OIL PALM BIOMASS RESIDUE IN MALAYSIA : AVAILABILITY AND SUSTAINABILITY

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Abstract

Oil palm plantations cover over 5 million hectares of land in Malaysia. This large area of plantations generates massive amount of oil palm biomass residue. Plantations and mill plants are the main sites of biomass residue generation. Oil palm biomass residue is classified into six types as oil palm frond (OPF), oil palm trunk (OPT), empty fruit bunch (EFB), mesocarp fibre, palm kernel shell (PKS) and palm oil mill effluent (POME). This report presents the generation rates and amounts of each type of biomass residue during the period of 2008 to 2012.

Keywords: Oil Palm Biomass; Oil Palm Frond (OPF); Oil Palm Trunk (OPT); Empty Fruit Bunch (EFB); Mesocarp Fibre; Palm Kernel Shell (PKS); Palm Oil Mill Effluent (POME)

1. Introduction

Malaysian agriculture sector significantly generates 11% of Malaysia's Gross National Income (GNI). In the process of creating this value, a huge amount of biomass product is generated every year, including but not limited to palm oil, rubber and rice. As Malaysia is the world's second largest producer of crude palm oil, the palm oil industry is the 4th largest contributor to the country's GNI accounting for about 8 percent with almost RM 50 billion of GNI. Correspondingly, this generates the largest amount of biomass, estimated at 80 million dry tons annually, which has a significant commercial potential [1].

Over the past 20 years, the palm oil industry in Malaysia has grown rapidly. In December 2012, Malaysia had 5.08 million hectares of oil palm plantation, increased by 11.8 % in comparison with 2008 and contributes 39 % of the world's total palm oil production and 44 % of world exports [2]. In 2012, Malaysia produced 18.79 million ton of crude palm oil (CPO) as shown in Fig. 1. However, the CPO production sometimes decreased when the fresh fruit bunch (FFB) productivity decreased as a result of unusual weather patterns of hot and dry conditions and excessive rainfalls as shown in Fig. 1 [3, 4]. This huge amount of CPO production generates massive biomass residue which created a major disposal problem. Oil palm industry generates about 70 million ton of biomass residue in Malaysia [5]. The fundamental principles of waste management are to minimize and to recycle the waste, and recover the energy as much as possible. The final residue such as ash will be utilized as a fertilizer or disposed [6]. The oil palm biomass residue has extensively been studied as alternative raw material for biofuel production [7-12], paper-making pulp [13-15], wood production [16-22] and biobased chemicals [23, 24].

This work discusses the generation rate and amount of oil palm biomass residue in Malaysia for the last 5 years. The biomass residue profile in 12 States of Malaysia was also discussed.

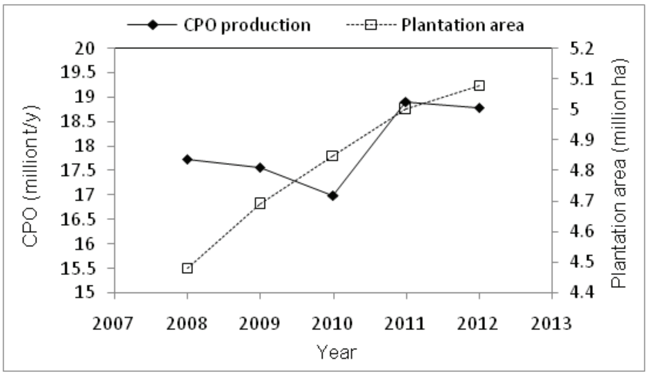

Figure 1. CPO production and plantation area in Malaysia

2. Oil Palm Biomass

The oil palm *(Elaeis guineensis)* is a tropical tree known as the African oil palm found in western and central Africa, is one of two species of oil palms in the *Arecaceae* or palm family. Mature trees are single-stemmed, and grow up to 20 m tall [25]. Oil palm trees are cultivated in Malaysia as an agricultural crop. The production of palm oil generates biomass residue from plantation and mill sites. This biomass residue can be classified into six types: oil palm fronds (OPF) and oil palm trunks (OPT) produced at plantation site, empty fruit bunches (EFB), palm kernel shells, mesocarp fibre and palm oil mill effluent (POME) produced at mill sites (Fig. 2). Since the large amount of biomass residue is generated yearly, Malaysia has the potential to utilize the biomass residue efficiently and effectively to

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other valued products. Thus, this ensures that the oil palm biomass residue can be obtained sustainably [5].

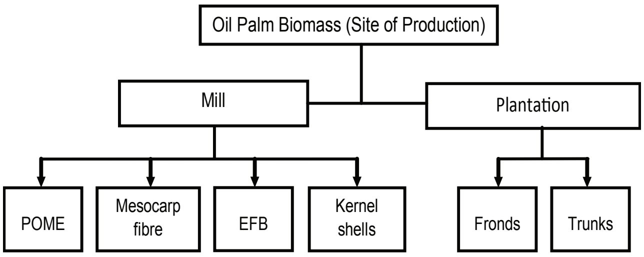

Figure 2. Oil palm biomass residue and source of generation

2.1 Oil palm biomass residue generated from plantation site

In 2012, Malaysia had 5.08 million hectares of oil palm plantation. This large plantation area generated huge amount of lignocellulosic materials in the form of fronds and trunks as shown in Figs. 3 and 4. The oil palm fronds are collected during pruning and replanting activities with average generation rate of 9.8 t-dry/ha-plantation/y and 14.9 t-dry/ha-replantation/y, respectively (Table 1). Studies reported that OPF is comprised of 25.5 % (dry basis) of hemicellulose material, which has great potential to use as a feedstock for biofuel and biobased material production [26-31]. Oil palm trunk (OPT) is the second type of biomass residue generated during replanting activities. The estimated trunk generation rate is 62.8 t-dry/ha-replantation/y (Table 1). In order to estimate the annual generation amounts of these three biomass residues (OPF pruned, OPF upon replantation and OPT upon replantation) from the generation rates above, we need the total plantation area and the replantation area for each year in Malaysia. The total plantation area is available from the MPOB (Malaysian Palm Oil Board) website, and is plotted in Fig. 3. In 2009 and 2010, a total of 207,754 hectares of old palm trees had been felled for replanting [3]. Thus, the estimated percentage of replantation area is 2.2 % (207,754/(4,690,000+4,850,000)) of the total plantation area. We applied this percentage to each year between 2008 and 2012, and obtained the estimated amounts of OPF pruned, OPF upon replantation and OPT upon replantation as shown in Fig. 3. About the OPT, it is worthwhile to mention that the average generation rate of 2.52 t-OPT/ha/y reported in a previous paper [29] is also available to estimate the generation amount of OPT.

Table 1. Generation rate of oil palm biomass from plantation site

Site	Residue type	Generation rate						Moisture (%)			Representative generation rate
		Unit	Ref [32]	Ref [33]	Ref [34]	Ref [35]	Ref [36]	Ref [6]	Ref [37]	Ref [38]	
Palm plan-tation	Trunk (generated at replanting)	t-dry/ha-replanta-tion/y	37	75.5	84	43	74.4	70	-	73.3	**62.8**
	Fronds (generated at replanting)		-	14.4	16.2	-	14	-	63.5	-	**14.9**
	Fronds (pruned)	t-dry/ha-planta-tion/y	9.7	10.4	11	5.7	12	-	63.5	-	**9.8**

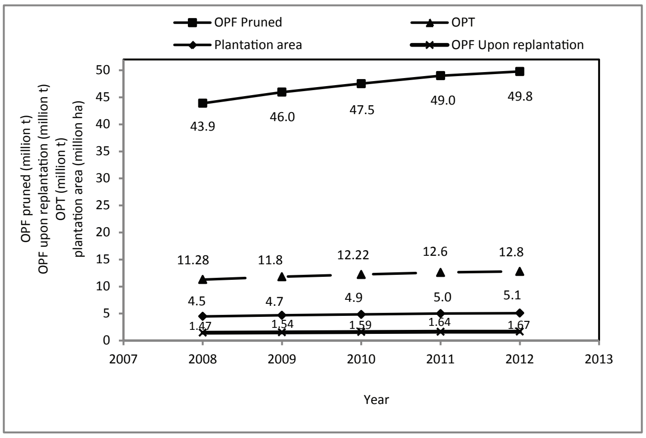

Figure 3. Oil palm biomass residue generated from plantation site

Based on data collected from MPOB, Fig. 4 shows the oil palm plantation area in each state of Malaysia and estimated biomass generation. Sabah had the largest oil palm plantation area than any other state with total area of 1.44 million hectares in 2012, generated 14.61 and 3.63 million-t/y of OPF (from pruned and replanted) and OPT, respectively. Sarawak as the second largest oil palm plantation state with total area of 1.07 million hectare generated about 10.9 and 2.71 million-t/y of OPF (from pruned and replanted) and OPT, respectively. In contrast, Perlis had the smallest oil palm plantation area of 284 hectare produced very low quantity of oil palm biomass.

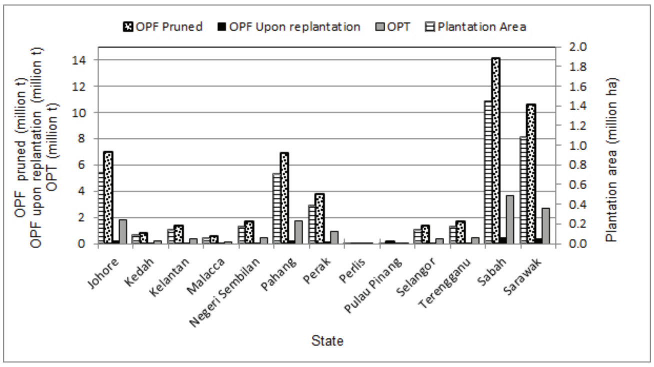

Figure 4. Oil palm biomass generated from state's plantations in 2012

2.2 Oil Palm biomass residue generated from mill site

The process of CPO and palm kernels production in palm oil mill generates huge quantity of biomass residue such as EFB, fibre, shell and POME as shown in Fig. 2. These types of biomass residue may be utilized to produce value-added products. The estimation amount of these residues mainly depends on the amount of FFB processed by palm oil mills. Table 2 shows the average generation rate of byproducts from FFB processed. From 2008 to 2012 Malaysian palm oil mills processed up to 92.9 million tons of FFB per year. This processed FFB generated large amount oil palm biomass, which reached up to 52 million t-wet/half year as shown in second half of 2012.

Table 2. Generation rate of oil palm biomass from mill site

Site	Type of biomass residue	Unit	Generation rate						Moisture (%)		Representative generation rate
			Ref [39]	Ref [40]	Ref [32]	Ref [41]	Ref [42]	Ref [36]	Ref [32]	Ref [6]	
Palm oil mill	EFB	t-wet/t-FFB processed	0.22	0.23	0.22	0.19	0.19	0.22	65	60	**0.18**
	Mesocarp fibre		0.14	0.11	0.13	0.12	-	0.135	42	39.8	**0.13**
	Kernel shell		0.06	0.05	0.06	0.05	-	0.05	17	-	**0.054**
	POME		0.67	-	-	0.58	0.67	-	-	95	**0.64**

Typically 1 ton of CPO required 5-7.5 m^3 of water and more than 50% of the water ends up as palm oil mill effluent (POME). Untreated POME contains high organic matter presented as chemical oxygen demand (COD) and biochemical oxygen demand (BOD) with concentrations of 69,500 mg/l and 25,000 mg/l, respectively [43]. The high content of organic matter in POME had been utilized to produce biogas and the technology has been commercially used within Asia Pacific Region.

EFB is one of the most targeted oil palm biomass residues in the market; it could be utilized to produce bioalcohol, solid fuel, pulp and many other value-added products. Over the last five years, the estimated amount of EFB generated every six month ranged between 7.75 to 10.79 million t-wet/half year. The first half of 2012 recorded the lowest generation of EFB during the last five years. However, the second half of 2012 recorded the highest by 10.8 million t-wet/half year. Results show low generation of EFB in the first half of 2008 to 2012, while the second half of the same period recorded higher generation amount (Fig. 5). This is attributed that a high amount of FFB was processed in second half year than the first half. In general, the EFB generation slightly decreased from 2008 to 2010 as 17.5 to 16.6 million t-wet/y. Then it gradually increased to 18.47 million t-wet/y in 2012.

Mesocarp fibre is a byproduct of oil palm fruits after extraction process. It is wildly used as biomass fuel for steam boiler due to its porous nature. The mesocarp fibre average generation rate estimated in this study is 0.127 t-wet/t-FFB processed. The results show the generation amount of fibre ranged between 4.6 to 6.4 million t-wet/half year. Generally, fibre generation decreased by 5.3 % from 2008 to 2010 as the processed FFB decreased (Fig. 5). In contrast, from 2010 to 2012 the fibre generation increased by 10 %.

Oil palm kernel shell is one of the byproducts from FFB processed, commonly known as palm kernel shell (PKS). It has a complex pore structure and fibre matrix, which could be good feedstock for premium activated carbon production [44]. In addition, it could be used as a solid biofuel to partially replaced fossil fuels [45]. The generation rate of PKS from FFB processed is 0.054 t-wet/t-FFB processed. This type of biomass residue generated in low quantity, and its maximum generation amount was recorded as 4.65 million t-wet in 2011.

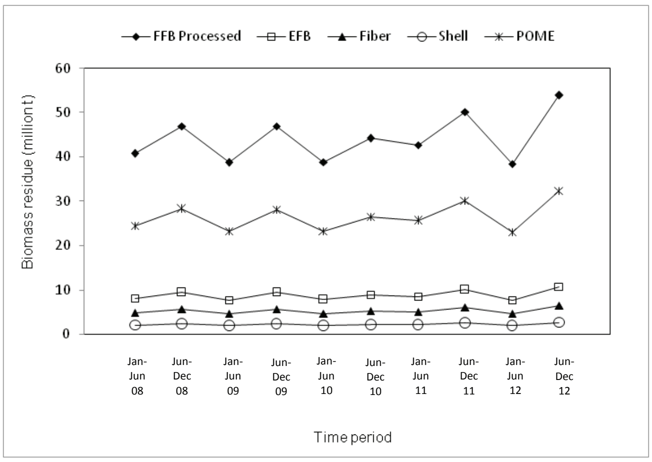

Figure 5. Oil palm biomass generated from mill site

Fig. 6 shows the oil palm biomass generated in Malaysia in 2012. State of Sabah processed the biggest amount of 26 million t-FFB in 2012 and generated a huge amount of biomass at their palm oil mills as EFB, fibre, kernel shell and POME with average amounts of 5.27, 3.16, 1.32, and 15.82 million t-wet in 2012, respectively. Johor is the second biggest player in palm oil industry in Malaysia, and processed 14.85 million t of FFB in 2012 and generated 2.97 million t-wet of EFB, 1.78 million t-wet of fibre, 0.74 million t-wet of kernel shell and 8.92 million t of POME. Sarawak ranks as the third state in FFB processing. According to the MPOB annual report, Pulau Pinang processed about 0.49 million t of FFB only and generated a small amount of oil palm biomass as shown in Fig. 6.

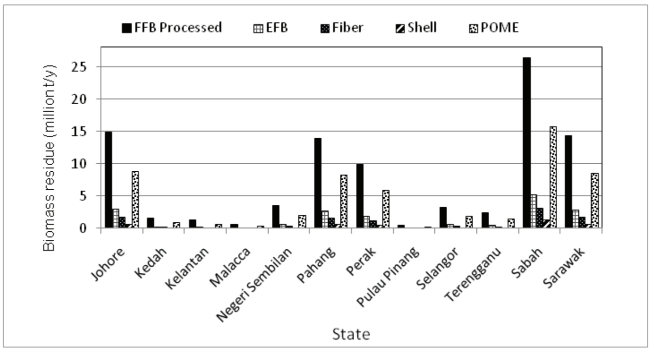

Figure 6. Oil palm biomass generated from state's mills in 2012

Conclusion

In this work, the availability and sustainability of oil palm biomass residue in Malaysia have been reported. The generation amount of biomass residue from oil palm plantations and mills mainly depend on plantation size and processed FFB, respectively. The oil palm biomass residue has great potential to be used as alternative raw material for woody materials, pulp, biofuel, and biobased chemicals. Currently, Malaysia is the world's largest exporter and the second largest producer of palm oil. Thus Malaysia has the potential to be one of the major sources of oil palm biomass residue and a contributor of renewable energy in the world.

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