Chapter 4
Peatland in Malaysia

Lulie Melling

Abstract Malaysia has approximately 2.6 Mha of peatlands, of which about 70 % (∼1.6 Mha) are in Sarawak. Tropical peatland forest is a unique dual ecosystem of both rainforest and peatland. Its topo-morphology is strongly influenced by the hydrological conditions, which then determine the vegetation structure, species composition, and peat type. The tropical peatland forests are divided into six (6) phasic communities with three (3) main forest types, namely the Mixed Peat Swamp forest (PC1), Alan forest (PC2 and PC3) and Padang Alan forest (PC4). Their formation and development controlling factors, characteristics, and classification are described in the following. Some insights into the conservation and sustainable use of peat in Malaysia are also provided. To date, tropical peatland in Malaysia is still a largely unknown ecosystem and one of the understudied environments in the world. Hydrology is the dominant factor affecting the formation and functioning of peatland ecosystems by influencing the forest type and flow of nutrients. Knowledge on the topo-hydrological characteristics of the peatlands is notably important for understanding the physical and chemical properties of the peat. An understanding of the variability of peat properties in tropical peatland that are highly influenced by its structure and species composition is critically needed to formulate the strategies for conservation and sustainable management of tropical peatland.

Keywords Tropical peatland • Ombrogenous peat • Biosequence

4.1 Introduction

Malaysian peatlands cover an area of about 2.6 Mha (Mutalib et al. 2002). Sarawak, one of two Malaysian states on the island of Borneo possesses the largest extent of peat, over 1.6 Mha. They represent about 70 % of all Malaysian peatlands (Fig. 4.1, Table 4.1). In contrast to temperate peatlands which is mainly covered by sedge and moss, tropical peatlands in low-elevation areas are forest-covered peatlands. High rainfall and high temperatures are also the main features that differentiate tropical

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Fig. 4.1 Distribution of lowland peatlands in Malaysia (Source: Department of Agriculture Malaysia 2002; Department of Irrigation and Drainage Sarawak 2014)

Table 4.1 Distribution of peat in Malaysia

State	Area (ha)
Sarawak	1,657,600
Johor	228,960
Pahang	219,561
Selangor	194,300
Perak	107,500
Terengganu	81,245
Sabah	86,000
Kelantan	7,400
Negeri Sembilan	6,300
Total	2,588,866

Source: Mutalib et al. (1991)

lowland peats from temperate-boreal ones (Zinck 2011). Earlier reports on peatlands in Malaysia were by Coulter (1950, 1957), Browne (1955), and Anderson (1958, 1961, 1964) and in the Annual Reports of the Forest Department (1957, 1962).

Almost all of lowland peat occurs in low-lying, poorly drained depressions or basins in coastal areas. In Sarawak, they are found in the administrative divisions of Kuching, Samarahan, Sri Aman, Sibu, Sarikei, Bintulu, Miri, and Limbang (Mutalib et al. 1991), and some at high altitudes such as on Mount Mulu (Whitmore 1984). In Peninsular Malaysia, peats are found in the coastal areas of West Johore, Kuantan and Pekan districts, the Rompin-Endau area, northwest Selangor and the Trans-Perak areas in the Perak Tengah and Perak Hilir districts. Peats are also found in Sabah; on the coastal areas of the Klias peninsula, the Krah Swamp in Kota Belud, the Sugut and Labuk estuaries, the and Kinabatangan floodplains (Mutalib et al. 1991).

4.2 Formation and Structure of Tropical Peatland

The ombrogenous (rainfed) peat particularly of Sarawak were formed in the few thousand years since the last glaciation of the Ice Age (Wilford 1960; Muller 1965; Morley 1981). Lowland tropical peatland in co-existence with swamp forests is a unique characteristic that contributes to the accumulation of thick surficial layers of peat. Tropical peat is generally heterogeneous, consisting of slightly or partially decomposed woody materials of the standing or preexisting forest. Well preserved tree trunks, branches and coarse roots are generally found within a matrix of dark brown amorphous organic material (Page et al. 2006). The peatlands were initially developed in depressions in marshy alluvial plains, where organic litter and debris accumulates rapidly, up to 4.5 mm/year (Anderson 1964) due to the permanently saturated and anaerobic conditions that greatly decreased the rate of biomass decomposition.

Bordered by the sea and rivers with greater peat accumulation towards the centre of the peatland, the peat is moulded into an inverted saucer-like shape, creating a prominent dome shape. The base of the peat is irregular giving a wide range in the peat depth. The depth of peat is generally shallower near the river mouths and increases inland. In general, deeper peat is found towards the centre of individual peat basins. However, this is not always the case as the deepest peat at 20.7 m depth was found in a Mixed Peat Swamp forest in Loagan Bunut National Park, Sarawak (Melling et al. 2006). On the seaward side of the swamps, the borders consist of mudflats or sandy beach deposits. On the landward side, there are sometimes very narrow levees or no levees at all. Along the rivers, levees of mineral soils form the boundaries (Anderson 1964; Whitmore 1984; Melling 2000; Melling and Hatano 2004). As shown in Fig. 4.2, even though the peat surface is relatively flat, it is highly uneven because of the hummocky microrelief. The highest point of the peat

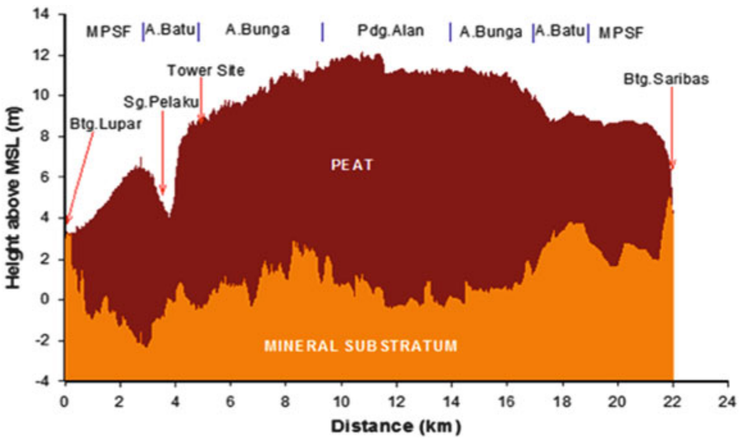

Fig. 4.2 Cross-section at Maludam National Park (Source: Melling and Hatano 2004)

dome is more than 10 m above mean sea level. The cross sectional profile shows that the peat depth ranges from 1 m to more than 10 m. Generally, the surface of the mineral substratum is above the mean sea level (Melling 2000; Melling and Hatano 2004; Melling et al. 2006). Knowledge on the topo-hydrological characteristics of the peatland is critically important for understanding the physical and chemical properties of the peat.

4.3 Peat Soil Classification

Initially, the three major regions in Malaysia, Peninsular Malaysia, Sarawak, and Sabah used different soil classification systems. As for Peninsular Malaysia, Coulter (1950) suggested the following classification according to inherent fertility status: *Eutrophic*, *Oligotrophic*, or *Mesotrophic* groups. Subsequently, Law and Selvadurai (1968) used other criteria based on carbon loss by ignition and peat depth. On the basis of carbon loss by ignition, organic soils were separated into organic clay (20–35 %), muck (35–65 %) and peat (>65 %). Classification based on peat thickness like shallow (50–100 cm), moderate (100–150 cm), deep (150–300 cm) and very deep (>300 cm) was proposed by Paramananthan et al. (1984). In Sarawak, the classification of organic soil was based on the thickness of the organic soil component, the nature of the substratum and ash content (Melling and Hatano 2004). The von Post humification scale was used to classify the degree of decomposition. Sabah used the FAO/UNESCO Legend (1990) of soil classification. Organic soils in Sabah were classified as Dystric or Eutric Histosols (Mutalib et al. 1991).

Developing soil correlations among the three regions have been quite challenging due to differences in definitions and classifications. To rectify this, the Committee for the Standardisation of Soil Survey and Evaluation in Malaysia (COMSSSEM) under the Department of Agriculture, Malaysia in collaboration with the Sarawak Tropical Peat Research Laboratory Unit has developed a Malaysian Unified Classification System (2014) which is a modified version of Soil Taxonomy (Soil Survey 2010). This classification system adopts the local conditions and classifies the different types of peat based on wood content and peat depth (Tables 4.2 and 4.3).

Table 4.2 Classification based on the wood contents

Wood content			
Degree of woodiness		Size of wood	
Terminology	Wood volume (%)	Terminology	Wood diameter (cm)
Few	0–5	Fibre	<2
Common	>5–15	Small	2–5
Many	>15–35	Medium	5–10
Abundant	>35	Large	10–15
		Very large	>15

Source: Malaysian Unified Classification System (2014)

Table 4.3 Classification based on peat depth

Peat depth	
Organic soil material depth (cm)	Terminology
<50	Peaty phase
50–100	Very shallow
>100–200	Shallow
>200–300	Moderately deep
>300	Deep

Source: Malaysian Unified Classification System (2014)

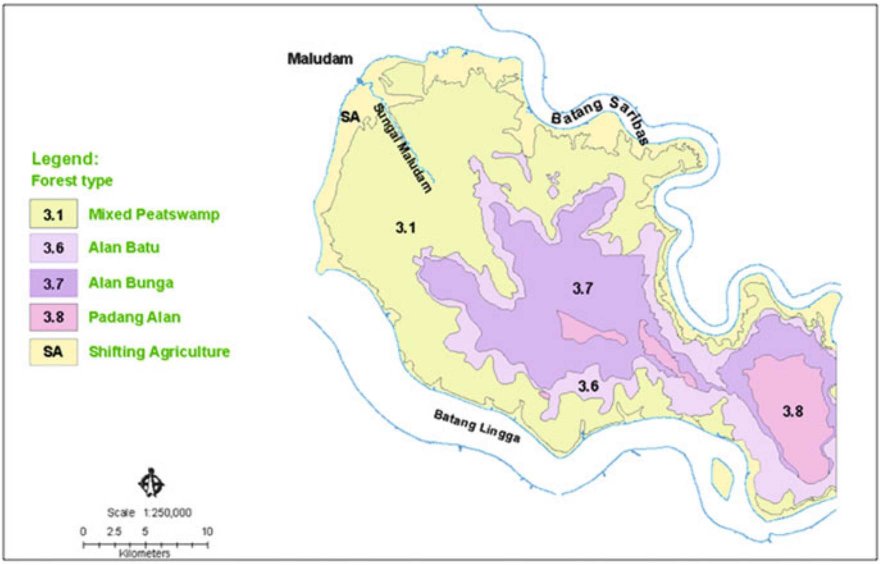

Fig. 4.3 Forest types of the Maludam National Park (Source: Melling et al. 2007)

4.4 Biosequence of the Peatlands

Tropical peatland forest is a unique dual ecosystem, characterised by both rainforest and peatland. It is highly influenced by the characteristics and nature of the peatland. Peatlands mostly have concentric forest zones differentiated by the different forest types. This phenomenon as compared to the other parts of Malaysia is quite distinct in Sarawak and this may be due to the extensiveness of each peat basins. In Sarawak, there are six types of concentrically zoned communities clearly distinguished from the margin to the centre of the tropical peatland forest as shown in Fig. 4.3 (Anderson 1961, 1963, 1964; Melling et al. 2007). Each community has characteristic species and structures in response to the topo-morphology of the peatlands and the fertility of the peat soils which is highly influenced by the hydrological condition. These six communities do not necessarily co-exist in every locality but the number of trees generally decreases across the catena (Anderson 1976). Due to the lower fertility towards the centre of the peatlands, vegetation decreases in canopy height, total biomass per unit area, and average girth of certain tree species while leaf thickness increases (Anderson 1963; Philips 1998). In the most mature swamps found furthest inland, the full sequence of these forest types is more developed. These species have pneumatophores, stilt roots, extensive buttresses, and sclerophyllous leaves as physiological adaptation to both waterlogged and water stress conditions. In waterlogged condition, pneumatophores are quite dominant. In water stress conditions when the low water table is coupled with high porosity resulting in lower capillary rise, the plants tend to have sclerophyllous leaves to prevent moisture loss.

The forest types, differentiated by species composition and structure of the vegetation are classified into different types called phasic communities (Anderson 1961; Melling et al. 2007) (Fig. 4.4 and Table 4.4). The less woody Mixed Peat Swamp forest (PC1) has the most decomposed peat profile, indicated by its higher bulk density. This forest type is usually found at the lower elevations where it receives water and nutrients from a larger area of upslope, and thus is richer in species composition than the other five communities. The Alan forest dominated by *Shorea albida* is the woodiest peat. Alan forest can be divided into two types, namely Alan Batu (PC2) and Alan Bunga (PC3) forests. The Alan Batu forest is mostly found in environments with major abiotic stresses. As physiological adaptation, the *Shorea albida* in Alan Batu forests has bigger buttresses that are almost invariably hollow and with very dense shell-walls (Melling et al. 2007). Due to the harsh environment, the roots of the *Shorea albida* in the Alan Batu forest are also more extensive compared to *Shorea albida* in Alan Bunga. The extensive root system creates vacant layers of about 20–30 cm in diameter within the top 100 cm of the peat profile (Yonebayashi et al. 1995; Melling 2000). The Padang forest (Padang Alan (PC4), Padang Selunsor (PC5) and Padang Keruntum (PC6) forests) is a dense pole-like forest that is accordingly named after its dominant tree species such as Alan, Paya, or Selunsor, whereby its biosequence is influenced by the surrounding hydrology. The pole-like nature of the trees also implies the lower fertility condition of the peat in this zone. The peat in this forest is not woody but very fibrous. Thus, the peat is very porous and has lower bulk density. This is probably due to the restricted lateral water movement, creating a more anaerobic peat soil surface (Melling et al. 2007). As for PC6, the vegetation is almost like that of savannas with shorter trees having extensive aerial roots. Due to the existence of these aerial roots, the peat in this forest tends to be more fibrous and corky in nature.

4.5 Peat Physical Characteristics

In its natural condition, the peat bulk density and porosity varies with the different forest types. The peat also varies in its profile morphology (Melling 2000; Melling et al. 2007). The bulk density of the three main forest types, namely Mixed Peat Swamp, Alan Batu, and Alan Bunga at Maludam National Park ranged from 0.10

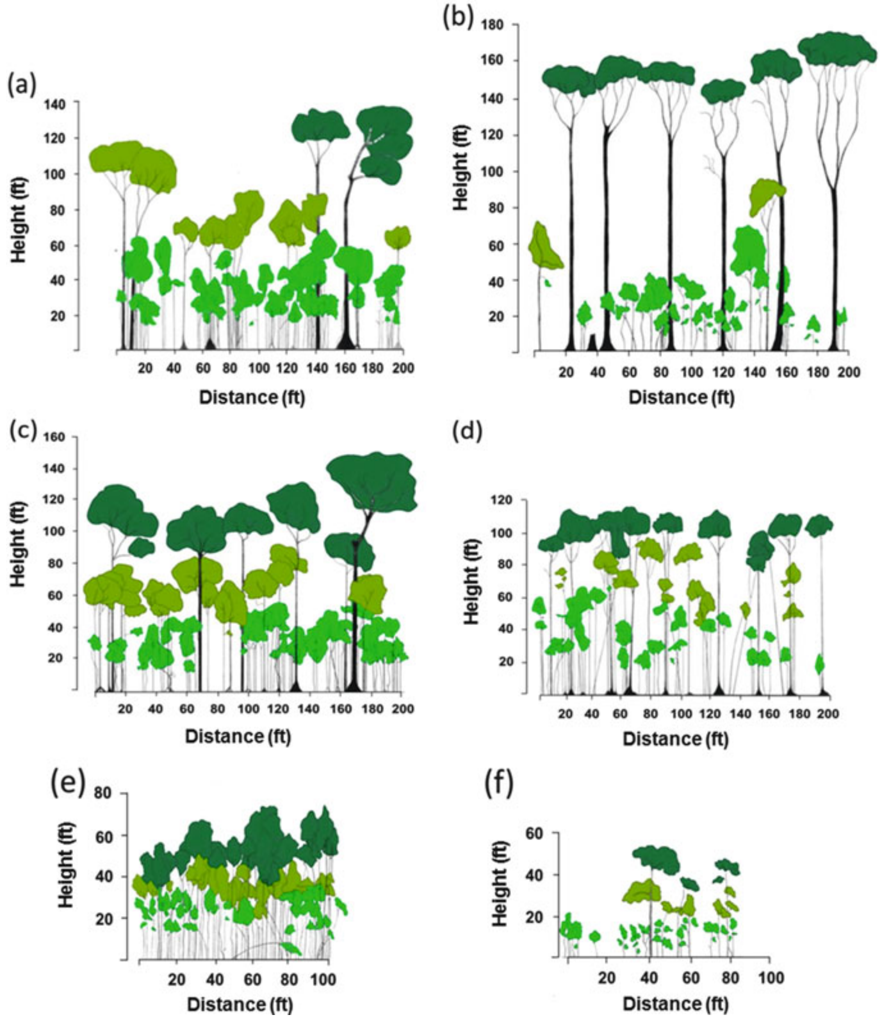

Fig. 4.4 The phasic communities (PC) of tropical peatlands in Sarawak; (**a**) Mixed Peat Swamp forest (PC1), (**b**) Alan Batu forest (PC2), (**c**) Alan Bunga forest (PC3), (**d**) Padang Alan forest (PC4), (**e**) Padang Selunsor forest (PC5), and (**f**) Padang Keruntum forest (PC6) (Source: Anderson 1961; Melling et al. 2007)

to 0.13 g cm^{-3} as shown in Table 4.5. Mixed Peat Swamp forest being more decomposed in nature, thus attributes to its higher bulk density as compared to the other forest types. Melling et al. (2008) reported a similar finding whereby the Mixed Peat Swamp forest in Loagan Bunut National Park recorded the highest bulk density with a value of 0.16 g cm^{-3} as compared to 0.12 g cm^{-3} of the Alan forest. The total porosity for Mixed Peat Swamps, Alan Batu, and Alan Bunga forests were more than 90 %. In another study by Melling et al. (2007) also in Loagan Bunut

Table 4.4 Principal characteristics of the phasic communities (PC) of forest in tropical peatlands in Sarawak

PC	Forest association	Principal characteristics
PC1	*Gonystylus-Dactylocladus-Neoscortechinia* association. Locally known as Mixed Peat Swamp forest	Principal species are *Gonystylus bancanus*, *Dactylocladus stenostachys*, *Copaifera palustris* and 4 species of *Shorea*. Initial phase of the tropical peatland forests. Found at peatland margins with structure and physiognomy similar to lowland dipterocarp rain forest on mineral soil. Structurally most complex and species rich phase. Uneven canopy in which its emergent species may attain a height of 40–50 m with a density of 120–150 tree species ha^{-1}. Epiphytes and climbers are abundant. *Shorea albida* is absent
PC2	*Shorea albida-Gonystylus-Stenonurus* association. Locally known as Alan Batu forest	Similar to PC1 but dominated by scattered very large trees (>3.5 m girth) of *Shorea albida*. It has an uneven and irregular canopy. The trees usually show evidence of being moribund, with staghead crowns and markedly hollow stems. The boles are heavily buttressed. Intermediate trees of *S. albida* are rare. *Stemonurus umbellatus* is an indicator species for this community
PC3	*Shorea albida* consociation. Locally known as Alan Bunga forest	Entirely dominated by *Shorea albida* with 70–100 trees ha^{-1}. It has an even upper canopy, which varies in height between about 45 and 60 m. The buttresses are much lower and narrower than in PC2. *Gonystylus bancanus is* extremely rare or absent. Middle storey is generally absent but a moderately dense understorey is dominated by a single species, either *Tetractomia holttumii*, *Cephalommappa paludicola* or *Ganua curtisii. Pandanus andersonii* forms dense thickets in the shrub layer. Herbs, climbers and epiphytes are rare
PC4	*Shorea albida-Litsea-Parastemon* association. Locally known as Padang Alan forest	Principal species are *Shorea albida*, *Calophyllum obliquinervum*, *Cratoxylum glaucum and Combretocarpus rotundatus*. Dense, even canopy forest at 30–40 m in height which is composed of relatively small-sized trees (<40–60 cm girth) that give the forest a pole-like and xerophytic appearance. These trees are very liable to wind damage. Herbs, terrestrial ferns, climbers, and epiphytes are rare or absent. Small, prostrate shrubs (*Euthemis minor* and *Ficus deltoidea* var. *motleyana*) are indicator species
PC5	*Tristania-Palaquium-Parastemon* association. Locally know as Padang Selunsor forest	Principal species are *Tristania obovata*, *Palaquium cochleariifolium*, *Dactylocladus stenostachys and Parastemon spicatum*. Narrow transitional forest between PC4 and PC6; dense, even and closed canopy with few with average heights of 15–20 m of high density (850–1,250 stems ha^{-1}). Herbaceous layer rare or absent
PC6	*Combretocarpus-Dactylocladus* association. Locally known as Padang Keruntum forest	Only one tree species, *Combretocarpus rotundatus*. Resembles an open savanna woodland with stunted, xeromorphic trees. The trees only exceed 1 m girth and seldom reach the maximum height of 13 m. Patchy shrub layer present. Pitcher plants (*Nepenthes* spp.) and epiphytic vegetation (*Myrmecodia tuberose* and *Lecanopteris sinuosa*) are indicator species

Source: Anderson (1961), Melling et al. (2007)

Table 4.5 Physical characteristics of Mixed Peat Swamp, Alan Batu and Alan Bunga forests in Maludam National Park

Properties	Mixed Peat Swamp	Alan Batu	Alan Bunga
Bulk density (g cm^{-3})	0.13	0.11	0.10
Water filled pore space (%)	74.0	74.1	75.1
Total porosity (%)	95.3	95.9	97.5

Source: Melling (2013)

National Park, the peat hydraulic conductivity under the Alan forest and Mixed Peat Swamp forest were 0.0378 cm/s and 0.0038 cm/s, respectively. Generally, due to its low permeability, the hydraulic conductivity of more decomposed Mixed Peat Swamp forest is lower than the other forest types (Melling and Katimon 2013). The soil profile description is important to understand more on the peat morphology in tropical peatland (Fig. 4.5).

4.6 Peat Chemical Characteristics

Peat type, peat thickness, humification level, topography and hydrology influence the chemical properties of the peat (Tie and Kueh 1979; Melling and Hatano 2004; Melling et al. 2006, 2007). The chemical characteristics of Maludam National Park are shown in Table 4.6.

As shown in Table 4.6, tropical lowland peats are generally acidic (pH 3.2–pH 3.8). Peat with extremely low pH (<3.2) is generally influenced by acid sulphate properties (Maltby et al. 1996) but the pH of peat water will be higher (pH 4.0–4.5) due to the dilution effect.

The highest Pyrophosphate Solubility Index (PSI) was recorded in Mixed Peat Swamps for both peat depths. Higher PSI indicated that the less woody Mixed Peat Swamp forests have higher humification rates than Alan Batu and Alan Bunga forests (Melling et al. 2007). Loss on ignition (LOI) in peat is very high ranging from 98.0 to 99.3 %. The ash content values of peat for all forest types were less than 10 %. This shows that peat has very low mineral content which is a cause of the low fertility. Low ash values also indicate that the peat is an ombrogenous type that receives water and nutrient input only through precipitation (rainfed).

The organic C content of peat in all forest types ranged from 52.3 to 58.2 % and is found to be slightly higher in the subsoil than at the surface. In the peat soil, N is largely found in organic form. Total N ranged from 1.4 to 1.9 % in all forest types in which higher N contents are recorded at the surface than in the subsoil. The C/N ratio in Mixed Peat Swamp forest was the highest, as compared to Alan Batu and Alan Bunga forest. In tropical peatland, the C/N ratio is high (ranging from 28.2 to 41.6 %) due to its woodiness. The C/N ratio is generally used as an indicator for the degree of decomposition (Broder et al. 2012). Generally, residues with low N content or high C/N ratios have slower decomposition rates. During the

(a)

Location : 2º 49’ N 111º 54’ E
Vegetation/Land use : Mixed Peat Swamp Forest (PC1)
Peat depth : 400 cm
Parent material : Woody Peat
Topography and terrain class : Flat; 1AO

Soil Classification :

a) USDA Soil Taxonomy – Eleventh Edition
(Soil Survey Staff, 2010)
Typic Haplofibrists

b) FAO/UNESCO Legend (FAO, 1990)
Dystric Histosols

Profile description

Depth (cm)	Description
0 - 15	Dark brown (7.5 YR 3/2); hemic; abundant very fine to fine roots; many medium roots; many fibres; few medium woods; clear smooth boundary.
15 – 30	Dark brown (7.5 YR 3/2); fibric; few very fine roots; many fine to medium roots; many medium woods; diffuse smooth boundary.
30 – 70	Dark reddish brown (5 YR 3/4); fibric; abundant fine to medium roots; many small to medium wood; common large woods.
70+	Dark reddish brown (2.5 YR 3/4); fibric; many to abundant fibres, many medium woods.

(b)

Location : 01⁰ 27’ N , 111⁰ 08’ E
Vegetation/Land use : Alan Batu Forest (PC2)
Peat depth : 960 cm
Parent material : Woody Peat
Topography and terrain class : Flat; 1AO

Soil Classification :

c) USDA Soil Taxonomy – Eleventh Edition
(Soil Survey Staff, 2010)
Typic Haplofibrists

d) FAO/UNESCO Legend (FAO, 1990)
Dystric Histosols

Profile description

Depth (cm)	Description
0-30	Dark reddish brown (5 YR 3/2); hemic; many fine to medium roots and few large roots; clear smooth boundary.
30-75	Very dark brown (7.5 YR 2.5/3); fibric; abundant fine to medium and large roots; many medium woods; many vacant space; clear wavy boundary.
75-125	Very dark brown (7.5 YR 2.5/2); fibric; many to abundant medium woods; many water channel.

Fig. 4.5 Soil profile description of (**a**) Mixed Peat Swamp (PC1) and (**b**) Alan Batu forest (PC2)

Table 4.6 Chemical characteristics of Mixed Peat Swamp, Alan Batu, and Alan Bunga forests in Maludam National Park

Properties	Mixed Peat Swamp		Alan Batu		Alan Bunga	
	0–25 cm	25–50 cm	0–25 cm	25–50 cm	0–25 cm	25–50 cm
Soil pH	3.5	3.4	3.7	3.7	3.5	3.6
Pyrophosphate Solubility Index, PSI	38.5	42.5	6.7	11.5	3.3	8.8
Loss on ignition (%)	98.0	99.1	98.4	99.2	99.3	98.2
Ash (%)	2.0	0.9	1.6	0.8	0.7	1.8
Total carbon (%)	57.0	58.2	53.6	54.9	52.3	54.5
Total nitrogen (%)	1.8	1.4	1.9	1.7	1.7	1.8
C/N ratio	31.7	41.6	28.2	32.3	30.7	30.3
Water soluble K (mg kg^{-1})	48.1	12.7	107.1	59.1	69.5	44.9
Water soluble Ca (mg kg^{-1})	32.9	27.9	41.1	41.3	46.8	51.0
Water soluble Mg (mg kg^{-1})	20.1	16.4	27.5	25.4	23.9	19.9
Water soluble Na (mg kg^{-1})	72.7	79.1	94.8	98.9	99.7	111.8
Water soluble Br (mg kg^{-1})	5.5	8.8	9.0	10.6	6.2	6.7
Water soluble NH_4 (mg kg^{-1})	82.0	31.1	72.1	39.6	31.2	24.6
Water soluble NO_2 (mg kg^{-1})	0.23	0.14	0.42	0.12	0.26	0.12
Water soluble NO_3 (mg kg^{-1})	63.3	34.7	69.6	39.2	24.9	19.2
Water soluble PO_4 (mg kg^{-1})	335.1	86.3	244.7	109.1	143.9	82.3
Water soluble SO_4 (mg kg^{-1})	25.5	17.4	13.0	11.0	6.3	10.0
Water soluble F (mg kg^{-1})	4.3	3.8	6.0	4.9	6.7	7.6
Water soluble Cl (mg kg^{-1})	51.4	66.9	115.0	92.0	107.2	74.5
Available P (mg kg^{-1})	218.3	60.1	168.9	97.5	119.8	60.6
Available Fe (mg kg^{-1})	226.8	205.3	190.8	191.1	114.1	107.5
Available Mn (mg kg^{-1})	22.2	14.6	28.4	19.3	11.1	10.1
Available Cu (mg kg^{-1})	0.3	0.1	0.4	0.2	0.4	0.2
Available Zn (mg kg^{-1})	5.8	6.1	17.5	14.5	8.6	8.2
Hot water B (mg kg^{-1})	1.7	2.0	1.7	1.8	1.9	1.4
CEC (cmol kg^{-1})	38.5	41.3	30.6	30.3	29.6	31.2
Exchangeable K (cmol kg^{-1})	0.5	0.2	1.0	0.7	0.8	0.6
Exchangeable Ca (cmol kg^{-1})	3.1	2.1	4.6	2.4	3.7	2.1
Exchangeable Mg (cmol kg^{-1})	4.4	3.7	6.2	5.2	5.1	4.0
Exchangeable Na (cmol kg^{-1})	0.4	0.5	0.4	0.5	0.4	0.5
Base saturation (%)	22.1	15.6	41.1	29.8	34.8	24.6
Total P (mg kg^{-1})	782.0	292.1	819.9	463.9	637.9	365.3
Total K (mg kg^{-1})	239.0	144.4	396.2	292.4	348.7	253.9
Total Ca (mg kg^{-1})	1228.5	1068.8	1499.1	991.5	1284.7	849.6
Total Mg (mg kg^{-1})	650.2	587.0	844.4	680.9	700.2	541.8
Total Fe (mg kg^{-1})	973.3	721.5	586.2	458.7	402.4	276.4
Total Mn (mg kg^{-1})	21.7	13.6	26.4	16.4	11.7	10.1
Total Cu (mg kg^{-1})	3.9	2.9	2.6	2.0	2.6	1.8
Total Zn (mg kg^{-1})	13.4	15.7	29.2	25.5	31.0	18.5
Total B (mg kg^{-1})	5.0	6.1	6.1	6.3	5.9	5.5

Source: Melling (2013)

decomposition process, the C/N ratio decreases, indicating that relatively more C than N is reduced in the process. The C/N ratio of deep tropical peat is higher than with temperate peat due to the high lignin content of the tree remains.

Cation Exchange Capacity (CEC) of peat is high, ranging from 29.6 to 41.3 cmol kg^{-1}. The cation Exchange Capacity (CEC) indicates the ability of peat soil in retaining or releasing nutrients. The high CEC in peat is not due to the presence of basic cations (K, Ca, Mg, and Na) but due to the dissociated carboxyl groups which release H^+ ions resulting in higher acidity in peat. In peat, there is a very limited supply of exchangeable cations, leading to lower base saturation (ranging from 15.6 to 41.1 %) in all forest types.

4.7 Sustainable Management of Tropical Peatlands

Malaysia aims to manage its tropical peatlands sustainably in an integrated manner to conserve resources and generate sustainable benefits for current and future generations. The goal can be attained by improving knowledge in the functions and characteristics of these peatlands, and developing and implementing strategic sustainable management. Various agencies were established, inter alia, to enforce and implement strategies for the sustainable management of peatland. Among these agencies are the Ministry of Resource Planning and Environment, Forest Department, Sarawak Forestry Corporation, Natural Resources and Environment Board, Sarawak Biodiversity Centre and Drainage and Irrigation Department (Sawal 2012). The tropical Peat Research Laboratory Unit was established in 2008 to conduct research and development on tropical peatland, and to disseminate scientific knowledge and provide advisory support pertaining to the management of tropical peatland. In support of resource conservation, the state of Sarawak has targeted approximately 1.24 Mha or 10 % of its land area covering a diverse type of habitats as Totally Protected Areas (TPAs). These TPAs comprises of national parks, wildlife sanctuaries and nature reserves (Khathijah et al. 2005). Moreover, the state of Sarawak plans to set aside 6.0 Mha as a Permanent Forest Estate (PFE) and other sensitive areas like water catchment areas (Sawal 2012). Two national parks in Sarawak are described below.

4.7.1 Maludam National Park, Sarawak

Maludam National Park, which represents the largest Totally Protected Peatland Forest in Sarawak was gazetted in May 2000. The Park covers an extensive area of 43,147 ha of TROPICAL PEATLAND FORESTs off the Maludam Peninsula in the Betong Division, which comprises the largest single TROPICAL PEATLAND FOREST dome in Northern Borneo. The area is divided into two parts by the Maludam River. The Park contains the only viable population in the world of the highly endangered Red Banded langurs (*Presbytis melalophos cruciger*), the endangered Proboscis monkey (*Nasalis larvatus*) and Silvered langurs (*Presbytis cristata*) (endemic to Borneo). Long-tailed macaques (*Macaca fascicularis*) are also very common here. Existence of more than 201 species of birds, 61 species of mammals, 6 species of amphibians, 11 species of reptiles, 28 species of freshwater fishes and 218 species of flora have also been documented. The birds of the Maludam area are very diverse with a few highly endangered species. Conspicuous birds include the Black Pied, and Rhinoceros hornbills (*Anthracoceros malayanus*, *A. albirostris and Buceros rhinoceros*), Common Blue-eared and Stork-billed kingfishers (*Alcedo atthis*, *A. meninting and Pelargopsis capensis*), Striated herons (*Butorides striatus*), Green imperial pigeons (*Ducula aenea*), and Greater Racket-tailed drongo (*Dicrurus paradiseus*). One of the most interesting findings was the sighting of the Masked Finfoot (*Heliopais pensonata*), a vagrant from continental Southeast Asia which has never before been sighted in Borneo island (Khathijah et al. 2005).

4.7.2 Loagan Bunut National Park

Loagan Bunut National Park, gazetted in 1990, covers an area of 10,736 ha between the Sg. Tinjar and Sg. Teru rivers, in the upper reaches of the Baram River basin in Sarawak. The park supports the only freshwater floodplain lake in Sarawak, an ox-bow lake, freshwater swamp forest, dryland forest, rivers, and riverine forests with resident populations of at least 6 mammal species (Mohd-Azlan et al. 2006), 12 bird species (Laman et al. 2006), 4 reptile species (Das and Jensen 2006) and 6 tree species (Tawan et al. 2006) which are categorised as globally threatened by the World Conservation and Monitoring Centre (WCMC). These include the endemic Grey Leaf Monkey (*Presbytis hosei*), Flat-headed Cat (*Felis planiceps*), Wrinkled Hornbill (*Aceros corrugatus*), Asian Black Hornbill (*Anthracoceros malayanus*) and a potentially viable Tomistoma (*Tomistoma schlegelii*) population (UNEP-WCMC 2014). The lake in Loagan Bunut National Park supports the water bird species, including the Oriental Darter (*Anhinga melanogaster*), Lesser Fish Eagle (*Ichthyophaga humilis*), Storm's Stork (*Ciconia stormi*) and Lesser Adjuntant Stork (*Leptoptilos javanicus*), which can also be categorized as the "flagship" species of Loagan Bunut National Park (Laman et al. 2006).

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