A Survey on the Usage of Biomass Wastes from Palm Oil Mills on Sustainable Development of Oil Palm Plantations in Sarawak

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Abstract. As one of the world’s largest palm oil producers and exporters, Malaysia is committed to sustainable management of this industry to address the emerging environmental challenges. This descriptive study aims to evaluate the oil palm planters’ opinions regarding the usage of biomass wastes from palm oil mills and its impact on sustainable development of oil palm plantations in Sarawak. 253 planters across Sarawak were approached for their opinions about the usage of empty fruit bunch (EFB), palm oil mill effluent (POME), mesocarp fibre (MF), and palm kernel shell (PKS). This study revealed that the planters had generally higher agreement on the beneficial application of EFB and POME in oil palm plantations. This could be seen from the higher means of agreement rating of 3.64 – 4.22 for EFB and POME, compared with the rating of 3.19 – 3.41 for MF and PKS in the 5-point Likert scale (with 5 being the strongest agreement). Besides, 94.7 percent of the planters’ companies were found to comply with the Environmental Impact Assessment (EIA) requirements where nearly 38 percent carried out the EIA practice twice a year. Therefore high means of agreement were correlated to the compliance of environmental regulations, recording a Likert rating of 3.89 to 4.31. Lastly, the usage of EFB and POME also gained higher Likert scale point of 3.76 to 4.17 against MF and PKS of 3.34 to 3.49 in the evaluation of the impact of sustainability in oil palm plantations. The planters agreed that the usage of EFB and POME has reduced the environmental impact and improved the sustainable development, and its application has been improved and increased by research and development. However, the planters were uncertain of the impact of usage of biomass wastes with respect to the contribution to social responsibility and company image in terms of transparency in waste management.

1. Introduction
The oil palm planted area in the state of Sarawak, Malaysia is expanding rapidly, with its current region of approximately 1.4 million hectares of oil palm land bank, including 0.5 million hectares on peat [1, 2]. Due to the limitation of fertile soil profile, Sarawak planters have established valuable experience and knowledge over decades for oil palm cultivation on peat [3]. With the increase of plantations and the maturing palm age profile, the number of palm oil mills grows almost linearly in Sarawak in order to match the production of fresh fruit bunches (FFB). At the same time, the greatest challenge faced by this industry is to strike a balance between the environment and the social economy. Sarawak Energy Berhad (SEB), the state’s energy provider, projects an increase of FFB production from 9.3 million ton/year in 2008 to 21.0–25.5 million ton/year in 2015 [4]. With such a tremendous capacity of FFB production, processed by 73 palm oil mills across Sarawak, a systematic, effective and efficient waste management system is indispensable especially for the palm biomass wastes for sustainable development of the industry.

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The biomass residues from the palm oil industry in Sarawak have proven to have great potential to achieve industry self-reliance in fuel by using the waste to produce high pressure steam for turbines in power generation. This reduces the use of fossil fuel and subsequently minimise the emission of greenhouse gases (GHGs). It also creates more job opportunities especially in renewable energy industry in the state. Trapping and converting bio-methane gas emitted from the POME treatment pond has also successfully contributed to clean energy supply and reduction of GHG emission [5, 6]. Beside its application in palm oil mills, the composted POME and EFB can be applied as organic fertilisers in oil palm plantations in order to reduce the application of inorganic fertilisers, increase the oil palm yield, and improve the physical and chemical properties of soil by increasing the organic matter (OM) content. Bunch ash (BA) produced from the complete combustion of EFB in furnaces is also widely used as alkaline and potassium sources for nutrient recycle, especially for the plantations on peat area [5, 7].

This study aims to study the oil palm planters’ opinions regarding the usage of the palm oil mill biomass wastes and to evaluate the impact of their usages on sustainable development in oil palm plantations in Sarawak. This study also provides illustration regarding the compliance of government policy and environmental regulations, especially the Environmental Quality Act (EQA) 1974 and Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations (1977) which influence the growth of palm oil industry toward sustainable development.

2. Research background and framework

Non-governmental organisations (NGOs) have constantly criticised the development of palm oil industry, particularly in Malaysia and Indonesia because both countries have supplied almost 90% of the global palm oil demand. Misleading studies have always linked the palm oil industry to several environmental issues such as deforestation, species extinction, pollution, climate change, and forest fire brought by burning during land clearing activity in the preliminary stage of oil palm planting, for example, the Kalimantan forest fire during 1997 – 1998 [8]. In Malaysia, biomass wastes generated from palm oil industry account for 85.5% of total biomass production in Malaysia. This gigantic amount of biomass wastes will trigger a tremendous impact to the environment if they are not handled in an appropriate manner [9].

To address the severe sustainability challenges of palm oil industry, the Roundtable on Sustainable Palm Oil (RSPO) was established in 2004 to answer to the global call on sustainable palm oil production [10, 11]. To obtain the RSPO certification, the respective production process is subject to the rigorous verification of RSPO Principles and Criteria in order to fulfil the regulations, social benefit, environmentally friendliness, as well as economic viability, which broadly cover various aspects such as transparency, compliance of regulations and laws, commitment to long term economic and financial viability, best practices by growers and millers, sustainable environment, and continuous improvement [11, 12]. The produced palm oil from the certified growers and millers of RSPO is known as Certified Sustainable Palm Oil (CSPO). Malaysia and Indonesia are the world CSPO leading players which have contributed 90% or approximately 5.4 million tons out of the total 6 million tons of CSPO in 2012, with the remaining contributed by countries like Papua New Guinea, Brazil, Colombia and others. The total CSPO produced has achieved 12.53 million tons, being 20% of the total palm oil produced globally in March 2015, as reported by RSPO [11]. This implies that the standard sustainable management of biomass wastes from palm oil industry has been in place for some times.

In Malaysia, several practices have been adopted by the oil palm industry to enhance the sustainability of the industry in terms of environmental regulations, agriculture practices, codes of practices, and conservation efforts. One of the greatest challenges for palm oil millers toward sustainable development is the handling of the biomass wastes in compliance to environmental regulations, such as the EQA 1974 [13]. Composting technique is technologically simple and relatively inexpensive in treating the biomass wastes which is widely carried out by most oil palm plantations in Sarawak. Besides, trapping and converting methane gas emitted from the POME treatment pond to generate electricity power is another potential beneficial use of the biomass wastes in Sarawak. Evidently, a recent biomass power plant project launched in Mukah, Sarawak in November 2015 has projected a production capacity of 90 tons
per hour or equivalent to a reduction of 60 thousand tons carbon dioxide annually. It is undeniable that the biomass wastes from palm oil mills have great potential in various aspects, which bring about a win-win situation toward achieving sustainable development for the industry.

3. Research methodology

3.1. Research approach and design

This is a descriptive study where questionnaires were administrated to the oil palm planters across Sarawak to collect the planters’ opinion regarding the usage of biomass wastes from palm oil mills and its impact on sustainable development of oil palm plantations. The study was conducted on 20 percent of 1,500 palm oil planters in Sarawak, mainly from the northern, central and southern regions of Sarawak, with membership or non-membership of Incorporated Society of Planters (ISP), a professional body representing the Planters of Malaysia and other territories.

The hypotheses generally align to correlation between sustainable development and usage of the major biomass wastes from the millers. The major biomass wastes under study were EFB and POME which typically account for 30-32 percent and 57.4 percent respectively, while MF and PKS normally contribute to 18 percent and <10 percent respectively [14, 15]. As such, the hypotheses are listed as below:

Hypothesis 1: Usage of EFB and POME from palm oil mill influences sustainable development in oil palm plantations.

Hypothesis 2: Usage of MF and PKS from palm oil mill influences sustainable development in oil palm plantations.

3.2. Data collection and analysis

This study proposed a stratified random sampling with sampling population based on the area of plantations, i.e. small (below 3,000 hectares), medium (3,000 to 5,000 hectares) and corporate (more than 5,000 hectares) plantations in Sarawak. The primary data were collected based on the oil palm planters’ experience in operation and management of oil palm estates or plantations. The respondents were given self-administered questionnaires. The first part of the questionnaire was designed to understand the oil palm planters’ employment background such as the present working region, professional membership, work responsibility, company status, work experience, palm oil mill facilities and compliance of environmental assessment. The second part of the questionnaire collected information related to the planters’ experience in utilisation, application and disposal of biomass wastes from palm oil mills in their oil palm estates or plantations. Lastly, in the third part of the questionnaire, the respondents were surveyed for three attributes which were the benefits and advantages derived from the usage of biomass wastes, the enforcement of environmental regulations, and the contribution of biomass waste usage to five sustainable criteria. The respondents were required to grade their agreement using the 5-point Likert scale, ranging from 1 being “strongly disagree” to 5 “strongly agree”. Oral explanation was provided by the researcher to help respondents to understand the questions. The sampling via questionnaire survey took approximately three months to complete, from November 2015 to January 2016. The data from the questionnaires were interpreted and analysed using the statistical analysis tool, SPSS (originally abbreviated for Statistical Package for the Social Sciences) software. For the estimate of reliability, the Cronbach’s Alpha was applied to assess the internal consistency.

4. Findings and discussion

4.1. Background of the respondents

Approximately 300 respondents were met for the survey and 253 persons responded accordingly, which represented 84% of the targeted sampling size. From the frequency analysis as illustrated in figure 1, the respondents from the smallholder planters occupied 56.5 percent out of 253 respondents. The medium-size and the corporate planters corresponded to 25.7 percent and 17.8 percent respectively. As the
majority respondents, the smallholder planters were mostly field conductors, supervisors and assistant managers working for the associated and subsidiary companies and divisions of corporate plantations.

53.4 percent of the respondents came from northern Sarawak, such as Bintulu, Tatau, Miri, Suai, Limbang and Lawas. Respondents from the central region (Sarikei, Bintangor, Sibu, Daro and Mukah) and southern region (Kuching, Sri Aman, Betong, and Pusa) of Sarawak are relatively small, which made up 28.9 percent and 17.8 percent respectively. The availability and accessibility of the oil palm planters in northern Sarawak was the major reason of high response rate in this region.

The oil palm planters who took part in this survey study were represented by the ratio of the ISP members to non-ISP members of four to six (4:6). There is no special requirement to be an ISP member. Most of the palm oil machinery suppliers, mill engineers, and materials suppliers were engaged with the ISP membership by subscription of an annual membership fee of RM 170 for the purpose of business trading with the plantation directors and planters during the planters’ conferences and other related business activities. Number of respondents with ISP membership is 21 percent lower than those of non-ISP membership. This is because the ISP members are mostly holding managerial and directorship role and they prefer to appoint their non-ISP subordinates (mainly the smallholder planters) to attend to the questionnaire study. However the subscription of ISP membership would not affect the oil palm planters’ experiences and professionalism in answering the questionnaire survey of this study.

The reliability analysis was determined by the Cronbach’s Alpha index. Table 1 shows that this study has achieved significant and approachable Cronbach Alpha index at 0.870. Therefore, this study has sufficient reliability. The use of simple English in the survey questionnaire and the design of questions which are closely related to the planters’ experiences and knowledge regarding the usage of palm oil mill biomass have contributed to the reliability of this study. Additional explanation was provided to the respondents during the survey which may help to boost the Cronbach’s Alpha figure and hence increase the reliability of this study.

| Table 1. The reliability analysis of Cronbach’s Alpha. |
|---------------------------------|---------------------------------|-----------------|
| Cronbach’s Alpha                | Cronbach’s Alpha Based on Standardized Items | N of Items   |
| 0.870                           | 0.874                             | 24             |

Figure 1. Characteristic of the respondents based on the areas of oil palm plantations in Sarawak.

![Figure 1. Characteristic of the respondents based on the areas of oil palm plantations in Sarawak.](image-url)
4.2. Descriptive statistics

Table 2 summarises the oil palm planters’ opinions as means of agreement rating based on the 5-point Likert scale (from 1: strongly disagree, to 5: strongly agree) concerning the following three main parts:

**Part A: Usage of biomass wastes from palm oil mills in oil palm plantations**

**Part B: Government policy regarding the usage of palm oil mill biomass wastes**

**Part C: Impact of the usage of palm oil mill biomass wastes on sustainable development**

Part A is designed to capture planters’ opinions on the several benefits obtained from the usage of the palm oil mill biomass wastes. The common benefits listed are: a) increase crop yields, b) increase nutrient uptake, c) reduce operational cost, d) good commercial value, e) reduce the usage of inorganic fertiliser, and f) good nutrient value. The planters indicated higher means of agreement of 3.64 to 4.22 for the beneficial usage of EFB and POME, whereas the usage of MF and PKS recorded a neutral range of agreement of 3.14 to 3.41. Among the six benefits rated for EFB and POME, the planters held a more neutral opinion for their commercial values, which recorded the lowest mean of 3.64 compared with the other benefits as shown in table 2. In contrast, the commercial values of MF and PKS were more recognised by the planters with the highest mean of agreement of 3.64 among the other benefits for these two biomass wastes.

Part B of the questionnaire collects the oil palm planters’ opinions about the role of government policy especially the EQA 1974 and Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations (1977) whereby the EIA requirements are embedded within the framework of the EQA 1974 and are enforced by the state’s Natural Resources and Environment Board (NREB) to enable the state government to promote sustainable management of natural resources within Sarawak. Table 2 indicates that the planters strongly agreed that NREB plays an important role in enforcing environmental regulations and policies in Sarawak with a rating of 4.31. They also agreed that the practice of EIA under EQA 1974 is important concerning the usage of biomass wastes with a rating of 4.07.

Part C is intended to study the planters’ opinions on the impact of the usage of biomass wastes from palm oil mills on sustainable development in five criteria, namely: a) reduce environmental impact, b) improvement by research and development, c) improve sustainable development in palm oil industry, d) increase social responsibility, and e) improve company image in terms of transparency in waste management. Again, the planters indicated higher rating of agreement for the usage of EFB and POME in contribution to sustainable development with means of rating from 3.76 to 4.17 for the aforementioned six criteria. For the usage of MF and PKS, although the planters recognised the impact of the usage of these two biomass wastes to sustainable development with level of agreement rated at 3.70, they showed lower agreement for the impact in reducing environmental impact (3.34), increasing social responsibility (3.48), and improving company image (3.49). Comparison of means analysis on the impact of the usage of EFB and POME as well as MF and PKS for these three parts of questionnaire survey is shown in figure 2.

**Table 2.** Descriptive analysis of the oil palm planters’ opinions on the usage of biomass wastes from palm oil mills in Sarawak.

| Descriptions | N   | Minimum | Maximum | Mean    | Variance | Std. Deviation |
|--------------|-----|---------|---------|---------|----------|----------------|
| Part A. The opinions of the usage of biomass waste from palm oil mills. |
| **I) EFB & POME** |     |         |         |         |          |                |
| a. Increase Crop Yields | 253 | 0       | 5       | 4.22    | 0.671    | 0.451          |
| b. Increase Nutrient Uptake | 253 | 2       | 5       | 4.15    | 0.695    | 0.482          |


c. Reduce Operational Cost 253 0 5 3.87 0.925 0.855
d. Good Commercial Value 253 1 5 3.64 0.923 0.851
e. Reduce Inorganic Fertiliser 253 0 5 3.76 0.899 0.809
f. Good Nutrient Value 252 2 5 3.98 0.730 0.534

II) MF & PKS
a. Increase Crop Yields 253 1 5 3.23 0.862 0.743
b. Increase Nutrient Uptake 253 1 5 3.19 0.887 0.787
c. Reduce Operational Cost 253 0 5 3.14 0.897 0.805
d. Good Commercial Value 253 1 5 3.41 0.857 0.735
e. Reduce Inorganic Fertiliser 253 0 5 3.22 0.903 0.816
f. Good Nutrient Value 253 1 5 3.27 0.831 0.691

Part B. The government policy regarding the usage of the palm oil mill biomass wastes.

a. EQA 1974 (EIA) 253 2 5 4.07 0.731 0.535
b. Regulations 1977 253 2 5 3.89 0.812 0.659
c. NREB 252 2 5 4.31

Part C. The impact of the usage of biomass wastes on sustainable development.

I) EFB & POME
a. Reduce Environmental Impact 253 2 5 4.17 0.723 0.523
b. Sustainable Development 253 2 5 4.07 0.607 0.368
c. Increase Social Responsibility 253 2 5 3.76 0.746 0.557
d. Improve Company Image 253 1 5 3.76 0.807 0.652

II) MF & PKS
a. Reduce Environmental Impact 253 0 5 3.34 1.104 1.219
b. Sustainable Development 253 1 5 3.70 0.765 0.586
c. Increase Social Responsibility 253 1 5 3.48 0.738 0.544
d. Improve Company Image 253 1 5 3.49 0.800 0.640

III) All Biomass Wastes
e. Continuous Improvement by 253 2 5 4.04 0.645 0.415
Research and Development (R&D)
Government Policy and Compliance of Environmental Regulations, and Sustainable Development

Figure 2. Comparison of means analysis on impact of the usage of biomass wastes from palm oil mills in oil palm plantations in Sarawak.

4.3. Usage of biomass wastes from palm oil mills in oil palm plantations

4.3.1. Increase crop yields

As shown in table 3, none of the respondents disagreed on the impact of the usage of EFB and POME to increase crop yields. 227 out of 253 respondents (89.7%) agreed on the benefit of MF and PKS in crop yields. Among them, 85 planters rated strong agreement. On the other hand, 46 out of 253 respondents (18.2%) disagreed on the benefit of MF and PKS in crop yields while 43.1 percent held neutral opinions. The positive responses from the planters on the usage of EFB and POME indicate that these two biomass wastes are well recognised for their applications in the fields. MF and PKS are mainly used by millers as feedstock of bio-fuel for boiler station and engine room instead of field application.
Table 3. Cross tabulation analysis of the impact to increase crop yields.

| Particulars | IncreaseCrop Nutrients Uptake by Usage of EFB & POME | Total |
|-------------|---------------------------------|-------|
|             | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |
| Area of <3,000 Ha Plantations | 1 | 21 | 78 | 43 | 143 |
| 3,000 to 5,000 Ha Plantations | 0 | 8 | 34 | 23 | 65 |
| >5,000 Ha Plantations | 1 | 10 | 20 | 14 | 45 |
| Total | 2 | 39 | 132 | 80 | 253 |

| Particulars | IncreaseCrop Nutrients Uptake by Usage of MF & PKS | Total |
|-------------|--------------------------------|-------|
|             | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |
| Area of <3,000 Ha Plantations | 3 | 24 | 66 | 43 | 7 | 143 |
| 3,000 to 5,000 Ha Plantations | 0 | 8 | 31 | 19 | 7 | 65 |
| >5,000 Ha Plantations | 5 | 8 | 21 | 9 | 2 | 45 |
| Total | 8 | 40 | 118 | 71 | 16 | 253 |

4.3.2. Increase nutrient uptake

Similarly, table 4 shows that 83.8 percent of the planters agreed on the benefit of EFB and POME in increasing the nutrient uptake of the crops in oil palm plantations. Razak, Shylaja [5] and Yusoff [16] reported that the application of EFB and POME in the fields directly increased the soil organic matter and soil condition, especially when coupled with the use of bunch ash (produced when EFB is fully incinerated) in peat areas to reduce the soil acidity.

65.6 percent of the planters either disagreed or gave neutral views towards the usage of MF and PKS in oil palm estates to increase crop nutrient uptake. The remaining agreed on the increase of nutrient uptake by the usage of MF and PKS which is likely attributed to their experience in using MF as raw material to compose with decanter cake in EFB composting plant. The mixed compost is then applied in oil palm fields to increase nutrient uptake.

4.3.3. Reduce operational cost

It can be seen from table 5 that majority of the oil palm planters in Sarawak (72.7%) agreed on the reduction of operational cost by using EFB and POME in oil palm plantations while 17.8 percent were neutral about this impact and 9.1 percent disagreed. The dissent may arise from the concern of higher labour cost required to apply EFB as mulching in the estates than to apply the common fertilisers. Higher disagreement (21.3%) was recorded for the usage of MF and PKS because of less exposure of the usage of these two biomass wastes.
4.3.4. Good commercial value

Research suggests that biomass wastes from palm oil mills have good commercial value in palm oil supply chain to enhance its economic viability [17]. This is supported by the positive agreement of 157 planters (62.7%) on EFB and POME, and 117 planters (46.2%) on MF and PKS, out of 253 planters surveyed in this study (see table 6). These planters mainly came from the companies which own palm oil mill facilities. These companies trade their EFB and POME to the outsiders, especially the nearby smallholder planters for mulching purpose. When the biomass wastes were circulated for internal use or for own plantations, the respective planters inclined to disagree or hold neutral opinion about the commercial value of these wastes. For example, the Tradewinds group of plantations in Sarawak stipulates that the palm oil mill operations would subsidise RM 5 per metric ton for the EFB being used by their own estates to encourage reuse, reapplication and disposal of these organic wastes, in order to

Table 4. Cross tabulation analysis of the impact to increase crop nutrient uptake.

| Particulars          | Increase Crop Nutrients Uptake by Usage of EFB & POME | Total |
|----------------------|------------------------------------------------------|-------|
|                      | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |
| Area of Plantations  | <3,000 Ha         | 1         | 21      | 78     | 43              | 143 |
|                      | 3,000 to 5,000 Ha | 0         | 8       | 34     | 23              | 65  |
|                      | >5,000 Ha         | 1         | 10      | 20     | 14              | 45  |
|                      | Total             | 2         | 39      | 132    | 80              | 253 |

Table 5. Cross tabulation analysis of the impact to reduce operational cost.

| Particulars          | Reduce Operational Cost by Usage of EFB & POME | Total |
|----------------------|------------------------------------------------|-------|
|                      | 0 Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |
| Area of Plantations  | <3,000 Ha         | 0         | 0       | 17     | 22 | 69              | 35  |
|                      | 3,000 to 5,000 Ha | 0         | 0       | 3      | 15 | 32              | 15  |
|                      | >5,000 Ha         | 1         | 1       | 2      | 8   | 21              | 12  |
|                      | Total             | 1         | 1       | 22     | 45 | 122             | 62  |

| Particulars          | Reduce Operational Cost by Usage of MF & PKS | Total |
|----------------------|---------------------------------------------|-------|
|                      | 0 Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |
| Area of Plantations  | <3,000 Ha         | 1         | 1       | 30     | 66 | 39              | 6   |
|                      | 3,000 to 5,000 Ha | 0         | 0       | 10     | 30 | 19              | 6   |
|                      | >5,000 Ha         | 0         | 5       | 8      | 17 | 13              | 2   |
|                      | Total             | 1         | 6       | 48     | 113 | 71             | 14  |
address the environmental impact. In fact, MF and PKS may have greater commercial value than EFB and POME as the former is potential exported commodity to be processed into activated carbon and biofuel. Some local private limited millers pelletise MF and PKS for export market in order to diversify their business activities and to increase revenue.

Table 6. Cross tabulation analysis of the good commercial value.

| Particulars          | Commercial Values by Usage of EFB & POME | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed | Total |
|----------------------|----------------------------------------|--------------------|-----------|---------|--------|----------------|-------|
| Area of:             |                                        |                    |           |         |        |                |       |
| <3,000 Ha            |                                        | 0                  | 17        | 42      | 69     | 15             | 143   |
| 3,000 to 5,000 Ha    |                                        | 0                  | 7         | 10      | 34     | 14             | 65    |
| >5,000 Ha            |                                        | 2                  | 8         | 10      | 14     | 11             | 45    |
| Total                |                                        | 2                  | 32        | 62      | 117    | 40             | 253   |

| Particulars          | Commercial Values by Usage of MF & PKS  | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed | Total |
|----------------------|----------------------------------------|--------------------|-----------|---------|--------|----------------|-------|
| Area of:             |                                        |                    |           |         |        |                |       |
| <3,000 Ha            |                                        | 0                  | 20        | 58      | 52     | 13             | 143   |
| 3,000 to 5,000 Ha    |                                        | 0                  | 5         | 29      | 26     | 5              | 65    |
| >5,000 Ha            |                                        | 3                  | 5         | 16      | 16     | 5              | 45    |
| Total                |                                        | 3                  | 30        | 94      | 94     | 23             | 253   |

4.3.5. Reduce the usage of inorganic fertiliser

Table 7 reveals that 66.4 percent of the planters agreed that the use of EFB and POME in field application has substantially reduced the usage of inorganic fertiliser whilst only 37.5 percent agreed on the beneficial use of MF and PKS in this respect. It is well known that the bunch ash from EFB is a great alternate source of alkaline and potassium to replace the chemical fertiliser [18]. However the usage of MF and PKS in field application is uncommon practice for most planters in this survey.

4.3.6. Good nutrient value

Similarly, 75.5 percent of the planters recognised the nutrient value of EFB and POME while only 36.0 percent agreed on the nutrient value of MF and PKS as shown in table 8. As mentioned earlier, most planters only explored the usage of EFB and POME in oil palm estates. Hence they were less aware of the beneficial properties of MF and PKS. This also explains why most researches concentrate on the exploration of useful chemical characteristics of POME, EFB and bunch ash, instead of MF and PKS [19].
Table 7. Cross tabulation analysis of the impact to reduce the usage of inorganic fertiliser.

| Particulars       | Reduce in the Usage of Inorganic Fertilizers by Usage of EFB & POME | Total |
|-------------------|---------------------------------------------------------------------|-------|
|                   | 0                      | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |       |
| Area of Plantations | <3,000 Ha             | 0                  | 1         | 16      | 42     | 65              | 19     |
|                   | 3,000 to 5,000 Ha     | 0                  | 0         | 1       | 13     | 35              | 16     |
|                   | >5,000 Ha             | 1                  | 0         | 0       | 3      | 8               | 18     |
|                   | Total                 | 1                  | 1         | 20      | 63     | 118             | 50     |
|                   | Reduce in the Usage of Inorganic Fertilizers by Usage of MF & PKS    | Total |
|                   | 0                      | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |       |
| Area of Plantations | <3,000 Ha             | 1                  | 3         | 22      | 65     | 48              | 4      |
|                   | 3,000 to 5,000 Ha     | 0                  | 0         | 8       | 33     | 16              | 8      |
|                   | >5,000 Ha             | 0                  | 4         | 8       | 14     | 15              | 4      |
|                   | Total                 | 1                  | 7         | 38      | 112    | 79              | 16     |

Table 8. Cross tabulation analysis of the impact of good nutrient value.

| Particulars       | Good Nutrients Value by Usage of EFB & POME | Total |
|-------------------|-------------------------------------------|-------|
|                   | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |       |
| Area of Plantations | <3,000 Ha             | 3          | 34       | 73      | 33     | 143           |
|                   | 3,000 to 5,000 Ha     | 0          | 14       | 34      | 16     | 64            |
|                   | >5,000 Ha             | 1          | 9        | 23      | 12     | 45            |
|                   | Total                 | 4          | 27       | 130     | 61     | 252           |

| Particulars       | Good Nutrients Value by Usage of MF & PKS      | Total |
|-------------------|-----------------------------------------------|-------|
|                   | Strongly Disagreed | Disagreed | Neutral | Agreed | Strongly Agreed |       |
| Area of Plantations | <3,000 Ha             | 0          | 19       | 75      | 40     | 9             |
|                   | 3,000 to 5,000 Ha     | 2          | 6        | 33      | 18     | 6             |
|                   | >5,000 Ha             | 2          | 7        | 18      | 15     | 3             |
|                   | Total                 | 4          | 32       | 126     | 73     | 18            |

4.4. Government Policy and Compliance to Environmental Regulations

Out of 246 planters whose companies own palm oil mill facilities in this study, 94.7 percent have complied with the EQA 1974 to carry out the EIA practice. The remaining 5.3 percent are less sensitive to EIA requirements in which their business operations are under conservative proprietorship and joint venture with the local natives who are less aware of the environmental regulations.

Figure 3 illustrates that palm oil mills with capacity of 60 to 90 metric tons per hour (Mts/hr) contributed most to the frequency of EIA practices. Among the 129 mills of this capacity, 40 mills carried out EIA once a year, 47 did it twice a year, and 42 practised quarterly EIA. In terms of area of plantations, small planters (below 3,000 hectares) contributed significantly to the practice, with 46 who practised EIA once a year, 40 half yearly, and 38 on a quarterly basis (see figure 4).
Figure 3. Frequency of EIA practice versus palm oil mill capacity.

Figure 4. Frequency of EIA practice versus area of oil palm plantations.
From table 9, the correlation index (sig. 2-tailed) between palm oil mill capacity and frequency of EIA practice is 0.646, which indicates that there is a positive relationship between palm oil mill capacity and frequency of EIA practice. This is due to the fact that greater palm oil mill production capacity directly generates more biomass wastes, and hence higher requirement of EIA practice.

**Table 9.** Correlation analysis between area of oil palm plantations versus palm oil mill capacity and frequency of EIA practice.

| particulars                          | plantations hectares | palm oil mills’ capacity | frequency of eia practice |
|--------------------------------------|----------------------|--------------------------|---------------------------|
| area of plantations                  | pearson correlation  | 1.00                     | 0.119                     |
| sig. (2-tailed)                      |                      | 0.003                    | 0.009                     |
| sum of squares and cross-products    |                      | 30.337                   | 16.661                    |
| covariance                           |                      | 0.124                    | 0.072                     |
| n                                    |                      | 246                      | 233                       |
| palm oil mills’ capacity             | pearson correlation  | 0.190**                  | -0.030                    |
| sig. (2-tailed)                      |                      | 0.003                    | **0.646                   |
| sum of squares and cross-products    |                      | 173.337                  | -4.309                    |
| covariance                           |                      | 0.790                    | -0.139                    |
| n                                    |                      | 233                      | 233                       |
| frequency of eia practice            | pearson correlation  | 0.119                    | 1                         |
| sig. (2-tailed)                      |                      | 0.069                    | 0.646                     |
| sum of squares and cross-products    |                      | -4.309                   | 136.996                   |
| covariance                           |                      | -0.019                   | 0.590                     |
| n                                    |                      | 233                      | 233                       |

**. Correlation is significant at the 0.01 level (2-tailed).

As discussed in Section 4.2, the planters agreed that the practice of EIA under EQA 1974 plays an important role to reduce, reuse and dispose the biomass wastes from palm oil mills with a rating of 4.07. The agreement on Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations (1977) is slightly lower, recording a mean of agreement of 3.89. This may be due to the nature of Regulations 1977 which mainly regulate the palm oil millers in compliance with the proper treatment of biomass wastes produced from the mills, hence giving less impact to the oil palm planters.

Meanwhile, the role of NREB was strongly supported by the high mean of agreement of 4.31 from the planters as stated earlier (see table 2). This may be interpreted as a significant responsibility of NREB acknowledged by the planters to ensure the palm oil players and growers adhere to the environmental regulations.

**4.5. Evaluation of the impact of palm oil mill biomass wastes usage on sustainable development**

Respondents in this study generally agreed that the usage of biomass wastes especially EFB and POME was able to reduce the environmental impact from palm oil industry because it helps to reduce the amount of biomass residues need to be disposed from palm oil mills and subsequently mitigate the possible contamination to the environment. Besides, EFB and POME can be used as organic fertiliser, soil conditioner as well as alkaline and potassium sources to partially replace the usage of chemical fertiliser which further contribute to sustainable development.

On the other hand, the planters in this survey were less convinced of the impact of biomass waste usage to increase social responsibility and to improve company image in terms of transparency in waste management (means of agreement between 3.48 and 3.76). Social responsibility may be demonstrated
by mutual distribution of benefits from the proper management of source of biomass wastes from palm oil mills. For example, the palm oil mills may use the appropriate biomass residues such as MF and PKS to generate electricity which can be channelled to the nearby community as a form of social responsibility. Most palm oil mills in Sarawak use the power supply generated from the biomass wastes for worker quarters, daily mill and plantation operations instead of supplying it to the native communities who are living around. There are many impeding factors such as the limited capacity of power convertor, partly due to the company budget, and the concern of maintenance cost.

Besides, high transparency in the documentations, recordings and information sharing concerning the palm oil production processes to all stakeholders may boost the corporate image, especially in handling the biomass wastes from palm oil mills. This may include the involvement of external and internal audits in the administrative and operational processes. Several corporate plantations visited by the researcher during the process of sampling displayed EIA certificate issued by NREB at their respective administrative departments which evidently projected a healthy public image to the visitors. Although the respondents were uncertain about the impact brought to the company image by practising transparent management, more work can be done to reinforce this aspect as part of sustainable development in this industry.

Lastly, the planters agreed (with a rating of 4.04 in table 2) that research and development has continuously improved and increased the usage of biomass wastes in oil palm plantations. Previous studies on the nutrient value of EFB and POME supported the usage of these biomass wastes in oil palm plantations as soil conditioner to improve the soil organic matter, to raise soil pH, and to replace chemical fertiliser to some extent [3]. Indeed there exists a better understanding of the usage of palm oil mill biomass wastes through research and development.

5. Conclusion

In this study, the respondents rated their agreement from 3.64 to 4.22 in the Likert scale (with 5 being the strongest agreement) for several benefits brought about by the usage of EFB and POME in oil palm plantations. In general, they agreed that the usage of EFB and POME can increase crop yields, increase nutrient uptake, reduce operational cost, reduce the usage of inorganic fertiliser, and has good nutrient value. However they were more neutral about the commercial value of these two biomass wastes. In contrast, the usage of MF and PKS received lower acceptance with a neutral range of agreement of 3.14 to 3.41 for all the benefits surveyed. Besides, 94.7 percent of the planters’ companies were found to comply with the EIA requirements. The planters agreed to the significant role performed by NREB to enforce the EIA practice under EQA 1974 as well as compliance of Environmental Quality Regulations 1977, recording a Likert rating of 3.89 to 4.31.

Lastly, the planters agreed that the usage of EFB and POME has reduced the environmental impact and improved the sustainable development, and they recognised the importance of research and development to improve and increase the usage of biomass wastes. However the planters were uncertain of the impact of usage of biomass wastes with respect to the contribution to social responsibility and company image in terms of transparency in waste management. The usage of EFB and POME gained higher Likert scale point of 3.76 to 4.17 against MF and PKS of 3.34 to 3.49 in the evaluation of the impact of sustainability in oil palm plantations. Therefore the researchers accepted Hypothesis 1 in this study which states that the usage of EFB and POME from palm oil mill influences sustainable development in oil palm plantations.

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