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Classification of tropical lowland peats revisited: The case of Sarawak

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ABSTRACT

The mapping and classification of peats, particularly those in the tropics, have lagged far behind that of peats in temperate areas and that of mineral soils. Classification systems based on Keys to Soil Taxonomy and the World Reference Base for Soil Resources (WRB) although universal are believed to be more suitable for temperate peats. This study compares these classification systems with the latest Malaysian classification system for classifying and characterising tropical peats. The three classification systems were then tested using five soil map units to compare and evaluate the usefulness and suitability of each system. The results showed that the latest Malaysian classification system has an advantage for classifying and characterising tropical peats. This latest classification describes well the presence of decomposed and undecomposed wood, which is a distinct feature of tropical peat which cannot be adequately described by using the Soil Taxonomy and the WRB. The Malaysian system also supports classification of tropical peats up to soil series and phase level. Both the Soil Taxonomy and the WRB classification can possibly be improved to also describe tropical peats by adopting some of the criteria of Malaysian classification. Such changes will add value to the two systems to be more global in their application for classification on tropical peats which comprises 8% of global peatland. This will be useful in making major land use decisions involving tropical peat conservation and development for agriculture. The findings will also provide an avenue to explore further on the current views on greenhouse gas emission on tropical peatlands.

1. Introduction

In their natural state tropical peat swamp forests are characterised by dense forest vegetation and thick (up to 20 m) peat deposits and a ground water table that is at or close to the peat surface throughout the year (Hirano et al., 2009). Tropical peat soil constitutes over 8% (33–49 Mha) of the world's peat soils (Maltby and Immirzi, 1993) and 60% and 70% of tropical peat soils are found in Indonesia and Malaysia. Land use changes by conversion of tropical peatland for agriculture are becoming more significant. The state of Sarawak, Malaysia, registered an increase in the total planted oil palm area for example from 14,091 ha in 1975 to 839,748 ha in 2009 (Department of Statistics Malaysia, 2011). The increasing use of peatland for agriculture has often resulted in increase in fires and greenhouse gas (GHG) emissions. Therefore there is a need for more scientific studies for appropriate methods for their sustainable management (Silvius and Giesen, 1996). Shier (1985) raised the issue of lack of studies on tropical peat resources as compared to studies of peat resources in temperate zones, which have been well surveyed, classified and quantified. Page et al. (2007) have reported that in the twenty year period since that alert, the level of investigation and documentation of this important resource has not made significant progress. Consequently, very few publications on the mapping and classification of tropical peats are available.

Although tropical peatland is extensive, few studies have attempted to classify tropical peats (Andriesse, 1988; Yonebayashi et al., 1992). Despite major differences in ecological regime, structure, texture and composition among tropical peat deposits and between tropical peat deposits and their temperate counterparts, peat classifications developed in humid temperate regions are commonly used for classification of tropical peat deposits. Wust et al. (2003) explained that existing classification systems (including Von Post system) used for temperate and boreal peat deposits in temperate regions fail to fully characterise tropical peat. This is due to the fact that temperate and boreal peats are often dominated by bryophytes and shrub whereas tropical peatland 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. Wust et al. (2003) further highlighted the need for a new classification system for tropical peat as most current classification systems had failed to describe tropical peat/s.

International schemes such as Soil Taxonomy — Eleventh Edition (Soil Survey Staff, 2010) and the World Reference Base for Soil Resources (WRB) fail to adequately describe and address the differences

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in tropical peats, especially in relation to their depth, presence of wood and the underlying mineral substratum. Field classification is critical in the evaluation of peatlands for environmental, geological, geotechnical, agricultural, horticultural or energy purposes (Kivinen, 1980). Therefore, a revisit to the subject of peat classification in the tropics is both timely and justified to minimise the differences and improve the existing knowledge in the area of peat classification and enhancing the practical usefulness of the knowledge. The USDA classification system and the WRB have failed because both do not provide criteria to define peats at series and phase mapping levels for tropical peat area.

In an attempt to rectify this failure, Paramananthan (1998, 2010a) has modified the USDA system to suit local conditions. The original Malaysian classification system by Paramananthan (1998) was mentioned in the study by Wust et al. (2003) for evaluation of tropical peat in Tasik Bera, Malaysia and this system had been further modified in 2010. The Malaysian Taxonomy was developed using the same principles of the USDA's Soil Taxonomy i.e. for use in the mapping and interpreting soil surveys. As such it uses morpho-genetic criteria which we see in the field. However, tropical countries in South East Asia, basically being agricultural based countries, the emphasis is on criteria which affect agriculture. This is not like those of temperate peats where the study objectives maybe for coal formation and or mining of the peat. Thus the Malaysia classification uses criteria present mostly within 150 cm as these will affect the crop. However if we are looking at mining the peat or coal formation as in Ireland or Canada, we may need look at much deeper layers. There should be a balance between conservation and development — particularly when good agricultural land is scarce at a global scale. Thus the Malaysian peat classification modifies the Soil Taxonomy (USDA) to suit local conditions and can be applied to most tropical lowland peats. The Malaysian classification system was tested in Malaysia and Indonesia and it appears to work well. A total of 700,000 ha of tropical lowland peat in Southeast Asia were evaluated and mapped using the system to date.

The purpose of this study is to analyse this latest classification system presented in the Malaysian Soil Taxonomy — Revised Second Edition (Paramananthan, 2010a) and to evaluate its applicability for classification of tropical peats in Sarawak, comparing it with the international systems of the USDA Soil Taxonomy and the WRB. The study will further suggest that some of the criteria be used to improve the USDA Soil Taxonomy and the WRB for tropical peatland mapping. The practical usefulness of this Malaysian classification in making major land use decisions for oil palm cultivation will also be explored.

2. Materials and methods

The initial approach was to carry out a literature review on the three classification systems i.e. WRB, USDA classification system and the Malaysian Soil Taxonomy. Differences of the classification systems and its practicality for field applications were explored. The objective was to compare the criteria used at the different categoric levels of the three systems. The lower the categoric level, the more criteria are used. It is also pertinent to note that in the USDA's Soil Taxonomy, the family criteria used are selected on their usefulness for interpreting the soil data for agricultural uses. On the other hand the WRB is more for providing maps on a global scale. To test the usefulness of the three classifications five peat profiles mapped to the phase level in Sarawak, Malaysia were selected as shown in Table 2.

The soils selected were then classified and the classifications compared using the Malaysian Soil Taxonomy, USDA's Soil Taxonomy and the WRB. The study presents a detailed comparison of the Malaysian Soil Taxonomy to the WRB and the USDA Soil Taxonomy to evaluate the adequacy of the three systems for description and classification of the soils.

3. Results and discussion

3.1. Differences in criteria used in the classification of organic soils

A comparison of the criteria used in the three classifications; WRB (FAO, 2006), Keys to Soil Taxonomy, Eleventh Edition (Soil Survey Staff, 2010) and the Malaysian Soil Taxonomy — Revised Second Edition (Paramananthan, 2010a) is given in Table 1. All three systems have the same definition of organic soil material (OSM). The Malaysian classification has an additional criterion of loss of ignition of 65% as this has historical significance. All the three classifications also define fibric, hemic and sapric materials using the rubbed fibric content, but the amounts (1/3, 2/3) used in the Malaysian system differ from those used in Soil Taxonomy (3/4, 1/6) and in the WRB system (2/3, 1/6). Wood is not defined in the WRB, but coarse fragments are defined in both Soil Taxonomy and Malaysian systems. Both the Malaysian system and Soil Taxonomy define a control section, but use different depths; the WRB does not define a control section.

Further differences appear when the classification systems are compared (Table 1). The WRB has only 3 levels; Reference Soil Groups and Prefix and Suffix qualifiers. Soil Taxonomy and the Malaysian Soil Taxonomy each has seven categorical levels — Order, Suborders, Great Groups, Subgroups, Family, Soil Series and Phase. The criteria used at different levels differ, e.g. Suborders and Great Groups. For example, the USDA Soil Taxonomy applies the nature of the OSM at the suborder level while the Malaysian system applies it at the subgroup level. Depth-Ombro and Topo are used to distinguish Great Groups in the Malaysian system but not in the other two systems. Although criteria such as particle size class and mineralogy are defined in Soil Taxonomy for use at the family level, these criteria are only used for Terric subgroups. No clear criteria have been proposed in the USDA Soil Taxonomy for use at the soil series and phase levels for other subgroups. While clear criteria such as the presence/absence and nature of wood are used in the Malaysian classification, they are not used in the other two systems.

3.2. Comparison of the classifications of selected peat soils

In order to interpret and manage agricultural crop and to make decision on land conservation and GHG emissions, it is necessary to map the soils at the phase level so that any criteria that affect yield and management can be identified and mapped. Thus the crucial level of mapping used in Malaysia is the soil series and phase. The soil series and phases used for soil mapping in Malaysia are based on the Malaysian Soil Taxonomy — Revised Second Edition (Paramananthan, 2010a) and the Keys to the Identification of Malaysian Soils Using Parent Materials (Paramananthan, 2010b). In order to compare the usefulness of the three classifications the five profiles selected were classified (Table 2). This table indicates that the WRB (FAO, 2006) can only differentiate these soils by using the Prefix qualifiers — sapric (4) and hemic (1). Even at the Suffix qualifiers level, the WRB cannot clearly differentiate the five soils mapped.

The USDA's Soil Taxonomy distinguishes the shallow (50 cm–100 cm) and moderately deep (100 cm–150 cm) organic soils of Malaysia from the deep and very deep soils. The two shallow soils both belong to the Terric subgroups and subsequently can be further separated at the soil series level using the particle size class and mineralogy classes of the Terric layers which occur between 75 and 100 cm depths. In the case of deeper soils (>150 cm) — non-Terric subgroups, the USDA Soil Taxonomy does not define criteria for use at lower categoric levels.

The Malaysian system clearly differentiates the deep Ombro (>150 cm) from the shallow to moderately deep — Topo (50 cm–150 cm) at the Great Group level. The presence/absence and nature of wood which greatly affect the performance of crops are criteria applied at the soil series level. Thus the classification which includes the presence/absence of wood and its stage of decomposition is helpful for investors to make a decision on land use and suitability for oil palm cultivation.

Table 1
Comparison of criteria used for organic soils in World Reference Base (FAO, 2006), Keys to Soil Taxonomy (Soil Survey Staff, 2010) and Malaysian Soil Taxonomy (Paramananthan, 2010a).

Soil characteristics	World Reference Base (FAO, 2006)	Keys to Soil Taxonomy — Eleventh Edition (Soil Survey Staff, 2010)	Malaysian Soil Taxonomy — Revised Second Edition (Paramananthan, 2010a)
1. *Kinds of organic soil materials*			
a) Definition of organic soil material (OSM)	▪ Not saturated > 20% organic carbon = (O.C.) ▪ Saturated > 18% O.C. if clay is 60% or more. ▪ Or more than 12% O.C. if clay is zero %	▪ Not saturated > 20% O.C. ▪ Saturated > 18% O.C. if clay is 60% or more. ▪ Or more than 12% O.C. if clay is zero %	▪ Not saturated > 20% O.C. ▪ Saturated > 18% O.C. if clay is 60% or more. ▪ Or more than 12% O.C. if clay is zero %. ▪ >65% loss on ignition. ▪
b) Kinds of OSM	Fibric material: ≥2/3 fibres after rubbing or ≥2/5 after rubbing and yield colour values 7/1, 7/2, 8/1, 8/2 on chromatographic paper	Fibric material: ≥3/4 fibres after rubbing or ≥2/5 after rubbing and yield colour values 7/1, 7/2, 8/1, 8/2 on chromatographic paper	Fibric material: >2/3 fibres after rubbing
	Sapric material: <1/6 fibre after rubbing and colour value to right of 5/1, 6/2 and 7/3	Sapric material: <1/6 fibre after rubbing and colour value to right of 5/1, 6/2 and 7/3	Sapric material: <1/3 fibres after rubbing.
	Hemic material: 1/6–2/3 fibres after rubbing. Intermediate between Fibric/sapric.	Hemic material: 1/6–2/3 fibres after rubbing. Intermediate between Fibric/sapric.	Hemic material: 1/3–2/3 fibres after rubbing.
	Wood: Wood not defined. Not used.	Wood: Coarse fragment. >2 cm diameter	Wood: >2 cm diameter. ▪ Undecomposed wood. ▪ Decomposed.
c) Control section	Not defined.	Sphagnum/moss: 160 cm (60 + 60 + 40). Others: 130 cm (30 + 60 + 40).	150 cm (50 + 50 + 50).
2. *Classification*			
Definition of Soil Group — Histosols	Soil Group — Histosols Cumulative within 100 cm of the soil surface ≥ 60 cm thick if 75% (vol) is moss fibres. Others 40 cm more thick. Starting within 40 cm of soil surface.	Order — Histosols 60 cm or more if bulk density ≤ 0.1 moss fibres > 3/4 40 cm or more if sapric/hemic or fibric materials with less than 3/4 moss fibres and bulk density ≥0.1	Order — Histosols Minimum cumulative thickness ≥ 50 cm within 100 cm or more than half the solum if less than 100 cm.
		Suborders Folists — well drained. Fibrists — poorly drained, more fibric material in subsurface tier, no sulfidic/sulfuric material. Saprists — more sapric material on subsurface tier. Hemists — others.	Suborders Folist — well drained. Gambist — poorly drained.
		Great group e.g. Haplosaprists/Haplohemists/Haplofibrists Sulfidic materials within 100 cm — Sulfihemist. Sulfuric horizon within 50 cm — Sulfohemist. Haplohemist/Haplosaprists.	Great group Ombrogambist >150 cm thick Topogambist 50–150 cm thick
	Prefix qualifiers e.g. folic, fibric, hemic, sapric	Subgroups Central concept/integrades/extragrades e.g. Haplosaprist — lithic/terric/hemic/typic. Terric = Mineral layer > 30 cm within control section, below surface tier.	Subgroups Nature of subsurface tier (50–100 cm) e.g. fibric/hemic/sapric/typic/sulfidic
	Suffix qualifiers e.g. thionic, dystric, eutric, drainic	Family Specific criteria important to plant growth — only defined for Terric Sub-Groups e.g. particle size, mineralogy, reaction class, soil temperature regime, soil depth classes.	Family Nature of substratum e.g. marine clayey. Soil temperature regime e.g. isohyperthermic
		Soil series Other properties (Not defined)	Soil series Presence/absence of wood; decomposed/undecomposed e.g. non-woody/wood undecomposed. Origin of organic deposit (autochthonous/allochthonous)
		Phase Not defined.	Phase e.g. nature of surface tiers; ash content, reaction class, salinity class, depth phases, drained/undrained.

Table 2
Comparison of the classification of the soils using World Reference Base, USDA Soil Taxonomy and Malaysian Soil Taxonomy.

Classification system / Categoric level	World Reference Base (FAO, 2006)	Keys to Soil Taxonomy Eleventh Edition (Soil Survey Staff, 2010)	Malaysian Soil Taxonomy Revised Second Edition (Paramananthan, 2010a) and Keys to Identification of Malaysian Soils (Paramananthan, 2010b)	World Reference Base (FAO, 2006)	Keys to Soil Taxonomy Eleventh Edition (Soil Survey Staff, 2010)	Malaysian Soil Taxonomy Revised Second Edition (Paramananthan, 2010a) and Keys to Identification of Malaysian Soils (Paramananthan, 2010b)
Soil map unit (phase level)	*Linggi series/moderately deep*			*Baram series/moderately deep*		
Order/soil group	Histosol	Histosols	Histosols	Histosol	Histosol	Histosol
Sub-group	–	Saprist	Gambist	–	Saprist	Gambist
Great group	–	Haplosaprist	Topogambist	–	Haplosaprist	Topogambist
Sub-group Prefix qualifiers	Sapric	Terric Haplosaprist	Sapric Topogambist	Sapric	Terric Haplosaprist	Sapric Topogambist
Family	Dystric	Dysic	Marine-clay,	Dystric	Dysic	Marine-sand
Suffix qualifiers	Drainic	Isohyperthermic	Isohyperthermic	Drainic	Isohyperthermic	Isohyperthermic
Soil series	Criteria not applicable	Clayey, mixed, dysic, isohyperthermic	Non-woody autochthonous	Criteria not applicable	Sandy, siliceous, dysic, isohyperthermic	Non-woody autochthonous
Phase	Criteria not applicable	Criteria not applicable	Low ash, dysic, non-saline, sapric, drained, moderately deep	Criteria not applicable	Criteria not applicable	Low ash, dysic, non-saline, sapric, drained, moderately deep
Soil map unit (phase level)	*Kenyana series/very deep*			*Naman series/very deep*		
Order/soil group	Histosols	Histosols	Histosols	Histosols	Histosols	Histosols
Sub-group	–	Saprist	Gambist	–	Saprist	Gambist
Great group	–	Haplosaprist	Ombrogambist	–	Haplosaprist	Ombrogambist
Sub-group Prefix qualifiers	Sapric	Typic Haplosaprist	Sapric Ombrogambist	Sapric	Typic Haplosaprist	Sapric Ombrogambist
Family	Dystric	Dysic	Marine-clay	Dystric	Dysic	Marine-clay
Suffix qualifiers	Drainic	Isohyperthermic	Isohyperthermic	Drainic	Isohyperthermic	Isohyperthermic
Soil series	Criteria not applicable	Criteria not applicable	Wood-undecomposed Autochthonous	Criteria not applicable	Criteria not applicable	Non-woody Autochthonous
Phase	Criteria not applicable	Criteria not applicable	Low ash, dysic, non-saline, sapric, drained, very deep	Criteria not applicable	Criteria not applicable	Low ash, dysic, non-saline, sapric, drained, very deep

Classification system / Categoric level	World Reference Base (FAO, 2006)	Keys to Soil Taxonomy Eleventh Edition (Soil Survey Staff, 2010)	Malaysian Soil Taxonomy Revised Second Edition (Paramananthan, 2010a) and Keys to Identification of Malaysian Soils (Paramananthan, 2010b)
Soil Map Unit (Phase level)	Bayas series/very deep		
Order/soil group	Histosols	Histosols	Histosols
Sub-group	–	Hemist	Gambist
Great group	–	Haplohemist	Ombrogambist
Sub-group prefix qualifiers	Hemic	Typic haplohemist	Hemic ombrogambist
Family	Dystric	Dysic	Marine-clay
Suffix qualifiers	Drainic	Isohyperthermic	Isohyperthermic
Soil series	–	Criteria not applicable	Wood-decomposed autochthonous
Phase	–	Criteria not applicable	Low ash, dysic, non-saline, sapric, drained, very deep

Table 3
Keys to the identification of Lowland Peats (Gambists).

Depth of organic soil materials	Soil moisture regime	Poorly drained (aquic) — gambist								
	Dominant material in subsurface nature (50–100 cm) of underlying tier substratum/mineral materials	Sapric			Hemic			Fibric		
		Non woody	Wood decomposed	Wood undecomposed	Non woody	Wood decomposed	Wood undecomposed	Non woody	Wood decomposed	Wood undecomposed
Shallow (50-100 cm) and moderately deep (100-150 cm) topogambists	Marine clay sulfidic (>15% clay)	Penor			Bakri			Merapok		
		Penor			Nipis	Bakri			Merapok mahat	
	Marine clay (>15% clay)	Linggi			Epai			Mukah		
		Linggi		Trus			Epai		Mukah	Binu
	Marine sand calcareous (<15% clay)	Mengalum								
		Mengalum								
	Marine sand sulfidic (<15% clay)	Long putat								
		Long putat								
	Marine sand (<15% clay)	Baram						Igan		
		Baram	Kabala	Simalau					Igan	
	Riverine/colluvial clay (>15% clay)	Erong			Gali			Changkat lobak		
		Erong				Gali		Changkat lobak		

	Soil moisture regime	Poorly drained (aquic) — gambist								
		Sapric			Hemic			Fibric		
	Riverine/colluvial sand (<15% clay)				Pak bong					
					Pak bong					
Deep (150-300) and very deep (>300 cm) ombrogambists	Marine clay sulfidic (>15% clay)	Primaluck			Pontian			Klias		
		Primaluck		Teraja		Pontian		Arang	Klias Luk	
	Marine clay (>15% clay)	Naman			Bayas			Anderson		
		Naman	Retus	Kenyana		Bayas	Gedong			Anderson
	Marine sand calcareous (<15% clay)									
	Marine sand sulfidic (<15% clay)									
	Marine sand (<15% clay)	Telong			Adong					
			Telong	Suai		Adong	Alan			
	Riverine/colluvial clay (>15% clay)	Liku			Gondang			Salleh		
		Liku		Karap		Gondang	Taniku		Salleh	Tinjar
	Riverine/colluvial sand (<15% clay)	Kabok								
			Kabok							

Key: Bayas (shaded) Soil family; Bayas Soil series. Luk = allochthonous

It is clear from Tables 2 and 3 and the discussion above, that the Malaysian Soil Taxonomy — Revised Second Edition (Paramananthan, 2010a) and the Keys to the Identification of Malaysian Soils Using Parent Materials (Paramananthan, 2010b) currently used in Malaysia better classifies and assists the mapping and description of tropical peats. Current international systems such as the WRB (FAO, 2006) and the Keys to Soil Taxonomy — Eleventh Edition (Soil Survey Staff, 2010), were developed using temperate peats and are less useful in soil mapping of tropical peats. This supports the earlier findings of Wust et al. (2003). Therefore, there is a need to modify or incorporate some of the elements such as the presence or absence and nature of wood to improve the international systems.

The wood in tropical peats is similar to skeletal grains (e.g.: petroplinthite gravels) of mineral soils. Where such skeletal grains occur in mineral soils these are recognised at the family level as for example clayey skeletal or clayey over clayey skeletal depending on the depth at which the coarse fragments occur. Hence such criteria can also be used in peat soils e.g.: woody sapric or sapric over woody sapric.

Both the Soil Taxonomy and WRB are considered global classifications. In the Soil Taxonomy if the mineral layers occur within the control section (130 cm) then the soil is classified as a Terric Sub-Group e.g. Baram Series and Linggi as used in this paper. For Terric Sub-groups the particle-size class, and mineralogy are determined using the underlying Terric material. This clearly ignores the upper say 100 cm of organic soil material on which a crop will be planted and managed on tropical peat. For the deep peats (>150 cm) little or no criteria are proposed to define families, series and phases in both the Soil Taxonomy and WRB.

3.3. Usefulness of the Malaysian classification system

The depth of the peat and the presence of wood, and to what extent it is decomposed is not emphasised or used in both the Soil Taxonomy and WRB systems which are considered global. Hence the inclusion of these criteria in the global classification will upgrade these systems without upsetting the classification of temperate peats and will improve both the soil taxonomy and WRB and make it applicable for both temperate and tropical peat/s. The presence of wood in a soil is one of the criteria which determines whether a particular piece of land should be selected for agriculture or left for conservation. Peatland showing the presence of undecomposed wood say within 1 m or 50 cm depth should be left for conservation instead of developing it for agriculture. This will meet the global call for peat conservation. The presence or absence and nature of wood which greatly affect the performance of crops are used at the soil series level. 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 (Mathews and Clarence, 2004). The presence of wood within 100 cm also encourages termite infestation and is detrimental to most crops. The presence of wood on peat surface will also result in higher cost for mechanical removal of stumps and wood during early development stages. This will also have an impact on the payback and IRR (investment rate of returns) on any crop planted on the land. Thus the classification which includes the presence/absence of wood and its stage of decomposition will help investors to make a decision on land use and suitability for agricultural development. However, if there is no wood or decomposed wood is present within the surface 150 cm depth, food crops such as oil palm can be cultivated. Of the world's 13.4 billion ha of land surface about 3 billion ha is suitable for crop cultivation and about 1.4 billion ha is already cultivated. The remaining potentially cultivable areas are believed to be under tropical forest and said to be highly sensitive to conservation and environmental issues such as tropical peatlands. It will be useful to identify new lands on a selective basis for agriculture and food production at a global scale in line with the increase in global human population which is projected to grow from 8 billion in 2025 and 10 billion by 2050 (Moran, 2011). This will compliment efforts of increasing global food production through improvement of land productivity per unit area through agricultural intensification. Areas identified as not suitable for agriculture through soil survey and with the above classification system can be left for conservation. This will lead to selective development of peat for agriculture rather than an indiscriminate approach to peat development as currently being practised. Indiscriminate development on peat will result in peat swamp destruction which can lead to loss of biodiversity, loss of habitat for wildlife, disturbance of the hydrological cycle and reduction in water supply, increased rates of oxidation and compaction, modification of micro-climate due to logging of peat forest, increased run-off and erosion and reduction in climate stabilization function (Phillips, 1997). Global deforestation is estimated to be at a rate 3.6 million ha annually for agriculture and forestry expansion (Lian et al., 2011). This can be addressed through conservation strategies of peat swamp forest by using the improved soil classification system.

The use of the new classification system will answer the call for sustainable management of peat through scientific work and observation as highlighted by Silvius and Giesen (1996). This can be carried out by excluding peatland with undecomposed wood close to the surface for purpose of conservation instead of agriculture. By 2010, there were 2.3 million ha of peat swamp forest worldwide cleared and left as degraded land. The latest classification system will be useful in identifying areas which are suitable for reforestation. Through reforestation the peat ecosystem on degraded land can be revived.

The emphasis of wood and its nature whether decomposed or undecomposed is important as wood plays a very important role to GHG emission. GHG emission is determined by three factors i.e. quantity of carbon stored in peat, degree of drainage of peatland which oxidises the peat and releases carbon dioxide and large emissions of carbon dioxide caused by fires. Strack (2008) estimated that 30 million ha of peatland in the world is used for agriculture another 15 million ha for forestry while less than 5 million ha is mined. Oleszczuk et al. (2008) estimated average emission of temperate and boreal regions at 15,944 kg ha^{-1} yr^{-1} of carbon dioxide. Friends of the Earth (2008) estimated a mean carbon dioxide emission at 70,000 kg kg ha^{-1} yr^{-1} for tropical peat which is 1.5–4.5 times more than temperate regions when peatland is drained. The large amount of CO_2 emission from tropical peat has been challenged by Melling (2010) 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 peatland were also pointed out by Vasander and Jauhiainen (2008). Undecomposed logs and large pieces of wood fragments are recalcitrant carbon which are not easy to breakdown or decompose. The presence of wood within profiles also creates voids which are filled with water or air which will result in lower bulk densities and carbon stocks. Amount of wood will also determine the biomass available to fuel peat fires which is also a large contributor of GHG emission. Hard wood is recalcitrant and contributes to low GHG emissions. The Malaysian and Indonesian peats mostly have sapric material with no wood in the upper 50 cm and hence should have lower GHG emissions. Lack of detail characterization of peat is probably one of the important reasons why conflicting data on GHG emissions of tropical peats are reported. The recognition of wood and its nature in the Malaysian classification system and its application for field soil surveying on peat will reopen a new frontier for research on values of greenhouse emission for tropical peat.

4. Conclusion

Tropical lowland peats have a distinctly different morphology compared to temperate and boreal peats. Tropical peat deposits often form peat domes having a discoidal shape and have logs and wood within their profiles. Using five soil series mapped at phase level in Malaysia, the study has shown that the current international peat classifications such as the World Reference Base (FAO, 2006) and the Keys to Soil Taxonomy (Soil Survey Staff — Eleventh Edition, 2010) do not adequately characterise and differentiate tropical lowland peats. The Malaysian classification system does a better job. There is therefore a need to modify and incorporate some elements from the Malaysian peat classification system into the international peat classifications systems. The Malaysian classification system also helps in determining land use and management decisions for agriculture development and conservation. Selective development of peatland reduces stress on land shortage for food production in line with the increase in global population. Conservation on the other hand reduces the impact of global deforestation and improves sustainable management of peatland through reforestation. Inclusion of the wood criteria to peat classification system will further enhance research on GHG emission as wood fragments do play an important role as recalcitrant carbon and carbon emission.

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