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A Comparative Study of the Use of Organic Carbon and Loss on Ignition in Defining Tropical Organic Soil Materials

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ABSTRACT

Organic soils or Histosols or peats as they are commonly referred to, are characterized by the presence of large amounts of organic soil materials (OSM), which is commonly quantified by the Walkley and Black (1934) (WB) method to determine the soil organic matter (SOM) using a correction factor of 1.724. SOM of Histosols is also identified through a combustion (loss on ignition, LOI) or elemental C-analysis (with a carbon-nitrogen-sulfur (CNS) analyzer with combustion and gas density detector). These methods were established using temperate and boreal peat deposits and here we demonstrate that tropical peat deposits require a modified approach. Typical SE-Asian tropical lowland peat pedons from rain forest and oil palm settings were sampled and the material analysed using a CNS analyzer, WB-C and LOI. The ratios for LOI:CNS-C for the 20 samples yielded values between 2.00–3.09 with a mean of 2.50 while the LOI:WB-C ratio yielded values from 1.75 to 2.58 with a mean of 1.94. A comparison of these values for topsoils and subsoils showed mean ratios (LOI:WB-C) of 1.94 and 1.89 for topsoils and subsoils, respectively. The forest samples had higher LOI:WB-C ratios than the subsoils from oil palm settings (1.94 vs 1.84). These values suggest that the standard factor of 1.724 to correct OSM to SOM for tropical soils is untenable. The values to convert CNS and WB-C values of tropical topsoils/subsoils to SOM or LOI should be 2.5 or 1.9, respectively. Our results indicate a significant difference in the soil organic carbon (SOC) of tropical lowland peats depending on the method used.

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Histosols; organic soils; soil classification; soil organic carbon; soil organic matter; tropical peat soils

Introduction

Organic soils or Histosols or peats are soils dominated by organic soil materials. These soils are found in areas where the decomposition or breakdown of plant residues is slower than their rate of natural production or addition to the soil; which results in a build-up of plant remains forming thick (>50 cm) organic soils. Most organic soils are found in cold or boreal climates where the low temperature during large parts of the year hampers break-down of the plant remains. Similarly, highland tropical organic soils also experience relatively low temperatures and water-logging conditions during parts of the year, however, lowland organic soils of the tropics rely exclusively on waterlogged conditions (at least part of the year) and poor drainage conditions for reduced breakdown of the plant remains. The physical and chemical characteristics of the resultant organic soil materials depend largely on the type of vegetation and thus litter that

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accumulates, as well as rate and process of organic matter breakdowns. Boreal and temperate organic soils are often dominated by remains of mosses (i.e. *Sphagnum*), sedges, grasses and shrubs, while tropical lowland organic soils are mostly developed over wetland forests with only few shrubs/sedges (Anderson 1964; Anderson, 1983; Morley 1981). Despite these stark different environmental conditions, most definitions and international peat classification systems such as the Keys to Soil Taxonomy – 12th Edition (Soil Survey Staff 2014) and the World Reference Base for Soil Resources 2014-update 2015 (IUSS Working Group WRB 2015) do not differentiate tropical and temperate/boreal peats adequately. Thus, current definitions of organic soil materials (OSM) and the classification of organic soils or Histosols simply refer to these as peats, despite the fact that many studies have highlighted the contrast between tropical and high latitudinal organic soils and their distinct properties (e.g. Andriesse, 1988; Veloo, Paramananthan, and Van Ranst 2014; Veloo, Van Ranst, and Paramananthan 2015; Wüst, Bustin, and Lavkulich 2003). Decades of extensive soil surveys of tropical lowland organic soils carried out by the first author and others have shown that global definitions are poorly applicable for tropical organic soils (Paramananthan 2016; Paramananthan & Wahid Omar, 2015; Wüst, Bustin, and Lavkulich 2003). Therefore, definitions of OSM and that of Histosols especially with reference to those mapped in tropical regions need to be reexamined.

The definition of OSM of organic soils and Histosols depends on the estimation of the organic carbon present. The USDA's Keys to Soil Taxonomy – 12th Edition (Soil Survey Staff 2014) and the World Reference Base for Soil Resources 2014-update 2015 (IUSS Working Group WRB 2015) both use the organic carbon (OC) content as determined by the Walkley and Black (1934) method (WB method). The soil organic carbon content is then conventionally converted to SOM using a correction factor of 1.724 (assuming that organic matter contains on average 58% carbon) (Pribyl 2010). As the WB method is often time-consuming, other methods have been used to determine organic carbon and organic matter (e.g. Jolivet, Arrouays, and Bernoux 1998). For definitions of tropical organic soils, loss on ignition (LOI) of more than 65% or ash content (100 – LOI%) of <35% are used to define peats (Andriesse 1974; ICCC, 2012; Leamy and Panton 1966; Minister of Agriculture, Indonesia 2009; Rieley and Page 2005; Wüst, Bustin, and Lavkulich 2003).

Although the correction factor of 1.724 for organic carbon to determine SOM is widely used, it has been reviewed and other values suggested (Matus et al. 2009; Pribyl 2010). The question arises as to whether the factor of 1.724 based on temperate organic soils and mineral soils can be applied to tropical organic soils. Several studies from tropical peatlands (e.g. EKONO 1981; Wüst, Bustin, and Lavkulich 2003) showed that the organic carbon contents increase with increasing decomposition of organic materials. As such, coarse fibric peats may have organic carbon values of 48–50% (LOI ≈ 82–86%), while hemic peats (more humified) have values of 53–54% (LOI ≈ 91–93%) and highly humified peats, or sapric peats, have organic carbon contents of 58–60% (LOI ≈ 100%). These changes also indicate an increased polymerization of the carbon compounds. In tropical organic soils, it is common that under highly decomposed peat layer, less humified peat layers are found, i.e. less humified peat layers occur at depths. In addition, most tropical peatlands initially experienced minerogenic environmental conditions, which resulted in occasional flooding and input of mineral matter in the basal peat layers. Such soil structures result in upper soil layers having higher OC values than the sub-surface or deeper layers. A study of tropical peats in Sarawak (Malaysia) showed that the ratio LOI/OC was around two times OC percent on average, but in that study, shallow peats (ratio of 4) had higher values than the deeper peat (ratio of 2.5) (Tie and Lim 1976). Such analyses have not been repeated elsewhere, but if these values are correct, the definitions of tropical organic soil materials and Histosols should be different from that of temperate and boreal peats.

The objective of this study is to investigate the ratio of LOI:OC for tropical organic soils based on peat soil profiles from Malaysia and investigate the correction factors of OC to OM for tropical soils. Three soil profiles each from an undrained peat swamp forest in Johore State and from an oil palm estate in Perak State in Malaysia (Figure 1) were investigated and the data presented together with proposed correction factors for tropical Histosols.

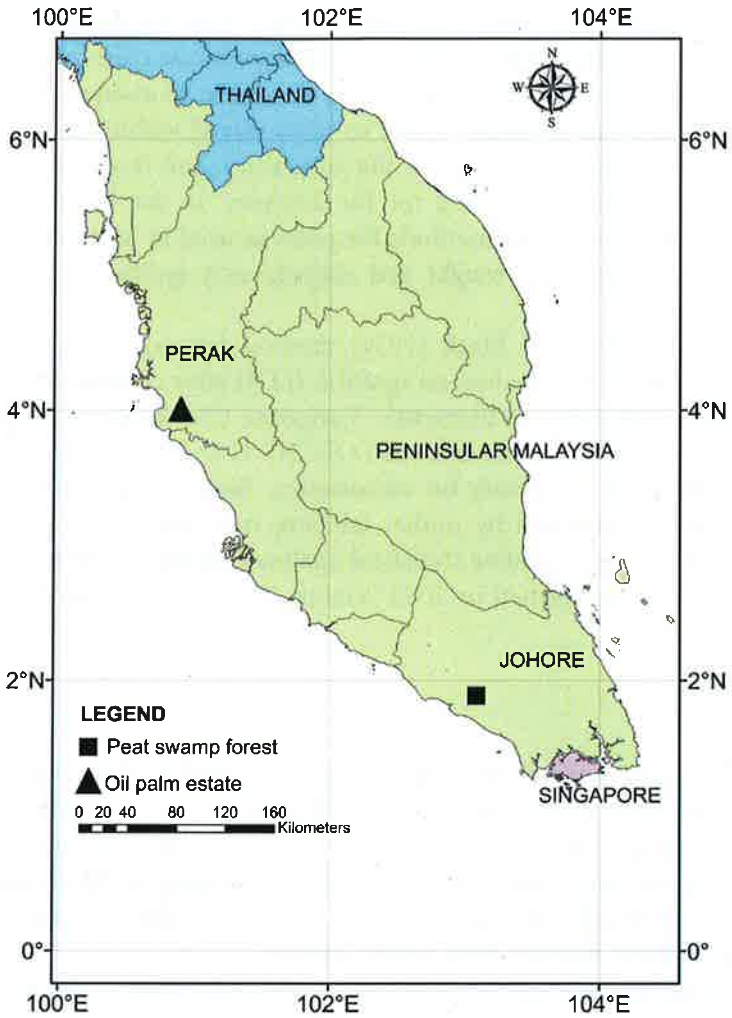

Figure 1. Location of study sites in peninsular malaysia showing both johore peat swamp forest reserve and perak oil palm plantation.

Materials and methods

Two areas, a peat swamp forest and an oil palm estate in tropical Malaysia were selected for this study and in each area, three organic soil profiles were collected. The first site is a peat swamp forest located in Johore State, while the second site is in an oil palm estate located in Perak State (Figure 1). Peat samples were collected with a Macaulay peat corer and peat profiles retrieved. At each study site, triplicate samples for each depth were collected and bulked to form one sample in sealed plastic bags and dispatch to laboratory analysis. One of the main problems with tropical organic soils is field sampling and sample preparation. This is particularly true when the soils have wood in their profiles. The presence of more than 20% wood within a particular layer is recognized in Malaysia by using 'wd' or 'wu' depending on whether the wood is decomposed or undecomposed in the horizon nomenclature (Paramananthan and Omar 2015). The wood could be one large log or many small twigs, branches etc. of varying sizes. For soils testing, all wood pieces with diameter of > 2 cm are discarded. This procedure is adopted from mineral soils where coarse fragments (>2 mm) are also excluded. In tropical organic soil profiles, high variability within the various organic layers is common. Removal of large fragments is particular critical when using a Macaulay peat auger in the sampling process and not a soil pit.

The location where the soil sample is collected is also important as it can influence the results. During sampling, the water table of the soils in the oil palm estate was controlled at 60 cm below surface, while the rainforest peat soils had water tables close to the surface (and therefore soil samples were relatively wet). In addition, Pedon P2 (Johore forest reserve) was located about 100 m from the foot of a small hill within the forest reserve in Johore. Consequently, this Pedon (P2) has a certain amount of detrital mineral matter (sand or clay) mixed within the organic soil. Layers were identified, sampled (Ziploc bags), air-dried in the laboratory, and fragments (> 2 cm) removed and discarded. The air-dried samples are used for the analyses. In the laboratory, peat samples were analysed using the standard analytical methods for peats as used in Malaysia (Anonymous 1980s) as samples are oven dried to constant weight and subsequently ignited in a furnace at 550°C for 6 hours.

In addition to the Walkley and Black (1934) method for organic carbon (oxidized air-dried sample using K-dichromate), and the loss on ignition (LOI) after combustion at 550°C for 6 hrs, the carbon was also determined using an Elementar VarioMax CNS analyzer. A total of 20 organic soil layers identified were analysed and the ratio of LOI:CNS-C and LOI:WB-C calculated. All analyses were carried out in the same laboratory for consistency. Based on a brief statistical analysis of the data, data outliers were determined by outlier labeling rule that used 2.2 as multiplier (Hoaglin, Iglewicz, and Tukey 1986). Comparative statistical analyses (independent t-test, ANOVA and Tukey multiple comparison) were performed in SPSS version 20 (SPSS Incorporate 2011).

Results

The soils in the Johore peat swamp forest reserve were mapped as the Gondang Series (Soil Series/ Phases: Gondang Series deep to very deep; Soil Management Group: Oewd/riverine clay) with deep (150–300 cm) to very deep (>300 cm) organic soil (Table 1). The soils are dark brown and highly decomposed sapric organic soil material to 60 cm depth overlying partly decomposed hemic organic soil material with decomposed wood pieces in the subsurface (50–100 cm) tier. The organic soils overlie riverine clay material and are very poorly drained.

The three soil pedons in the Perak oil palm estate were identified as the Bayas Series (Soil Series/ Phases: Bayas Series very deep; Soil Management Group: Oewd/marine clay) that are very deep according to the Malaysian Soil Taxonomy – Revised Second Edition Paramananthan 2010a) and the Keys to the Identification of Malaysian Soils Using Parent Materials (Paramananthan 2010b). These peats are very deep (>300 cm) organic soils, brown to dark brown with highly decomposed (sapric) organic soil material to 50 cm depth. Below 50 cm depth, the material is a partly decomposed (hemic) organic soil material. Some decomposed wood pieces occur below 75 cm depth. Underlying non-sulfidic marine clay occurs at 150 cm to over 300 cm below the surface and these soils are very poorly drained. For both sites, the peat soil classification in comparison with the USDA's Keys to Soil Taxonomy – 12th Edition (Soil Survey Staff 2014) and the World Reference Base for Soil Resources 2014 – update 2015 (IUSS Working Group WRB 2015) is given in Table 1.

Table 1. Classification of the two soil types from Johore forest reserve (Gondang Series) and Perak oil palm estate (Bayas Series) identified in the study.

Soil Series/depth phase	Malaysian Soil Taxonomy – Revised Second Edition (Paramananthan 2010a)	Keys to Soil Taxonomy 12th Edition (Soil Survey Staff 2014)	World Reference Base for Soil Reference 2015 (IUSS Working Group WRB 2015)
Gondang Series/ deep (150–300 cm) very deep (>300 cm)	Hemic Ombrogambists. Riverine clayey, isohyperthermic. Decomposed wood, autochthonous dysic, deep/very deep.	Typic Haplohemists dysic. Other criteria not applicable.	Hemic, dystric HISTOSOLS Hyperorganic
Bayas Series/ very deep (>300 cm)	Hemic Ombrogambist. Marine, clayey, isohyperthermic. Decomposed wood, autochthonous dysic, very deep.	Typic Haplohemist dysic. Other criteria not applicable.	Hemic, dystic, drainic HISTOSOLS Hyperorganic

Table 2 shows the data of the CNS, WB and LOI analyses of the peat samples. The data from the peat swamp forest in Johore shows that two peat profiles (Pedons P1 and P3) have high C (CNS>32 wt-%) and LOI values (>98 wt-%), while the peat profile with the detrital influx from the nearby hill (i.e. Pedon 2) has CNS values ~25 wt-% and LOIs of 60–65 wt-%. The C and LOI data of the peat profiles (Pedons S1, S2 and S3) of the palm oil estate in Perak show that CNS values are higher (41–48 wt-%%), but LOI values lower (90–97 wt-%) than the data from the Johore peat swamp forest soils. However, the WB-C data for the two areas are comparable and range between 47–54 wt-%, except for Pedon P2, which has WB-C values between 25–34 wt-%. In general, the C values between the peat layers of the CNS and WB methods differ by 13–20 wt-% in the peat swamp forest (P1, P3), but only 5–8 wt-% (except S1 25–50 cm with 10 wt-%) in the samples of the oil palm estate.

Downhole trends are difficult to identify. Pedon P1 appears to have the highest CNS value in the top soil with slightly lower values downprofile. In contrast, P3 has slightly elevated CNS values in the subsurface compared to the surface layer. In the oil palm estate, all three peat profiles show a slightly increasing C content with depth (Table 2).

Calculated SOM values (Table 2) using the common correction factor (1.724) demonstrate that the values of the WB method are slightly lower than the LOI values (a value difference of about 1–15), but CNS corrected SOM values are markedly different (20–30 wt-%). A comparison of the ratios LOI:CNS-C and LOI:WB-C is also established and shows that the ratios range mostly between 1.8–2.5. Because of the difference in carbon content from the two methods, the LOI:CNS-C ratios are higher than those for LOI:WB-C values. Average values for all peat samples (except Pedon 2) show that the 17 samples from both locations have mean LOI:C (CNS method) of 2.5 while the LOI:C (WB method) is 1.9, respectively (Table 3). Both values are much higher than the standard correction factor of 1.724 currently being used converting WB-C values. In particular, the forest peat soil has a LOI/C (WB method) ratio of 1.96, while the Perak oil palm peat deposits have a ratio of 1.84. When the carbon values of the topsoils and subsoils are compared, the means for all samples were 2.45 and 2.60 (CNS-C) and 1.89 and 1.91 (WB-C), respectively (Table 3). The ratios of the peat swamp forest samples in Johore are consistently higher than those from the oil palm plantation peat swamp in Perak. However, despite the difference, all results suggest that the value of organic carbon x 1.724 (WB-C to OM) to obtain the amount of SOM is too low for tropical organic soils and correction factors closer to 1.9 (1.84–1.96) provide more accurate values (Table 3) for these peat deposits (both from the oil palm areas and peat swamp forest).

Based on the t-test analysis (Table 4), the study found that the OC measured by the CNS (44.53 ± 2.09 wt-%) was significantly lower than the WB-C (51.63 ± 1.13 wt-%) and LOI (54.98 ± 1.22 wt-%). There were statistically significant differences for OC analysis determined by LOI, CNS and WB as determined by ANOVA [$F(2,48) = 82.465$, $p < 0.001$]. A Tukey post hoc test revealed that the carbon determined by LOI (96.52 ± 4.68 wt-%) was statistically significant higher than WB (87.92 ± 3.11 wt-%) as well as CNS (68.07 ± 10.00 wt-%).

Discussion

To date, there are marked debates about how to define and classify organic soils in the tropics in particular for the utilization of agricultural purposes. Hence, Roundtable on Sustainable Palm Oil (RSPO), Malaysian Sustainable Palm Oil (MSPO) and Indonesian Sustainable Palm Oil (ISPO) propose that for organic soils, an OSM should be defined as LOI greater than 65% as identified in several classification studies (e.g. Veloo, Paramananthan, and Van Ranst 2014, 2015; Wüst, Bustin, and Lavkulich 2003). To be called peat, the cumulative thickness of OSM must be more than 50 cm within the upper 100 cm of the soil profile. In order to determine OSM and SOM, various methods are currently utilized including the Walkley and Black (1934) method to determine organic C and utilize a conversion factor to calculate SOM.

This study was initiated to investigate these carbon conversion methods for applicability of tropical soils as the "standard" factors were developed for temperate organic soils or Histosols and

Table 2. Analytical data of the six pedons from Malaysia showing carbon content determined by CNS, WB and LOI method, soil organic matter calculated using the WB method as well as LOI-carbon ratios.

							OC			SOM		Ratio	
Location	Landuse	Pedon #	Sample #	Soil Series/depth phase	Horizon	Depth in cm	CNS wt-%	WB wt-%	LOI wt-%	CNS-C *1.724	WB-C *1.724	LOI/ CNS-C	LOI/ WB-C
Peninsular Malaysia, Johore	Air Hitam Forest Reserve	P1	p11	Gondang Series/very deep	Oa_1	0-25	36.8	49.4	86.5	63.4	85.1	2.35	1.75
			p12		Oa_2	25-50	32.4	50.1	98.6	55.8	86.4	3.04	1.97
			p13		$Oewd_1$	50-75	32.3	51.6	98.7	55.7	89.0	3.05	1.91
			p14		$Oewd_2$	75-100	33.3	54.2	98.6	57.3	93.4	2.97	1.82
		P2	p21	Gondang Series/very deep	Oa_1	0-12	26.5	25.3	65.4	45.7	43.7	2.47	2.58
			p22		Oa_2	30-Dec	27.0	32.8	59.6	46.5	56.5	2.21	1.82
			p23		Oewd	30-170	26.9	34.2	60.7	46.4	59.0	2.26	1.77
			p24		c	170-220	1.5	1.6	8.1	2.6	2.8	5.30	4.91
		P3	p31	Gondang Series/very deep	Oa_1	0-25	33.3	47.2	98.4	57.5	81.3	2.95	2.09
			p32		Oa_2	25-50	32.9	48.5	98.8	56.8	83.6	3.00	2.04
			p33		$Oewd_1$	50-75	34.2	51.9	98.8	58.9	89.4	2.89	1.90
			p34		$Oewd_2$	75-100	35.3	49.5	109.2	60.9	85.3	3.09	2.22
			p35		C	325+	3.1	3.0	7.4	5.3	5.2	2.40	2.44
		S1	s11	Bayas Series/very deep	Oa_1	0-25	41.8	49.5	90.0	72.0	88.1	2.15	1.82
Peninsular Malaysia, Perak	Oil Palm Estate		s12		Oa_2	25-50	40.9	51.3	95.9	70.5	88.4	2.34	1.87
			s13		Oewd	50-75	45.7	51.6	96.4	78.7	88.9	2.11	1.87
		S2	s21	Bayas Series/very deep	Oa_1	0-25	44.8	52.1	93.7	77.3	89.8	2.09	1.80
			s22		Oa_2	25-50	43.9	51.5	94.4	75.7	88.8	2.12	1.86
			s23		Oewd	50-75	45.8	52.3	97.1	79.0	90.1	2.12	1.86
		S3	s31	Bayas Series/very deep	Oa_1	0-25	44.6	50.8	94.2	76.9	87.6	2.11	1.85
			s32		Oa_2	25-50	45.6	52.4	96.0	78.6	90.4	2.10	1.83
			s33		Oewd	50-75	47.7	53.4	95.5	82.2	92.0	2.00	1.79
			Mean				39.5	51.0	96.5	68.1	87.9	2.50	1.95
			SD				5.8	1.8	4.7	10.0	3.1	0.4	0.2

Table 3. Summary of the ratios (LOI/C) using different methods (CNS-C, WB-C) for the tropical peat soils of Malaysia. Pedon 2 (3 samples) from Johore are excluded due to their siliciclastic detritus input.

Samples	method	Johore + Perak (17 samples)	Johore Forest Reserve (8 Samples)	Perak Oil Palm Estate (9 samples)
All depths	LOI/C (CNS)	2.50 (17)	2.92 (8)	2.13 (9)
Topsoils (Oa1,Oa2)		2.45 (10)	2.83 (4)	2.15 (6)
Subsoils (Oewd, Oe)		2.60 (7)	3.00 (4)	2.08 (3)
All depths	LOI/C (WB)	1.90 (17)	1.96 (8)	1.84 (9)
Topsoils (Oa1, Oa2)		1.89 (10)	1.96 (4)	1.84 (6)
Subsoils (Oewd, Oe)		1.91 (7)	1.96 (4)	1.84 (3)

have not been validated for the suitability of tropical soils. Two tropical field areas in Malaysia were selected, a pristine rain forest peat swamp in Johore State and an oil palm plantation in Perak State. Both areas represent thick peat deposits although the oil palm plantation has a controlled water level (i.e. ~60 cm below surface), which usually implies elevated oxidation and hence organic matter degradation in the surface layers. In both areas, three soil profiles were collected and all profiles, with the exception of one (i.e. Pedon 2) in the peat swamp area (Johore) that showed elevated minerogenic influx (mineral detritus) due to proximity to a small hill, are very deep (>300 cm), and have high LOI (generally >94 wt-%) with peat soils belonging to the Gondang and Bayas Soil Series (Table 1) (Paramananthan 2010c).

The soils of the two areas have different C contents and LOIs, and indicate that former vegetation composition, preservation and degradation of the OM play an important role in these tropical organic soils. In particular conversion to agricultural uses of peat forests with controlled water tables (e.g. oil palm conversions) will change the rate and pathway of surface layer degradation.

A review of the data given in Table 2 suggests that all the WB-C values range between 47–54 wt-% (except P2 horizons) for all the organic layers. The six pedons sampled in the two areas of Malaysia are thicker than 150 cm and thus classified as Histosols according to the USDA's Keys to Soil Taxonomy – 12^{th} Edition (Soil Survey Staff 2014). In addition, the peats have LOI values >87 wt-% (with P2 having 60–65 wt-%) and fall within tropical peat soils according to the modified classification for tropical soils (Fig. 8 in Wüst, Bustin, and Lavkulich 2003)

All three soils from the oil palm estate have carbon values >40 wt-% (CNS method) in the shallow layers (<75 cm), while the peat forest samples have values between 32–37 wt-% (Table 2). In addition, LOI values of the rain forest peat soils are generally (except P2) >98 wt-%, while in the oil palm peat soils, LOI values are between 90–97 wt-% which could indicate partial degradation due to artificial lowering of the water table over the last few years. In contrast, the carbon values of the WB method are fairly similar for both rain forest and oil palm plantation sites. The difference in carbon values between the CNS and WB methods may be due to the different approach of the methods. The CNS instrument analyses strictly elemental levels (C, N, S), while in the oxidation analysis of the WB method, other compounds such as S and carbonates are at least partially targeted too. Hence, the topsoil in the oil palm plantation may have elevated degraded C and S compounds due to the controlled lower water level and hence enhanced (i.e. prolonged) artificial aeration.

Almost all peat profiles in Malaysia have sapric material in the upper 50–60 cm of the soil profile (using the rubbing test). A lithological discontinuity is indicated by charcoal fragments at this depth. The subsurface layer can be sapric, hemic or fibric material with or without wood. Pollen analysis also suggests the upper surface layer has grass pollen, while the below consists of tree pollen (Paramananthan 2016). Hence, these records illustrate that changing environmental conditions over the last few hundred years have influenced topsoil compositions of these Histosols.

Also, when comparing the carbon values for the different degradation levels of the soil layers, the Oa (sapric) samples have lower C values in both methods compared to the hemic materials (Oewd) values. The WB-C values for sapric and hemic (25–52 wt-% for sapric and 33–54 wt-% for hemic including the P2 profile) from Johore and Perak States are much lower than the 58–60 wt-% and 53–54 wt-% for sapric and hemic, respectively, reported from other sites (EKONO 1981).

The results of this study highlight an issue for the standard carbon conversion factor commonly used in temperate organic soil environments (i.e. WB-C to SOM method). CNS carbon values for the two areas in Malaysia show marked different values while having very similar WB values, which could be a result of the various recalcitrant carbon forms. A common conversion factor therefore will inevitable result in similar SOM data when using the WB method, but using elemental C, a conversion would result in very different amounts of SOM. The calculated conversion factors in this study range mostly between 1.9–3.0 and demonstrate that the value of 1.724 is too low for tropical organic soils.

The statistical investigations for this study were applied to eliminate a biased interpretation and evaluate a mathematical approach. A Tukey post hoc test revealed that the carbon determined by LOI (96.52 ± 4.68 wt-%) was statistically significant higher than WB (87.92 ± 3.11 wt-%) as well as CNS (68.07 ± 10.00 wt-%). Comparisons of our data with data from organic soils of the alpine grassland in the Tibetan Highlands show that SOC_{CNS} and SOC_{WBC} have a relatively strong statistical correlation when the common correction factor was applied (Chen et al. 2015). Based on the result of this study, the standard conversion factor for WB-method for tropical organic soils, should be modified from 1.72 to 1.9. In the case of converting CNS carbon values to SOM values, the conversion factor should be 2.5. It is suggested that in tropical soils, the standard conversion factor proposed from the WB-method should not be applied as it underestimates the final SOM, which may be due to the presence of various forms of recalcitrant carbon (i.e. polymerized organic matter) in these soils.

Conclusion

This study investigated the applicability of the common and routine conversion factor to determine SOM from OC of tropical peats. Samples from six peat profiles all >150 cm deep from a peat forest reserve and an oil palm plantation in Malaysia were analysed (carbon, LOI) and conversion factors and ratios for both the Walkley and Black (1934) and the CNS elemental methods identified. The ratios of the various analytical method's results suggest that in tropical peat soils, the conversion factor of OC to SOM from the WB-method should be 1.9, while the factor for CNS carbon should be 2.5, respectively. A comparison of C-values derived from CNS, WB and LOI methods indicate that the use of LOI for tropical organic soils provides 1) a better estimation of the organic matter (incl. polymerized organic compounds) than the Walkley and Black carbon or CNS data and 2) a simpler measure for peat classification when using conversion factors to determine SOM. Most laboratories in SE Asia can easily perform an LOI test, but the WB-C analysis requires access to chemicals and laboratory facilities, which can be difficult for some parts of SE Asia. Hence, it is proposed that the LOI rather than the WB-C or CNS methods may be used to define organic soil materials and Histosols for tropical lowland organic soils.

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