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Peat Characteristics and its Impact on Oil Palm Yield

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ABSTRACT

The yield potential of oil palm planted on peat land has always been a controversial subject. Most past soil research on oil palm yield on peat land was mainly based on the depth and drainability. Little attention was given to the impact of peat characteristics on oil palm from a yield perspective. This study tests the hypothesis that physical soil properties such as peat maturity, presence of wood, depth and nature of underlying substratum affects oil palm yield. The initial study involved the evaluation of soil mapping units on estates in Sibu, Sarawak, East Malaysia and from this exercise of four organic soil mapping units which reflected the different characteristics of soils were selected. Data on peat depth, presence and absence of decomposed and undecomposed wood, nature of underlying substratum and peat maturity (fibric, sapric and hemic) were collected, analyzed and interpreted. Comparisons were also made on mineral soil found at the same location. Yield data were analyzed from primary sources from oil palm estates. Results show that different types of peat have significant effect on oil palm yield ranging between 9.47 - 22.92mt/ha. Peat maturity has the most significant effect on yield. Sapric peat showed a yield range of 19.48-22.92mt/ha as compared to hemic peat ranging between 9.47- 13.37mt/ha. Palms planted on soils with sandy substratum showed significant 18 -142% higher yields compared to those over marine clay as underlying material. No significant differences were observed in the yields due to the different depths and presence/absence of wood as a single factor. However, a combined factor of peat maturity and presence with nature of wood do have significant impact on yield.

The study further confirms that sandy spodosol like Bako series perform 30 - 40.44% lower yields compared to peat soils such as Telong and Naman series.

The results are important as peat areas with specific physical soil properties and showing poor yields can been left for conservation prior to development. Thus selective development based on semi detailed soil surveys producing maps giving peat characteristics and its impact to oil palm yield is possible. However, a more balanced view and future research should be emphasised to other issues such as cost of development of peatland compared to the price of crude palm oil in the world market, biodiversity, social issues, Green House Gas (GHG) emissions and potentials of improving productivity on existing organic and mineral soils need to be further explored. The study therefore challenges the existing believe that peat depth is very significant in determining oil palm yield. The study also enhances the need for soil surveys for land use decisions and wise use of peatlands. Further research is recommended to narrow the knowledge gaps and uncertainties on peatland.

1. Introduction

Peat lands cover an estimated area of 400million hectares or equivalent to 3% of Earth's land surface. Tropical peat land is in the range of 30-45million ha which is 10-12% of the global peat land resource [1]. Wise use of tropical peat land had been emphasized taking into considerations the tradeoffs between development and conservation [2]. While perennial crop cultivation such as oil palm on peat land can be seen as a solution for rural development, peat land conservation has also attracted global attention especially from a climate change perspective. The 2013 Supplement to the 2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories: Wetlands - Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment - (Wetlands

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Supplement) provides new and supplementary guidance on estimating and reporting greenhouse gas emissions and removals from lands with organic soils and with wet mineral soils in Wetlands and other land-use categories with these soil types that are subject to human activities [3]. The yield viability and economic feasibility of peat land cultivation for agricultural crop had been questioned such as the Mega Rice Project in Central Kalimantan where one million hectares of peat land converted for rice cultivation had failed [4]. There are also views that Best Management Practices (BMP) should be used to improve yield for crop cultivation such as oil palm on peat land [5].

Currently, the yield economics of oil palm cultivation on peat land is commonly related to two major issues. Firstly land selection taking peat depth and drainability into consideration and secondly Best Management Practices (BMP) which are implemented after initial land development. Depth is related to whether the soils are shallow (0-100 cm), moderately deep(>100 cm -300 cm) and deep (>than 300 cm) [6]. Drainability refers to sustainable drainage conditions where long term sustainable drainage in relation to the depth of underlying mineral subsoil level rather than the present ground surface to the river water levels. Tie and Melling [7] identified four classes (good, moderate, poor and very poor) of drainage differentiating gravity drainage as against the tidal cycle of nearby rivers even after all the surface peat had subsided.

In the past, the land selection criteria used for the development of tropical peats for agricultural development were its depth and drainability [7–9]. As such, many important tropical peat soil characteristics such as peat maturity, the presence/absence of wood, nature of wood (decomposed/undecomposed) and the nature of the underlying mineral substratum were not used in their mapping and classification and also in their land suitability evaluation [10,11]. Consequently current soil mapping and classification systems such as the *Keys to Soil Taxonomy* [12] and the *World Reference Base for Soil Resources 2006* [13] which were developed for temperate peats also do not recognise the presence of wood and hence cannot be fully used in the tropics [10,14]. This is due to the fact that temperate and boreal peats are often dominated by bryophytes and shrub whereas tropical peat land in contrast have various tree species with root penetration to several metres. Rate of biomass production and decomposition is high resulting from decaying roots and root exudates.

Veloo et al., [10] proposed using the Malaysian classification system which takes into consideration depth, morphology, nature of wood and underlying mineral substratum to compliment international classification schemes.

Many of the tropical peat characteristics such as their depth, presence and nature of wood and subsurface tier characteristics therefore need to be mapped as these may impact strongly the suitability and management of tropical peat lands for crops such as oil palm [15]. These characteristics may seriously impact the economics of cultivation and management of oil palms on peat particularly from the yield perspective [6]. For example, being close to coastal areas, the underlying subsurface tier are usually marine clay (often sulphidic), riverine alluvium or sand [16]. Tahir et al.,[17] indicated that both riverine alluvium and sand can be mined to construct roads by building up foundation with spoils (dug below peat layers) from adjacent drains. Good road networks are critical in determining crop evacuation, transportation and crop quality which enhances the yield of oil palm. Peat characteristics are also expected to influence other factors such as GHG emissions and performance.

The objective of this paper is to explore the impact of physical properties of tropical peat on oil palm yield. This study tests the hypothesis that physical soil properties such as peat maturity, presence of wood and nature of underlying substratum and depth affects oil palm yield.

2. Materials and methods

The initial approach was to study the existing information available on estates already planted with oil palm on peats in the in Sibu Sarawak, Malaysia. An area of about 11,970 ha were selected on areas already planted with oil palms and palms are now matured. A reconnaissance soil map of the estates in the region at a scale of 1:125,000 published by the Department of Agriculture and geological and vegetation maps were studied. A semi-detailed soil survey using an intensity of one auger examination point for every 20 hectares was carried out using a system of free traversing for the whole area involved. At each examination point the soil was examined using Maculay peat auger and Jerret soil auger to a depth of 125 cm or to the underlying mineral subsoil layer.

Soils were described and identified using the Malaysian Soil Taxonomy Revised Second Edition [18] and Keys to Identification of Malaysian Soils [19]. The classification of the soils was also compared with the USDA Soil Taxonomy [12] as an equivalent classification for purposes of international comparison.

Following the semi-detailed soil survey, a complete randomized design involving fields of five type of soils i.e. Naman (Typic Haplosaprist-No wood),Telong (Typic Haplosaprist-decomposed wood), Bayas (Typic Haplohemist-decomposed wood), Gedong (Typic Haplohemist-undecomposed wood) and Bako (spodosol) were used on plot size of between 60-110 hectares as described in Table 1. Uneven replications of four to six plots for each type of soil were used in the study. Criteria for selection of treatments were standardised for fair comparison of treatments i.e. Fields with same age of planting and same type of planting material were selected for the above purpose. The selection of Bako series (sandy podzol) is based on the fact that this is the only significant mineral soil available within the same locality on these peat areas. This soil was selected to make a comparison of the four peat soils with a mineral soil available at the same locality.

With the information on the morphological and physical characteristics of the soils of oil palm fields, actual oil palm yield data were collected and statistically analysed using one way statistical analysis (Anova). The Anova analysis evaluates if the four factors related to physical soil properties i.e. peat maturity, presence of wood, nature of underlying mineral substratum and depth have a significant impact on oil palm yield. The interaction of the above factors affecting oil palm yield is not covered in this study.

3. Results

3.1. Descriptive Statistics

The yield of oil palms in Fresh Fruit Bunches (FFB) planted on five different types of soil, Naman(Oa) deep, Telong deep (Oawd), Bayas(Oewd) very deep, Gedong(Oewu) very deep, and Bako(spodosol mineral) were analysed (Table 2). Four of the soil types are peat and one i.e. Bako series are mineral sandy soils found at the same locality within the peat soil area.

Based on the one-way ANOVA analyses (Table 3) and results as shown in Table 2, Table 4, Figure 1 and Figure 2 the following can be deduced:

- The different types of soil has significant effect on oil palm yield. Telong series (deep) shows the highest yield with a mean yield of 22.92mt/ha and Gedong series (very deep) results with the lowest mean yield at 9.47mt/ha.

Table 1
Classification and soil characteristics of the four soil [18,19].

Soil Series/Depth Phase	Classification at Series (Phase Level) (Paramananthan, 2010a)	Equivalent Classification – Keys to Soil Taxonomy (Soil Survey Staff, 2010)	Main Characteristics
Naman/deep (Oa)	Sapric Ombrogambist, marine-clayey, isohyperthermic, non-woody, autochthonous [deep (150-300 cm), sapric]	Typic Haplosaprist, dysic, isohyperthermic (No criteria at series/phase level)	• Sapric material to 100 cm. • No wood to 100 cm. • Deep (150-300 cm) to marine clay. • Surface tier – sapric.
Telong/very deep (Oawd)	Sapric Ombrogambist, marine-sandy, isohyperthermic, decomposed wood, autochthonous [very deep (>300 cm), sapric]	Typic Haplosaprist, dysic, isohyperthermic (No criteria at soil series/phase level)	• Sapric material to 100 cm. • partially decomposed wood 50-100 cm depth. • Very deep (>300 cm) to marine sand. • Surface tier– sapric.
Bayas/very deep (Oewd)	Hemic Ombrogambist, marine-clayey, isohyperthermic, decomposed wood, autochthonous [very deep (>300 cm), sapric]	Typic Haplohemist, dysic, isohyperthermic (No criteria at soil series/phase level)	• Hemic material (50-100 cm). • Decomposed wood in 50-100 cm depth. • Very deep (>300 cm) to marine clay. • surface tier – sapric.
Gedong/very deep (Oewu)	Hemic Ombrogambist, marine-clayey, isohyperthermic, undecomposed wood, autochthonous [very deep (>300 cm), sapric]	Typic Haplohemist, dysic, isohyperthermic (No criteria at soil series and phase level).	• Hemic (50-100 cm). • Undecomposed wood in 50-100 cm. • Very deep (>300 cm). • Surface tier – sapric.
Bako (Mineral Soil)	Typic Haplohumod Sandy soils over isohyperthermic Strongly cemented sandstone	Typic haplohumod Sandy siliceous Isohyperthermic cemented	• Bako (Mineral soil) • Moderately deep (50-100cm). • Loose structure less sand • Strongly cemented • spodic horizon (50- 100cm) depth. • Soils developed over • Sandstone

Note: Oa (Organic and sapric), Oawd (Organic,sapric and decomposed wood), Oewd(Organic, hemic and decomposed wood), Oewu (Organic, hemic and undecomposed wood) refers to soil management group.

- Peat maturity or stage of decomposition has the most significant effect on yield for peat soil. Soils with sapric materials (Naman/Telong) gave significantly better yields (19.48-22.92mt/ha) than soils with hemic materials (Gedong/Bayas 9.47-13.37mt/ha).
- Palms planted on soils with sandy substratum (Telong) had significantly higher yields by 18 -142% compared to those over marine clay as underlying material. Telong series showed 22.92mt/ha compared to those over marine clay (Naman, Bayas and Gedong-yielding between 9.47mt/ha–19.49mt/ha.
- No significant differences were observed in the yields due to the different depths(< than and > than 300 cm) of soil.
- Presence/absence of wood as a single factor does not significantly affect yield of palms on peat.
- However combined factor (peat maturity and wood) showed that Telong (Sapric with decomposed wood) with 22.92mt/ha performed better than Naman series (which has no wood) with 19.49mt/ha. The Bayas series (hemic, decomposed wood) with 13.37mt/ha performed better than the Gedong series (hemic, undecomposed wood) which only had 9.47mt/ha.
- Sandy spodosol like Bako series perform 30 - 40.44% lower yields compared to peat soils such as Telong and Naman series.

Mineral soil (sandy spodosol like Bako series) perform poorly at 13.65mt/ha compared with some of the peat soils such as Telong

Table 2
Mean yield of fresh fruit bunches (2003–2013).

Soil Series	Soil Management Group	N	Mean	Range	Standard Deviation
Naman Deep	Oa (organic, sapric, no wood)	4	19.50	18.71-20.62	0.89
Telong deep	Oawd (organic,sapric, decomposed wood)	6	22.92	19.65-25.18	2.26
Bayas Very Deep	Oewd (organic,hemic, decomposed wood)	5	13.37	11.71-15.33	1.31
Gedong Very Deep	Oewu (organic, hemic, undecomposed wood)	5	9.47	8.17-10.70	0.91
Bako	Mineral soil	6	13.65	10.28-16.01	2.19
	Total	26	15.83	8.17-25.18	5.21

Table 3
Factors affecting oil palm yield on peat soils.

Source of Variation (Dependent: Yield)	d.f.	s.s.	m.s.	v.r.	F
Soil Type	4	616.765	154.191	51.85	<0.001**
Nature of underlying mineral Substratum	1	134.79	134.79	5.94	0.023*
Peat Depth (<300 cm & >300 cm)	1	0.40	0.40	0.01	0.906
Presence of Wood	1	18.22	18.22	0.66	0.424
Peat maturity (sapric, hemic)	1	316.57	316.57	20.95	<0.001**

* Significant at 0.05 level.
** Significant at 0.01 level.

Table 4
Mean yield of FFB by soil type from year 1 to year 11(2003–2013).

Year	Naman deep	Telong very deep	Bayas very deep	Gedong very deep	Bako (mineral soil)
2003	10.02	6.61	6.27	1.80	4.16
2004	13.86	9.59	7.91	3.26	7.05
2005	18.50	14.43	10.58	4.45	9.39
2006	18.16	21.83	9.44	5.79	11.45
2007	20.57	26.32	10.36	9.34	11.66
2008	17.60	27.23	13.92	11.05	13.98
2009	20.88	27.01	15.66	11.93	16.47
2010	21.45	26.93	16.58	12.59	17.93
2011	23.35	32.15	18.90	12.61	19.07
2012	24.74	31.10	17.60	13.64	19.85
2013	25.21	28.97	19.82	17.67	19.16
Mean	19.49	22.92	13.37	9.47	13.65

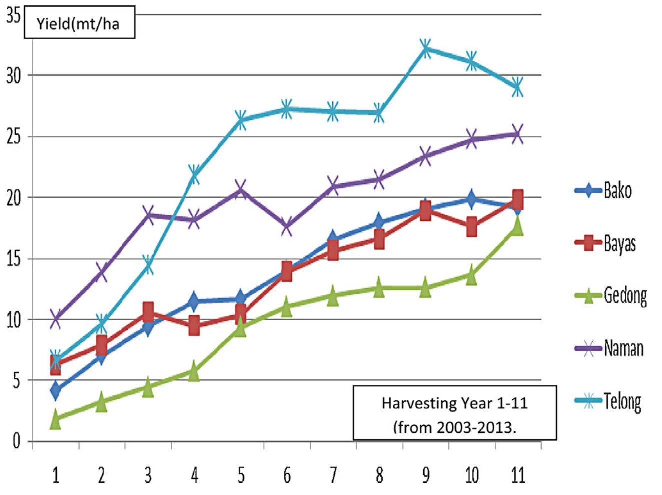


Fig. 1. Mean yield of FFB by soil type from year 1 to year 11(2003–2013).

(22.92mt/ha) and Naman (19.48mt/ha). However, mineral soil performed higher than peat like Gedong series (9.47mt/ha).

4. Discussion

4.1. Peat characteristics and their impact on Oil Palm Yield

Generally sapric peat (Figure 2a and 2b*)* i.e. Naman and Telong series within 50-100 cm depth shows a higher yield than hemic peat Figure 3a and3b. i.e. Bayas and Gedong series. This is possibly due to the fact that oil palm roots are mainly in contact with the highly decomposed sapric material which is a good rooting and growth medium as compared to the hemic material. Most oil palm feeder roots are concentrated within 0 cm to 50 cm depth as effective rooting zone [20]. Another possibility for the above observation is that hemic peat with higher level of porosity may not have good nutrient retention properties especially in the higher rainfall areas. In the study area the average 5 years annual rainfall exceeds 4000 mm. Presence or absence of wood (as a single factor) as shown in Figure 5 contrary to the general believe shows that it has no impact on oil palm yield especially in the first 5 years in harvesting.

However, when a combination of decomposition stage and wood are considered, hemic material with undecomposed wood (Gedong series) appears to have multiple disadvantages with issues related to poor rooting, growth medium, high porosity and poor nutrient retention. As such yields of Gedong series (hemic undecomposed wood) gave the lowest mean yield (9.47 mt/ha). The presence of wood on hemic material will further reduce oil palm yields as high volume of wood biomass (Figures 4 and 5) resulting in inadequate space for inter-row stacking results in woody debris encroaching into oil palm circles resulting in half moon access which impedes good harvesting standards and crop loss. The presence of wood affects growth and yield for agricultural crop such as oil palm when roots get in contact with wood material resulting in poor uptake of nutrients and pre-mature desiccation of fronds [15]. The presence of wood within 100 cm also encourages termite infestation and is detrimental to most crops.

Where sapric materials occur with decomposed wood Telong series gave better yields than the Naman series which had no wood. The possible reasons could be that where the wood is only encountered below 75 cm depth (for Telong series) and this affects the yield in initial years. However, after the 8th year when oil palm roots are in contact on partly undecomposed wood at 75 cm depth, oil palm yields appear to decline as compared to Naman series which has no wood and yields are still remain on the increasing trend. Another reason for the decline in yield after the 8th year is that with undecomposed wood, possibility of termite attack and loss of yield due to lower stand can be a reason for a lower yield after 8 years as compared to Naman series which has no wood. Dolmat [21] indicated that clearing as much as possible the partially hidden stumps and logs protruding from the ground is important in the long run to achieve better growth and higher productivity of oil palm as termite problem is reduced.

Although yield of Telong series declines after the 8th year as shown in Figure 1, the average yield of Telong series for the last four years (year 8 to year 11) is still higher as compared to Naman

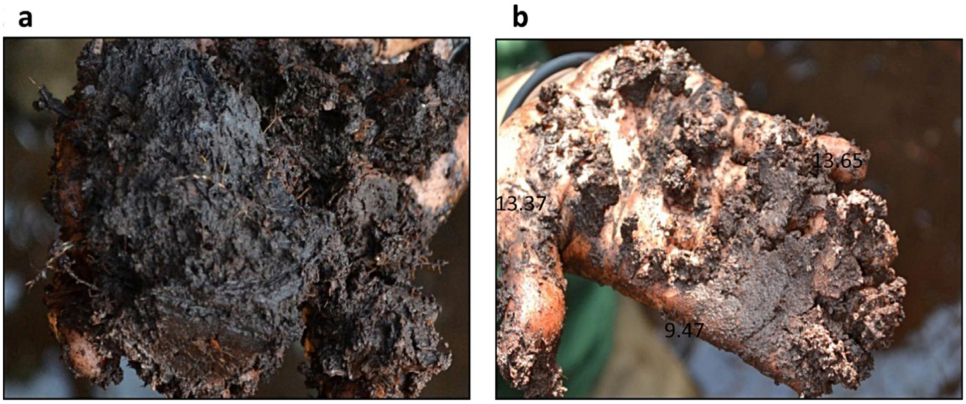


Fig. 2. a. Sapric Peat.
b. Sapric peat after rubbing.

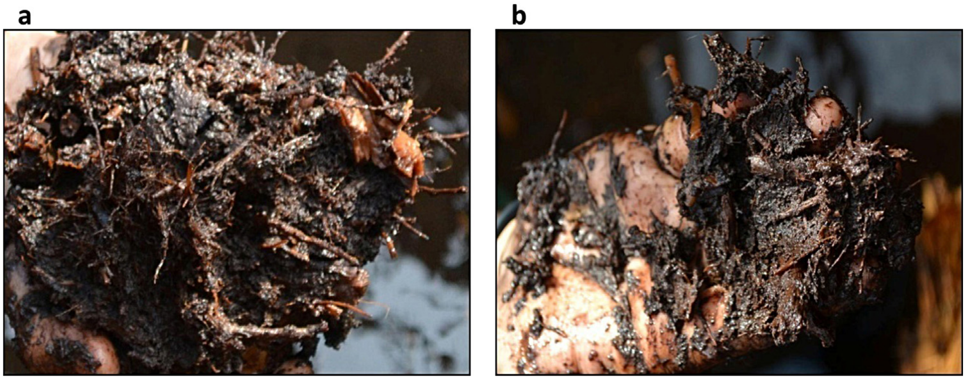
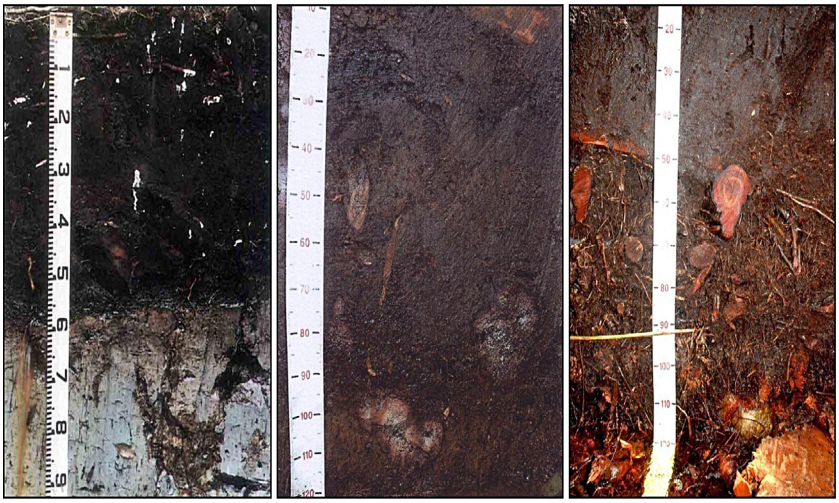


Fig. 3. **a.** Hemic Peat
b. Hemic peat after rubbing.



No wood Decomposed wood Undecomposed wood

Fig. 4. Peat with No wood, decomposed wood and undecomposed wood.

Table 5
Average yield for 11 years and for last 4 years by soil type.

Soil Type	Mean 11Years (2003-2013)	% *	Mean Yield Last 4 Years (2010-2013)	%*
Naman	19.49	100.00	23.63	100.00
Telong	22.92	+117.60	29.87	+126.40
Bayas	13.37	-31.40	18.23	-77.10
Gedong	9.46	-51.46	14.10	-59.67

Note: * Indicates % compared with Naman Series (which is without wood)

by 26.40% as shown in Table 5. While Naman is still on a yield uptrend as against Telong which is declining. More time is required to observe the overall impact of both soil on yields of oil palm.

Soils with sandy mineral substratum (Telong series) has higher yield than mineral clay (Naman, Bayas and Gedong series) as shown in the results. Although the depth of mineral substratum below 100 cm may not have direct impact on the oil palm rooting zone within 100 cm, the impact can be from the perspective of water management. Mineral clay at the substratum will impede good drainage and cause flooding at soil surface which will affect harvesting operations during monsoon season. High water table also impedes good palm growth and induce “wet feet” symptoms which impedes nutrient uptake. As for sandy mineral substratum, where better drainage is possible, surface flooding is minimised and impact of yield is not much affected. Mining of sand from the underlying layer of peat to be used as road material on peat areas as observed in the study area, also contributes to efficiency in access and timely evacuation and crop transportation to processing centres which minimises leakages and wastages in terms of yield achievement.

The general view [22] that all mineral soils are better yielding than peat can be challenged in this analysis. Sandy soil within peat areas is proven to perform worse than at least 3 types of peat soil in this case (i.e. Telong, Naman and Bayas) mainly due to the spodic horizon which has an impact on drainage and root proliferation within the 50 cm depth. Sandy soil also has poor moisture and nutrient retention capacity besides its low CEC due to lack of organic material. Therefore, while making comparison between mineral and peat soils, merits of the type of mineral and peat soils and its characteristics should be taken into consideration rather than generalising them into one category (peat or mineral).

4.2. *Other factors and future research recommendations*

Any sustainable agricultural development will not be solely dependent on yield feasibility of land for cultivation. Peat land cannot be developed solely based on its characteristics and its impact to the yield economics of oil palm cultivation. Other factors in relation to cost of development and price of crude palm oil in the world market should also be considered as the overall IRR (Internal Rate of Return) and payback period will determine the overall economics

Fig. 5. Undecomposed wood material on soil surface.

of the crop. Future research in this area is recommended. Apart from economics social issues, biodiversity and GHG emission should also be taken into consideration.

Veloo [23] reported that there are many negative impacts reported by converting peat swamp forest into oil palm plantations. Deforestation and the transformation to oil palm plantations in the tropics have led to a high rate of species decline [24]. This loss is significant because reductions in species diversity are considered to be irreversible and therefore the need to conserve peat swamp forests in the Indo-Malayan region is clearly urgent [25].

Current studies also indicate that the transformation of an intact peat swamp area to oil palm plantations leads to a release of Green House Gasses (GHG) to the atmosphere [1,26–28]. Peat land emits greenhouse gases in the forms of CO_2, CH_4 (methane) and N_2O. Of these three gases, CO_2 is the most important because it forms the highest amount emitted by peat land, especially converted peat forest to agriculture or settlements. CH_4 is measurable in peat forests that are normally saturated or submerged. CO_2 emissions dominate drained peat, whereas CH_4 emissions decrease significantly or even become undetectable in drained peat land. N_2O emissions occur from nitrogen-rich soils. Part of the leached nitrate into the anaerobic layer is reduced into N_2O. [3].

Draining inland organic soils lowers the water table and increases the oxygen content of the soil, thus increasing CO_2 emissions. CH_4 emissions from drained inland organic soils are generally negligible because the soil carbon is then preferentially oxidized to CO_2. However, methanogenesis may take place in drainage ditches with a higher water table causing significant sources of CH_4 to the atmosphere. Drained organic soils can also emit significant amounts of N_2O from nitrogen in the organic matter or nitrogen added by fertilization. Rewetting inland organic soils raises the water table again, decreases CO_2 emissions, rapidly decreases N_2O emissions to close to zero, and increases CH_4 emissions compared to the drained state as the oxygen level in the soil drops and methanogenesis starts again [3].

The ongoing and future expansion of oil palm plantations may, or may not, result in future emissions of CO_2, the most significant GHG linked to land use, depending on the type of land cover that is converted for new plantations. For example, if expansion occurs on forest landscapes with high above- and below-ground carbon stocks, then net emissions linked to the sector will be proportionally large. In contrast, if the source of land for new plantations has low C stock value, such as shrub land or agroforest, then future expansion could be considered carbon neutral. In some cases, expansion might actually be carbon positive if the initial carbon stock is less than that of oil palm as is the case with grassland and most types of annual crops. [29].

Peat fires increases CO emissions owing to burning or oxidation of one or a combination of plant biomass, necromass and peat layers [30]. Fires often occur during land-use change from forest to agriculture or other land uses [31]. Fires can also occur during long drought periods. Under traditional farming practices, burning can be done intentionally to reduce soil acidity and improve soil fertility. But, on the other hand, this practice increases the contribution of peat to CO_2 emissions [30].

Transformation of forest to agricultural use involves increased management activities such as use of machinery, inputs of fertilizer and mill operations, many of which may promote CH_4 emissions such as those from mill effluent and biomass burning in mill boilers. Soil subsidence can cause the peat surface to drop to levels that enable the water table to reach and rise above the new surface level in periods of high rainfall. This may lead to flooding of adjacent land and downstream areas [32]. In addition, because of the soil subsidence and reduced water retention, the freshwater buffer function of the peat swamps decreases, resulting in a decreased buffer against salt water intrusion in the dry seasons [33].

Oil palm plantations especially large scale estates have frequently been associated with negative social impacts on rural communities and indigenous people. Although oil palm frequently appears to improve income, it affects social relations and land ownership in rural areas in ways that may ultimately work against the well-being of the people. Human rights abuse by plantation companies especially during land acquisition and plantation development This is evident at the study site where land encroachment and claims issues were reported among indigenous tribes i.e. Ibans and local Malays surrounding the Sibu complex site.

There are also knowledge gaps and uncertainties related to the development of peat land for palm cultivation. There is a huge scarcity of information on GHG emission from tropical peat land which is used for agriculture. Emission estimates from tropical peat lands converted from their wet natural forest condition to a drier form of human land use are large numbers with wide confidence intervals [3,30]. Husnain et al. [34] indicates that no significant differences among the different land-use systems in the same landscape influencing CO_2 flux. Unexplained site variation seems to dominate over land use in influencing CO_2 flux. The large amount of CO_2 emission from tropical peat has been challenged by Melling *et al.* [35] where the method of extrapolating CO_2 emission for tropical peat based on experience and results of temperate peat were questioned. Similarly, uncertainties regarding GHG emissions from tropical peat land were pointed out by Vasander and Jauhiainen [36]. In the end, the IPCC accepted a system where the means of accepted data sets serve as default values [3]. Lack of detailed characterization of peat is probably one of the important reasons why conflicting data on GHG emissions of tropical peats are reported. It is also argued that oil palm plantations store more carbon than alternative agricultural land uses [37]. The Malaysian and Indonesian peats mostly have sapric material with no wood in the upper 50 cm and research on its impact to GHG emissions should be further explored.

Information on the social and economic effects of oil palm development is scarce and contradictory. There is also a need for alternative production scenarios that allow ecologically and socially sustainable oil palm development and give the highest yields with the lowest social and environmental impacts. Social studies including plantation owners, people depending on forest products, smallholders, and indigenous people on a peat swamp area should be carried out.

Fairhurst [5] opined that focusing efforts on yield improvements on the existing cultivation base, and by limiting expansion to lands that have already been degraded, many of the concerns that are currently being levied against the industry can be addressed. He further argued that a 35% increase in yield is not unrealistic. Improving productivity on existing land will put less pressure on the development of peat land which comes with a package of negative impacts, uncertainties and knowledge gaps.

5. Conclusions

Oil palm yield on peat varies significantly under the various type of peat soil i.e. Telong, Naman, Bayas and Gedong soil series. This is mainly due to the characteristics of the individual peat soil. Among the various soil factors evaluated (depth, mineral substratum, peat maturity, presence and absence of decomposed undecomposed wood) peat maturity (sapric or hemic) plays the most significant role in determining the oil palm yield. Type of mineral substratum for peat also shows some impact with sandy substratum showing higher yields as compared to marine clay substratum. Peat depth which were usually used as a criteria for development had been found not significant in determining the yield of oil palm. However, this study shows that absence and presence of wood and its rate of decomposition do have an impact especially on hemic peat.

Mineral soils (sandy Bako series) recorded lower yields than three types of peat in this study. The general believe that mineral soils are better yielding than peat is proven to be not true based on our analysis. Merits of the type of mineral and peat soils and its characteristics should be taken into consideration rather than generalising them into one category (peat or mineral).

The use of semi detailed soil surveyed maps however can help to delineate areas which are obviously not suitable or economical less viable and hence should not be cleared for planting.

Although yields on selective peat soils are encouraging on sapric peat with no wood or decomposed wood and with underlying sand material, decision to develop peat land should not be solely based on yield factor. Other factors in relation to cost of development and price of crude palm oil in the world market which determines the overall economics of oil palm cultivation should be looked into. Other social issues, impact to biodiversity and GHG emission should also be taken into consideration. There are many negative impacts reported by converting peat swamp forest into oil palm plantations. This is coupled with knowledge gaps and uncertainties which need to further researched and answered. Peat land cannot be developed solely based on its characteristics and its impact to the yield of oil palm cultivation. Improving productivity through best management practices on existing land should be prioritised rather than expanding land areas on peat land which should be treated as a last resort.

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