CHAPTER 3

Characteristics of Tropical Lowland Peats

Introduction

Tropical peats like mineral soils of the tropics are quite different from temperate peats. Tropical peats are formed under quite different climatic and edaphic conditions compared to temperate peats. Temperate peats are mainly derived from the remains of low growing plants (bryophytes *Sphagnum* spp. *Gramineae* and *Cyperaceae*). Tropical lowland peats, on the other hand, are formed from forest species and hence tend to have large amounts of undecomposed and partially decomposed logs, branches and other plant remains. Peat can attain a thickness of over 20.7 m as found in Loagan Bunut National Park (Melling et al., *2006*) and consists mainly of organic substances with a high acidity (pH 3-4) and ash content of less than 5%.

Walking in these tropical lowland peat forests can be extremely hazardous as one's feet hardly touch the ground per se. One has to carefully step on the aerial and buttress roots of the current vegetation which tend to form a dense interlocking root mat. Due to this difficulty of walking in these forests most people's experiences of the tropical lowland peats are derived or based on what they observe at the edges of the swamp. Thus most people consider the tropical lowland peats to have a thick luxuriant forest with a high biomass and to be continually waterlogged. Contrary to common beliefs tropical lowland peats are not uniform and are not always under water. These peat forests consist of a lateral variation of vegetation types resulting in a horizontal or lateral zonation of forest species and hence above ground biomass as one walks from the edge of the swamp to the centre. These peat swamps are dome-shaped – a fact that is not readily discernible in the field. When one examines a vertical profile morphology of the plant debris making up the forest base, a vertical layering of organic soil materials with different stages of decomposition and amount of wood or even layers of water can be seen. Thus tropical lowland peats exhibit both a horizontal zonation and vertical layering. Understanding of this zonation and vertical profile layering is critical for the conservation or utilization of these areas. Failure to recognize the structure and zonality of these forests can lead to wrong estimates of the biomass, biodiversity and the role of these forests as a sink or source of greenhouse gas emissions.

Horizontal Zonality of Tropical Lowland Peats

Buwalda (1940), working in Sumatra, was probably the first to report that different plant communities exist in the peat swamp forest depending on the thickness of the peat and the distance from the river. Where the peat is more than three metres thick, he reported that the vegetation is poorer than that at the shallow depths. On very thick peat deposits, *Myrtaceae* and *Calophyllum* species with tall slender trunks growing close to one another dominate. In the central or inner parts of the forest, the thickest layers show a more open vegetation with poorly developed, twisted and stunted trees and scattered pools containing deep brown water with a pH of 3.0 to 3.5. This *Myrtaceae-Calophyllum* forest is rich in *Nepenthaceae* whilst mosses, ferns and *Cyperaceae* cover the soils. On peat deposits shallower than three metres deep, the undergrowth consists of *Araceae, Commelinaceae, Palmae (Zalacca conferata, Licula)* and ferns. The soils has a pH of 3.5 to 4.5. Based on these studies in the Indragiri Area, Buwalda (1940) reported six different vegetation types with the dominance of one or more species. Anderson (1961, 1963, 1964) working on Borneo Island (Sarawak and Brunei) described a similar situation.

Ecology of the Tropical Lowland Peat Swamp Forests

In spite of the work of Buwalda (1940) little was known about the ecology of the Peat Swamp Forests in Southeast Asia. Perhaps the most comprehensive and best known study of the ecology of the Tropical Lowland Peat Swamp Forest was carried out by Anderson over a period of ten years in the 1950s (Anderson, 1961, 1963, 1983). Anderson recorded 253 tree species (including 40 small trees which rarely exceeded 10 m in height in the Tropical Lowland Peat Swamp Forest. Many of these species recorded by Anderson are also found in other forest types outside peat swamp forest. It is also significant to point out that many of the species which are largely confined to the periphery of the Tropical Lowland Peat Swamp Forest also occur in the Lowland Dipterocarp Forest. On the other hand, the species that are present in the forests located in the centre of the swamps are mainly those that are found on the poorer soils, frequently podzols of the heath forest (Anderson, 1963).

The Tropical Lowland Peat Swamp Forests show conspicuous changes in vegetation types from its periphery to the centre of each dome-shaped peat swamp (Buwalda, 1940; Anderson 1961). Anderson who studied these swamps in Sarawak, Malaysia and adjacent Brunei on the island of Borneo had used the term "Phasic Community" (PC) to designate a dominant vegetation zone. Anderson recognized six distinct Phasic Communities or zones on the basis of their floristic composition and structure of the vegetation in each zone *(Table 3.1 and Figures 3.1 and 3.2).* They were numbered PC1 at the periphery to PC6 in the centre of the Peat Swamp. The main changes that characterize these concentric zonations which are fairly easily seen on aerial photographs have been summarized by Tie (1990) as follows:-

a) An almost complete change in the floristic composition from one zone to another was evident. *Dactylocladus stenostachys* is the only tree species found in all six zones. Amongst the ground flora, only the sedge *Thorachostachyum bancanum* has a similar distribution.

b) There was reduction in the number of tree species per unit area and total number of species recorded from the edge to the centre. In sample plots of 0.2 ha, PC1 and 2 have 30-35 tree species (>30 cm girth), PC3 and 4 have about 12-25 species and finally in PC6 less than 5 species occur.

c) A general increase in the number of stems (> 30 cm girth) per unit area was evident. In PC1, it varies between 600-700 trees per ha, whereas in PC4, 650-850 stems usually occur and in the low dense forest of PC5, the number increases to 1,200-1,350 trees per ha. PC3 is the exception with only 350-600 stems per ha. In the open, stunted forest of PC6, very few stems of more than 30 cm girth are found.

d) There was a decrease in the average size of a species from the periphery to the centre. *D. stenostachys*, for example, may attain a girth of up to 6 m and a height of 30 m in PC1 but in PC6 it occurs no more than a small tree, usually less than 4 m in height. *Shorea albida* also decreases in size from a girth of up to 8 m and a height of 60 m in PC2 to pole-like in PC4 where they are usually 60-120 cm in girth.1

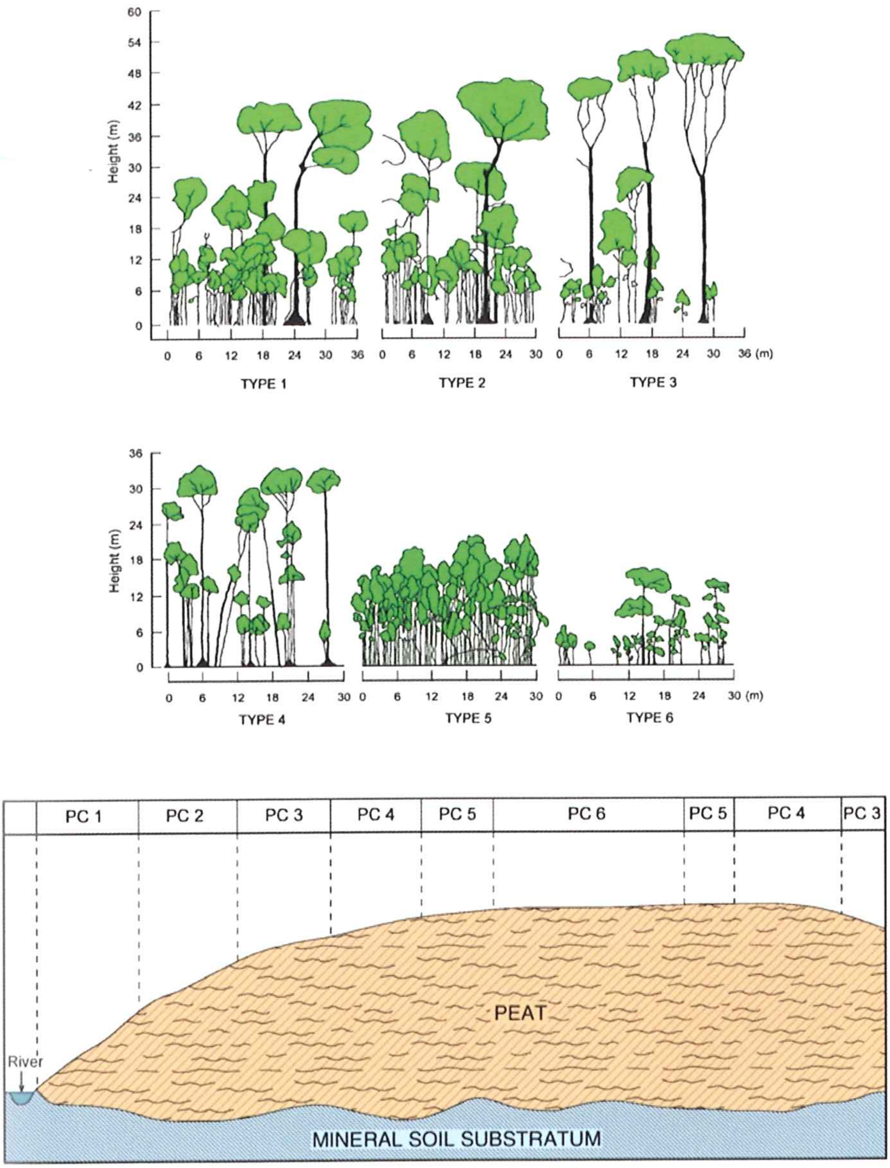
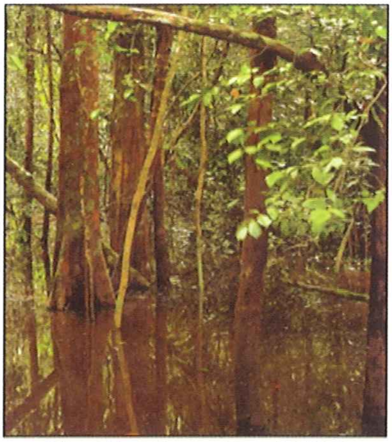


Figure 3.1. *Lateral zonation of vegetation in the six phasic communities* (after Anderson, 1961)

EXAMPLES OF FOREST TYPES



Mixed Peat Swamp Forest (PC-1)

Alan Batu Forest (PC-2)

Alan Bunga Forest (PC-3)

Padang Alan Forest – *Shorea Albida* (PC-4)

Tristania-Parastemon-Palaquium Forest (PC-5)

Padang Raya Forest (PC-6)

Figure 3.2. *Examples of peat swamp forest types [Source:* Hazebroek, H.P. and Abang Kashim Ab. M. 2001 (PC-1); Adrian Wong (PC-2, PC-3); Uyo *et al.*, 2010 *(Shorea Albida* – PC-4); Chua, K.H. (PC-5); Hazebroek, H.P. and Abang Kashim Ab. M. 2006 (PC-6)]

TABLE 3.1. CHARACTERISTICS OF THE SIX PHASIC COMMUNITIES (PC)

PC	Name	Main tree species	
		Upper storey	Middle-understorey
1	Gonystylus-Dactylocladus-Neoscortechinia Association (Mixed Peat Swamp Forest) (MPSf)	*Gonystylus bacanus* (Ramin), *Dactylocladus stenostachys* (Jongkong), *Shorea* spp., *Copaifera palutris*	*Neoscortechinia kingii* *Alangium havilandii*
2	Shorea albida-Gonystylus-Stemonurus Association (Alan Swamp Forest) (ASf) (Alan Batu Forest)	*Shorea albida*, *Gonystylus bacanus*	*Stemonurus umbellatus*
3	Shorea albida Association (Alan Bunga Forest) (ABf)	*Shorea albida*	*Tetractomia holttumii*, *Cephalomappa paludicola*, *Ganua curtisii*
4	Shorea albida-Litsea-Parastemon Association (Padang Alan Forest) (PAf)	*Shorea albida*, *Litsea crassifolia*	*Parastemon spicatum*
5	Tristania-Parastemon-Palaquium Association (TPPf) (Padang Paya Forest – PPf)	*Tristania obovata*, *Parastemon spicatum*, *Palaquium cochleariflolium*	Saplings of bigger trees
6	Combretocarpus-Dactylocladus Association (Padang Keruntum Forest) (PKf)	*Combretocarpus rotundatus* (Keruntum)	*D. stenostachys* *Litsea crassifolia*, *Garcinia cuneifolia*

PC	Emergent height (m)	Girth	Stems* per ha	Species⁺ per 0.2 ha	Canopy	Other features of trees and ground flora	Occurrence
1	40-50	n.a.#	600-700	30-55	Uneven; multi-storeyed	Structure and physiognomy similar to MDF on mineral soils; many species with pneumatophores, stilt roots and buttresses; *Zalacca conferta* may form dense thickets especially on shallow peats.	Periphery zone of swamps, especially Rajang Delta and near the coast.
2	up to 60	2-4 m, few up to 7 m	n.a.	40-45	Uneven; multi-storeyed	Similar to PC 1 but with scattered very large *S. albida* trees; large trees usually hollow and with stag-headed crowns; *Nepenthes bicalcarata* and *Pandanus andersonii* frequent.	Common; extensive in Rajang Delta.
3	45-60	1-3 m	350-600	10-20, usually <15	Even	Middle storey sparse; lower storey moderately dense; cauliflower-like crowns of *S. albida* distinctive on air-photo; large trees heavily buttressed; *P. andersonii* frequent.	Extensive in Lupar-Saribas and Baram swamps, largely absent in Rajang Delta.
4	30-40	60-120 cm	650-850	10-25	Mainly even; dense	Very slender stems giving pole-like aspect; dense understorey 3-6 m high; *Nepenthes spp.* quite frequent.	Common in central areas of swamps in Rajang Delta and as transition zones in Baram.
5	15-20	mostly <60 cm	1,200-1,350	11-18	Even; dense	Understorey sparse; herbaceous plants largely absent; some pitcher plants.	At transition zones in Baram and Brunei swamps.
6	Few >12	45 cm, few 75-90 cm	Few	<5	Open; shrub-like	Stunted, xeromorphic, with pneumatophores; *Myrmecophytes* and *Nepenthes spp.* numerous; sedge, *Thorachostachyum bancanum* and *P. ridleyi* abundant; sphagnum moss also occurs.	Only in central areas of swamps along middle reaches of Baram River.

* Stems with 30 cm girth or larger; ⁺ Tree species with 30 cm girth or larger; # (information) not available.

Source: Summarised from Anderson, 1961, 1963, 1964, 1983

Structure and Development of the Tropical Lowland Peat Swamps

Anderson (1961) also studied the structure of the peat swamps in Sarawak by means of level surveys and borings to the substratum. There is a general rise in elevation in a convex form from the river or coast to the centre of peat swamp. The absolute rise and the convexity at the periphery become more pronounced with distance from the sea. The maximum elevation of 20.7 m above mean sea level was recorded at Loagan Bunut National Park, Sarawak (Melling *et al.*, 2006) while the most pronounced convexity of the swamp surface was observed at Tanjung Pasir swamp near Marudi *(Figure 3.3)*. The central raised part of the peat swamp is almost flat with a rise of less than half a metre per kilometer. With the rise in surface elevation, there is sometimes a corresponding fall in the level of the basal mineral materials, usually clays or silty clays, from the river-bank or coast into the swamp centre. This often gives the peat deposit a lenticular or discoidal cross-section.

Groundwater flow in the peat swamp is apparently confined to the top 1-2 m. The presence of well preserved woody material in the peat deposit below the surface indicates cessation of decomposition and suggests complete stagnation of sub-surface water. Layers of water as thick as 30 cm can sometimes occur within the peats.

Hydrology of Tropical Lowland Peat Swamps

The present author hypothesizes that the peat basin is actually a 'confined basin' with higher land consisting of levees on two edges, coastal ridges or coastal plain on the seaward site and hills on the landward side. Thus all the water which is already inside the swamp and that which is added on by rains cannot get out until it overflows the levees in periods of very heavy rainfall. In normal rainfall situations the rainwater that is still confined inside the swamp will exert an upward pressure causing the dome to form *(Figure 3.4)*. The heavier the rainfall, and addition of water from the hills, the greater the pressure build-up causing the dome to become more convex inland compared to domes nearer the coast.

Peat Types and Profile Morphology

Peat characteristics within a peat swamp vary according to its position. Generally most chemical properties such as exchangeable cations, and pH decrease from the edge of the swamp to the centre of the dome. Similarly when one examines the vertical profile morphology of the peat dome a distinct peat profile structure can be seen *(Figure 3.5)*. The organic soil materials making up the profile often change from highly decomposed sapric material in the surface through a partly decomposed hemic material to an undecomposed fibric material at depth. This change corresponds to a decrease of bulk density with depth. Water-filled pores often also thus increase with depth. Logs *(Figure 3.6)*, twigs and branches can occur at any depth within the profile. Hydric (water layers) *(Figure 3.7)* also can occur within the profile. Thus the types of profile morphology not only varies from one peat swamp to another but also between different locations within an individual peat swamp. Illuviated carbon or humilluvic carbon *(Figure 3.8)* often occurs as a layer at the interface between the organic materials and the mineral substratum.

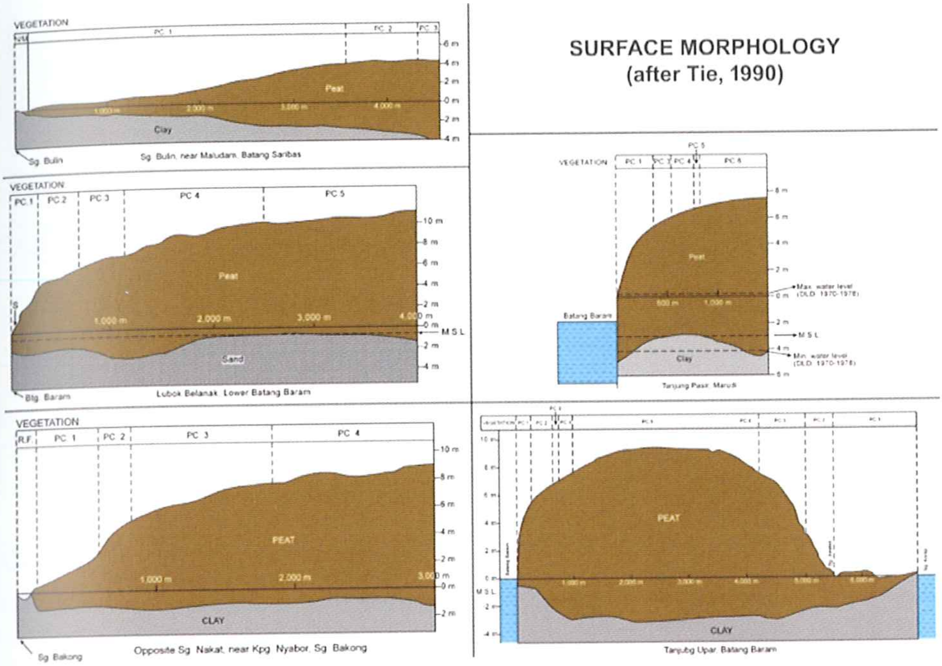


Figure 3.3. *Surface morphology of peat domes* (after Tie, 1990)

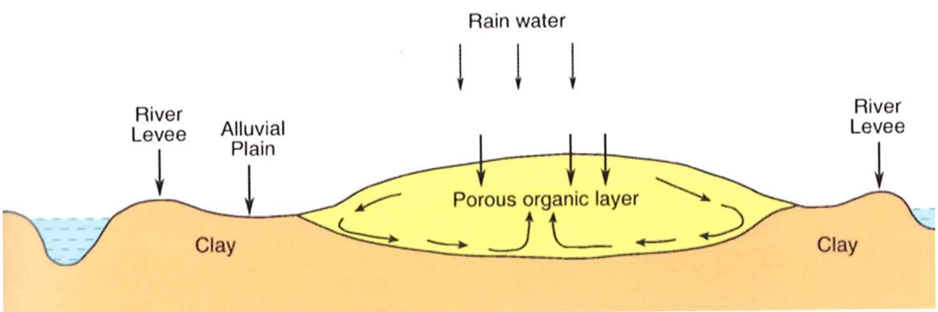


Figure 3.4. *Hydrology of peat swamps (Source:* Paramananthan, 2008b)

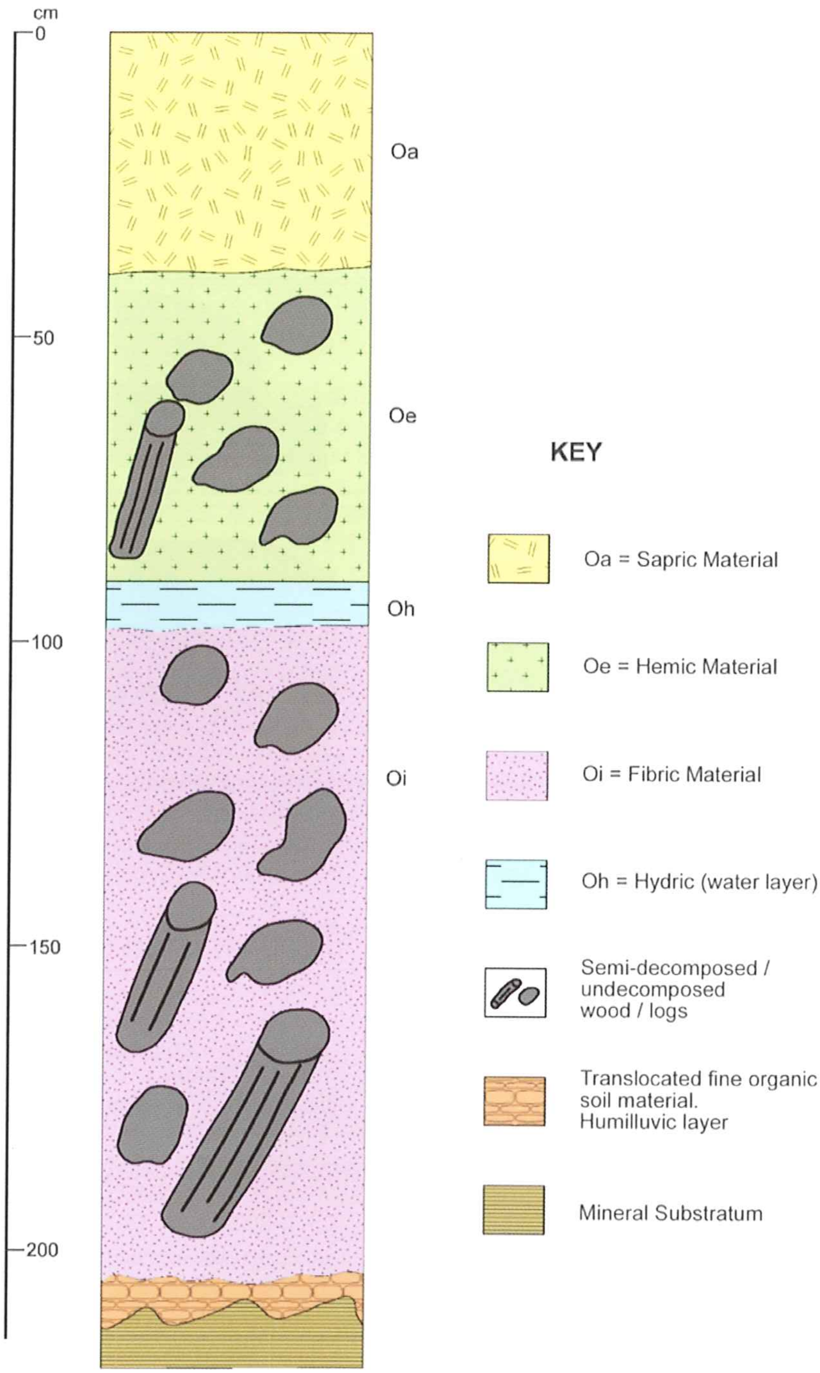


Figure 3.5. *Vertical profile morphology of a peat swamp (Source:* Paramananthan, 2008b)

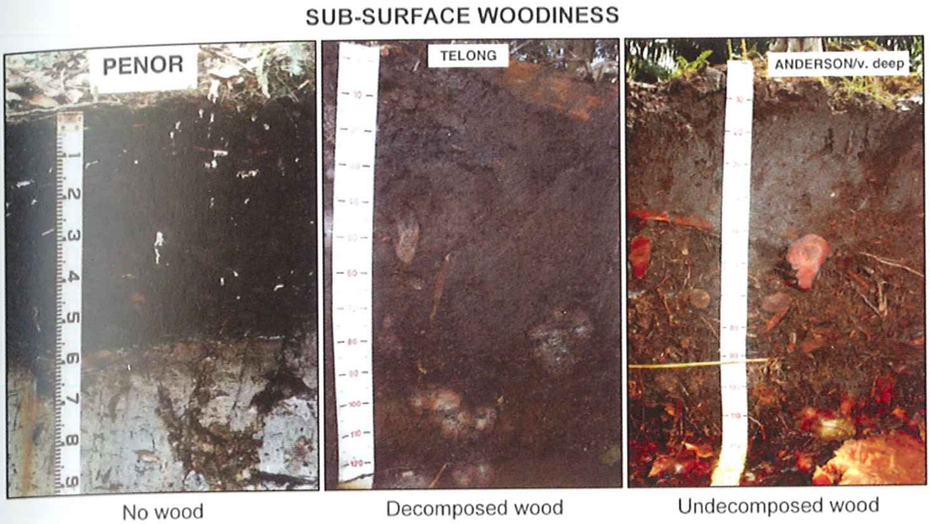


Figure 3.6. Presence of wood in tropical lowland peats (Source: Paramananthan, 2008b)

Current Environmental Issues on Peat Development

Due to its very fragile nature any development or disturbance of the peatlands is expected to change the natural ecological balance. Thus many environmental issues ranging from the loss of biodiversity and habitats to loss of above ground biomass can be expected. Loss of carbon in the subsurface by decomposition can also take place. These, it is claimed will contribute to greenhouse gas emissions and global warming. How much of these statments are facts and how much of these are just estimates will be covered in the subsequent chapters.

HYDRIC LAYER (VACANT LAYER)

Layer of water in peat profile

Figure 3.7. *Hydric layer in tropical towland peat (vacant part was water)* *(Source:* Paramananthan, 2008b) (Uyo *et al.*, 2010)

HUMILLUVIC MATERIALS

Karap/very deep

Naman/deep

Figure 3.8. *Humilluvic carbon at the organic soil material/mineral soil material interface* *(Source:* Paramananthan, 2013b)