in Table 2. Vegetables, spices, herbs, industrial crop, and fruits are not displayed in this study. In Table 2, biomass energy from paddy was the highest at 93 PJ/year. It is followed by oil palm at 34 PJ/year, rubber at 19 PJ/year, corn at 7 PJ/year and 1 PJ/year each for palm and tapioca. Based on Mazlina (2005), the total energy consumption from the crop residue in 1998 was 0.79 Mtoe and was expected to increase in 2010 with a total of 1.18 Mtoe. With the assumption that the total energy supply in Malaysia in 2000 is 1,974 PJ/year as reported in the Eight Malaysia Plan, the potential of Terengganu biomass energy of 156 PJ/year is capable to contribute to 9 percent of the national energy production.

Table 2. Potential biomass energy for selected crops in Terengganu

Type of Crops	Biomaas production (million ton) per year	Biomass residue	Energy recovery product (RPR)	Low Heating value Million ton	Energy potential (PJ/tahun)
Paddy	9.67	Rice husk	0.22	2.13	31.76
		Rice straw	0.40	3.87	61.31
	5.48	EFB pada 65% MC	0.21	1.15	21.55
Palm Oil		Fibre	0.13	0.71	6.55
		Shell	0.06	0.33	5.56
Rubber	0.64	Rubber tree leaves			
		Wood			
		Total number of rubber biomass	0.67		19.38
Sugarcane	0.09	Bagasse of sugarcane	0.32	0.03	0.50
Maize	0.90	Corn cob	0.45	0.41	6.74
Coconut	0.11	Fibre	0.36	0.04	0.58
		Coconut shell	0.16	0.02	0.29
		Palm frond	0.23	0.03	0.37
Cassava	0.67	cassava (stalk)	0.09	0.06	1.00
SUM					155.59

Sources of Energy and Waste Coefficient: Lim, 1986a; Lim, 1986b; Hemstock and Hall, 1995; Koopmans and Koppejan, 1997; Lim et al., 1999; Shinya and Matsumura, 2008; EPU-TRG, 2012

Based on Table 2, it can be observed that the potential biomass energy utilisation in Terengganu is high at 156 PJ/year. However, based on the monitoring and survey done with the involved personnel during the conducted study, only 2 percent of the total crop residue was reused for the purpose of fuel production. The focus on biomass utilisation was centred in the oil palm sector in Terengganu. According to Sufian (2017), several oil palm mills in Terengganu fully utilised the oil palm residues such as fibres, fruits, mesocarps, and empty fruit bunches (EFB) as the boiler fuel to generate steam and electricity for the mills. This management practice is known as zero waste management system.

Referring to the rice production sector, the total area of rice cultivation area in 2017 in Terengganu was approximately 16,516 hectares with Besut dominated the highest scale area of 7,648 hectares (Sufian, 2017). Therefore, it is undeniable that the composition of the energy release from the rice straw open burning activities was estimated to be 0.79 PJ/year with a potential energy of 61 PJ/year. Due to the existence of the biggest BERNAS rice mill in Besut, the total of rice husks and straws generated from the harvesting and milling activities was about 5 million tonnes per year. However, it is estimated that only 2 percent of this overall biomass residue is utilised for energy production. The remaining residue will be dumped in landfill and openly burned.

Livestock waste

Table 3 shows the total of annual biomass energy production from livestock residue in Terengganu. In this study, the livestock wastes were categorised into several livestock waste sources, namely faeces and urine, waste from slaughterhouses (inedible parts such as bones, fats, blood, skins, viscera, and furs), feedlot, and carcass. A detailed calculation procedure for methane potential of animal production as presented in Table 3 have been based on ration taken from the work of Bhattacharya (1997) and Latifah et al. (2013). The total potential biomass energy for the livestock subsystem is 374 PJ/year. Theoretically, this value is capable to contribute to 22 percent of the national energy production. However, a few constraints might emerged in the utilisation of this biomass namely the type of livestock, feed amount, season, nutrition, condition of the livestock, humidity, location and breeding system. The statistics for the waste from pig is zero because the pig breeding activity is prohibited in line with the current population scenario in Terengganu that are mostly Muslim.

Table 3. Total annual potential biomass energy production from livestock waste in Terengganu

Animal	Populatior Head	Dung production (kg head^{-1}day^{-}	Total dung produced kt head^{-1} y	Recoverab Fraction	Dry Matte (DM) (%)	Recoverab DM (Mt)	Volatile Solid fract (kg VS kg	Biogas Yield m^3 kg^{-1} VS	Biogas potential (Mm^3 year	Energy potential PJ
Buffalo	10530	10.5	40.2	0.50	18	3.62	0.80	0.43	1.25	26.1
Cattle	96277	9.4	329.4	0.60	17	33.6	0.93	0.31	9.69	202.4
Goat	35146	3.6	46	0.33	31	4.71	0.60	0.49	1.38	28.8
Sheep	3324	3.6	4.34	0.33	31	0.44	0.60	0.49	0.13	2.7
Poultry	3430027	0.1	125.2	1.00	33	41.32	0.47	0.28	5.44	113.6
	3575304		**545.14**			**83.69**			**17.89**	**373.6**

Sources of Energy and Waste Coefficient: Bhattacharya, 1997; Devendra, 1997; Essel et al., 1997; Sopian et al., 2005; Shinya and Matsumura, 2008; TVSD, 2012

The highest potential biomass energy production from livestock waste was cattle at 202 PJ/year, followed by poultry at 114 PJ/year, and the remaining was 31 PJ/year for goat, sheep, and buffalo. According to Hemstock and Hall (1995), the average ratio of biomass availability for each livestock is approximately 5.4 EJ/year. For cattle raising, the cattle manure can be applied in fermentation process to produce methane.

Agricultural biomass energy flow analysis

This section displays a simplified scheme of the energy flow in an agricultural system using the Material Flow Analysis method. The focus of the study was to selectively assess for the potential agricultural biomass energy based on the value of the energy flow shown in Figure 1. The is a huge potential for biomass energy in the crop production subsystem, with a total energy flow of 509 Gigajoule per year compared to the livestock subsystem, which is 374 PJ/year as depicted in Figure 1.

This study shows that the value of 509 PJ/year is the total input from imported crop products, grazing crops, and selected crops. Only 1 percent (9 PJ/year) of the crop residue

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was converted to biomass energy. The remaining 500 PJ/year was used as compost fertiliser, feedstuff product, animal bedding, value-added products, openly burned, landfill, and chemicals. The efficiency rate for crop biomass products are also reportedly low with only three percent from the agricultural waste was recycled into fertilisers or pelleted animal feed products. This study also found that currently, no power station in Terengganu uses any kind of agricultural waste such as bagasse, rice husks and others. In addition, the enforcement to recycle agricultural wastes such as pastures, molasses and other crop residues is only at a small scale. According to the Terengganu Agriculture Census 2016, the total raw data for the activities was not recorded.

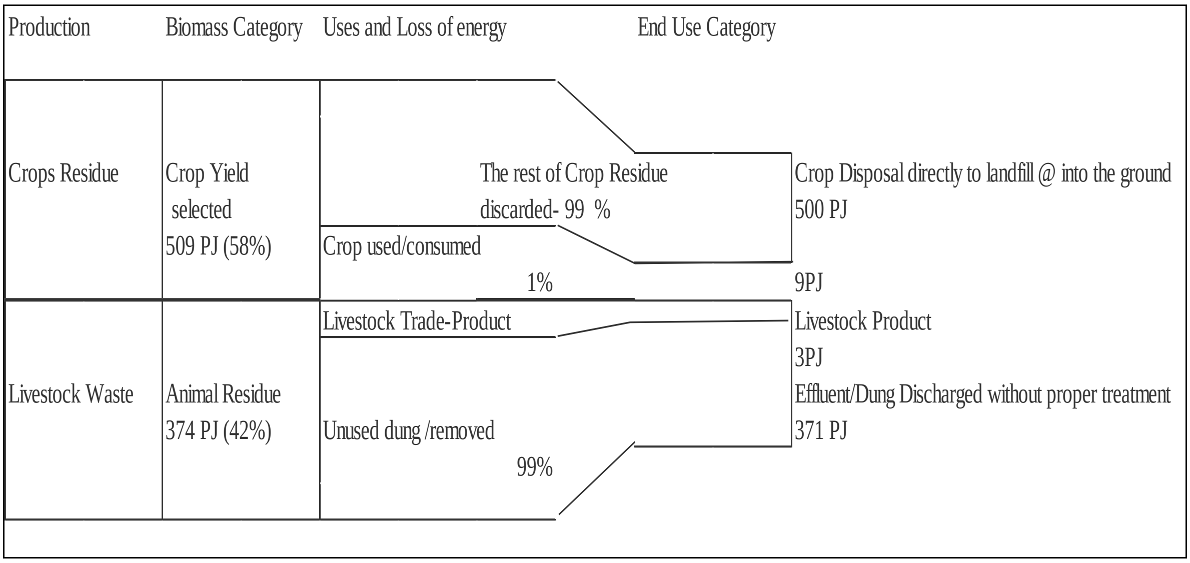

Figure 1. Schematic diagram of biomass energy flow model for agricultural system in Terengganu in 2017

Figure 1 shows that the livestock waste total was 374 PJ/year and the utilisation status was also low at 1 percent (3 PJ/year). Most of the livestock waste were used as compost fertilizer. The introduction of the biogas system for livestock waste has not been attempted. This is because the waste collection itself is limited and cannot be obtained in a large quantity. There are also other limiting factors such as high technological cost, law, lack of information, and so forth.

As a conclusion, Terengganu has a huge potential to preserve energy from agricultural biomass. Domestically, Terengganu produced approximately 553 kilo tonne of agricultural biomass residue per year in 2017. If the Besut district, which has a rich repository of biomass resources, is directly utilised to build a biomass power plant, the anticipated local energy demand in Terengganu may be fulfilled. Concurrently, nature preservation can be nurtured in this region.

Uncertainty analysis

As for the validation, the most significant flow of the research result display caused by 'various uncertainties'. There were several factors that contributed towards this the uncertainties in this study. These factors were related to the differing and irregular numbers and values obtained. Examples of these factors were the level of statistical data collection, fluctuation in nutrient concentration and mass dry weight, system definition, and the short time projection. Some measures have been taken to minimise these uncertainties including the use of various references from multiple sources. For instance, almost all of the results in this study were recorded in annual average. The assessment on the types of agricultural wastes should include forest and organic domestic wastes in order to complete the system analysis. In addition, expanding the literature review and conducting the validation with in situ sampling could also improve the uncertainty reading raised in this research.

Table 4 shows the manure discharge load from the livestock sector was the most sensitive towards Biomass Energy (BE). By making ±45 percent change, 2367 GJ of this energy could be recovered as green energy. In the calculation of energy flow in animal manure disposal, there was a clear certainty in terms of size and age of livestock, level of water and food intake, fresh weight or dry weight of manure, energy coefficient, and so on. Another variable with a high uncertainty in the BE analysis was the per capita estimates of animal wastewater discharge. The absence of wastewater treatment plant in this region has complicated the acquisition of accurate data. Moreover, the lack of literature review related to the energy flow in the wastewater within Terengganu region has also added to the difficulty in the research analysis. In addition, the sensitivity change in crop yield and crop residue was small. If there was a change in energy and waste coefficient, the value of flow change would be small. This is because most of the energy waste coefficient values have been extensively studied by local researchers. In fact, the statistical data on crop production was originally from the archive of the Department of Agriculture Terengganu (DOA-TRG, 2017).

Table 4. Uncertainty of the simulation results for BE to the Terengganu's agriculture system

Parameter	Variables	Mean values	Uncertainties (%)	Uncertainties
Biomass Energy (BE)	Animal wastewater	10.9 GJ/ton/yr	±50	±4.9 GJ/ton/yr
	Manure discharge	67E3 GJ/kton/yr	±60	±40 GJ/kton/yr
	Crop residue disposal	1.9 GJ/ton/yr	±45	±0.86 GJ/ton/yr
	Methane emission loss to air	0.09 GJ/ton/yr	±35	±0.03 GJ/ton/yr

Agricultural Waste Governance System in Terengganu

Waste governance can be defined as the behaviour in the society and group connections in a certain area (Jordan, 2017). Meanwhile, environmental governance is related to a set of service complex such as source availability (Guangqin Li et al., 2018). Agricultural waste management, as with solid waste management, in Terengganu is subjected under Solid Waste and Public Cleansing Management Act (Act 672). Looking at the operational governance process in the harvesting phase, the collecting phase, the transportation phase, the consumption and marketing phase and the disposal phase in the study region, the authors found that the practice on land is very different from the gazetted law. For instance, at the disposal phase, four choices for agricultural waste disposal are being implemented, which open are burning, open disposal, recycling and compost and disposal at a landfill site (Latifah, 2015). This is because the participating member for each organisation and process is different. It is clear that from social disagreement, policies and knowledge from the stakeholders around the research area. According to Agamuthu et al. (2009), low courtesy and non locality are the contributing factors to the weakness in the enforcement of the solid waste management policies in Malaysia.

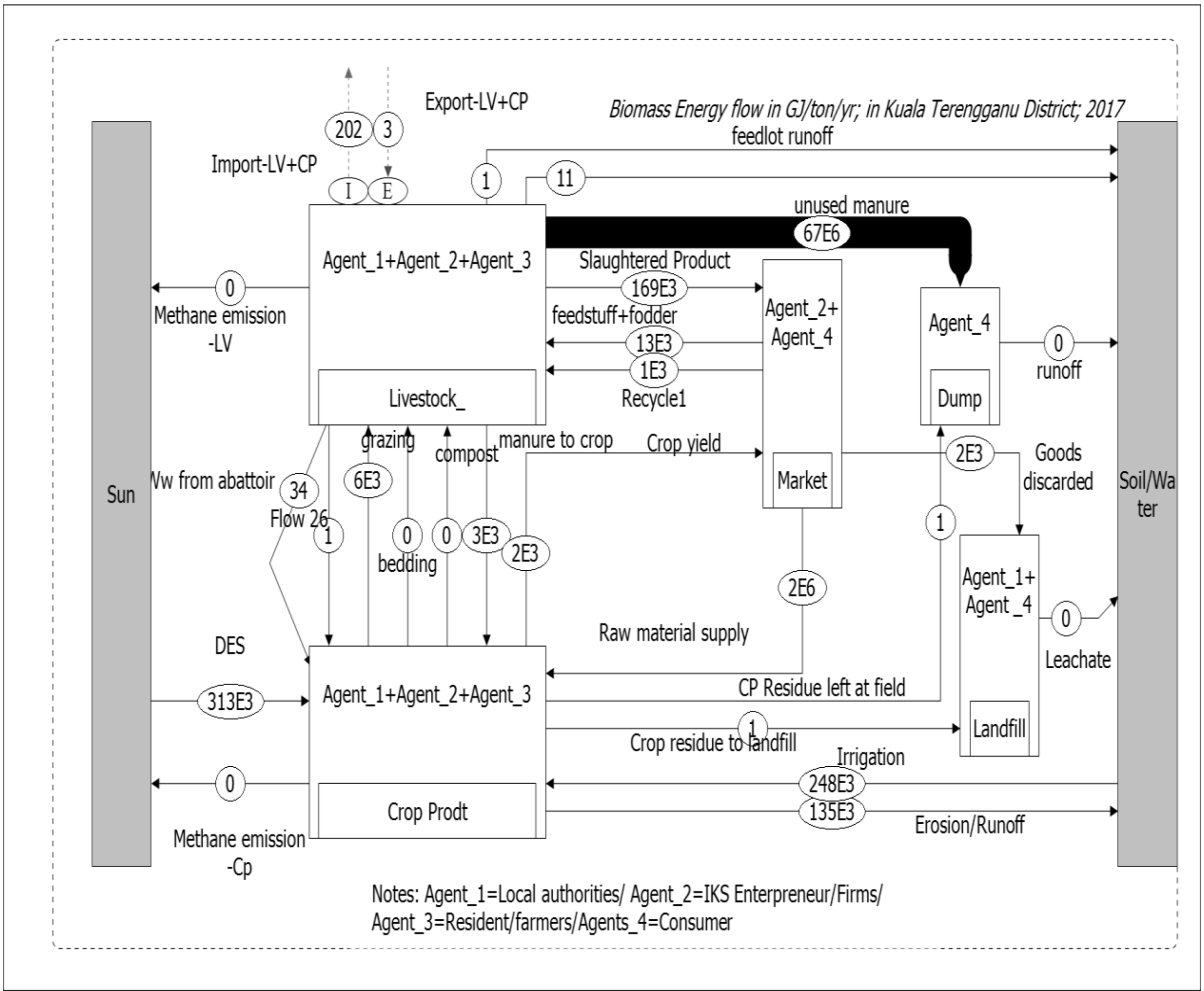

Figure 2. Agent involvement in MFA model for biomass energy flow management

Through the MFA approach, the produced MFA model framework as depicted in Figure 2 included questionnaires and detailed sampling from the selected population and sample. Overall, the authors conclude that the governance system for agricultural waste management is still mediocre in the studied region. This is because it is only enforced by the Agent_1:local authority of Terengganu and the federal government. The determination of Agent_2: the Secretariat of Terengganu's Entrepreneur Development Council (MSPUT) managed to channel approximately RM396 million to finance the business of 36,006 entrepreneurs (IKS) in 2017. RM34.2 million worth of grant was given to 1,134 IKS entrepreneurs in Terengganu. The grant was channelled to 13 entrepreneurship agencies, among them were YPU, the Agriculture Department, Rubber Industry Smallholders Development Authority (RISDA), Malaysian Investment Development Authority (MIDA), Small and Medium Enterprises Corporation (SME Corp), Indigenous People's Trust Council (MARA), Federal Agricultural Marketing Authority (FAMA), Fisheries Development Authorities of Malaysia (LKIM), Central Terengganu Development Authority (KETENGAH) and Standard & Industrial Research Institute of Malaysia (SIRIM). In addition, 439 training programmes were held for 36,783 entrepreneurs and 262 promotional programmes, both local and abroad, for 19,753 entrepreneurs. Meanwhile, the involvement of Agent_2: agricultural biomass-based agropreneurs registered under Terengganu Entrepreneur Development Foundation (YPU-TRG) in 2017 was under the scale of one tenth. In 2014, the statistics issued by YPU-TRG identified 13 successful entrepreneurs, most of whom were from the food production business and manufacturing sector, songket and batik making industries and the manufacturing sector. Approximately 96 percent of agricultural biomass-based agropreneurs in Terengganu are unregistered.

Overall, the biomass energy of agricultural wastes management practice in Terengganu still requires a big improvement, especially in the development of agricultural wastes treatment. The findings revealed that the potential utilisation of biomass energy can be implemented in this region due to the fact that it has an abundant availability of agricultural wastes resources. There was no strong competition between the land use for food crop production and the land use for energy crop production in Terengganu region. The dependency on outside raw supplies including fertilisers and feed can be minimised through the reuse of local resources productivities. The influence of agriculture waste flow display in the MFA model can certainly explain the negative impact from the agriculture waste flow imbalance in this region. The negative feed rate in the livestock diet, excess nutrient accumulation in soil, increasing rate of soil erosion, release of untreated animal wastewater, and release of methane gas from open burning and livestock sector are the issues that affect the relative changes in the deterioration of environmental quality. Therefore, the authorities, especially the environmental decision makers, must be aware of these points of changes. In fact, the related law enforcement must be enhanced and implemented efficiently and stringently in this region. Consequently, the conservation of sensitive agricultural land use areas can be maintained, especially in terms of their ecosystem stability.

Generally, specific research regarding the governance field in agricultural waste-based biomass energy is much needed to drive the momentum in sustainable energy development planning in the near future. Attention also needs to be given to the merging of allied science and social science. This is because any research regarding the constituents of the nature as well as research in the behaviours and practices of the society can increase the efficiency in the enforcement of sustainable agricultural waste management.

Conclusion

The agricultural sector, specifically the crop subsystem, has a huge potential for future energy production in Terengganu. Even though currently it still has not been commercialised, the abundance of agricultural biomass such as straws, rice husks, bagasse, corn cobs, livestock waste and waste from livestock feed processing can contribute towards zero greenhouse gas emission to the atmosphere. Economy generation, specifically in rural areas, can be increased especially considering that fossil fuel costs are increasing each year. This is also in line with the environmental procedures and regulations in Malaysia which follow the Clean Development Mechanism (CDM) under the Kyoto Protocol and preservation of the biodiversity.

Indeed, the evaluation of agricultural biomass energy flow using the MFA method was able to give a comprehensive representation for the overall movement of the agricultural biomass energy and the role of each player is important for the studied system. There is still an urgent need for improvement in the aspect of governance practices such as community participation, corporate bodies, agropreneurs, source separation at origin, recycling and composting, development of waste quality standards and technological facilities and collaborations between technical institutions and universities. In the end, the need and responsibility to promote the policies, regulations and the best agriculture management practices must be intensified to change the condition and lifestyle of the Malaysian society.

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