A QUICK SCAN OF PEATLANDS IN MALAYSIA

Wetlands International – Malaysia

March 2010

Project funded by the Kleine Natuur Initiatief Projecten, Royal Netherlands Embassy

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PREFACE

Malaysia, comprising the regions of Peninsular Malaysia, Sabah, and Sarawak, supports some of the most extensive tropical peatlands in the world. Malaysia's peatlands mainly consist of peat swamp forest, a critically endangered category of forested wetland characterised by deep layers of peat soil and waters so acidic that many of the plants and animals found in them do not occur in the other tropical forests of Asia. The peatlands of Malaysia play a critical role in preserving water supply, regulating and reducing flood damage, providing fish, timber, and other resources for local communities, and regulating the release of greenhouse gases by storing large amounts of carbon within peat. They also support a host of globally threatened and restricted-ranged plants and animals.

Despite these values, the peatlands of Malaysia are the most highly threatened of all its forests and wetlands. Vast areas of peat swamp forest have been cleared, burnt, and drained for economic development and few of Malaysia's peatlands remain intact. Remaining peatlands continue to be cleared, particularly for oil palm plantations, to meet domestic and international demand for palm oil and other agricultural products. While this demand is increasing, international consumers are also implementing more stringent requirements for forest-certified and 'green' products. This is creating new demands on Malaysia to meet its national and international commitments toward climate change protocols and biodiversity conservation while still achieving its economic targets. Yet the development of management strategies is hindered because little data is available on the extent and status of Malaysia's peatlands, and no national strategy for peatland management exists.

This report presents the first national assessment of peatlands in Malaysia. It identifies remaining peatlands of high conservation value, and presents preliminary recommendations toward the development of a national strategy for Malaysia's peatlands. The report comes at a critical time for the management of Malaysia's forests and wetlands, and is a first step toward developing a national strategy for Malaysia's peatlands. The report's findings were presented at the first international 'Roundtable for Sustainable Palm Oil Conference', held in Malaysia in November 2009. Importantly, the report is preliminary in nature: data is limited or unavailable for many areas, and available data ranges from two to nine years old. In this respect the report highlights the need for new data and provides a framework for more detailed studies in the future.

Many individuals and agencies assisted in the preparation of this report, and we thank them all. The project was funded by the Kleine Natuur Initiatief Projekten (KNIP) through the Royal Netherlands Embassy, without which this project would not have been possible. We hope the report will strengthen the management and sustainable use of peatlands in Malaysia.

Alvin Lopez

Director

Wetlands International–Malaysia

ACKNOWLEDGEMENTS

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Photo credit – Lim Kim Chye

ABBREVIATIONS AND CONVENTIONS

Abbreviations

CC	Canopy Cover (%)
DBH	Diameter at Chest Height
DOA	Department of Agriculture
GHG	Green House Gas
HCVF	High Conservation Value Forest
KNIP	Kleine Natuur Initiatief Projecten (Royal Netherlands Embassy)
msl	mean sea level
RSPO	Roundtable on Sustainable Palm Oil
SEPPSF	South East Pahang Peat Swamp Forest
WI-MP	Wetlands International-Malaysia Programme

Conventions

Quickscan	Term applied by Wetlands International for rapid status assessments including desktop review and limited site visits
HCVF	Forests that possess one or more of the following attributes: (1) globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia); (2) globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance; (3) areas that are in or contain rare, threatened or endangered ecosystems; (4) provide basic services of nature in critical situations (e.g.watershed protection, erosion control); (5) areas fundamental to meeting basic needs of local communities (e.g.subsistence, health); (6) areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities) (source: http://assets.panda.org/downloads/hcvffinal.pdf).

Report citation

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1. INTRODUCTION TO PEATLANDS IN MALAYSIA

This report presents the results of a ‘quickscan’, or rapid assessment, by Wetlands International-Malaysia Programme (WI-MP) to assess the current status, extent, distribution, and conservation needs for peatlands in Malaysia. The assessment was conducted from 2007-2009, and comprised desktop review and mapping followed up by rapid field visits to selected sites.

1.1 Overview

Tropical lowland peatlands cover about 23 million hectares in South-east Asia, of which the natural vegetation is predominantly peat swamp forest. A major characteristic of peat swamp forests is that they are permanently waterlogged; leading to reduced decomposition of organic matter from plant litter, which then accumulates as peat.

1.1.1 Development and structure

Most of the lowland peatlands in Malaysia have developed along the coast, behind accreting mangrove coastlines, where sulphides in mangrove mud and water restrict bacterial activity, leading to the accumulation of organic matter as peat. Many peatlands which are now far inland developed along the former coastline such that some may be around 100 km inland such as the peat areas around Marudi in Sarawak. The age of the oldest inland peat areas has been estimated as 4,000-5,000 years. The peatlands formed along the coast do not form an unbroken area, rather, they develop as individual units on the alluvial plains between rivers flowing to the sea.

A typical situation is that a peat dome develops between two rivers. The rivers possess natural levees in their floodplain stage, and as the levees fall away from the river, a thin strip of alluvium is left which has been deposited by the river flooding. On these mineral soils, freshwater swamp forest develops. Flooding along the margins of the rivers, which progressively diminishes as one gets further away from the river, prevents the development of peat. This separates ‘topogenous’ peats, which receive inputs of nutrients from river water, from ‘ombrogenous’ peats or bogs, which receive input of water only in the form of rainfall. The result is a dome-shaped area of peat between the two rivers. In relatively young domes, there is a very limited central bog plain, but in older ones, the bog plain is extensive. Figure 1 and Figure 2 depict a cross-section of a peat dome in Miri Division, Sarawak and a diagrammatic representation of a highly developed dome with an extensive central bog plain. Anderson (1964) likened the shape of these more developed, older domes to that of an inverted saucer.

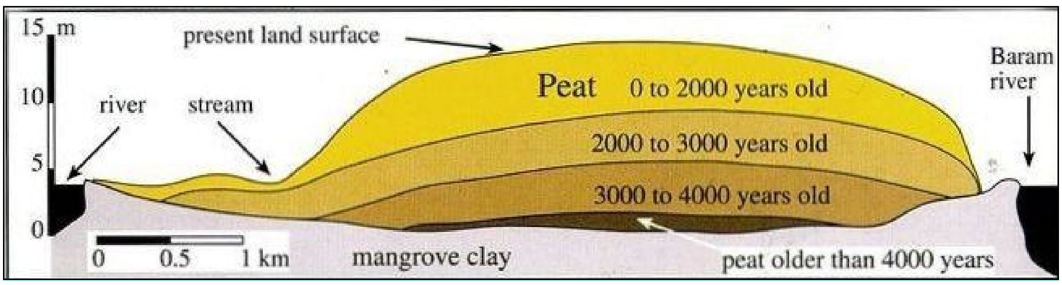

Figure 1: Cross-section of a highly-developed peat dome in the Baram Valley, Sarawak, showing the depth and age of the peat. Source: Hazebroek and Abang Kashim (2000); modified from Tie and Esterle (1991).

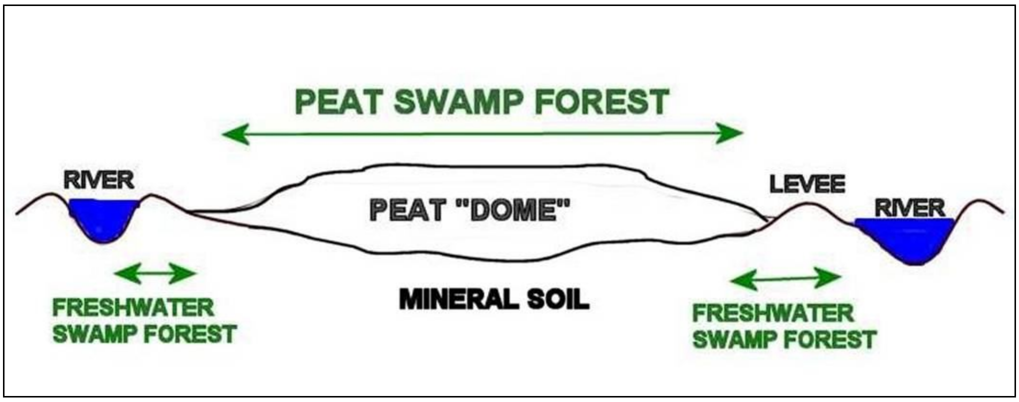

Figure 2: Diagrammatic representation of a more highly developed inland peat dome, showing the extensive flat bog plain in the centre. The bog plain may be 10 m higher than the river level. The mineral soil base may be below mean sea level.

Peat domes are considered as discrete hydrological units, although they will also be influenced by the discharge and level of the rivers that surround them. Inundation by freshwater will only occur at the margins of the swamp where it borders the river or the freshwater swamp forest zone. Thus, the higher parts will only receive water in the form of rainfall. Dreissen (1977) notes there is a decrease in the levels of inorganic nutrients from the margin to the centre of the peat domes, with the centre particularly lacking in phosphorus and potassium.

On the bog plain, where the water table is lowest, drought stress may occur during drought periods. Combined with this, the plants may also reduce water uptake due to the high levels of tannins and other plant chemical defences leached from the litter into the soil water (Bruenig 1990).

It appears that most of the peatland areas around the coasts of Malaysia have this domed structure, but there may be a few which do not possess a domed structure and may be fairly uniform in depth and elevation. Peat depth at the centre of the dome may reach 12 m, such as in the inland domes around Marudi in Sarawak (Anderson and Muller 1975).

1.1.2 Underlying mineral soil

Peat can develop over both sand and clay. In most cases as in Figure 1, the level of the surface of the sub-soil is fairly constant. In some cases, ridges or hillocks may occur in the peat swamps which distort the usual trend in increasing peat depth towards the centre of a peat dome. For example, sand ridges, probably old beach deposits, can form low ridges in the peat swamps. One such example is close to the Merchong River in South East Pahang Peat Swamp Forest (SEPPSF). A profile of a peat in Naman Forest Reserve in Sarawak demonstrates this (Figure 3). In these cases, very thin peat soils over sand may be juxtaposed with areas of deep peat >3 m deep, leading to marked differences in the forest species composition and structure over small areas.

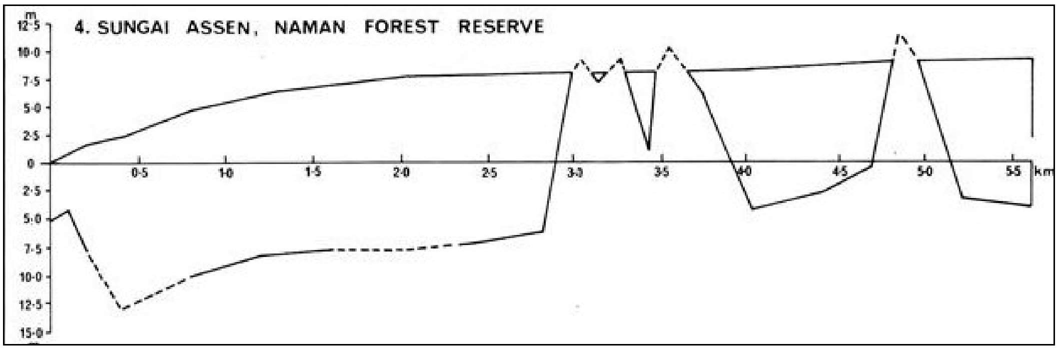

Figure 3: Hills and ridges of mineral soil breaking through the peat surface in Naman Forest Reserve in Sarawak. Source: Tie (1990).

An important feature is that the mineral soil layer below the peat may be below mean sea level. (Figure 4) shows a cross section of a peat dome on the west side of the Baram River close to Marudi. As can be seen, the mineral soil layer is, at points, 2 m below mean sea level (msl). This has important implications for drainage of peatlands in that, as the land subsides through the oxidation of peat carbon, flooding will become more and more prolonged as the level of the land approaches sea level and consequently becomes increasingly difficult to drain.

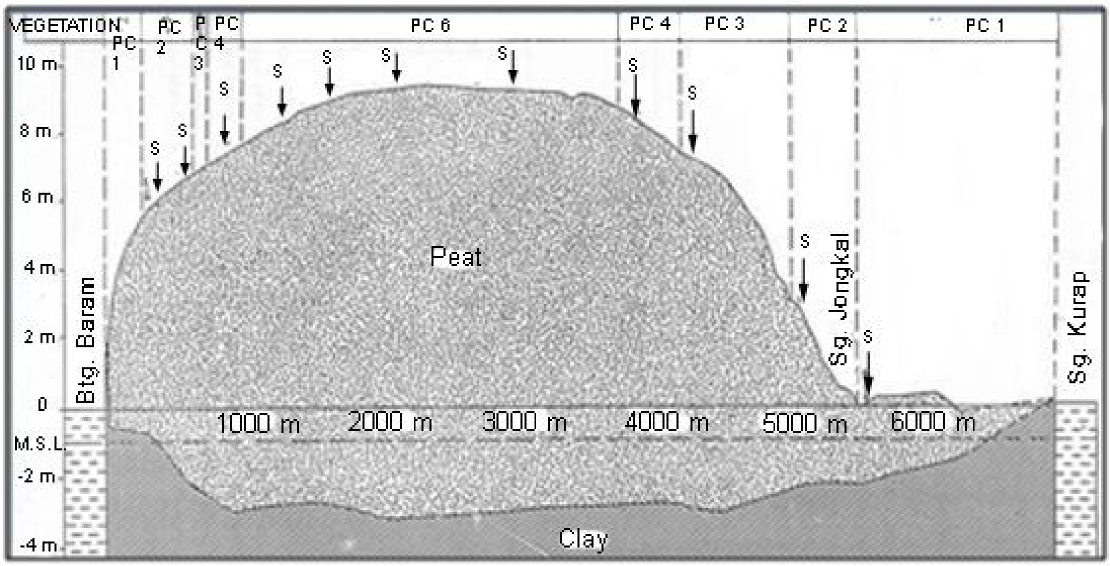

Figure 4: Cross-section of a peat dome close to Marudi showing how the base mineral soil is below mean sea level. Source: Tie (1990).

1.1.3 Water table

Peat is formed under waterlogged conditions and water logging is vital for its continued existence. For the maintenance of the organic soil carbon and/or continued accumulation of peat, the site must be waterlogged for most of the time. (Figure 5) shows the variation in the depth of the water table in SEPPSF on the east coast of Peninsular Malaysia from September 2002 to August 2004.

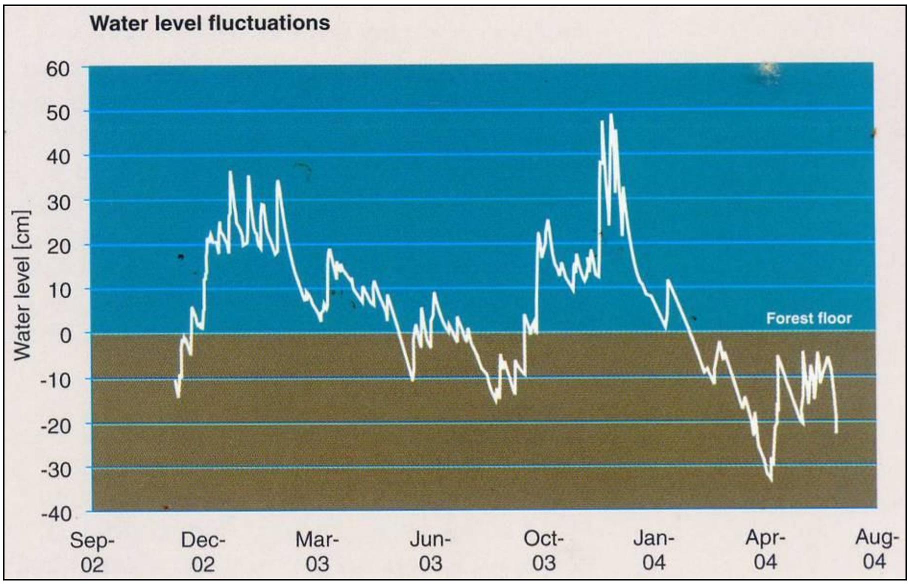

Figure 5: Variation in the water table in an intact peat swamp forest in Pahang State, Peninsular Malaysia. Source: Pahang Forestry Department (2005).

As a general rule, the water table must be 20-30 cm below the surface of the peat or higher to avoid drying out and decomposition of the peat, with the subsequent release of carbon dioxide (CO_2). As can be seen from Figure 5, the peat swamp was flooded during the wet season at the end of 2002 and 2003, when flood levels reached almost 50 cm. For most of the period the water table was above 20 cm, apart from a dry spell in April 2004, where it dropped below 30 cm.

Intact, waterlogged peatlands, such as this one, are net CO_2 absorbers – some CO_2 would probably have been released around April 2004, but for most of the year, the ecosystem would sequester more carbon than is released. In contrast, drained peatlands are net CO_2 emitters, since the water table would, for most of the time, be well below 20-30 cm.

1.1.4 Vegetation

The natural vegetation of peatlands in Malaysia is generally peat swamp forest. There are a few peatland areas with a natural vegetation of sedges, grasses and shrubs, as a result of extended periods of inundation, especially where peat areas are found around water bodies. There is much variation in the species composition of peat swamp forest and this is mainly related to peat depth and hydrology affecting water table depth and nutrient content. Due to the dome-like structure of most of Malaysia's peatlands, especially in Sarawak, several distinct peat swamp vegetation communities are found. The different types of vegetation communities on peat domes have been described in detail by Anderson (1963) for Sarawak and neighbouring Brunei. Relatively little information is available on peat swamp vegetation communities in Peninsular Malaysia and Sabah.

In Sarawak and Brunei, Anderson described six phasic communities of plants proceeding from the edge to the centre of the dome. Anderson described these as phasic communities because pollen analysis of bore samples on a peat dome just west of Marudi (Anderson and Muller 1975) indicated that the change in vegetation up the dome was paralleled by the same sequence of vegetation types with depth of peat i.e. a succession in time.

The major trends in the stature of the forest along the peat dome are thought to be concerned mainly with decreasing fertility, increased incidence of periods of water stress, and problems with uptake of water with very high concentrations of leached plant defensive compounds. A summary of the major characteristics of the different phasic communities is given in Table 1.

Table 1: Major characteristics of the peat swamp forest communities found on peat domes in Sarawak.

Phasic community	**Height (m)**	**Trees/ha > 5 cm dbh**	**Canopy and structure of forest**
Mixed peat swamp forest	40 - 45	150 - 170	Mixed, uneven. Dense middle and lower storeys
Alan (*Shorea albida*) batu forest	40 – 45 (*S. albida* emergents to 65 m)	150 -170	Mixed, uneven, with prominent emergents. Dense middle / lower storeys
Alan bunga forest	50 - 60	85 - 125	Canopy uneven, sometimes broken by gaps caused by lightning strikes and insect attack; middle storey almost absent, with dense understorey frequently dominated by a single species
Padang alan forest	35 - 40	450	Canopy even and mostly unbroken, marked pole-like structure
Padang Paya	15 - 20	1,000 - 1,250	Dense, even canopy with few emergents, herbaceous flora largely absent
Padang keruntum	Up to 7 m (*Combretocarpus rotandatus* to 20 m)	(mostly shrub-like forms)	Open aspect with only one tree species reaching up to 20 m. Most other species small in structure or shrub-like. Herbaceous flora consists of *Nepenthes*, sedges and *Sphagnum*

In Sabah, three vegetation communities have been described for peat areas (Fox 1972, cited in www.sabah.gov.my):

- *Dactylocladus stenostachys* / *Gonystylus bancanus*. The most common peat swamp forest type. Occurs mainly in southwest Sabah, particularly on the Klias Peninsular. The dipterocarps *Shorea platycarpa*, *S. scabrida*, and *S. teysmanniana* and Ramin *Gonystylus bancanus* are found in this forest type.
- *Dacrydium elatum* / *Gymnostoma nobile*. This rare forest type occurs close to the coast in Marintaman-Mengalong Forest Reserve south of Sipitang.
- *Lophopetalum multinervium*. This type of peat swamp is found in the Sugut Valley and Labuk on shallow peat and in areas transitional between peat swamp and freshwater swamp forest. There are also some areas in the Kinabatangan floodplain.

Fox (1972) reported that highly developed peat domes and their associated peat swamp forest communities such as those found in Brunei and Sarawak, are absent in Sabah. It is notable that the dominant tree species on deeper peats in Sarawak, the dipterocarp *Shorea albida*, is not found in Sabah (the northern limit of its distribution is Tutong District in Brunei).

In Peninsular Malaysia, no classification of peat swamp vegetation communities has yet been developed. However, it seems that most communities are of the mixed peat swamp forest type, with no distinct communities dominated by a single species. Appanah (1999) considered that there are floristic differences between the shallower and sandy peats of the east coast and the deeper peats over clay of the west coast.

1.1.5 Benefits provided by intact peatlands

Peat swamp forests provide a wide range of valuable goods and services, yet these are often ignored when peat areas are considered for development. An understanding and appreciation of the benefits provided by intact peatlands may be useful for reconsideration of conversion to unsustainable uses. The costs of conversion may well exceed the benefits of conversion, especially in the long term. Benefits can be divided into three groups (Table 2).

Table 2: Potential benefits provided by intact peatlands.

Grouping	**Benefit**
Direct uses (goods)	Forestry, agriculture, plant gathering, wildlife capture, fish capture, tourism/recreation, water supply
Functions (services)	Water storage/retention, carbon storage/sequestration, flood mitigation, maintenance of base flow in rivers, sediment, nutrient, and toxicant removal
Attributes	Biological diversity, cultural/spiritual value, historical value, aesthetic value

Peat swamp forests are significant carbon stores and sinks. They are one of the few ecosystems which, in their natural state, accumulate carbon. If peatlands are maintained in their natural state, CO_2 is sequestered as organic carbon in dead organic matter stored in the peat, moderating greenhouse gas emissions. When disturbed either by drainage and burning or both, carbon accumulated over centuries or millennia is rapidly released to the atmosphere contributing to the greenhouse effect and climate change.

Peat swamp forests are a source of valuable timber species, chief amongst which is Ramin *Gonystylus bancanus*. Other important timber species are *Dactylocladus stenostachys, Dryobalanops rappa*, and the Meranti group, especially *Shorea platycarpa, S. albida* and *S. uliginosa*.

Socio-economic importance is high, with hunting, fishing, small-scale logging and collection on non-timber forest products all being important.

Whilst peat swamp forest is less species rich then mixed dipterocarp forest in terms of tree species, many of the vegetation communities are globally significant for biodiversity conservation. Most significant are the communities found on peat domes in Sarawak. Peat swamp also contains rare and endemic tree species such as *Shorea albida*, which historically formed unique, mono-specific stands over wide areas in Sarawak. Although tree species such as *S. albida* and *Dryobalanops rappa* are not confined to peat swamp forest, they are endemic to north-west Borneo and mainly occur in peat swamp forest.

In terms of faunal diversity, peat swamp forests are vitally important since they are often the last intact forests remaining in the lowlands. They harbour at least 60 species of vertebrate fauna listed as globally threatened, such as the Orang-utan *Pongo pygmaeus*, Proboscis Monkey *Nasalis larvatus* and Sumatran Rhinoceros (UNDP 2006). Peat swamp forests also harbour a number of species that are confined to this habitat, such as the endangered False Gharial *Tomistoma schlegelii* (Bezuijen et al. 2001). The black waters of the peat swamp forests are known to have some of the highest freshwater fish biodiversity in the world. It is likely that many new species of plants and animals will be discovered in peat swamp forests in view of the relatively small number of biodiversity surveys that have been conducted compared to other types of forest in Malaysia.

Peat swamp forests also play important functional roles in regulation of water resources. Intact peat areas, i.e. those which have not been drained and generally have a canopy cover of more than 70%, act as huge water storage reservoirs. Whilst their ability to absorb large volumes of floodwaters is limited since the water table is normally high in intact peatlands, they can release the stored water gradually, thereby maintaining base flows in rivers during dry periods and preventing saline water intrusion. They can provide a supply of drinking water and water for industrial purposes year-round.

Such functions as flood control, flow regulation, water supply and prevention of saline water intrusion are crucial to maintain the integrity of downstream ecosystems and to prevent economic losses to agriculture and industry.

1.1.6 Consequences of drainage

The ‘knock-on’ effects which occur when peatland is drained are shown in Figure 6.

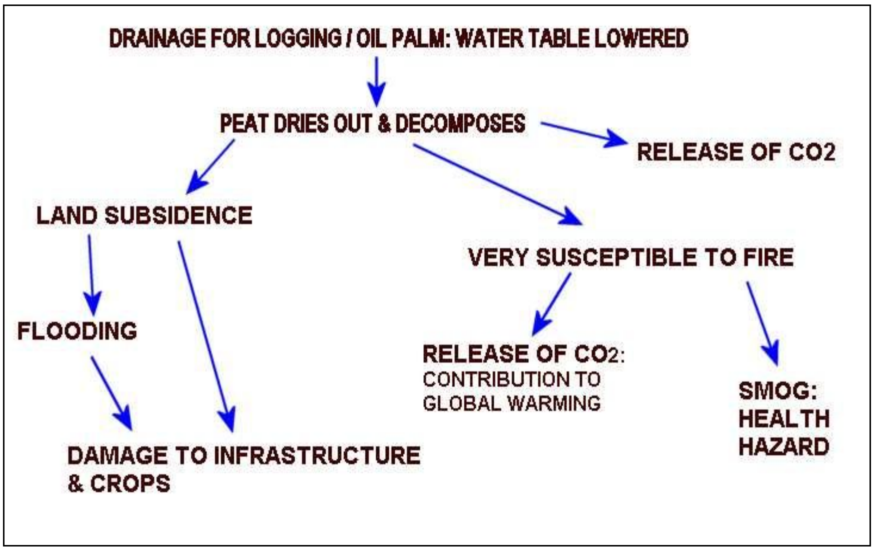

Figure 6: The consequences of peatland drainage.

Most concern for the drainage of peatlands is centred on the increased susceptibility to fire, leading to increased CO_2 emissions. Peat fires are the major source of the ‘haze’ that blankets parts of South-east Asia during dry spells, with serious implications for the health of citizens and for the economy.

The role of peatlands as carbon stores and sinks and the consequences of their disturbance are shown in Figure 7 and Figure 8.

The Indonesian peat forest fires during 1997–1998 covered 1.8–2.2 million ha and released between 3,000 and 9,400 Megatonnes (Mt) of CO_2 (Page et al. 2002), equivalent to 13–40 % of mean annual global CO_2 emissions. This enormous release of CO_2 resulted in the largest annual increase in atmospheric CO_2 concentrations since records began in 1957.

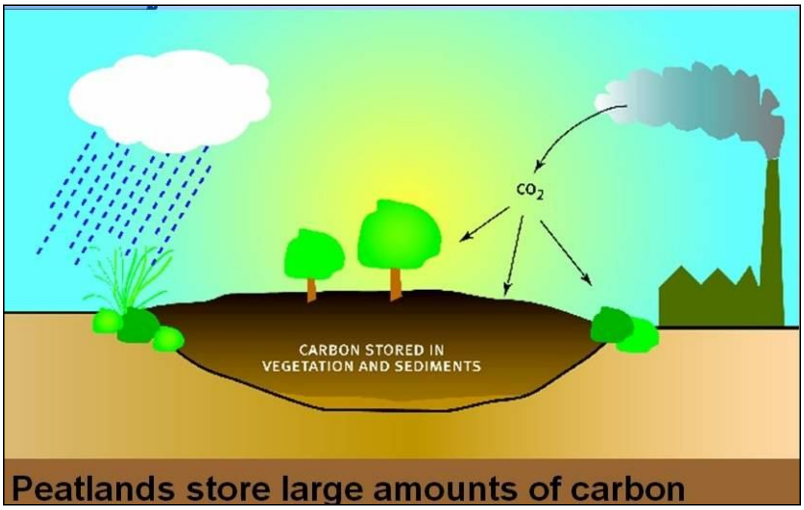

Figure 7: Figure showing that large amounts of carbon can be stored both in the peat and the living biomass in intact peatlands. They also accumulate carbon. Source: Wetlands International.

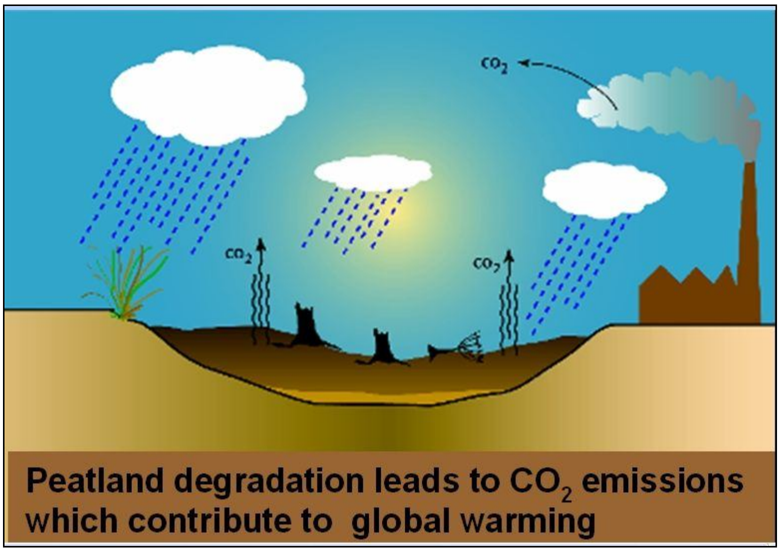

Figure 8: When peatlands are degraded, not only is the huge carbon store lost, but also the ability to sequester carbon. Source: Wetlands International.

Whilst fire has a dramatic and rapid effect in releasing CO_2 to the atmosphere, drainage of peatland without fire also results in a continuous and substantial release of CO_2 to the atmosphere, albeit at a slower rate. The current total peatland CO_2 emissions from drainage in South-east Asia are estimated at an average of 635 Mt per year (over 90% originating from Indonesia). Estimations of annual average fire related emissions vary between 500 Mt (Van der Werf et al. 2008) to 1,400 Mt (Hooijer et al. 2006). Together the drainage and fire related emissions from degraded peatlands in South-east Asia contribute around 8% of the global emissions from fossil fuel burning (Hooijer et al. 2006).

This significant source of Greenhouse Gas (GHG) emissions is not being addressed effectively at present since the Kyoto Protocol deals exclusively with GHG emissions from fossil fuel burning and not from land degradation sources.

Subsidence following oxidation and compaction can lead to serious and regular flooding in areas which have been drained. This is occurring in West Johor, where peatlands were drained for oil palm development over 30 years ago. The level of the land has fallen in relation to sea and river levels, such that flooding is commonplace and may persist for an appreciable length of time. Moreover, continued subsidence causes damage to roads, drainage structures and pylons such that maintenance costs are very high. Figure 9 shows subsidence measured in degraded peatland to the east of the Virgin Jungle Reserve in Pekan Forest Reserve. The degraded land has subsided up to 2 m (Pahang Forestry Department 2005).

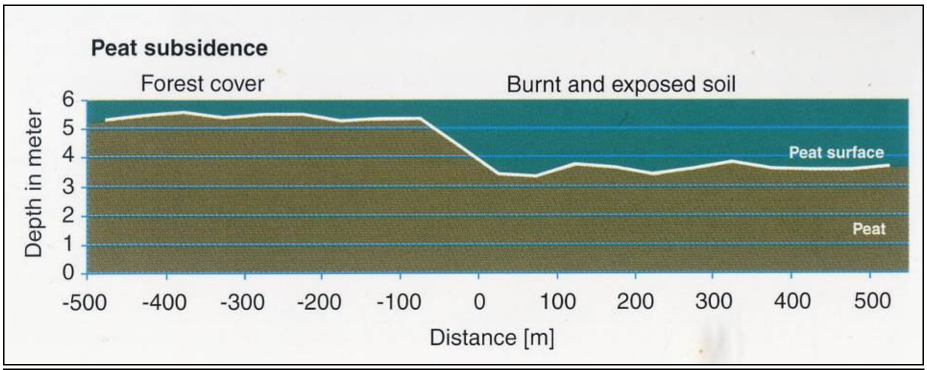

Figure 9: Peat subsidence at the eastern edge of South East Pahang Peat Swamp forest at the transition from undisturbed forest to degraded peatland.
Source: Pahang Forestry Department (2005).

In many areas, the goods and services that intact peat swamp forests provide make a compelling economic case for keeping them intact. However, the true value of the services that intact peat areas provide are generally not taken into account, thus there is a continued pressure and increasing practice to convert ‘these unproductive areas’ into other land uses such as oil palm plantations.

A large amount of peatland in Malaysia has already been drained for agriculture, mostly for large scale oil palm plantations, and there is great concern that the projected increased demand for oil palm (including as biofuel) will trigger further reclamation and subsequent drainage and degradation of intact peatland areas. Hooijer et al. (2006) estimate that the production of one tonne of palm oil on fully-drained peatland can result in CO_2 emissions of 10-30 tonnes due to peat oxidation. Thus, the demand for biofuel, the aim of which is to reduce CO_2 emissions, may actually cause substantially increased CO_2 emissions if plantations are established on peatland areas (Silvius 2007).

Currently there are three main driving forces that are behind the conversion of these ecologically sensitive forests:

- The opening up of more land for agro-industries, in anticipation of an increased global demand for palm oil as biofuel, is a serious threat. Of particular concern is the expansion of oil palm plantations into High Conservation Value (HCV) peat swamp forests.

- The conversion of these ecosystems into built up areas for housing and townships to meet the increasing demands of a rapidly growing human population.

- Continuing pressure to log these economically valuable forests.

1.1.7 Characteristics of peat soil in Malaysia

Peat soils are organic soils, defined as containing more than 65% organic matter. Peats in South-east Asia often contain more than 90% organic matter. They are acidic with pH levels as low as 3.5. They generally have a low nutrient content, except when flooded by rivers, with a high Carbon/Nitrogen ratio. The concentration of substances such as phenols and aluminium are sometimes high and may cause toxicity in plants. Water, air, mineral content and organic carbon content are the four main components of peat which are inter-linked and dependent on each other.

Water is a vital component but the volume of water varies – when fully saturated, peatlands may be composed of more than 90% water by volume.

Irreversible drying of peat is one of the characteristics of peat soil and may occur after prolonged and intensive periods of drying. Peatlands that are drained for land use changes but abandoned for prolonged periods will exhibit this phenomenon. It may cause severe drought stress in shallow rooting crops. This may be due to the hydrophobic nature of dried peat due to the presence of resinous coating which presumably forms upon drying (Coulter 1957). Such properties of resistance in re-absorption of water could also be attributed to adsorbed air films and iron coating around the peat material.

Bulk density of peat material depends on the amount of compaction, the botanical composition of the materials, the degree of decomposition and the mineral and moisture content (Andriesse 1988).

1.2 Study objectives

In order to effectively underpin any advocacy work on the conservation of HCV peat swamp forests and sustainable management of degraded peatlands, a 'quickscan' of the status of peatlands in Malaysia was urgently needed. The specific objectives of this study were as follows.

1. Determine the extent and status of peatlands in Malaysia.

2. Recommend policy changes to achieve more effective conservation of peatlands.

3. Identify strategic actions required to develop a long-term peatland programme for Malaysia, with the aims of achieving sustainable use and rehabilitation of peatlands, minimising CO_2 emissions, and halting the conversion (logging, burning, drainage) of HCV peat swamp forests.

4. Disseminate the findings of this study to national and international stakeholders.

2. METHODS

This study was conducted between 2007 and 2009, and comprised desktop review and mapping followed by rapid field visits to selected sites.

2.1 Definitions used in the current study

'Peatlands' and 'peat soil'.

For the current study, 'peatlands' were defined as all lands on peat soil. The definition of 'peat soil' follows the USDA Soil Taxonomy as: 'organic soil where the loss on ignition is greater than 65%. The minimum depth of the organic soil must be 50 cm and the organic soil material must make up more than half the total cumulative thickness of the upper 100 cm of the soil profile' (Paramananthan and Omar 2008; see Appendix 1).

Management categories.

Five categories were defined to identify the area and distribution of peatlands.

(1) 'Undisturbed/relatively undisturbed HCV forest'. No drainage undertaken in forest area (although there may be drainage in peripheral areas of peat), canopy cover >70%, and forest either unlogged or, logged selectively without drainage.

(2) 'Moderately disturbed peatland'. Peatland which has normally been drained and selectively logged. Canopy cover 30–70%, few fire events, canopy cover may be from residual trees left after the disturbance or from natural succession.

(3) 'Severely degraded peatland'. Peatland which has been drained and clear-felled, with frequent fire events. Vegetation mostly herbaceous (grasses/sedges/ferns) with scattered trees/shrubs, canopy cover <30%.

(4) 'Peatland under crops/husbandry'. Any peatland areas now used for agriculture, including oil palm plantations, pineapple, sago, and annual vegetable crops.

(5) 'Peatland used for infrastructure'. Peatland areas which have been effectively 'lost' through development of the built environment e.g. residential and industrial development on peat areas.

2.2 Determining the extent of peat soils in Malaysia

Peninsular Malaysia. To estimate the extent of peat soils in Peninsular Malaysia, a map was prepared by overlaying 2009 satellite imagery (Landsat Thematic Mapper, scale 1:50,000) on a 2002 map of land use provided by Department of Agriculture (DOA 2004). Mapping was conducted using ArcInfo GIS. This enabled calculation of the extent and distribution of peat soils, and current land uses on peat, in each state. To assess the accuracy of this map, existing data on peatlands from other Wetlands International reports were reviewed, and ground-truthing was undertaken in sites throughout the peninsular to assess the local extent and condition of peat soils (see below). In general, site visits confirmed the accuracy of land/soil classifications in the 2002 map of DOA, with one principle exception, the Sedili basins in Johor State. DOA (2004) classify these basins as peat soil, but various WI-MP surveys from 2003–2007 show that most of the swamp areas surrounding Sedili Besar and Sedili Kecil Rivers were mineral soil with only small pockets of peat. Thus the area of peat soil for Peninsular Malaysia shown in the current report is lower than the figure arrived at by analysis of the DOA soil maps alone.

The Department of Agriculture in Peninsular Malaysia follows the USDA Soil Taxonomy in defining 'peat soil' as soils which have loss on ignition of more than 65%. DOA also classifies peat soils in three categories based on depth: shallow peat (<150 cm), moderately deep peat (150–300 cm), and deep peat (>300 cm).

Sabah. Data for Sabah were obtained from DOA Sabah, which provided information on the extent and distribution of wetland soils. For this report, the area of the Klias soil association was used (Acres et al. 1975). These are peat soils, which may, in places, be intermixed with alluvium, but in which the peat soil predominates in the soil profile.

Sarawak. Current information on the extent and distribution of peat soil could not be obtained for Sarawak. Data was gathered from a variety of published reports and peat experts in Sarawak.

For the area of peat soil, the estimate from the Agriculture Capability Maps produced in 1986 is adopted (Tie, pers. comm.), contained in the reference Maas, Tie & Lim (1986). Information on the area and status of peat swamp forest was taken from Wong (2003), a forestry study which analyzed data from the year 2000. Wong's (2003) estimate of the total area of peatland in Sarawak in much lower than other estimates. It is assumed that she under-estimated the area of peatland which has been converted, but that the estimate of peat swamp forest was accurate. (These data were collected under the project 'Sustainable Management of Peat Swamp Forest with special reference to Ramin' under the umbrella of the Malaysia/Netherlands Joint Working Group on Sustainable Forest Management (Van der Meer et al. 2005; Wong 2003).

The estimate of the area of peat soils converted to agriculture is taken from Melling et al (1999). A major complication is that there has been some modification of Districts and Divisons in Sarawak such that some changes in peatland areas through time for certain Divisions may be a reflection of re-allocation of Districts (and also creation of new Divisions). There is little information available at present on these changes. This is clearly a priority for follow-up work,

2.3 Site visits

Rapid field visits were made to selected sites in Peninsular Malaysia, Sabah, and Sarawak, to assess the accuracy of desktop mapping and available information (see Section 2.2). Sites were visited for which there was a lack of recent data and/or which were under high threat from development. For each site, the status of the peat swamp forest was assessed, together with areas of peat soil that had been converted to other uses. Survey results are incorporated in the current study, including a case study of the Bakong/Baram peat dome near Marudi (Section 3.5). Survey sites in Peninsular Malaysia are shown in Figure 10, the position of the Bakong/Baram dome in Sarawak is in, and survey sites in Sabah (the Kinabatangan peatlands) are in Figure 12.

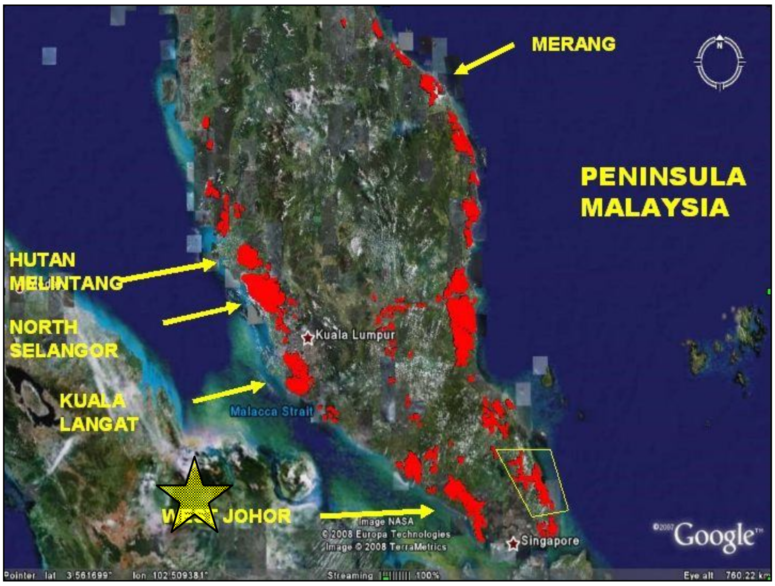

Figure 10: Peat soil areas in Peninsular Malaysia visited during the current study. Red areas are peat soil. The yellow square shows the Sedili Besar and Kecil valleys, which were excised from the total peat area for Peninsular Malaysia, since these valleys are mostly with mineral soils.

Figure 11: The Bakong / Baram peat dome to the west of Marudi (indicated by the star). The yellow line represents the border between Sarawak and Brunei.

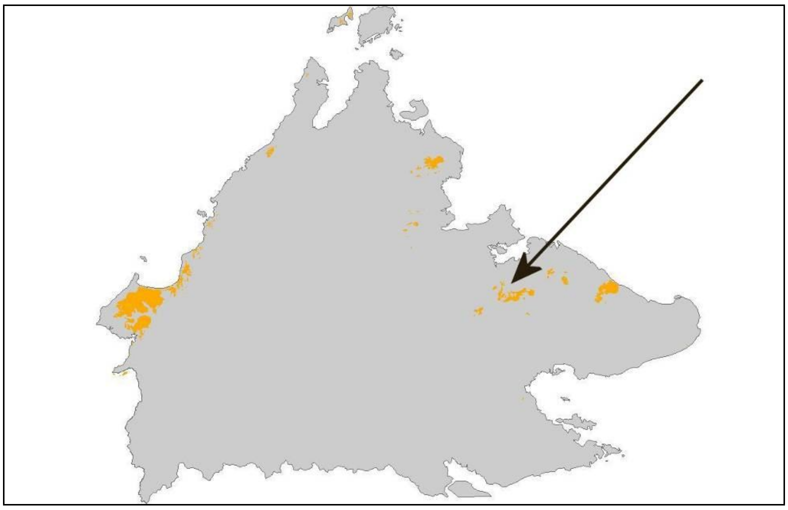

Figure 12: Location of the Kinabatangan peatlands, Sabah.

2.4 Limitations

1. Previous studies of peatlands in Malaysia have used different or interchangeable definitions of 'peatland' or 'peat soil', rendering comparisons with the current study difficult. In some reports, it is unclear whether area estimates are for peat swamp forest, peatlands, or peat soils.

2. No recent data could be obtained from the relevant government agencies for the present extent and distribution of peat soil areas in Sarawak. Three sources were used, Maas et al (1986) for the extent of the peat soil area; Wong (2003) for the status of the remaining areas of peat swamp forest; and Melling et al (1999) for the area of peatland converted to agriculture. Moreover, creation of new Divisions and re-allocation of Districts to different Divisions renders some of the estimates for Divisions confusing.

3. For Peninsular Malaysia, DOA (2004) land use maps do not classify peat swamp forest according to canopy cover, but classify them as 'swamp' or 'forest'. To address this in the current study, other sources of information were used to estimate the areas of the different categories of canopy cover (<30%, 30–70% and >70%). This information could be obtained for North Selangor and South East Pahang peat swamp forests, but no additional information could be obtained for Terengganu State; for this state, it is likely the area of peat swamp forest with more than 70% canopy cover has been over-estimated.

3. RESULTS

3.1 Overview

This sub-section summarises the key findings of the current study. Extent and distribution of peat soil areas for Malaysia under different land uses is summarised in Table 3.

1. National overview.

Peat soils encompass 2,457,730 ha (7.45%) of Malaysia's total land area (32,975,800 ha).

Sarawak supports the largest area of peat soils in Malaysia: 1,697,847 ha (69.08 % of the total peatland area in Malaysia), followed by Peninsular Malaysia (642,918 ha; 26.16%); then Sabah (116,965 ha; 4.76 %) (Table 3).

Table 3: The area (ha) of peat soil in Peninsula Malaysia, Sarawak and Sabah

REGION	ha	%
SARAWAK	1,697,847	69.08
PENINSULAR MALAYSIA	642,918	26.16
SABAH	116,965	4.76
TOTAL	**2,457,730**	

2. **Extent of undisturbed/relatively undisturbed peatlands.** Only 20% of peat soil areas in Malaysia are still under forest with a canopy cover of >70%.

3. No example of a hydrologically intact peat dome remains anywhere in Malaysia. Given that peat swamp forest ecosystems are dependent on maintenance of the intricate balance between hydrology, vegetation and soil, this renders peat swamp forest the most threatened ecosystem in Malaysia.

4. Peninsular Malaysia and Sarawak have a relatively similar area of undisturbed/relatively undisturbed peatlands, but Peninsular Malaysia has the greatest proportion of its peat soil area still under peat swamp forest with more than 70% canopy cover (35% compared to 13% in Sarawak) (Table 4).

Table 4: Status of peat soil areas in Malaysia. Values in parentheses are the proportion (%) of total peat soil area. See Methods for definitions of categories for intactness and land use.

Regions	Total peat soil area (ha)	Undisturbed/ relatively undisturbed (ha)	Moderately disturbed (ha)	Severely disturbed (ha)	Total mod + severely disturbed (ha)	Peat soils under infra-structure (ha)	Peat soils under waterbodies /aquaculture (ha)	Peat soils under agriculture (ha)
Peninsular Malaysia	642,857	226,026 (35)	66,353	47,686	114,039 (18)	15,512 (2)	5,628 (1)	281,652 (44)
Sabah	116,965	21,000 (18)	27,757	11,985	39,742 (34)	17,767 (15)	0	38,457 (33)
Sarawak[1]	1,697,847	223,277 (13)	488,357	426,926	915,283 (71)	nd	nd	554,775[2] (12)
Total	2,457,730	470,303 (19)	582,528	486,597	1,069,125 (44)	33,633 (1)	6,042	874,884 (36)

[1]Data for peat swamp forest from the year 2000 (Wong 2003). The total for moderately and severely disturbed peatland comprise Wong's classes of medium and low density peat swamp forest together with the cleared and burnt classes in her analysis.

[2] Data on area of agriculture on peat in Sarawak from Melling et al (1999)

5. For Sarawak, the figure of 223,277 ha (Table 4) of peat swamp forest with more than 70% canopy includes only ~18,000 ha of completely undisturbed peat swamp forest (Wong 2003): this is barely 1.8% of the total area of remaining peat swamp forest in Sarawak (1,054,844 ha). During the current study, site visits to Marudi in Miri Division revealed that peat swamp forest was being cleared on a peat dome north-west of Marudi for new oil palm plantations. The clearance included some of the last remaining vegetation communities of deep (~12 m) peat on top of the dome. This confirmed that the extent of remaining intact peat swamp forest in Sarawak is now substantially less than 18,000 ha. If this trend continues, there will be little or no remaining intact peat swamp forest in Sarawak in the near future.

6. For Sabah, only 18% of its peat soil area remains under peat swamp forest with >70% canopy cover. Extensive logging, burning, and drainage of peat swamp forest has occurred in most peat soil areas e.g. at Binsuluk Forest Reserve.

7. **Extent of peat soils under agriculture including oil palm.** For Malaysia, about 36% of peat soil areas are used for agriculture. Peninsular Malaysia has the highest proportion of its peat soil under agriculture (44%).**Sabah and Sarawak have similar proportion of peat soils under agriculture (33%).**

8. **Oil palm plantations on all soil types have expanded greatly in Malaysia** as a whole, from 642,000 ha in 1975 to just over 4.3 million ha in 2007, and most expansion has occurred in Peninsular Malaysia and Sabah (see Table 5 and references therein). In 2008, at least 510,000 ha of peatlands in Malaysia supported oil palm plantations. According to figures by TPRI (2009) (Table 5), there appears to have been no expansion of oil palm in peatlands in Peninsular Malaysia and Sabah between 2003 and 2008. For at least Peninsular Malaysia, these figures are inaccurate and under-

represent the extent of new oil palm development on peatlands. For example, the area of oil palm on peat in 2008 in Peninsular Malaysia (200,000 ha) differs with a figure of 222,957 ha for 2006 by DOA.

Table 5: Area of oil palm plantations on: (1) all soil types in Malaysia, 2000-2007 (source: MPOB 2008); (2) on peatlands in 2003 and 2008 (source: modified from TPRI 2009).

Year	**Peninsular Malaysia (ha)**	**Sabah (ha)**	**Sarawak (ha)**	**Total - Malaysia (ha)**
Area of oil palm on all soil types in Malaysia (from MPOB 2008)				
2000	2,045,500	1,000,777	330,387	3,376,664
2001	2,096,856	1,027,328	374,828	3,499,012
2002	2,187,010	1,068,973	414,260	3,670,243
2003	2,202,166	1,135,100	464,774	3,802,040
2004	2,201,606	1,165,412	508,309	3,875,327
2005	2,298,608	1,209,368	543,398	4,051,374
2006	2,334,247	1,239,497	591,471	4,165,215
2007	2,362,057	1,278,244	664,612	4,304,913
Area of oil palm on peatlands in Malaysia (from TPRI 2009)				
2003	200,000	10,000	100,000	310,000
2008	200,000*	10,000	300,000	510,000

*In contrast, DOA estimate that in 2006, 222,957 ha oil palm occurred on peatland in Peninsular Malaysia

9. The greatest expansion of oil palm plantations on peat soils has been in Sarawak, from 100,000 ha in 2003 to 300,000 ha in 2008 (Table 5), and large further expansions into peat soil areas are anticipated, due to the relatively limited availability of more suitable hilly lands. Additional details on oil palm development are provided in Sections 3.2.2, 3.3.1, and 3.4.1. In this respect, some figures for the area of peatland converted to oil palm in Sarawak seem anomalous. As can be seen from Table 5, the figure from TPRI (2009) is 100,000 ha for oil palm plantations for Sarawak in 2003. However, the estimate from Melling et al (1999) is 330,669 ha for oil palm on peatland prior to 1999. Moreover, the figure from MPOB (2008) for the year 2000 is 330,387 ha for all soil types in Sarawak. It may be that the figure of Melling et al (1999) refers to small-holder oil palm as well as plantations, although it seems unlikely that the difference between the estimates (over 200,000 ha), is due to small holder oil palm.

10. **Extent of moderately or severely disturbed peat soil areas.** For Malaysia, 44% of remnant peat swamp forests are moderately or severely disturbed, with the highest proportion in Sarawak (54%) (Table 4). Most disturbance has been due to logging. In Peninsular Malaysia, only 18% of peat

swamp forest appears to be moderately or severely disturbed, but it is likely that the extent of intact peat swamp forest in Terengganu State has been over-estimated due to a lack of data on forest quality.

3.2 Peninsular Malaysia

3.2.1 Overview

Peninsular Malaysia supports the highest area of peatlands under cultivation in Malaysia (44%); about 35% of all peatlands still retain peat swamp forest in relatively good condition (Table 6). Major peat soil areas are shown in Figure 13.

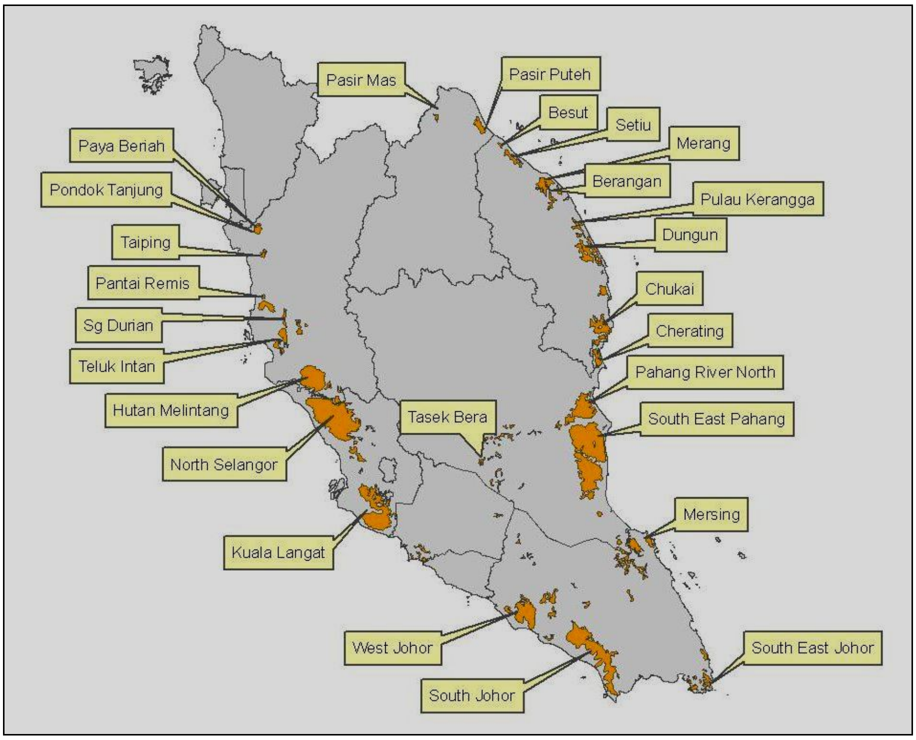

Figure 13: Major peat soil areas in Peninsular Malaysia.

The largest area of good quality peat swamp forest remaining in Peninsular Malaysia is in Pahang State (129,759 ha) followed by Terengganu State (51,759 ha) (Table 6 and Figure 14). It is likely that the extent of intact peat swamp forest in Terengganu State has been over-estimated due to a lack of data on forest quality; further ground-truthing is required to evaluate this figure.

Table 6: Extent of peat swamp forest (PSF) by State in Peninsular Malaysia. CC=canopy cover (see Methods). Values in parentheses are the proportion (%) of total area of peat soils.

State / Division	Total area of peat >65% organic soil at 50 cm depth (ha)	Relatively undisturbed PSF (CC>70%) (ha)	Moderately disturbed PSF (CC 30-70%) (ha)	Severely disturbed PSF (CC< 30%) (ha)	Peat soil area under infrastructure / extraction (ha)	Peat soil area under agriculture (ha)	Water bodies over peat soil (ha)
Johor	143,974	16,304 (11.3)	2,928 (2.0)	5,335 (3.7)	2,614 (1.8)	114,887 (79.8)	1,906 (1.3)
Pahang	164,113	129,759 (79.1)	8,834 (5.4)	4,015 (2.4)	520 (0.3)	20,869 (12.7)	116 (0.1)
Selangor	164,708	16,231 (9.9)	47,613 (28.9)	31,953 (19.4)	7,595 (4.6)	59,587 (36.2)	1,729 (1.0)
Perak	69,597	4,574 (6.6)	675 (1.0)	335 (0.5)	838 (1.2)	62,954 (90.5)	221 (0.3)
Terengganu	84,693	51,759 (61.1)	6,281 (7.4)	4,936 (5.8)	3,597 (4.2)	16,628 (19.6)	1,492 (1.8)
Kelantan	9,146	5,626 (61.5)	22 (0.2)	1,031 (11.3)	3 (0.1)	2,464 (26.9)	0
Negeri Sembilan	6,245	1,729 (27.7)	0	0	254 (0)	4,262 (68.2)	0
Federal Territory	381	44 (11.5)	0	81 (21.3)	91 (23.9)	1 (0.3)	164 (43.0)
Total	642,857	226,026	66,353	47,686	15,512	281,652	5,628

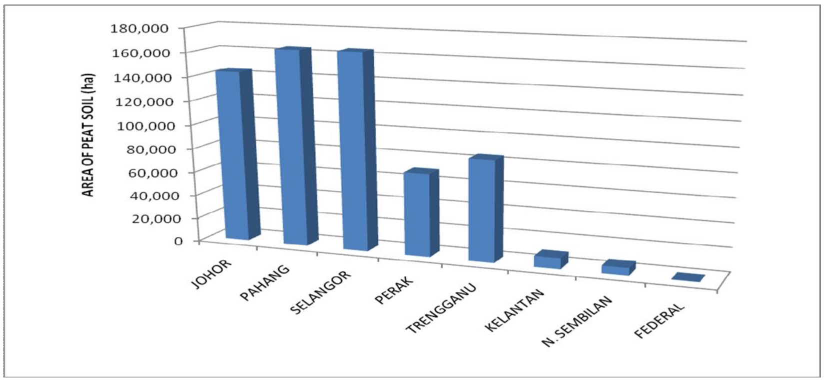

Figure 14: The area (ha) of peatlands in Peninsular Malaysia by State

3.2.2 Extent of relatively undisturbed peat swamp forest

Approximately one-third of peat soil areas in Peninsular Malaysia retain undisturbed or relatively undisturbed peat swamp forest (Table 6, Figure 15 and 16) Pahang State supports 129,579 ha of peat swamp forest with >70% canopy cover, which is 57% of the total area of good quality forest remaining in Peninsular Malaysia. Most of this area is contributed by South East Pahang, covering the Forest Reserves Pekan, Kedondong, Nenasi and Resak. When expressed as a percentage of the peat soil area in each state, Pahang has the greatest proportion of its peat areas under peat swamp forest with >70% canopy cover (78%), whilst Perak has the least (~7%) (Table 7). Selangor and Johor only have about 10% of their peat soil areas under peat swamp forest with >70% canopy cover (Figure 15).

Table 7: The area (ha) of peat swamp forest of more than 70% canopy cover in the different states of Peninsular Malaysia.

State / Division	Area of peat >65% organic soil at 50 cm depth (ha)	Relatively undisturbed PSF (CC>70%) (ha)	% Relatively undisturbed PSF from total peat soil area per state (ha)
Johor	143,974	16,304	11.3
Pahang	164,113	129,759	79.1
Selangor	164,708	16,231	9.9
Perak	69,597	4,574	6.6
Terengganu	84,693	51,759	61.1
Kelantan	9,146	5,626	61.5
Negeri Sembilan	6,245	1,729	27.7
Federal Territory	381	44	11.5
Total	**642,857**	**226,026**	**35.2**

PSF=peat swamp forest, CC=canopy cover.

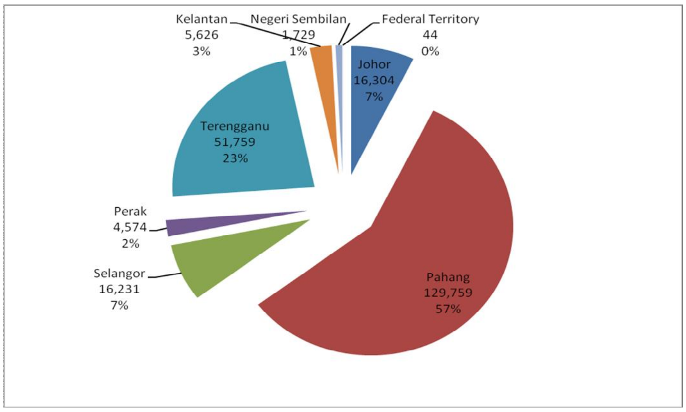

Figure 15: Area of peat swamp forest with >70% canopy cover by State, Peninsular Malaysia.

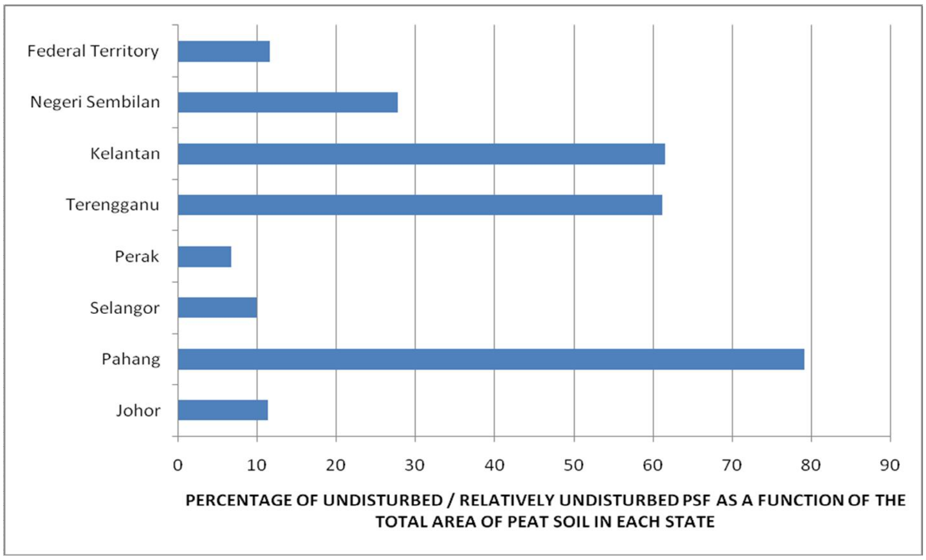

Figure 16: Percentage of peat swamp forest (PSF) with >70% canopy cover as a percentage of total peat soil area in each state.

3.2.3 Agriculture on peat areas

Johor has the greatest area of peat soil under agriculture (crops/husbandry) followed by Perak and Selangor (Table 4 and Table 6)

Despite having a large area of peat soil (164,113 ha), Pahang only has 20,869 ha under agriculture (Table 6 and Figure 17).

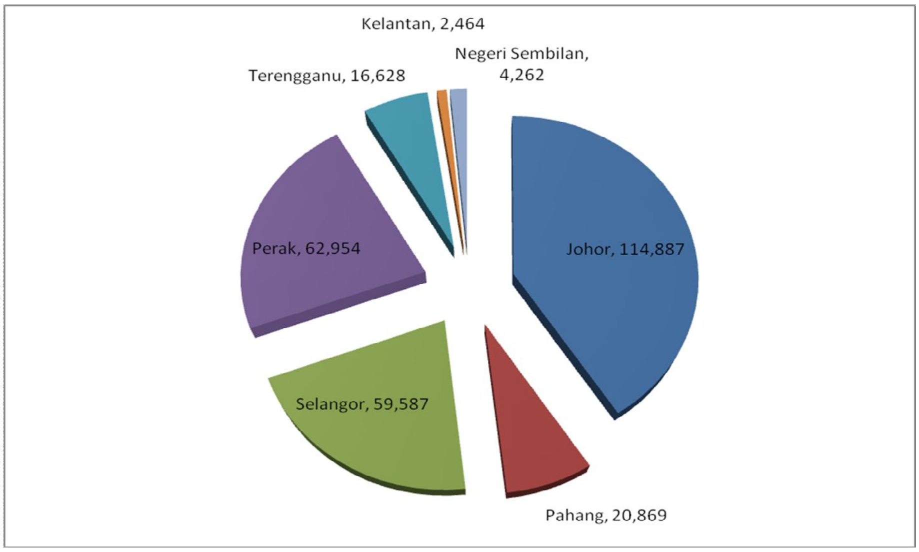

Figure 17: Total peat area (ha) in Peninsular Malaysia under agriculture by State

There are 281,652 ha of peat soils under cultivation in Peninsular Malaysia, of which 203,455 ha or 72% are under oil palm plantations (Table 7). Johor has the greatest extent of oil palm on peat soils (68,468 ha), followed by Perak (61,257 ha). One third of all oil palm plantations on peat in Peninsular Malaysia are found in Johor. By State, Perak has the highest proportion of its peatlands under oil palm (88%), compared to less than half in Johor (47.6%) (Table 8, Figure 18). The most complete data set for Peninsular Malaysia for figures on oil palm on peatlands is from 2002. According to DOA, in 2002 there was a total of 203,455 ha of oil palm plantations on peat in Peninsular Malaysia, which was 9.3% of total oil palm area (2,187,010 ha) (Table 8). This figure varies widely by state in Peninsular Malaysia: 33.7% of all oil palm is on peat soils in Selangor, with 19.6% of oil palm being on peat in Perak. In Kelantan, in contrast, only 0.3% of the total oil palm area is on peat. By comparison, available DOA figures for 2006 reveal there were 222,057 ha of oil palm on peat in Peninsular Malaysia out of total of 2,334,247 ha on all soil types (9.5%). Based on these figures, between 2002 and 2006 the area of oil palm on peat in Peninsular Malaysia increased from 203,455 ha to 222,057 ha (18,602 ha), from 9.3 to 9.5%.

Table 8: Extent of peatlands under oil palm plantation by State, Peninsular Malaysia.
*Source: DOA (2002).

State / Division	Area of peat >65% organic soil at 50 cm depth (ha)	Peat soil under agriculture (ha)	Peat soil under oil palm (ha)*	% peat soil area used for oil palm in each State (ha)	Total area of oil palm on all soils (ha)	% oil palm on peat soil compared to oil palm on all soil types (ha)
Johor	143,974	114,887	68,468	47.6	664,059	10.3
Kedah			No data		66,124	No data
Pahang	164,113	20,869	20,175	12.3	584,482	3.5
Penang					13,725	0
Selangor	164,708	59,587	46,456	28.2	137,770	34
Perak	69,597	62,954	61,257	88.0	313,080	20
Perlis					5	0
Malacca			No data		45,278	No data
Terengganu	84,693	16,628	6,925	8.2	156,198	4
Kelantan	9,146	2,464	174	1.9	75,784	0.3
Negeri Sembilan	6,245	4,262	No data	No data	130,505	No data
Total	**642,857**	**281,652**	**203,455**		**2,187,010**	

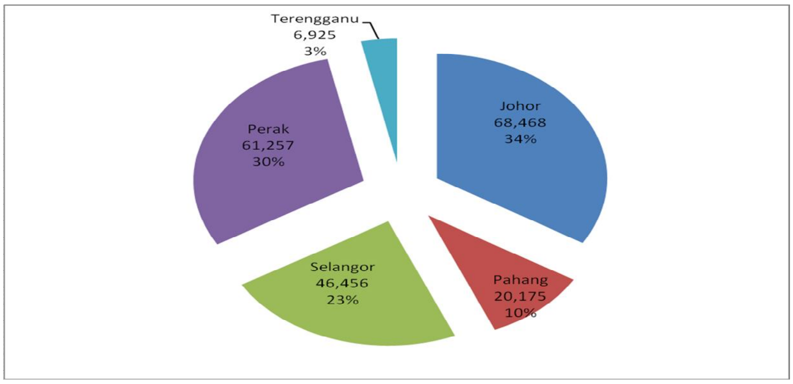

Figure 18: Extent (ha) and proportion (%) of oil palm on peatlands by State, Peninsular Malaysia.

3.2.4 Profile: State of Selangor

Selangor State encompasses 800,000 ha. The eastern part of the state is bordered by the Main Titiwangsa Range. The land gradually descends into low hills and floodplains to the west. The coastal regions are formed of marine alluvium. Peat formation in Selangor occurred in the river basins of Selangor River in the north and Langat River in the south. In the early 1950s, about 121,276 ha of total peat swamp forest area in Selangor were in pristine condition. Since then, large areas have been cleared for agriculture: in 1982, the area of undisturbed peat swamp forest was 94,400 ha and in 1986 it was 78,161 ha.

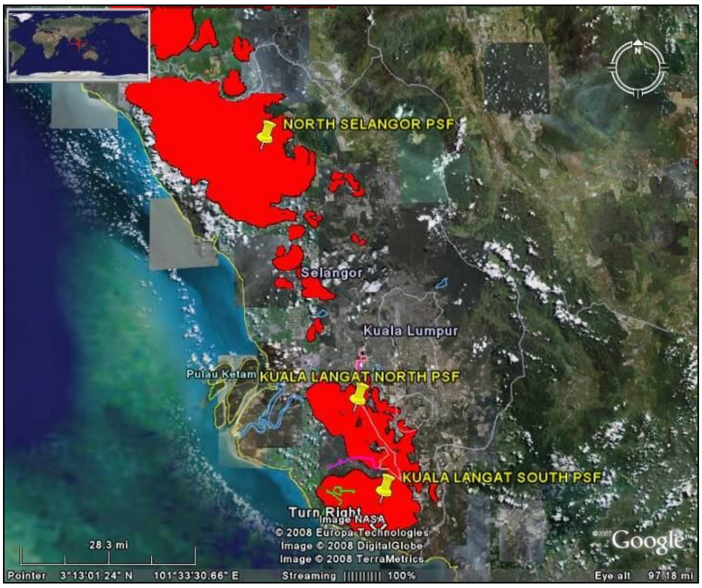

Figure 19: Major peatlands in Selangor.

Kuala Langat (KL) river basin catchment extended 2,350 km^2 covering a large area of South Selangor. Likewise in the north the Selangor River's extensive floodplains extended 1,960 km^2 (110 km long) (Abdul Jalil Hasan 2006), comprising numerous tributaries of Kerling, Kubu, Buloh, Rening, Batang Kali, and Sembah Rivers. With the conversion of extensive peatland areas in the last few decades, large areas have been left abandoned and degraded. Forest fires pose a major threat to these areas. Between 1995 and 2001, 750 ha of peatlands were destroyed by fire, including 500 ha in 1998. Some areas have suffered frequent fires and are dominated by herbaceous vegetation with little tree regeneration.

3.2.5 Profile: State of Johor

Johor has the largest area of coastal estuarine ecosystems in Peninsular Malaysia with varied wetlands types, such as coral reefs, sea grass beds, mangrove swamp forest, riparian fringes, and peat swamp forest. Peat soils in Johor have developed on marine soils, acid sulphate soils, and marine clays. The Johor west coast peat overlies acid sulphate soil and the east coast peat overlies sand and clay. During the site analysis, the Sedili Besar and Kecil basins were excised from the total peat extent for Peninsular Malaysia since the predominant soil type in Sedili is of alluvium covered with freshwater swamp forest (WI-MP 2005).

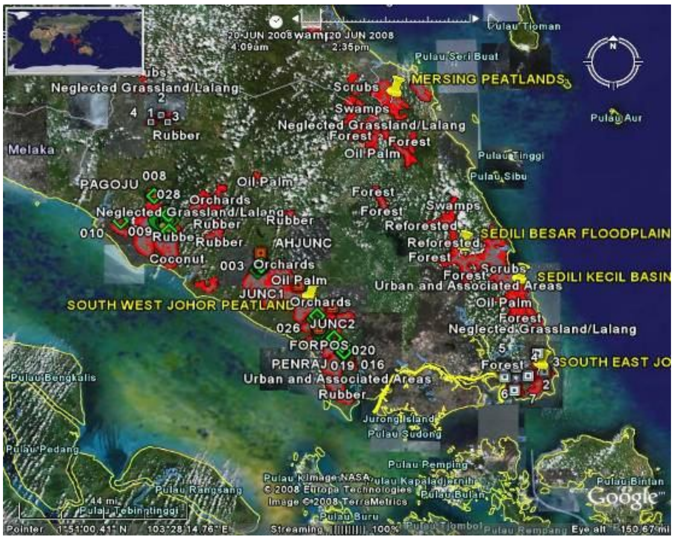

Figure 20: Peat Soil Areas in Johor State.

Conversion of peat swamp forest in Johor began in early 1974, when 95,000 ha of West Johor peatlands were converted for agricultural purposes (depth of converted peats is in Table 9). According to a GEC survey carried out in 1997 (23 years since the first phase of conversion), a subsidence rate of 1.2 m was recorded in the district of Pontian.

Table 9: Peat soil depths of converted peatlands in West Johor.

Peat depth (m)	Phase 1	Phase 2	Total	%
Shallow peat < 1.5	3,520	12,181	15,701	17
Moderately deep peat 1.5 to 3.0	14,184	5,863	20,047	21
Deep peat > 3.0	45,127	13,681	58,808	62
Total	**62,831**	**31,725**	**94,556**	

Oil palm plantations comprise a large proportion of the total area of peatlands in Johor utilised for agriculture (Table 10).

Table 10: Area of oil palm plantations on peatlands in Johor.

Region	Peat soil total area (ha)	Total area of crops / husbandry (ha)	Area of oil palm (ha)
South-West Johor	75,236	70,627	53,240
West Johor	53,764	41,705	13,100
East Johor (Mersing)	9,171	972	941
South-East Johor	5,803	1,583	1,187
Total	**143,974**	**114,887**	**68,468**

Along the west coast of Johor, the presence of acid sulphate subsoils may pose a serious problem to cultivated areas of peatland. With the loss of peat soil, the acid sulphate subsoils may eventually surface, unless the mineral soil lies below maximum drainage depth, in which case a lake would form. Crop yields on acid sulphate soils are generally low. In addition the environment will deteriorate to a level that local communities may have to abandon the area (Van den Eelaart 2003). Acid sulphate soils release large quantities of acidic water to adjoining canals, especially during the rainy seasons (Van den Eelaart 2003), which cannot be used for domestic purposes, will cause severe corrosion of metal structures, and mortality of fish. Only few species of fish may survive under these conditions.

3.2.6 Profile: State of Pahang

Pahang has a total of 197,768 ha of peatlands, comprising Pahang River North Peatland, and the Pekan, Nenasi, Kedondong, and Resak Forest Reserves, including several small peatland areas west of Pahang (Figure 21). Pekan Forest Reserve is the largest block with an area of 59,097 ha. Nenasi Forest Reserve has an area of 20,546 ha, between Bebar and Merchong Rivers. Resak and Kedondong Forest Reserves are smaller blocks of 9,681 ha and 1,818 ha respectively. Except for 14,949 ha in Pekan Forest Reserve (formerly logged state forest; recently reinstated as a Permanent Forest Reserve) and part of Nenasi Forest Reserve (clear-felled, apparently for oil palm development) the reserves are in good condition. A 200 ha block near the eastern margin of Pekan Forest Reserve is gazetted as Virgin Jungle Reserve (VJR).

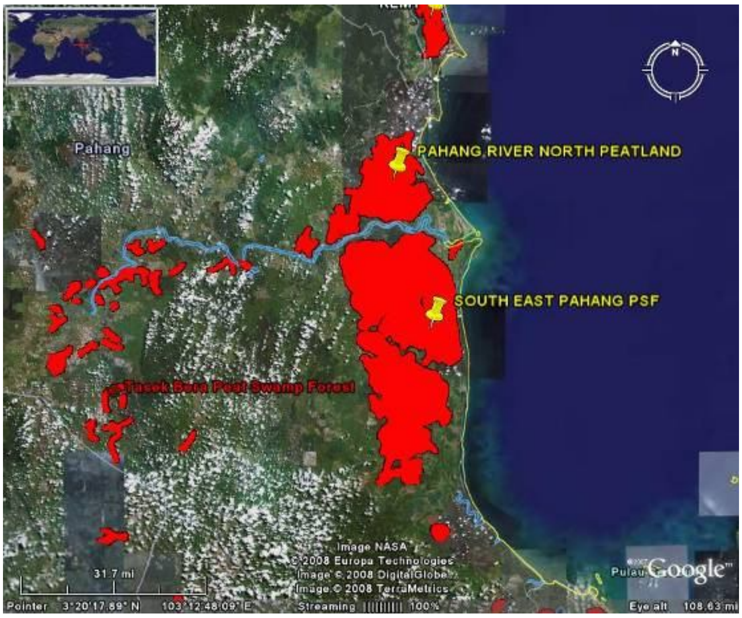

Figure 21: Peatlands in Pahang.

3.2.7 Profile: State of Terengganu

The coastal areas of Terengganu comprise a series of raised beaches interspersed with swales. Forest types include mangrove, *Melaleuca*, peat swamp, and freshwater swamp forests, along the banks of Caluk, Bari and Setiu Rivers (Figure 22).

Figure 22These forests were once important habitats for large fauna (e.g. Tiger) and many bird and reptile species; most have been severely degraded by logging and remnant forests are highly fragmented and rapidly being developed.

Figure 22: Major peatlands in Terengganu.

In the Merang peatland (Figure 23), extensive clearance of high quality peat swamp forest has occurred since 2007 followed by planting of oil palm. In April 2008, during the site visit, logging was observed west of the area cleared for oil palm, and logs were being floated out by drainage canals (Figure 24).

Figure 23: Merang peatland, Terengganu. Peat soil area is enclosed by the red line. The area cleared for oil palm can be clearly seen in the north.

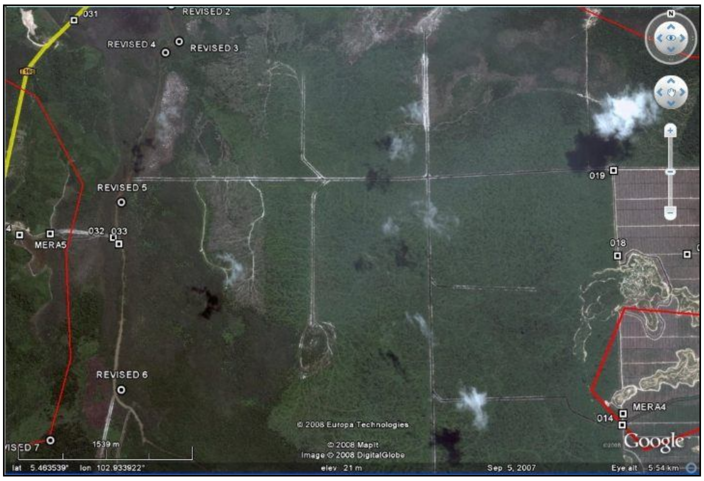

Figure 24: North-west area of Merang peatland, showing the eastern side of the new oil palm plantation and the logging of peat swamp forest to the west.

3.2.8 Profile: State of Perak

Perak originally had an area of 70,418 ha of peat swamp forest, located mainly along the coastal areas of the state (Figure 25). These peat swamp forests contributed to flood mitigation and helped regulate storm damage. Scientific and student-based research has been conducted for many years at Beriah peat swamp forest, located at the northern border of the State. This peat swamp forest supplies water for the nearby Keriah rice fields. The world's 'second smallest fish', the 'Perak fish', was discovered at Beriah.

Figure 25: Major peatlands in Perak.

3.2.9 Profile: State of Kelantan

Peat swamp forest in Kelantan covers approximately 9,146 ha (Table 6, Figure 26). Clearing and conversion of peat swamp forests began in the 1970s when paddy was extensively grown as the main food crop. Several incidences of forest fire occurred between 1998 and 2000 which destroyed ~605 ha of peatlands. *Melaleuca* trees (known locally as *Gelam*) grow extensively in these burnt and degraded areas. The state currently supports ~5,626 ha (61%) of relatively undisturbed HCV peat swamp forests. Remnant peatlands in Kelantan comprise three principle blocks: Berangan peatland (1,392 ha), Pasir Puteh peatland (6,433 ha), and Pasir Mas peatland (1,311 ha). Little published information is available on the biodiversity of Kelantan's peat swamp forests.

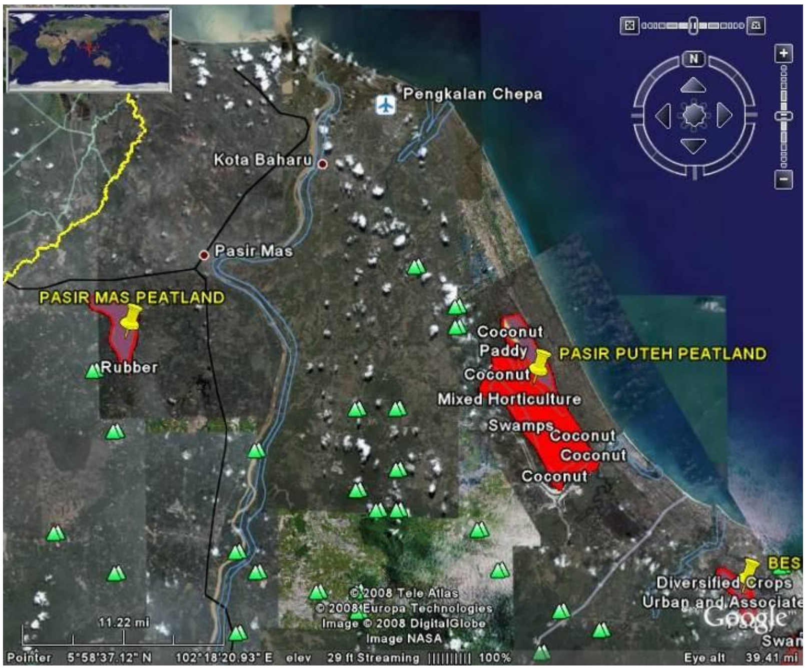

Figure 26: Major peatlands in Kelantan.

3.2.10 Profile: State of Negeri Sembilan

There are five small blocks of peatland areas around the coastal region of Negeri Sembilan and a sixth block further inland close to the north-east Johor State boundary (Figure 27). These cover a total area of 6,245 ha. Sixty-eight percent (68%) of peatlands support agriculture, including oil palm, rubber, mixed horticulture and diversified crops. About 1,729 ha comprise HCV peat swamp forests.

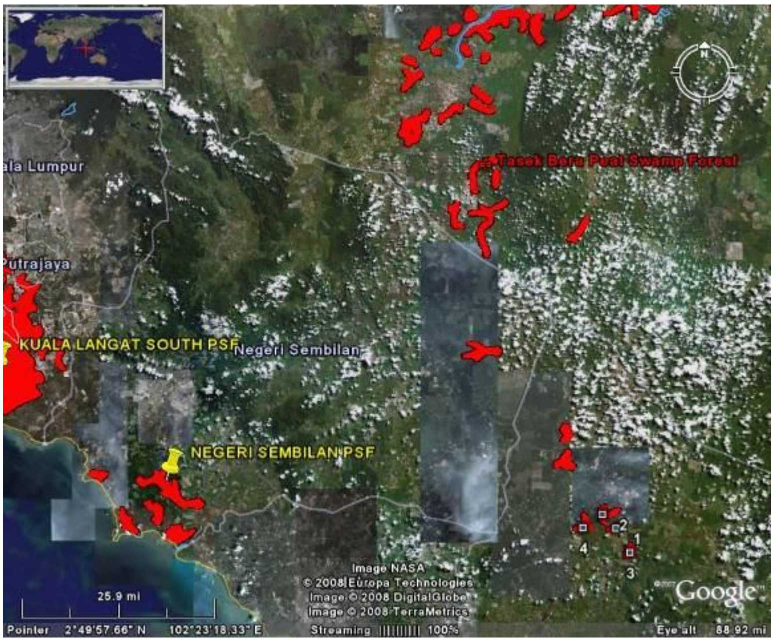

Figure 27: Major peatland areas in Negeri Sembilan.

3.2.11 Profile: Federal Territory

Approximately 380 ha of the Kuala Langat North Peatlands is located within the Federal Territory (Putrajaya) (Figure 28), including ~44 ha of relatively undisturbed HCV peat swamp forest. The remaining portion of this peatland within the Federal Territory includes ~21% severely degraded peatland and ~24% under infrastructure, within the new townships of Cyberjaya and Putrajaya.

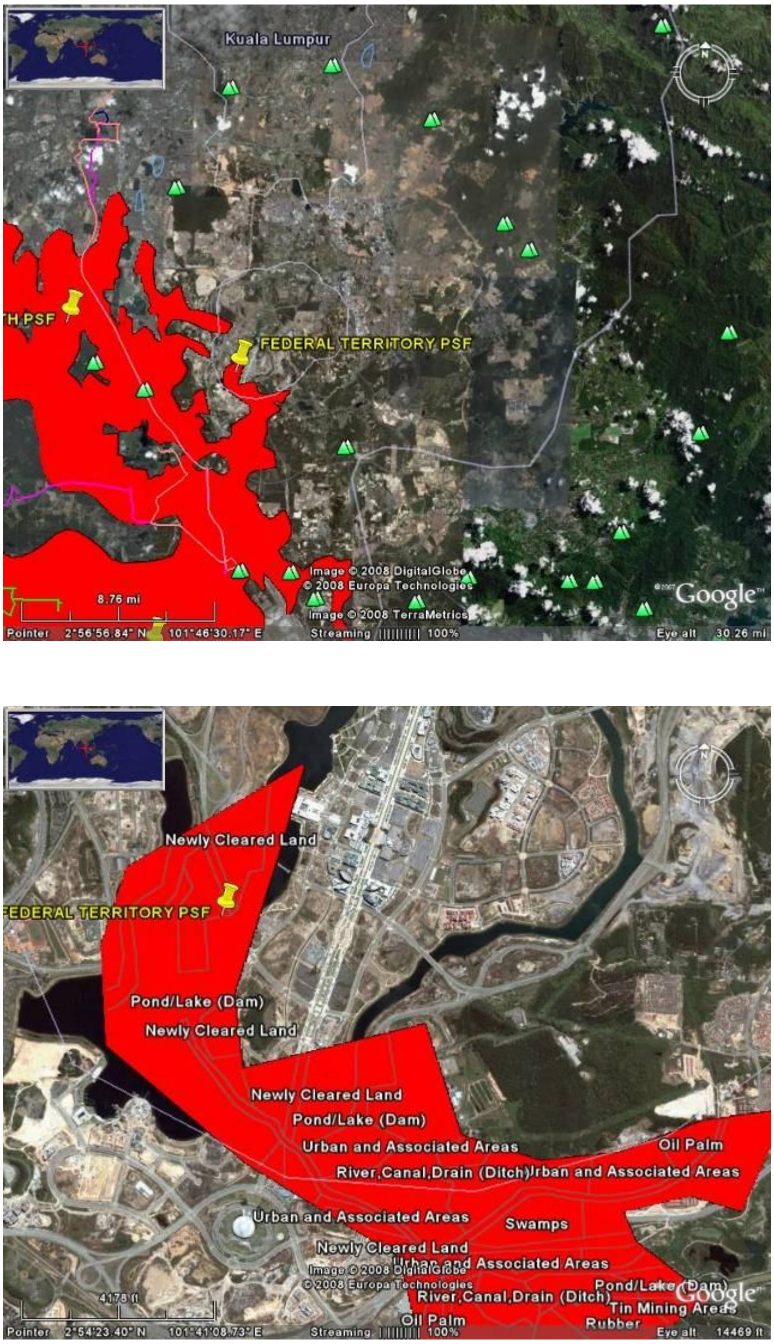

Figure 28: Peatlands in the Federal Territory

3.3 Sabah

3.3.1 Overview

Sabah has a land area of 7,361,900 ha with a coastline of 1,440 km. Most of its low-lying coastal regions have well established human settlements. Inland regions are largely mountainous, with lower human densities. Sabah supports high biodiversity values, including 167 mammal species (from a total of 197 species for Borneo) and 526 bird species (of which 395 species are residents, 35 are endemic to Borneo, and four are endemic to Sabah). In the last 30 years, Sabah's forest resources have been depleted due to unsustainable forest management practices, particularly timber logging. Subsequent large scale conversions of the forests to other land uses, such as oil palm plantations, have resulted in the loss of extensive areas of natural forest. Large areas of natural forest were destroyed by severe fires in 1981-1982 and were subsequently converted for agricultural purposes. These fires destroyed more than one million hectares of forest in Sabah; subsequent fires in 1992, 1998, and 2005, collectively consumed 16,375 ha of forest, including 12,000 ha of protected peat swamp forest in Binsuluk Forest Reserve. Approximately 75% of this reserve was destroyed by fires in 1998 and it seems that now due to subsequent fire events, particularly in 2005, there may be less than 1,000 ha left (Figure 29, Figure 30).

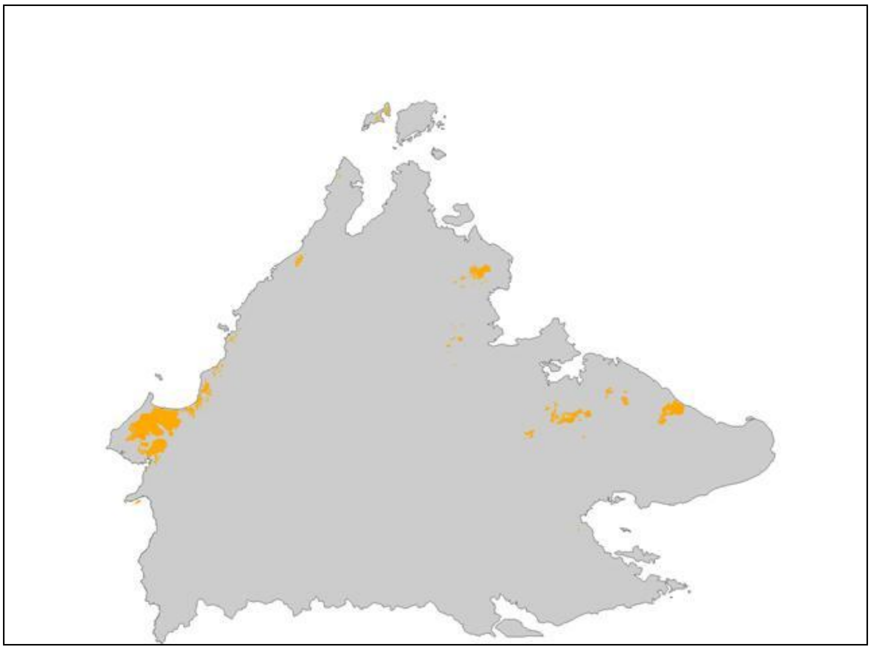

Figure 29: Distribution of peat soil areas of Sabah.

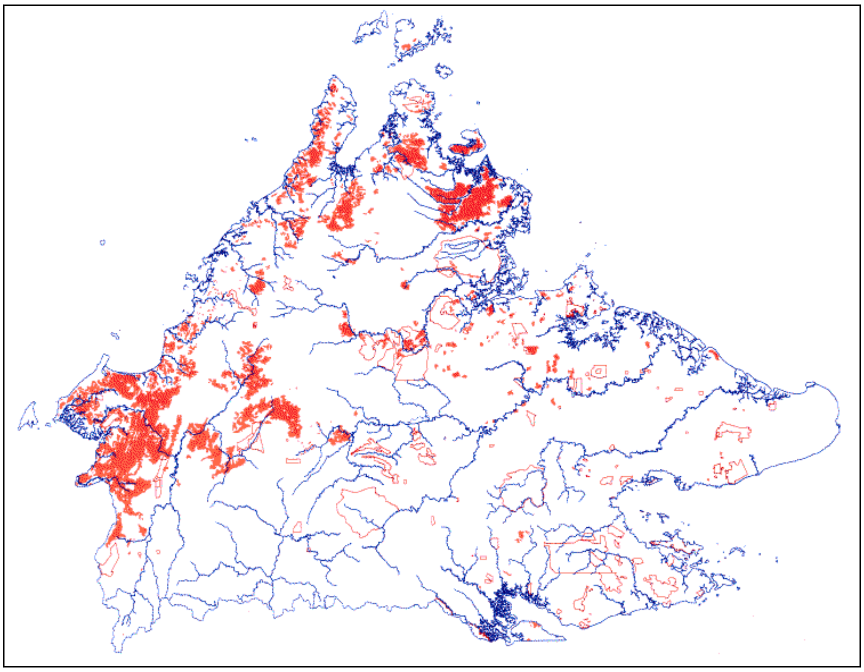

Figure 30: Areas affected by fires in Sabah in the year 1998 (shown in red).

According to DOA Sabah (unpublished data) there are 116,965 ha of peat soils in Sabah. These soils are under the 'Klias association' in the DOA classification. Available data is generally limited but is sufficient to estimate the location and extent of remaining HCV peat swamp forests: there are two remaining sites which support the largest areas of peat soil in Sabah, on the Klias Peninsula and, in the Kinabatangan–Segama Valleys.

The Klias Peninsula historically supported 60,500 ha of peat swamp forest (Fox 1972, quoted in UNDP/GEF 2007); in 2003, ~5,500 ha remained (Phua et al. 2008), comprising 3,630 ha in Klias Forest Reserve, 1,870 ha in Binsuluk Forest Reserve, and the remainder under degraded grassland after logging or conversion to agriculture (mainly rice). There are two large areas of intact peat soils in the Kinabatangan Valley: the largest is in the recently designated 'Lower Kinabatangan-Segama Wetlands' Ramsar Site, which includes 17,155 ha of intact peatland forest from a total of 78,803 ha of coastal wetland ecosystems (Ramsar 2008). The other area is in the Kinabatangan Valley between Batu Puteh and Bilit immediately north of the river. This covers 5,000 ha, but has been logged, with most timber trees removed. Much of the area is regenerating but has been badly affected by fire in the west close to Batu Puteh.

There is little information on other areas of peat soil, thus a preliminary estimate of the total intact area of peat swamp forest in Sabah is probably in the region of **22,655 ha, 19.4 % of the original area.** Of the 116,965 ha of peat soil, by 2008 ~10,000 ha (8.5%) had been converted to oil palm (TPRI 2009). This gives a total of intact forest and oil palm plantations of 27.9 %. The reminder comprises mainly disturbed areas and areas converted to agriculture other than oil palm. For oil palm on peat soils, available data is limited but indicates that: (1) most oil palm plantations are in a broad band in Sandakan and Tawau Divisons, on mineral soil in gently undulating country; (2) oil palm on peat (~10,000 ha) represents only 0.8% of the total area of oil palm development (1,278,244 ha) on all soil types in Sabah (MPOB 2009); (3) there has been no major conversion of large areas of peat soils in the Klias Peninsula, although some conversion has occurred around Bukau River east of the Klias Forest Reserve. Rapid assessments of all major areas of peat soils in Sabah are required to assess and update these figures.

Summary information for the largest peatland areas in Sabah is given below.

3.3.2 Profile: Klias Peninsula

The Klias peninsula historically included 60,500 ha of peat swamp forest, 14,500 ha of freshwater swamp forest, 8,700 ha of mangrove swamp, and 28,000 ha of transitional coastal swamp. There are five forest reserves located in this wetland region, of which the largest are Padas Damit freshwater swamp (9,027 ha) (an important waterbird area) and Binsuluk Forest Reserve (12,106 ha) (originally peat swamp forest but much was lost in fires in 1998 and 2005, with ≤1,000 ha intact forest remaining). In 1978 a total of 30,900 ha of Klias was gazetted as a Forest Reserve but in 1980 it was degazetted. Today the Klias Forest Reserve consists of only 3,630 ha peat swamp forest.

3.3.3 Profile: Kinabatangan Wildlife Sanctuary

There is an extensive area of peat (Klias Series) of ~14,000 ha on the north bank of the Kinabatangan River between Batu Puteh and Bilit, including parts of Pin Supu Forest Reserve, which covers 4,696 ha. Most of the peat swamp forest appears to have been logged in the 1960s but was not drained. The forest is regenerating, but with open areas of grasses, sedges and ferns. Forest canopy cover is 30-70%. *Alstonia* spp. are the only large remaining trees, indicating at least part of this site historically supported mixed peat swamp forest on shallow peats. This site lies within Kinabatangan Wildlife Sanctuary, which was gazetted on 16 November 1999 and supports 27,000 ha of floodplain forests under the jurisdiction of the Sabah Wildlife Department.

The Kinabatangan Wildlife Sanctuary consists of 10 separate blocks, many of which are separated by oil palm plantations and other cleared areas. The ‘Corridor for Life’ has been proposed to join these blocks along the Kinabatangan River. Figure 31 shows that the peat area is an important part of this corridor, connecting the Pin Supu and Gemantong Forest Reserves. The lower Kinabatangan peat swamp forests are of global importance for biodiversity and support populations of threatened fauna, including Storm’s Stork *Ciconia stormi*, Estuarine Crocodile *Crocodylus porosus*, and Proboscis Monkey *Nasalis larvatus*. Some of these forests have been entirely converted to oil palm plantations, forcing some fauna to migrate through plantations.

3.3.4 Profile: Lower Kinabatangan-Segama Ramsar Wetlands

Figure 31: Location of the new Ramsar site, Lower Kinabatangan-Segama Wetlands (from Ramsar 2008)

The Lower Kinabatangan-Segama Wetlands is the largest Ramsar site in Malaysia (78,803 ha) and was gazetted in October 2008. It encompasses the lower floodplains of the Segama and Kinabatangan Rivers and comprises three reserves: Kulamba Wildlife Reserve, Trusan Kinabatangan Forest Reserve, and Kula Maruap/Kuala Segama Forest Reserve, of mangrove and peat swamp forest. The peat swamp component covers 17,155 ha.

3.4 Sarawak

3.4.1 Overview

Sarawak has a total land area of 12,398,500 ha and encompasses most of the western portion of Borneo. No recent information on peatlands of Sarawak could be obtained for the current study (despite various requests for data from various agencies), hence access to primary sources of information was limited:

Estimates of the area of peatland in Sarawak in the literature vary substantially. Table 11 below gives the most common estimates in total and by division.

Table 11: Estimates of the peatland area in Sarawak

DIVISION	PEATLAND AREA (ha) Melling et al (1999)	PEATLAND AREA (ha) Mutalib et al (1991)	PEAT SWAMP AREA (ha) Wong (2003)	PEAT SOIL AREA (ha) Tie (pers. comm.): reference: Maas et al (1986)
SIBU / MUKAH	502,466	540, 800	386,402	600,387
SRI AMAN / BETONG	340,374	283, 076	237,536	340,374
MIRI	314,585	276, 579	240,233	295,995
SAMARAHAN	205,479	192, 775	168,170	165,581
SARIKEI	172,353	169, 900	158,194	74,414
BINTULU	168,733	146,121	78,016	157,422
LIMBANG	34,730	25, 300	17,183	34,730
KUCHING	26,827	23, 059	3,380	26,827
KAPIT	0	0	0	2,097
TOTAL	**1,765,457**	**1,657, 600**	**1,289,114**	**1,697,847**

Some of the differences may arise from changes in the boundaries of Divisions and creation of new divisions. For example, Sri Aman Division has been split into Sri Aman and Betong Divisions; and Sibu into Sibu and the new Mukah Division. In addition, one district in Sarikei Division has been re-allocated to the new Mukah Division (Tie pers. comm.). This would create differences between the estimates of areas for divisions before and after the boundary changes.

The estimate produced from the Agriculture Capability Maps of 1986 is adopted here (Tie pers. comm.), with a total of 1,967,847 ha of peat soil in Sarawak.

By far the lowest estimate is that of Wong (2003) at 1,289,114 ha, with the highest being that contained in Melling et al (1999) at 1,756,457 ha. This is a difference of almost half a million hectares (476,343 ha). The only primary literature source that could be obtained to examine the methodology used in deriving these estimates was that of Wong (2003).

It is unclear from the methodology and discussion contained in Wong (2203) as to why her estimate is much lower than the others. This study was primarily focused on assessing the quality (in terms of canopy cover) of peat swamp forest. It is possible, then, that Wong did not include peat soil areas which had been cleared and converted to other uses a long time in the past. Hence, only the data on the area and status of remaining peat swamp forest is used from Wong (2003).

Estimates of peat soils used for agriculture are taken from Melling et al (1999).

Thus a combination of three major sources is used to compile the information here for Sarawak. This is somewhat unsatisfactory – what is badly needed is an integrated study on the area and land cover / land use of peat soil areas in Sarawak so that these differences can be reconciled.

Tie (pers comm.) gives a breakdown of peat soils in Sarawak according to District and Division; and in relation to depth (shallow (50 – 150 cm) and deep peat (> 150 cm) (Table 12)

Table 12: The area (ha) of peat soils in Sarawak by Division, divided into shallow and deep peat (Tie pers. comm..)

District/Division	Shallow Peat	Deep Peat	Total
Kuching	2,564	7,128	9,692
Bau	0	0	0
Lundu	1,126	16,009	17,135
KUCHING	**3,690**	**23,137**	**26,827**
Serian	1,001	37,018	38,019
Simunjan	5,129	96,607	101,736
Samarahan	2,565	23,261	25,826
SAMARAHAN	**8,695**	**156,886**	**165,581**
Sri Aman	1,314	203,659	204,973
Lubok Antu	0	5,066	5,066
SRI AMAN	**1,314**	**208,725**	**210,039**
Betong	8,192	75,895	84,087
Saratok	6,128	40,120	46,248
BETONG	**14,320**	**116,015**	**130,335**
Sibu	0	217,561	217,561
Kanowit	0	3,877	3,877
SIBU	**0**	**221,438**	**221,438**
Mukah	5,941	197,677	203,618
Dalat	0	77,410	77,410
Matu/Daro	9,818	88,103	97,921
MUKAH	**15,759**	**363,190**	**378,949**
Miri	5,294	114,466	119,760
Baram	819	175,416	176,235
MIRI	**6,113**	**289,882**	**295,995**
Bintulu	33,240	124,202	157,442
BINTULU	**33,240**	**124,202**	**157,442**
Limbang	8,951	5,798	14,749
Lawas	2,332	17,649	19,981
LIMBANG	**11,283**	**23,447**	**34,730**
Sarikei	4,440	21,261	25,701
Julau	0	0	0
Meradong	1,564	47,149	48,713

District/Division	Shallow Peat	Deep Peat	Total
SARIKEI	**6,004**	**68,410**	**74,414**
Kapit	0	0	0
Song	0	0	0
Belaga	0	2,097	2,097
KAPIT	**0**	**2,097**	**2,097**
SARAWAK TOTAL	**100,418**	**1,597,429**	**1,697,847**

Wong (2003), used remote sensing analysis for assessing the status of the remaining peat swamp forest, She used three classes of canopy cover to assess the intensity of logging; more than 70% canopy cover to denote low intensity logging; 40 – 70% to denote medium intensity logging and less than 40% high intensity logging. Areas with a canopy cover of less than 10% were considered as non-forest. Table 13 gives the areas of each class for each division. The relatively undisturbed category includes both low intensity logging and natural, undisturbed areas of forest.

Table 13: Status of peat swamp forest (PSF) by Division in Sarawak.

Division	Relatively undisturbed PSF (ha) cc >70%	Moderately disturbed PSF (ha) cc 40-70%	Severely disturbed PSF (ha) cc < 40%	TOTAL
Limbang	701	1,256	5,436	7,393
Miri	63,279	60,930	100,158	224,367
Bintulu	18,756	26,712	25,540	71,008
Sri Aman	29,522	126,910	66,613	223,045
Sarikei	33,671	45,607	58,043	137,323
Sibu	44,567	162,825	115,396	322,788
Samarahan	32,781	63,206	54,759	150,746
Kuching	0	913	981	1,894
Total	**223,277 (19.6%)**	**488,359 (42.9%)**	**426,926 (37.5%)**	**1,138,562**

Data are from Wong (2003). See Methods for definitions of intactness and land use. Cc: canopy cover. The "Severely disturbed area" category includes her "cleared" and "burnt" classes.

Melling et al (1999), who give a higher total peatland estimate than that of Maas et al (1986), give the area developed for agriculture by division (Table 14). No information is available as to the specific date of the survey to collect this information.

Table 14: The total area (ha) of peat soil in Sarawak and the area developed for agriculture according to the estimates of Melling et al (1999)

Division	Total Peatland Area As Estimated By Melling Et Al (1999)	Area Developed For Agriculture (Ha)	% Of Peatland Area Developed For Agriculture
SIBU	502,466	269,571	54
SRI AMAN	340,374	50,836	15
MIRI	314,585	66,114	21
SAMARAHAN	205, 479	50,836	25

SARIKEI	172,353	61,112	35
BINTULU	168,733	47,591	28
LIMBANG	34,730	8,715	25
KUCHING	26,827	nd	
TOTAL	**1,765,547**	**554,775**	**31**

Ambak & Melling (1999) also give the areas of different crops cultivated on peatland converted to agriculture (Table 15). Note that the total for peatland used for agriculture is 423,070 ha, lower than the total of 554,775 ha given above. It is not known to what year these figures refer to.

Table 15: The area (ha) of peat soil in Sarawak used for different crops (Ambak & Melling 1999)

CROP	AREA OF PEATLAND USED (ha)	%
OIL PALM	330,669	78.2
SAGO	64,229	15.2
RUBBER	23,000	5.4
PADI	2,000	0.5
PINEAPPLE	1,895	0.5
MIXED HORTICULTURE	908	0.1
MISCELLANEOUS	369	0.1
TOTAL	**423,070**	

The following key points have been derived from the information provided by Tie, Melling et al (1999) and Wong (2003):

1. Peatlands cover 1,697.847 ha (13.7%) of Sarawak, principally near the coast (Figure 32). Sarawak historically supported the largest area of peat swamp forest in Malaysia, but has lost ~98.5% of primary forest (all types), mainly due to logging.

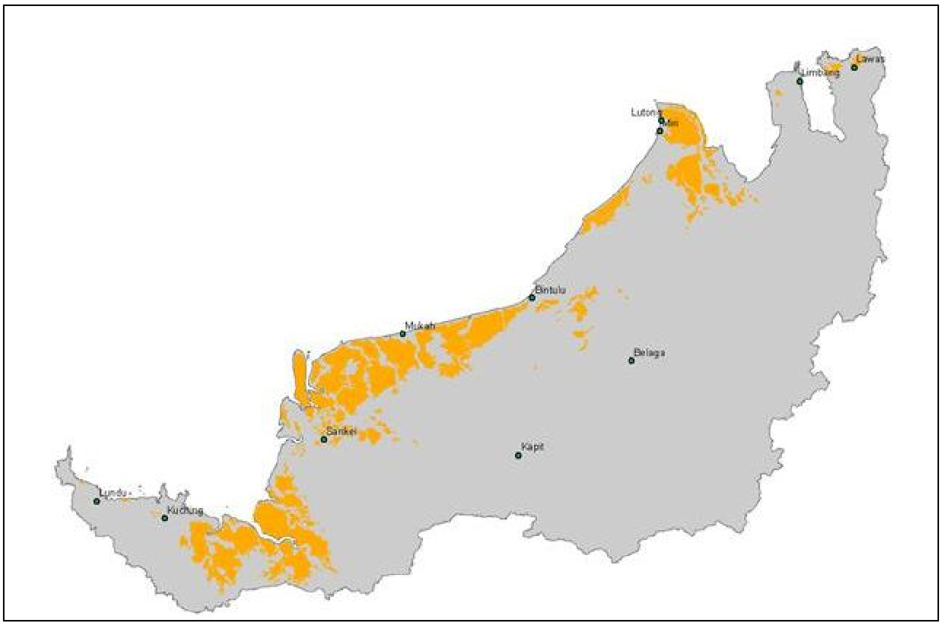

Figure 32: Major peatland areas in Sarawak.

2. According to the data of Wong (2003), the remaining peat swamp forest area amounted to 1,054,844 ha as of 2000 (excluding cleared and burnt areas). Less than 20% of this total is classified as undisturbed / relatively undisturbed peat swamp forest. Moreover, only 18, 920 ha out of the total of 223,277 ha for undisturbed / relatively undisturbed forest was considered to be untouched, at just 1.7%. These last remaining areas of untouched forest are confined to Miri and Limbang Divisions. Moderately and severely disturbed peat swamp forest, subject to logging, comprised 80.4% of the remaining forest in the year 2000.

3. It is likely that the original area of peat swamp forest was very similar to the estimated peat soils area, at around 1.6 million hectares. This figure has seen a steady decline in the last few decades. Anderson (1964) gave a figure of 1,465,940 ha for the early 1960s, a decrease of over 300,000 ha in about 40 years. Wong (2003) gives a total reaming of 1,126,834 ha for 1995 / 1996 as analysed from satellite imagery, a reduction of almost 72,000 ha from 1995/6 to 2000.

4. The figures of Melling et al (1999) show that 31% of peatland had been converted for agricultural purposes (554,775 ha) by the late 1990s. They estimated that 330,669 ha (78.2%) had already been converted to oil palm prior to 1999.

5. TPRI (2009) estimates that the area of oil palm on peat in Sarawak has risen rapidly in contrast to Peninsular Malaysia and Sabah, from ~100,000 ha in 2003 to 300,000 ha in 2008. (Note that, according to the figure of Melling et al (1999), 330, 669 ha had already been converted to oil palm prior to 1999). Wan Sulaiman et al. (undated) give figures for the ‘Sarawak Cumulative Agriculture Target’, which is one million hectares for oil palm development in 2010. Much of this will probably be developed on peatlands.

6. Peat swamp forests in Sarawak are under conversion for a wide range of agricultural uses (Table 15). As of 2003, 804,247 ha of peatlands were proposed for agricultural development. All proposed developments include oil palm has a component, together with sago, rice, rubber, pineapple, cocoa, orchards, pepper and citrus fruits. Oil palm is expected to be the major crop in most of these areas (Table 16).

Table 16: Development projects proposed / implemented in peatlands in Sarawak by 2000.

No.	**Agricultural project**	**Project area (ha)**	**Area under peat soils (ha)**	**Major crops proposed in project area**
1	Samarahan River Basins Study	86,170	8,160 (SP) 6,548 (DP)	Rubber, coconut, cocoa, oil palm, pepper, citrus, horticulture, padi
2	Kalaka-Saribas Area	164,750	87, 570 (DNR)	Oil palm, coconut, sago, pineapple, padi, field crops, cocoa
3	Kabong-Nyabor Oil Palm Area	2,000	2,000 (SP)	Oil palm
4	Baram IADP	746,300	(NA)	Oil palm, pepper, cocoa, rubber
5	Sebangan-Bajong Agricultural Feasibility Study	26,000	5,043 (SP) 13,093 (DP)	Oil palm, pineapple, padi
6	Daro-Kanowit Oil Palm Feasibility Study	82,730	4,636 (SP) 10,920 (DP)	Oil palm
7	Kalaka-Saribas Phase II	153,000	17,041 (SP) 101,556 (DP)	Oil palm

8	Lower Rajang Mukah IADP	893,150	42,150 (SP)	Oil palm, sago, pineapple, orchard, rubber, padi, coconut, cocoa, grazing ground
9	Daro-Mukah Coastal Zone Development Project	738,000	505,530 (DNR)	Oil palm, sago, coconut, cocoa, rubber, orchards, padi, field crops
TOTAL		**2,892,100**	**804,247 [SP = 79,030; DP = 132,117; DNR = 593,100]**	

Sources: Sogreah Consulting Engineers, EEC and Building Consultants (1985); Shawal (2003).
SP=Shallow peat, DP=Deep peat, NA=Not available. DNR=Depth not reported.

The projected rapid expansion of oil palm on peat in Sarawak compared to Sabah and Peninsular Malaysia is largely due to the availability of suitable lands for oil palm. 'Hilly-flat' lands are considered most suitable for oil palm development (Abu Bakar 2007), but Sarawak's land area only comprises 15-20% of this category. The principle land remaining which is available for oil palm is peatland (12% of Sarawak's lands; Abu Bakar 2007). In contrast, Peninsular Malaysia and Sabah's land areas comprise a much larger proportion of 'hilly-flat' lands (25-30% and 30-35% respectively; Abu Bakar 2007). It is notable that the sustainability of growing oil palm on peatlands has not been demonstrated, but negative impacts include CO_2 emissions/related climate change impacts, enhanced flooding, saltwater intrusion in coastal areas, and a reduction in drainable land. See Section 3.5 for a case study of oil palm on peatland in Sarawak.

Information used here is from three sources:

- Tie (pers. comm.) for the total area of peat soil per division,
- Wong (2003) for the area and status of peat swamp forest; and
- Melling et al (1999) for areas of peatland converted to agriculture.

3.4.2 Profile: Limbang Division

Limbang Division lies in the northern-most region of Sarawak and has a total area of 34,730 ha of peat soil (Figure 33). The peat swamp forest area comprises: 'severely disturbed' 5,435.95 ha, 'moderately degraded' 1,255.76 ha, and 'undisturbed/relatively undisturbed' 701.48 ha. The severely disturbed area comprises her classes of "low density forest", "cleared" and "burnt". Total area under crop cultivation according to the figures of Melling et al (1999) is 8,715 ha (57%).

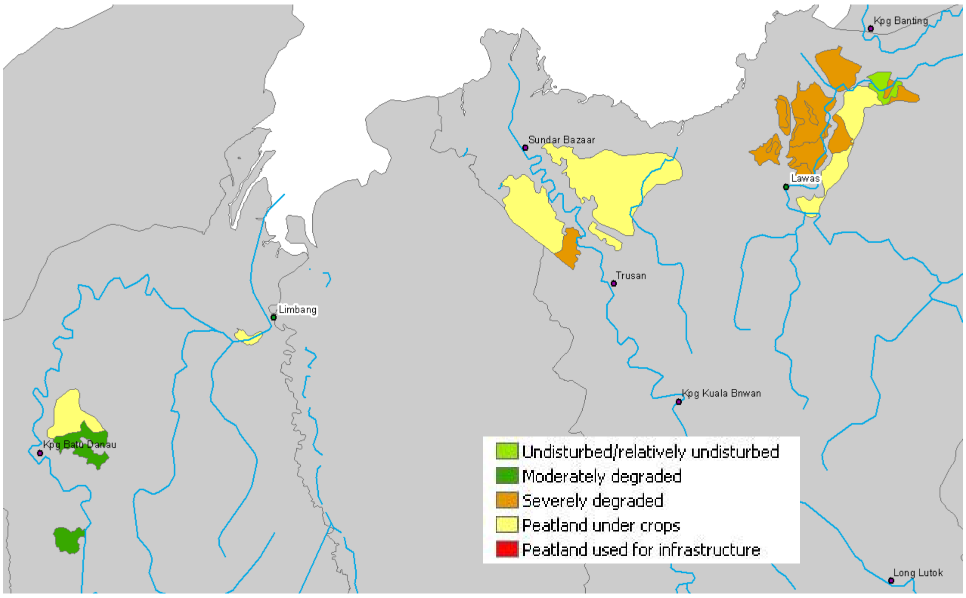

Figure 33: Distribution and status of peat swamp forest in Limbang Division. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.3 Profile: Miri Division

Miri Division has a peatland area of 295,995 ha. The remaining area of peat swamp forest is divided into: 'severely disturbed' 100,157.7 ha, 'moderately degraded' 60,929.8 ha, and 'undisturbed/relatively undisturbed' 63,279.4 ha (Figure 34). Total area under crop cultivation is 66,114 ha.

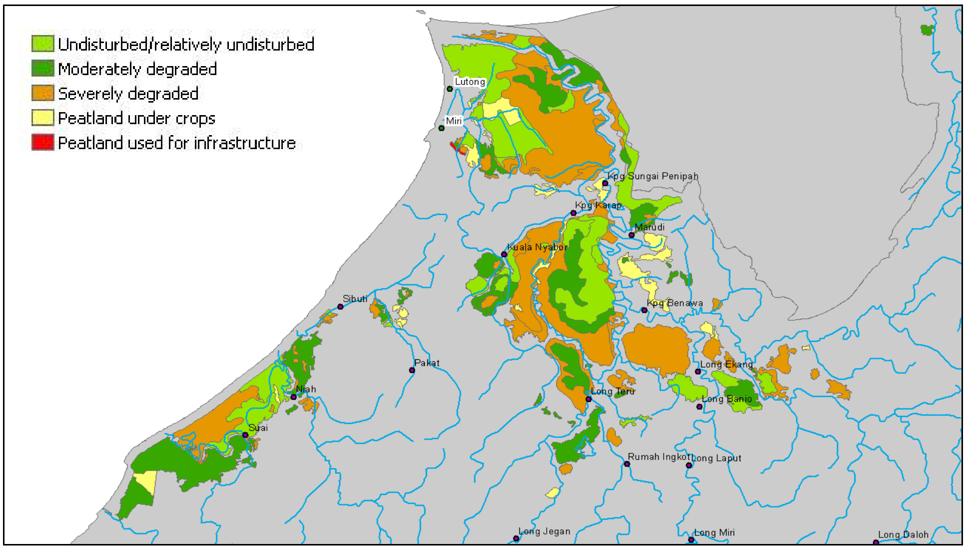

Figure 34: Distribution and status of peat swamp forest in Miri Division. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.4 Profile: Bintulu Division

Bintulu Division has a total peatland area of 157,442 ha. The remaining area of peat swamp forest is divided into: c ‘severely disturbed’ 25,540.48 ha, ‘moderately disturbed’ 26,711.57 ha, and ‘undisturbed/relatively undisturbed’ 18,755.55 ha (Figure 35). The total area under crop cultivation is 47,591 ha.

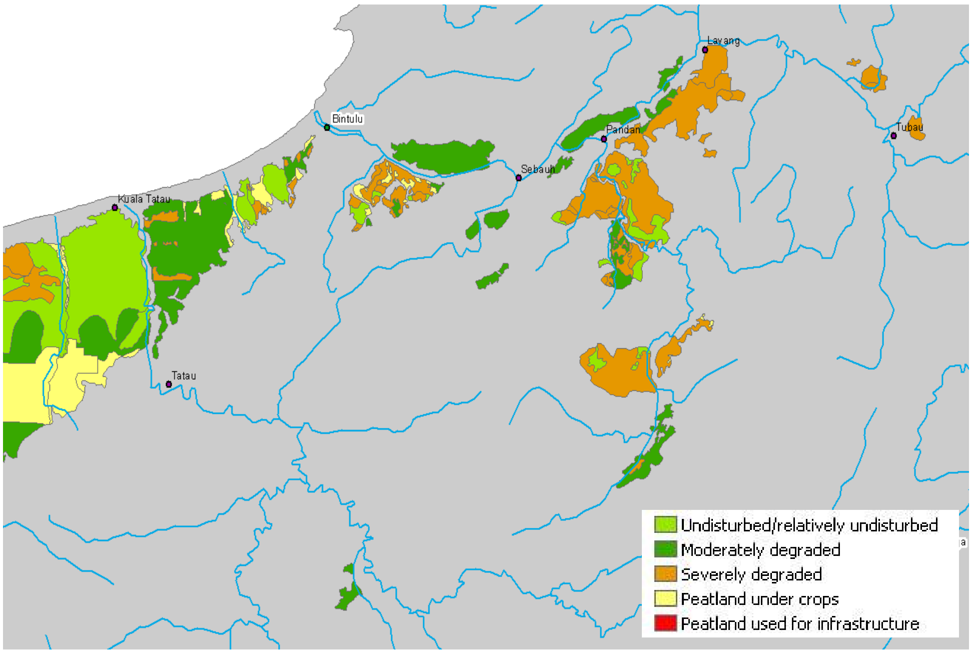

Figure 35: Distribution and status of peat swamp forest in Bintulu District. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.5 Profile: Sri Aman and Betong Divisions

Sri Aman and Betong Divisions have a total peatland area of 340,374 ha. The remaining area of peat swamp forest is divided into: 'severely disturbed' 66,613 ha, 'moderately disturbed' 126,910.04 ha (54%), and 'undisturbed/relatively undisturbed' 29,522 ha (Figure 36). Total area under crop cultivation is 50,836 ha.

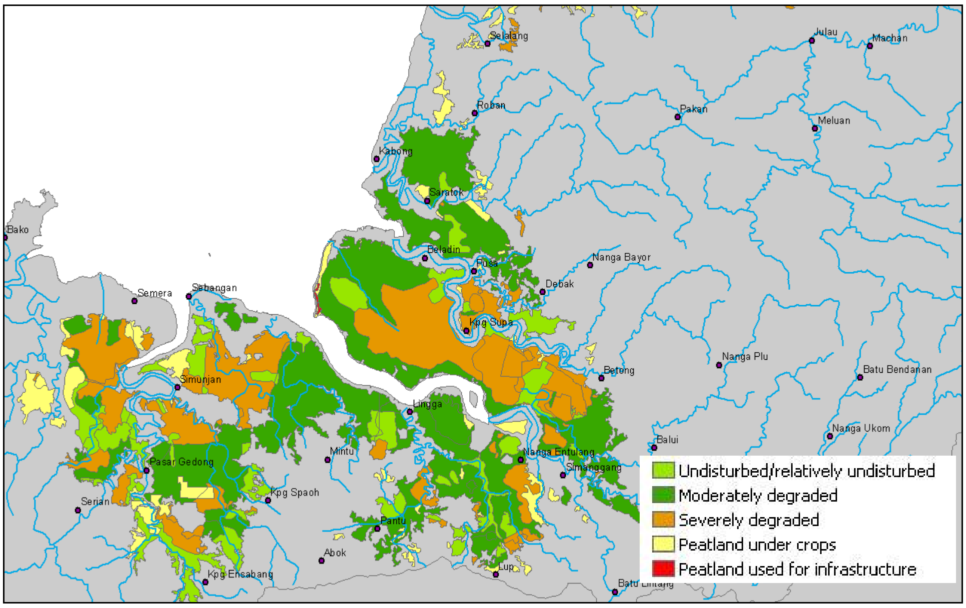

Figure 36: Distribution and status of peat swamp forest in Sri Aman and Betong Divisions. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999).

3.4.6 Profile: Sarikei Division

Sarikei Division has a peatland area of 74,414 ha. The figures for this Division are anomalous since one District has been transferred to the new Mukah Division. It is not known at present which District this was. The remaining area of peat swamp forest is divided into: ‘severely disturbed’ 58,042.79 ha, ‘moderately disturbed’ 45,606.83 ha, and ‘undisturbed/relatively undisturbed’ 33,671.17 ha (Figure 37). Total area under crop cultivation is 61,112 ha.

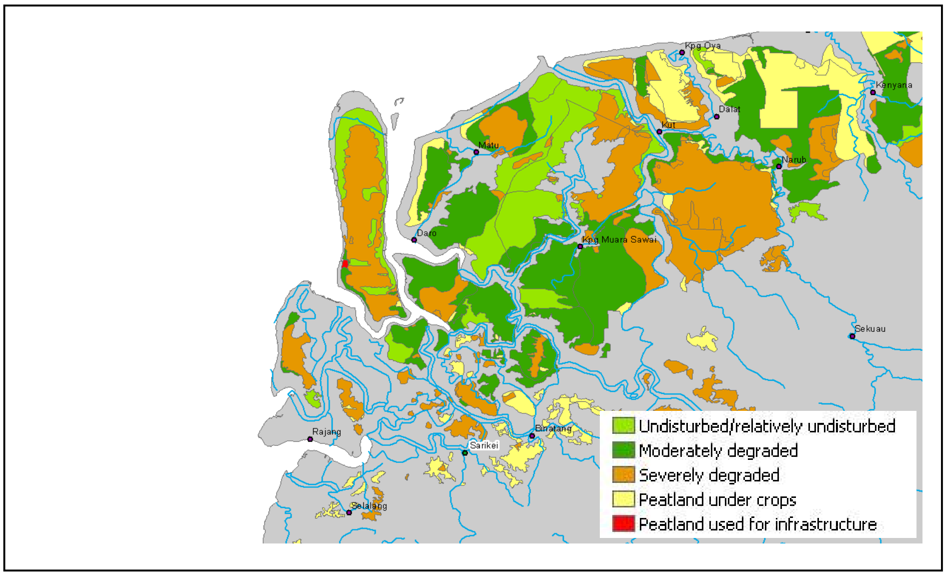

Figure 37: Distribution and status of peat swamp forest in Sarikei Division. . Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.7 Profile: Sibu and Mukah Divisions

Sibu and Mukah Divisions have a total peatland area of 600,387 ha. The remaining area of peat swamp forest is divided into: 'severely disturbed' 115,396.14 ha, 'moderately disturbed' 162,825.13 ha, and 'undisturbed/relatively undisturbed' 44,566.51 ha (Figure 38). The total area under crop cultivation is 269,571 ha. Peat swamp forest in Sibu and Mukah Divisions has been subjected to intensive logging since 1961, and there are currently no areas of remaining natural forest. More peat swamp forest has been converted to oil palm plantation in this division than anywhere else in Sarawak. The Sarawak Forestry Department has recommended that 37.8% of moderately degraded and 15.8% of undisturbed forest be included for restoration and rehabilitation projects.

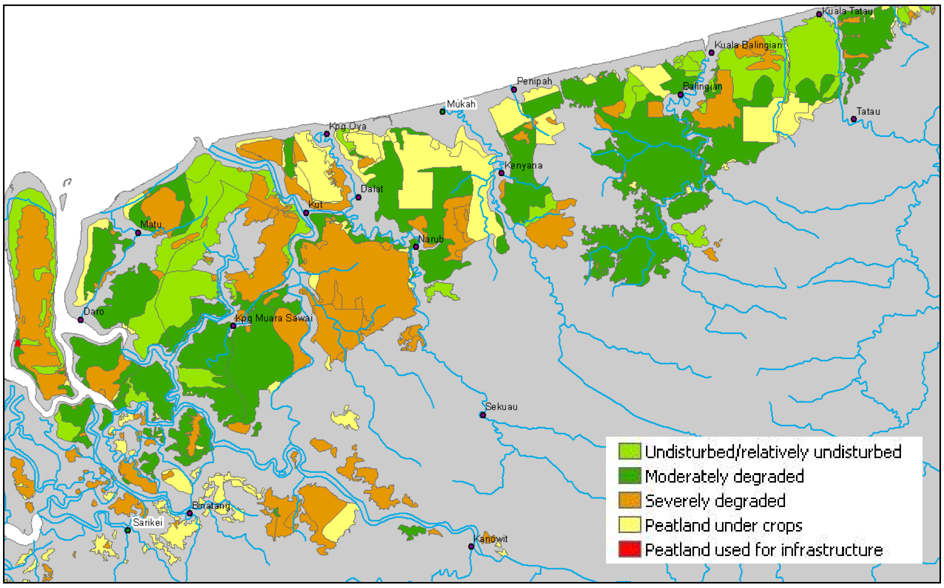

Figure 38: Distribution and status of peat swamp forest in Sibu Division. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.8 Profile: Samarahan Division

The total area of peatland in Samarahan Division is 165,581 ha. The remaining area of peat swamp forest is divided into: 'severely disturbed' 54,758.72 ha, 'moderately disturbed' 63,206.64 ha, and 'undisturbed/relatively undisturbed' 32,780.78 ha. The Total area under crop cultivation is 50,836 ha (Figure 39).

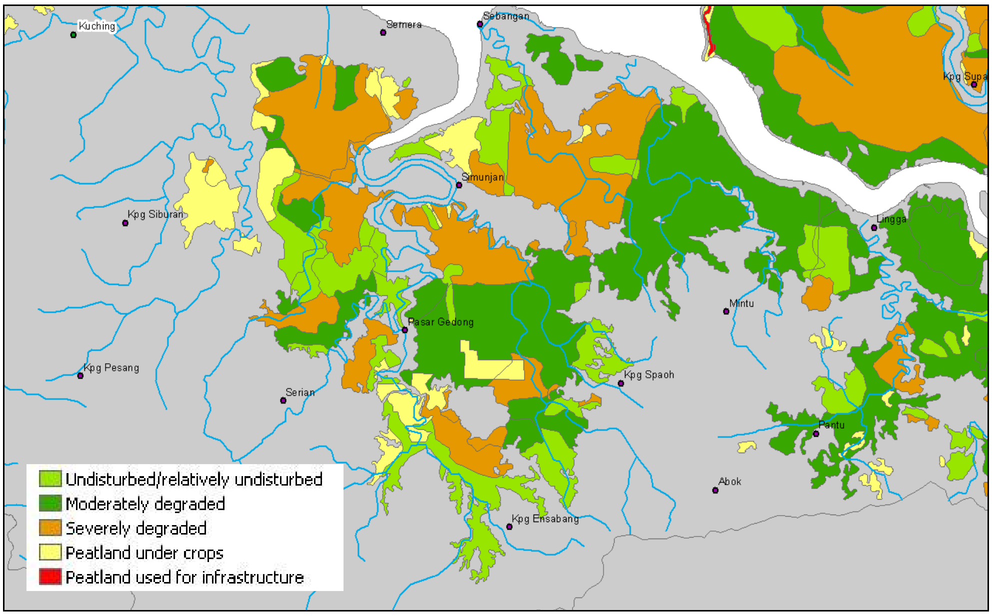

Figure 39: Distribution and status of peat swamp forest in Samarahan Division. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.4.9 Profile: Kuching Division

The total area of peat soil in Kuching Division is 26,827 ha. The remaining area of peat swamp forest is divided into: 'severely disturbed' 981.31 ha and 'moderately disturbed' 912.65 ha (Figure 40). There are no remaining areas of undisturbed/relatively undisturbed peatlands. There is no data from Melling et al (1999) on the area of peat soil converted to agriculture, though it is reasonable to assume that the area of peat soil not covered by forest has been converted to agriculture or has been lost to infrastructure.

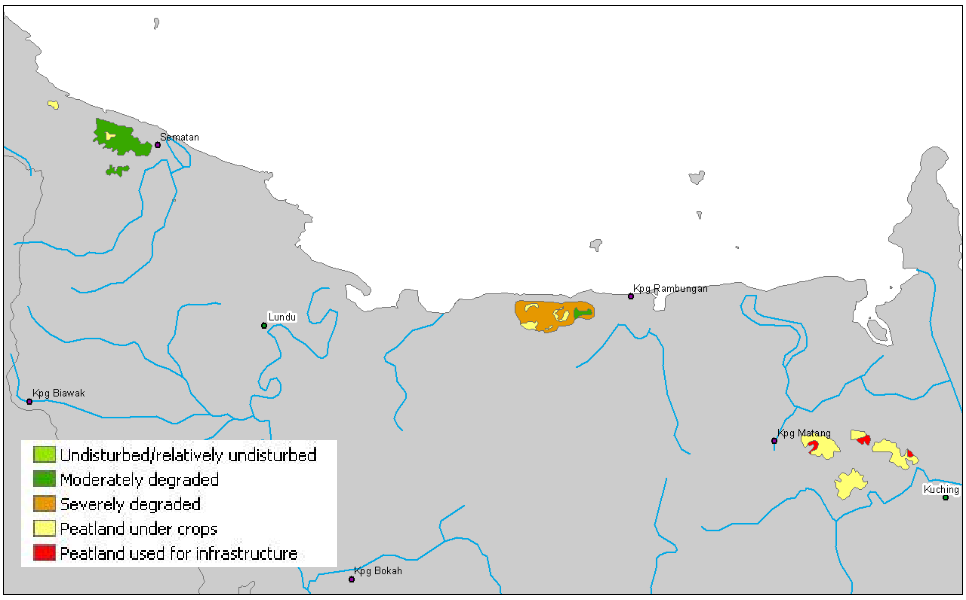

Figure 40: Distribution and status of peat swamp forest areas in Kuching Division. Data for status of peat swamp forest is from Wong (2003) – the area of peatland converted from forest is probably under-estimated. Due to this, the figures for peatland converted to agriculture are taken from Melling et al (1999)

3.5 Case study: Bakong / Baram peat dome

A ground-truthing survey for the current study was conducted in August 2008 on a peat dome west of Marudi and the Baram River. The Bakong/Baram peat dome, lying between the Baram and Bakong Rivers, stretches from just north-west of Marudi southwards for some 30 km on the west bank of the Baram River (Figure 41). It supports among the last undisturbed peat swamp vegetation communities in Sarawak.

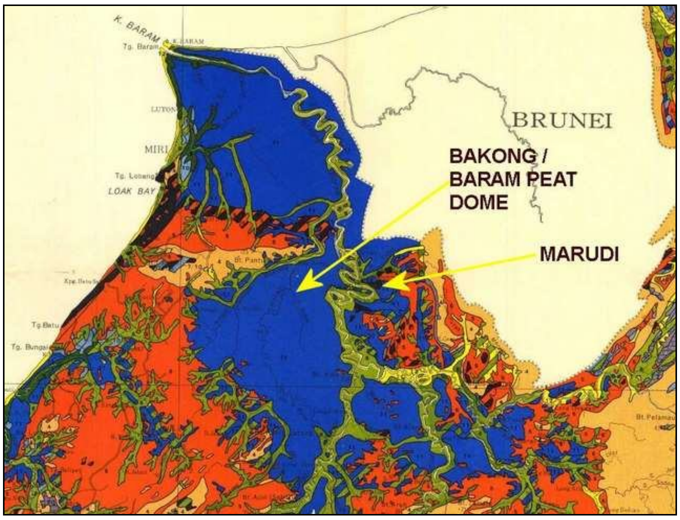

Figure 41: Location of field visit in Miri Division.
Blue areas represent peatland.

The Bakong/Baram peat dome is estimated to have formed over a period of 4,500 years. The dome is highly developed, with a depth of about 12 m in the centre, and it harbours all six phasic vegetation communities as described by Anderson (1963) as only occurring in northern Sarawak and Brunei. Communities ‘5’ (padang paya) and ‘6’ (padang keruntum) are globally significant unique ecosystems in terms of biodiversity. Figure 42 provides a classification of the state of the peat areas from 2000 where dark green represents undisturbed forest, blue represents moderately disturbed areas, yellow severely degraded areas and orange represents crops on peatland. As can be seen, the forest on the dome is the only undisturbed area of peat swamp forest in Miri Division, apart from an area bordering south-west Brunei. Data from 2000 indicate that only 18,920 ha out of 1.289 million ha of peat swamp forest in Sarawak was left undisturbed, a percentage of just 1.47%.

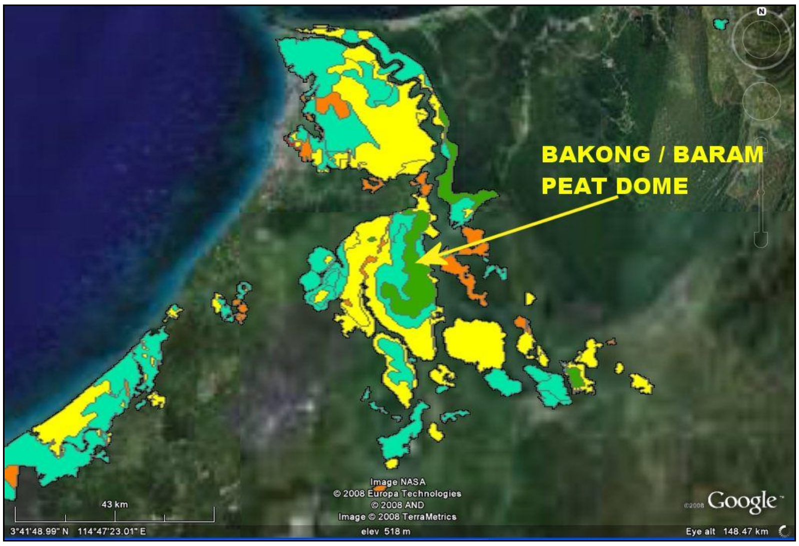

Figure 42: The Bakong/Baram dome holds some of the last undisturbed peat swamp forest communities in Sarawak (data from 2000). Undisturbed areas shown in green.

The fringes of the peat dome (containing alan batu and alan bunga forest) were logged about twenty years ago. Available literature indicates that up to 1975, when peat borings were taken in the area, the area was still intact. Fringes of the dome were logged in the 1980s and valuable timber species such as *Shorea albida* (Alan) and *Gonystylus bancanus* (Ramin) were removed. In 2008, these areas were severely degraded, with regular fire events and 2–3 m high bracken (*Pteridium aquiline*) predominating over wide areas. Figure 43 shows the areas visited in 2008. The red line represents a small gauge railway which has been constructed to extract logs, mainly keruntum, *Combretocarpus rotandatus*, from the top of the dome. The blue line in Figure 43 shows a motorable track, around which most of the peat swamp had been logged, drained and oil palm planted. The forest, consisting of the padang alan and padang paya communities, had been logged up to waypoint 37 on Figure 43.

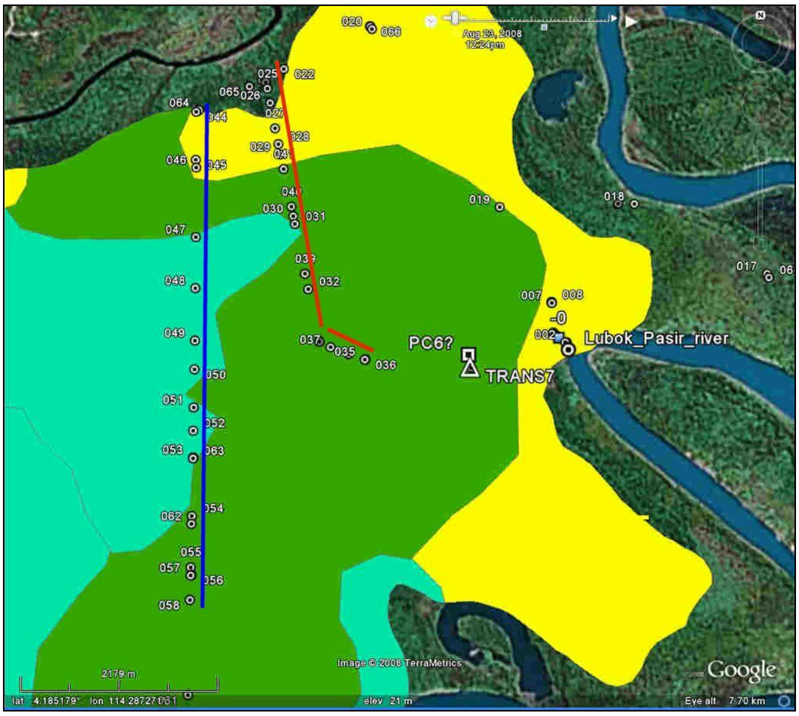

Figure 43: Areas visited at Bakong/Baram Dome in August 2008. The red line represents the logging railway to the top of the dome. The blue line represents the track through the newly planted oil palm.

Figure 44: Keruntum logs cut from the top of the peat dome being transported to Bakong River. In 2008, the parts of the peat dome at waypoints 35 and 36 remained unlogged and supported intact 'padang keruntum', but the construction of the railway into the 'padang keruntum' community at the top of the peat dome suggests that logging will take place there in the near future.

Figure 45: Intact Padang Keruntum (phasic community 6) on the top of the peat dome. The larger-sized trunk is Keruntum, whilst the shrub on the right is *Dactylocladus stenostachys* (Jongkong).

Figure 46: Looking south-east from the track: most of the dome has been drained and planted with oil palm.

Some of the padang keruntum community on the top of this part of the dome is still intact, but much had been cleared and planted with oil palm to the east of the track as shown in Figure 47.

Figure 47: Looking south on the constructed road.
Remaining Keruntum trees on the west side with cleared land on the east stretching towards the Baram River.

This clearing of the peat dome is the direct result of development of oil palm plantations in the area. A 99 year concession area of 12,904 hectare has been given to Sarawak Oil Palm Berhad. A public listed company, the main shareholder is Shin Yang Palm Oil, connected to the Shin Yang Group, which has logging as one of its main activities. An estate named Tinbarap has been established on the dome. Driving south on a newly constructed estate road up to the top of the dome, the padang keruntum forest on the east has been cleared, while the remaining forest on the west will eventually be cleared. Having travelled approximately 10 km, the land further ahead had already been cleared as far as the eye could see.

Key conservation issues at Bakong/Baram peat dome.

1. Under the Principles of the Roundtable on Sustainable Palm Oil (RSPO), the Bakong/Baram peat dome falls under HCV3 ('forest areas that are in or contain rare, threatened or endangered ecosystems'). This is counter to Principle 7.3 of the RSPO, which states, 'New plantings since November 2005 have not replaced primary forest or any area containing one or more High Conservation Values'. The peat dome is globally significant in terms of the conservation of ecosystem diversity. The two domes west of Marudi and the Ulu Mendaram peat dome that straddles Sarawak and Brunei border to the northeast of Marudi are the only three domes with all these six phasic communities and are thus the sole representatives of these unique vegetation communities in the world.

2. The environmental impact assessment (EIA) for the location of the new plantation was deficient. Under an EIA, the knowledge of the conservation significance of this landscape and its unique ecosystem should have been taken into consideration.

3. Palm oil can be a sustainable crop when based on best practices. However, when grown on drained peatland, palm oil cannot be sustainable due to decomposition and subsidence of the peat and the large emissions of greenhouse gasses. With substantial measures being taken by governments around the world, including the Malaysian government, to minimise GHG emissions, this development runs counter to sustainable development and efforts to mitigate climate change.

4. Part of the local community has been in conflict with the concessionaire over the land on which the oil palm plantations are being developed, which they claim as native customary land. This also contradicts the Principles and Criteria of the RSPO which requires prior and informed consent.

4. SUMMARY OF KEY FINDINGS

1. Total area of peat soil in Malaysia.

Peat soils encompass 2,457,730 ha (7.45%) of Malaysia's total land area (32,975,800 ha). Sarawak supports the largest area of peat soils in Malaysia: 1,697,847 ha (69.08 % of the total peatland area in Malaysia), followed by Peninsular Malaysia (642,918 ha; 26.16%); then Sabah (116,965 ha; 4.76 %).

2. Extent of good quality forest (canopy cover > 70%) remaining.

Within Malaysia, only 19% of peat soil areas are still under forest with a canopy cover of >70%.

- Peninsular Malaysia. Most intact peat swamp forest is in Pahang State (129,759 ha), which supports 57% of peat swamp forest with >70% canopy cover remaining in Peninsular Malaysia. Most of this area comprises the South East Pahang Peat Swamp Forest, within the Pekan, Kedondong, Nenasi and Resak Forest Reserves. Terengganu State appears to have the second highest area of intact peat swamp forest (51,759 ha) but the accuracy of this figure is questionable and is almost certainly an over-estimate. Perak State has the smallest area of intact peat swamp forest (~7%).

- Sabah. Approximately 21,000 ha (18%) of peat swamp forest has >70% canopy cover in Sabah. Most of these forests are in Klias Forest Reserve and the Lower Kinabatangan River, near the coast. There is relatively little information on peatlands in Sabah outside of the Klias Peninsula, and further surveys may document other peat swamp remnants.

- Sarawak. Approximately 223,277 ha of forest with >70% canopy remains in Sarawak, but this includes only 18,920 ha of completely undisturbed peat swamp forest, barely 1.7 % of the total area of peat swamp forest in Sarawak. These figures are from 2000 (Wong 2003) and it is likely the current area of peat swamp forest remaining in Sarawak is significantly less.

3. Oil palm development on peatland.

For the whole of Malaysia, about 36% of peat soil areas are used for agriculture. Peninsular Malaysia has the highest proportion of its peat soil under agriculture (44%).**Sabah and Sarawak have similar proportions of peat soils under agriculture (33%).**

- Peninsular Malaysia. Based on figures from DOA, in 2002 a total of 203,455 ha of oil palm was on peatlands in Peninsular Malaysia, representing 9.3% of total oil palm on all soil types (2,187,010 ha). DOA figures for 2006 indicate there were 222,057 ha of oil palm on peatlands, representing 9.5% of total oil palm on all soil types (2,334,247 ha), indicating that between 2002 and 2006, the area of oil palm on peatlands increased by 18,602 ha. Johor has the greatest extent of oil palm on peat soils (68,468 ha), followed by Perak (61,257 ha). One third of all oil palm plantations on peat in Peninsular Malaysia are found in Johor. In terms of the proportion of peat soil within the state, Perak has most of its peatlands under oil palm (88%) compared to just under half (47.6%) in Johor; this figure varies widely in the peninsular (33.7% in Selangor, 19.6% in Perak, 0.25% in Kelantan). Except for 2002 and 2006, there are few other recent data of oil palm on peatlands.

- Sarawak. The greatest expansion of oil palm plantations on peat soils has been in Sarawak, from 100,000 ha in 2003 to 300,000 ha in 2008 (Table 4), and large further expansions into peat soil areas are anticipated, due to the relatively limited availability of more suitable hilly lands Additional details on oil palm development are provided in Sections 3.2.2, 3.3.1, and 3.4.1

4. Extent of severely and moderately disturbed peatland in Malaysia.

For Malaysia, 44% of remnant peat swamp forests are moderately or severely disturbed, with the highest proportion in Sarawak (54%) (Table 3). Most disturbance has been due to logging. In Peninsular Malaysia, only 18% of peat swamp forest appears to be moderately or severely disturbed, but it is likely that the extent of intact peat swamp forest in Terengganu State has been over-estimated due to a lack of data on forest quality.

5. Conversion to oil palm.

The most pressing issue facing peatlands in Malaysia today is conversion to oil palm plantations, especially in Sarawak. Land managers generally agree that growing oil palm on peat which is more than one metre deep is ineffective. Oil palm requires a water table of 65–80 cm below the surface for optimum growth, so that to achieve optimal yields, peatlands must be drained to support oil palm. Compaction and subsequent decomposition of peat due to drainage, results in land subsidence: this necessitates further deepening of drains. This process will be repeated until most peat layers have been removed.

Profiles of peat domes in Sarawak have shown that the mineral soil base underneath the peat is often below mean sea level (e.g. Tie 1990). After drainage the peat will disappear – this may take 100 years or so in some cases, but will still happen. The land surface will then be below mean sea level, with the probability of more or less permanent flooding. The situation would be similar to that prevailing in the Netherlands at present, where much of the former peatland is now 4 m or more below sea level, necessitating continual pumping to prevent flooding. Long term climate change issues are also pertinent here. If climate change predictions are correct, there will be a rise in sea levels, resulting in increased flooding problems for low-lying coastal areas. If this sea level rise is combined with land subsidence due to peatland drainage, then flooding problems would be much more severe. Moreover, some of the marine clays underlying the peat are potential acid sulphate soils – when they are exposed, sulphide present under low oxygen conditions is converted to sulphuric acid, rendering the exposed clay extremely acidic with pH levels as low as 2.5. The sulphuric acid also attacks the clay minerals, releasing toxic levels of aluminium into drainage waters.

6. What can degraded peatlands be used for?

In the long term, if the present pressure for drainage of coastal peatlands continues, hundreds of thousands of hectares of low-lying former peatland around Malaysia could be permanently flooded, acidic, and unproductive.

7. Environmental impacts of peatland conversion.

The following questions should be addressed as a high priority: Have issues such as long term disappearance of peat and land subsidence been considered in development plans and mitigation plans for the predicted changes in climate and sea level rise? Are plans at present dominated by short term economic considerations? What site selection criteria are used to select areas suitable for conversion to oil palm? Are factors such as the depth of peat and the level of the mineral soil underlying the peat taken into consideration? Are biodiversity values taken into consideration? If they are, then the Baram/Bakong Dome in Miri Division might not have been cleared for oil palm.

8. Oil palm development and peat swamp logging.

The current study confirmed that clearance of good quality peat swamp forest followed by oil palm planting has occurred in at least two sites (Bakong/Baram dome, Sarawak, and Merang peatland, Terengganu State). This is clearly against RSPO principles, which state that areas of undisturbed forest should not be converted to oil palm.

9. National recognition.

Peat swamp forests are recognised by the Government of Malaysia as an Environmentally Sensitive Area (ESA) under Section 6B of the Town and Country Planning 1976 (Act 172) and in the 9th National Physical Plan (NPP). If any area is identified as an ESA then any development in that area must be brought up to the NPP Council and chaired by the Prime Minister. Every State Government is also required to comply with this Enactment if they plan to develop a peatland site. It seems this designation has been ignored in most EIAs for the development of peatlands. A recent analysis of 60 EIA reports involving conversion of peatlands to oil palm found that many reports did not address important issues such as loss of biodiversity, carbon dioxide emissions, drainage, impact on groundwater levels, and lack of compliance for mitigation measures stipulated in EIA reports and for post-EIA monitoring (Ten and Murtedza Mohamed 2002). Economic valuations of peat swamp areas are usually not included in EIAs but are critical to establish the monetary value of the goods and services they provide. This will provide economic indicators against which plans for conversion should be assessed.

10. Sustainable use.

If the services that intact peatlands provide, such as preventing saline water intrusion and maintaining minimum flows in rivers, storing huge amounts of carbon and sequestering carbon, are factored into the decision-making with regards to management of peatlands, there should be little doubt that remaining peatlands should be kept intact and degraded peatlands rehabilitated for sustainable use. Such sustainable use would involve the use of economic crops which can grow at a high water table of ~20-30 cm below the surface, which keeps the peat waterlogged and prevents decomposition (see Appendix 2).

11. High Conservation Value Forests (HVCF).

The largest HCV peat swamp forest in Malaysia is the South East Pahang Peat Swamp Forest (>100,000 ha). Over most of Malaysia, however, HCV forest is fragmented and in many cases surrounded by land uses which may negatively affect the hydrology of intact peat swamp forest. Such an example is Ayer Hitam Forest Reserve in the northern part of west Johor, which is a remnant of a much larger area of peat (Figure 48). The reserve is surrounded by drained agricultural land comprising rubber and oil palm. The challenge is to work with plantation owners to ensure that land management in buffer zones around the reserve does not negatively affect the value of the peat swamp forest remnant, whilst not affecting the yields of the crops grown in the buffer zones.

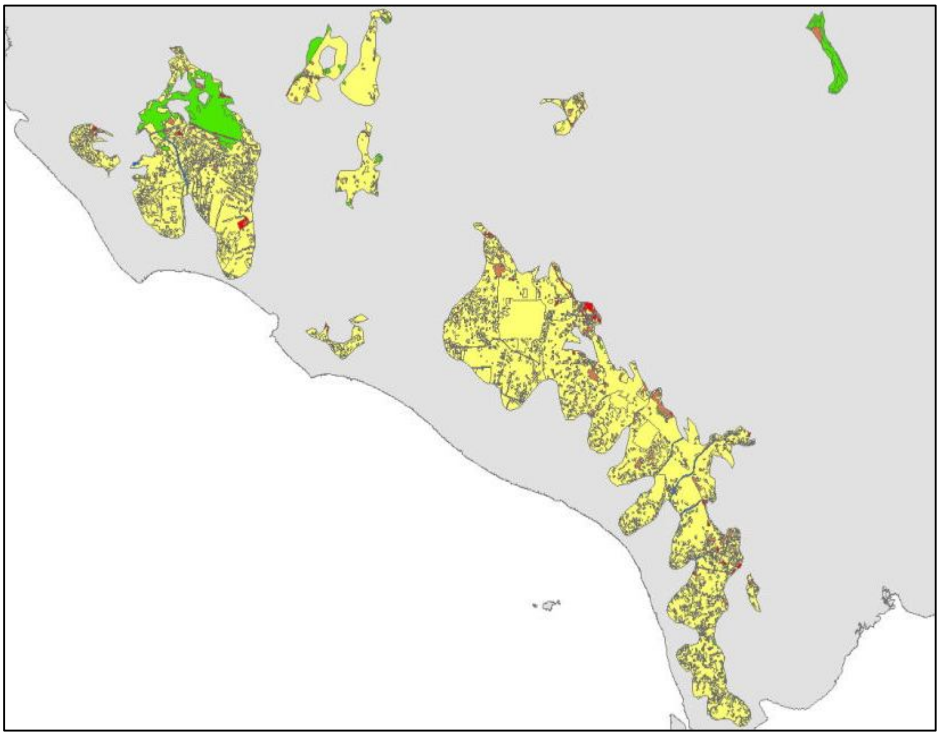

Figure 48: Ayer Hitam Forest Reserve, Johor, a fragment of High Conservation Value peat swamp forest.

5. RECOMMENDATIONS

The following recommendations were developed during a two-day workshop held in November 2008, in which findings of the current study were presented and discussed. Participants comprised a wide range of government, academic, and non-government agencies from Peninsular Malaysia, Sabah, and Sarawak. Complete workshop proceedings may be obtained from WI-MP.

1. Develop a National Goal / Vision for the wise use of peatlands.

A recommended national goal / vision for a peatland programme is: 'Malaysia's peatlands are conserved, managed sustainably, and rehabilitated for the benefit of all stakeholders and future generations'.

2. Develop a National Strategy to achieve the wise use of peatlands.

This strategy should include at least three components: (1) protection of the remaining high conservation value forests, (2) rehabilitation of degraded areas, and (3) sustainable use of intact peatlands. Sarawak is the highest priority for peatland management: less than 18,000 ha of intact peat swamp forest remains from an original total of ~1,289,113 ha. Buffer zones are urgently needed around remnant peat swamp forest, to control damaging land use, especially drainage, and re-establish connectivity. Some management activities could potentially be undertaken through existing landscape initiatives e.g. Central Mountain Spine Initiative (Peninsular Malaysia) and Heart of Borneo Initiative (Sabah, Sarawak).

3. Promote sustainable use of rehabilitated peatlands.

Growing crops on drained peatlands is largely unsustainable. In the long term, economic returns from sustainable forestry on undrained peatlands are greater than those from oil palm on drained peatlands.

[Workshop findings: At Sessang Research Station in Peninsular Malaysia, in experimental plots, the water table is kept at 30 to 50 cm with yield from oil palm of 25 tons/ ha. This yield is less than other stations where water table for oil palm is maintained at 50 cm to 70 cm, but subsidence is reduced substantially. This type of culture should be looked at more closely.]

4. Adopt a long-term approach to management.

Currently, short term planning dominates national and state land planning policies, and this is unsustainable in the long term.

[Workshop findings: the Sarawak State Government is planning for one million hectares of peatland to be converted to oil palm in the next few years.]

5. Target all stakeholders in promoting new policies on peatlands.

Pushing for policy change should include not only government policies, but also policies of other stakeholders, especially the private sector, including financing and lending institutions.

6. Strengthen RSPO criteria concerning oil palm development and peatlands.

RSPO criteria on oil palm development as it affects peatlands should be clarified and strengthened.

7. International governmental committee.

The governments of Malaysia and Netherlands have formed a joint committee to review carbon emissions from peat. All sectors should have input into the activities of this committee. When formulating specific recommendations in a programme for peatland wise use, these should be divided into incentives and disincentives. For each recommendation, the issue(s) addressed / rationale should be given.

8. Increase the knowledge base and expertise in peatland conservation and management.

A comprehensive database on peatlands in Malaysia is required. Wetlands International-Malaysia Programme is a suitable agency to support and maintain this database, as it has collected and currently maintains much national data on Malaysia's peatlands. A preliminary directory of Malaysian peatlands could be developed from existing information and stored in a GIS. This would strengthen data management and conservation actions, including communication strategies.

9. Capacity / awareness building in the public and private sectors.

A lack of understanding and awareness of peatlands and their conservation/management remains in the public and private sectors, particularly plantation companies and lending institutions. Issue-based seminars, developed for target audiences, should be undertaken to build capacity and awareness and strengthen engagement with these important stakeholders.

10. Establish the economic value of keeping peatlands intact.

A dollars and cents approach is needed, with comprehensive economic valuation of all the benefits provided by peatlands compared to scenarios when they are degraded or converted to other uses. Several case studies could be undertaken; one on an intact peatland, one on a degraded peatland, and one on peatland converted to oil palm.

11. Develop an effective communication strategy.

Sound justification is required for keeping peatlands intact and to rehabilitate degraded areas. Environmental economic assessments may present strong arguments for maintaining peatlands but so far there has been little effort to communicate this to decision-makers. There is a need to develop an effective communications strategy to support government policy and the private sector. This strategy should be based on scientific data for the values of intact peatlands.

12. Develop guidelines for EIA processes for projected developments on peatland.

The EIA process for developments on peatlands is currently deficient. New guidelines are required which specify the data which should be included in an EIA, important areas of HCV peat swamp forest in Malaysia, case studies of adverse impacts of failed projects, and examples of good EIA reports. These could be disseminated to plantation companies and companies/individuals undertaking EIAs.

13. Encourage targeted research.

There is much controversy over the sustainability of oil palm on peatland. One aspect of this is the amount of CO_2 emissions from intact peatland and oil palm on peat. Most of this research has centred on measuring flux of CO_2 from the soil. The true situation can only be revealed by establishing total carbon budgets for intact and degraded peatlands and oil palm on peat. Another important area is work (some of which is on-going) is the yield of oil palm at higher water tables and the crops (or combination of crops) which could be grown on rehabilitated peatlands, and which would bring good economic returns for small holders.

14. Fill the missing information gaps identified in the current study.

In some areas of Malaysia, data on the extent and condition of peatlands are outdated, absent, or difficult to obtain. Future work should try to fill these gaps to produce an updated inventory of Malaysia's peatlands.

6. REFERENCES

Acres, B.D., Bower, R.P., Burrough, P.A., Folland, C.J., Kalsi, M.S., Thomas, P., and Wright, P.S. 1975. The soils of Sabah. Vol.1. Classification and Description (with an introduction to volumes 1-5). Land Resource Study 20. Land Resources Division, Ministry of Overseas Development: London, U.K.

Abu Bakar, Ismael (2007) Agriculture on peat in Malaysia: Is it wise? Powerpoint Presentation at MARDI / RESTORPEAT workshop on Wise Use of Tropical Peatland, April 5 – 6. Johor Baharu, Malaysia.

Ambak, K. and Melling, L. 2000. Management Practices for Sustainable Cultivation of Crop Plants on Tropical Peatland. Pp.119-134 In: Proceedings of the International Symposium on tropical peatlands. Bogor, Indonesia, 22-23 November 1999. Hokkaido University and Indonesian Institute of Sciences: Bogor, Indonesia.

Anderson, J.A.R. 1964. The structure and development of the peat swamps of Sarawak and Brunei. Journal of Tropical Geography 18: 7-16.

Anderson, J.A.R. and Muller, J. 1975. Palynological study of a holocene peat and a miocene coal deposit from NW Borneo. Review of Palaeobotany and Palynology 19: 291-351.

Andriesse, J.P. 1988. Nature and Management of Tropical Peat Soil. Soil Resource Management and Conservation Service, FAO Land and Water Development Division: Rome, Italy.

Appanah, S. 1999. Flora survey of North Selangor Peat Swamp Forest. In: Chin, T.Y and Havmoller, P. (eds). Sustainable Management of Peat Swamp Forest in Peninsular Malaysia. Volume I, Resource and Environment. Forestry Department: Kuala Lumpur, Peninsular Malaysia.

Bezuijen, M.R., Webb, G.J.W., Hartoyo, P. and Samedi. 2001. Peat swamp forest and the false gharial (*Tomistoma schlegelii*) in the Merang River, eastern Sumatra, Indonesia. Oryx 35: 301-307.

Bruenig, E. F. 1990. Oligotrophic forested wetlands of Borneo. Pp 299-334 in: Lugo, A.E., Brinson, M., and Brown, S. (eds.) Ecosystems of the World 15 Forested Wetlands. Elsevier: Amsterdam, Netherlands.

Coulter, J.K. 1957. Development of Peat Soils in Malaya. Malatsian Agricultural Journal 40: 188-199.

Dreissen, P.M. 1977. Peat soils. In: Soils and Rice. pp. 763-779. IRRI: Los Banos, Philippines.

FAO. 1974. Soil Map of the World. UNESCO: Paris, France.

Hazebroek, H.P. and Abang Kashim bin Abang Murshidi. 2000. National Parks of Sarawak. Natural History Publications: Kota Kinabalu, Sabah, Malaysia.

Hooijer, A., Silvius, M., Wösten, H. and Page, S. 2006. PEAT-CO2, Assessment of CO2 emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943: Delft, Netherlands. Maas, E.F., Tie Yiu Liong and Lim Chin Pang 1986. Sarawak Land capability classification and evaluation for agricultural crops. Technical Paper No. 5 (2nd Edition), Soils Division, Dept. of Agriculture, Sarawak. 69pp.

Melling , L., Ambak, K., Osman, J. and Husni, A. 1999. Water management for the sustainable utilisation of peat soils for agriculture. Paper presented at the International Conference & Workshop on Tropical Peat Swamps, 27-29 July 1999, Penang, Malaysia.

Mutalib, A.A., Lim, J.S., Wong, M.H. and Koovai, L. (1991). Characterisation, Distribution and Utilization of Peat in Malaysia, Tropical Peat, in Proceeding of the International symposium on Tropical Peatland, Kuching, Sarawak, Malaysia, 7-16

Ninth Malaysia Plan. 2006. An Overview of Malaysia's National Biotechnology Policy, Biotechnology Corporation.

Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.V.,Jayak, A. and Limin, S. 2002. The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature 420: 61-65.

Pahang Forestry Department. 2005. Pekan Peat Swamp Forest, Pahang, Malaysia. The role of water in conserving peat swamp forests. Pahang Forestry Department/UNDP/GEF: Kuantan, Malaysia.

Paramananthan, S. and Omar, W. 2008 Proposals for the classification of organic soils of Malaysia. Paper presented at the Meeting and Seminar, MALAYSIA-NETHERLANDS JOINT COMMITTEE ON CARBON EMISSIONS. 7th-8th July 2008. Bangi, Selangor, Malaysia.

Phua, M.H., Conrad, O., Kamlun, K.U., Ficher, M. and Böhner, J. 2008. Multitemporal Fragmentation Analysis of Peat Swamp Forest in the Klias Peninsula, Sabah, Malaysia using GIS and Remote Sensing Techniques. Hamburger Beiträge zur Physischen Geographie und Landschaftsökologie – Heft 19: 81-90.

Ramsar. 2008. List of Wetlands of International Importance.

http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-31-218_4000_0__

Shawal P. 2003. Threats to the Peat Swamp Forest of Sarawak. JWG, Alterra/Sarawak Forestry Department: Kucing, Sarawak, and Wageningen, Netherlands.

Silvius, M. 2007. Palm oil expansion could boost carbon: The growing use of palm oil for biofuels production is often in conflict with environmental concerns. Bioenergy Business 1: 14-15.

Singh, G. 2008. Sustainable development of peatland for oil palm – UPB's experience. International Symposium and Workshop on Tropical Peatland: Wise Use and Impact Management. Kuching, Sarawak.

Ten Wuan Ping and Murtedza Mohamed. 2002. An Assessment Of The Environmental Impacts Of Peatland Development In Sarawak. Paper presented at the Malaysian Chemical Congress 12 – 13 December 2002, Kuching, Sarawak.

Tie, Y-L. 1990. Studies of peat swamps in Sarawak with particular reference to soil-forest relationships and development of dome-shaped structures. Unpublished Ph.D thesis, Polytechnic of North London, November 1990.

Tie, Y-L. and Esterle, J.S. 1991. Formation of lowland peat domes in Sarawak, Malaysia. Pp 81-89 in: Aminuddin (ed). Tropical peat: Proceedings of the International Symposium on Tropical Peatland. Kuching, Sarawak.

Tropical Peat Research Institute. 2009. Statistics of peatlands in Malaysia. A poster presented at the International Conference on oil palm and the environment; "Harmonising Oil Palm with the Environment". 14-15 August 2009, Malaysian Palm Oil Board.

Truong P. 2004. Regeneration of a mixed Swamp Forest in Sarawak (Malaysia), Study Based on Six Typical Mixed Swamp Species. Alterra: Wageningen, Netherlands.

UNDP. 2006. Malaysia's peat swamp forests: conservation and sustainable use. UNDP/NRE/DANIDA/GEF: Kuala Lumpur, Malaysia.

van den Eelaart, A. 2008. Swamp Development in Indonesia. Integrated Swamp development Project (ISDP), IBRD Loan 3755-IND, Indonesia.

Van der Werf, G.R., Demewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Mudiyarso, D., Peters, W., Morton, D.C., Collatz, G.J., Dolman, A.J., and DeFries, R.S. 2008. Climate regulation of fire emissions and deforestation in equatorial Asia. PNAS 105: 20350-20355.

Wan Sulaiman, W.H., Murtedza, M., Yusop, S., Noraini, B. and Hafsah, N. (not dated). Rehabilitation of Large-Scale Sago Planting on Deep Peat. Restorpeat / UNIMAS.

Wetlands International-Malaysia. 2005. Rapid Ecological Assessment of the Sg. Sedili Besar and Sg. Sedili Kecil Wetlands and Associated Ecosystems in Johor. Wetlands International-Malaysia, for Perbadanan Taman Negara Johor. November 2005.

Wong Lua Ming, J. 2003. Status of Peat Swamp Forest of Sarawak. Sarawak Forestry Corporation/Alterra Wageningen UR: Kuching, Sarawak / Wageningen, Netherlands.

APPENDIX 1. DEFINITIONS OF PEAT SOIL IN MALAYSIA

Definitions and classifications for soil mapping differ in Sabah, Sarawak and Peninsular Malaysia. As a result, the interpretation of the extent of peat soil by various authors varies slightly. According to Paramananthan and Omar (2008), the initial organic soil classification in Peninsular Malaysia adopted Coulter's (1957) classification system, where organic soils were classified according to their inherent fertility status, that is eutrophic, oligotrophic and mesotrophic groups. In 1966, a new criterion, the loss on ignition properties, was adopted:

- Organic clay: Loss of ignition of 20 to 35% at a depth of at least 15 cm from the surface.
- Muck: Loss of ignition of 35 to 65% and having a depth of at least 15 cm. Muck layers are said to be at least 60 cm thick and occur along the edges of peatland.
- Peat: Loss of ignition of more than 65% and ranging in thickness of 60 cm to 7.5 m.

The depth of peat was mapped as shallow peat (<60 cm); moderately deep peat (60 to 150 cm) and deep peat (over 150 cm). The depth of peat was later modified in 1983 as follows:

- Shallow peat: less than 150 cm,
- moderately deep peat: 150 to 300 cm thickness
- deep peat: more than 300 cm thickness.

Previous soil surveys in Sabah were combined to produce the 'Soils of Sabah' (Acres et al. 1975). In producing these reconnaissance soil maps of Sabah at a scale of 1:250,000, the soil mapping units were based on the draft Soil Map of the World (FAO 1974). Sabah adopted the definition for histosols (Paramananthan and Omar 2008):

'Histosols are soils which have an organic O horizon 40 cm or more [60 cm or more if the organic material consists mainly of sphagnum or moss or has a bulk density of less than 0.1 g/cc]. This horizon may extend continuously from the surface or represent the cumulative depth of the organic layers within the upper 80 cm of the soil; the thickness of the O horizon may be less when it rests on rocks or on fragmental material of which the interstices are filled with organic matter.'

Peat soils in Sabah are grouped under the Klias Association. Alluvium may be present, but organic materials predominate. This differentiates these peat soils from the Sapi Series which is composed of alluvium and peat, but in which mineral soil (alluvium) predominates). These 'Sapi Series' soils are mostly encountered in the floodplains of rivers, where the course of the river over the floodplain changes over time, so that alluvium deposited by the river may be inter-bedded with organic soil.

For Sarawak, Tie (1990) revised the existing classification using definitions from USDA Soil Taxonomy and the FAO/UNESCO Soil Map of the World legend with modifications to suit local conditions (Paramanathan and Omar 2008). Peat areas were further subdivided into shallow or topogenous peat (50-150 cm thick) and deep peat or ombrogenous peat more than 150 cm thick. These were further subdivided according to the thickness of peat and the underlying nature of mineral material (such as 'Igan', 'Mukah', 'Anderson', 'Limbang').

Paramananthan and Omar (2008) put forward a unified soil classification system for the whole of Malaysia, suggesting that the cumulative thickness of the organic soil matter 'should make up more than half the thickness to a depth of 100 cm. Depth of peat was then modified again for the unified Malaysian classification system as follows: shallow peat thickness 50 to 100 cm, moderately deep peat: 100 to 150 cm, deep peat: 150 to 300 cm and very deep peat: depth more than 300 cm. He proposed the use of the terms at 150 cm depth to separate topogenous and ombrogenous peats. This Unified Classification of Organic Soils of Malaysia has been accepted and used as a new system in Malaysia (Paramananthan and Omar, 2008).

Under Paramananthan and Omar's (2008) definition, Organic soils can be defined by the following:

1. Saturated with water for long periods (or artificially drained) and, excluding live roots, with an organic carbon content (by weight) of:

a. 18% or more if the mineral fraction contains 60% or more clay; **or**

b. 12% or more if the mineral fraction contains no clay; **or**

c. A proportional content of organic carbon between 12 and 18% if the clay content of the mineral fraction is between zero and 60% **or**

2. Never saturated with water for more than a few days and contains 20% or more (by weight) organic carbon **or**

3. Has a loss on ignition of more than 65% by weight.

According to point 3, where loss on ignition is more than 65% by weight, organic soils in this context are equivalent to the widely accepted definition of a peat soil. It is not clear where organic clays and muck soils fit into this classification.

Under this system, an area of organic soil as defined in Malaysia should meet one of the following requirements:

1. Organic soil material makes up more than half the total cumulative thickness of the upper 100 cm (40 inches).
2. The depth to bedrock is between 50 to 100 cm and the total thickness of the organic soil layers taken cumulatively is more than half the depth to bedrock.
3. The depth to bedrock is less than 50 cm and the total thickness of the organic soil layers taken cumulatively is more than half the depth to bedrock.

APPENDIX 2. AGRICULTURAL PRODUCTION ON PEATLANDS

Optimum water table levels for various crops is shown below (source: Ambak and Melling 2000). Sago, cassava, soy bean, sweet potato, asparagus and some other vegetables can be grown at water table levels at which peat decomposition would be prevented. Pineapple and oil palm are two crops which require a much lower water table for optimal yields, yet these two crops are very commonly grown on peat.

Crop	**Water table (cm)**
Oil palm	50 - 75
Pineapple	60 – 90
Sago	20 – 40
Cassava	15 – 30
Groundnut	65 – 85
Soybean	25 – 45
Maize	75
Sweet potato	25
Asparagus	25
Vegetables	30 - 60

Oil palm can be grown at higher water tables of 30 – 50 cm, but a lower yield is expected. Yield of oil palm grown at different water table levels in a plantation in Selangor is shown below. When grown at a higher water table with a mean of 44 cm, the yield was reduced by 15% from the optimum. Presumably, at a water table level of 20 – 30 cm below the surface, the yield would be reduced still more, perhaps by 50% from the optimum. However, a lower yield would be compensated for by the sustainability of the system, where the high water table prevents peat decomposition and associated subsidence of the land. In fact, when considered in the long term, the yield over the years may prove to be greater since the type of cultivation is sustainable. It is not clear at present what yields may be at such a high water table, but it would be a fruitful area for research.

Yields of oil palm grown at different water table levels. The percentages displayed in the right hand column show the difference from the optimum yield. From Singh (2008).

Water table condition	**Water table level (cm) (mean for 8 years)**	**Fresh fruit bunch yield (tonnes)**
Medium (optimal)	80 (21 – 165)	24.7 (100%)
Low	96 (13 – 165)	23.1 (84%)
High	44 (0 – 165)	23.3 (85%)

There are promising options for sustainable forestry since there are many valuable timber species which grow in peat swamp forest such as Ramin (*Gonystylus bancanus*), several types of Meranti (*Shorea platycarpa*, *S. pachyphylla*, *S. uliginosa* etc), and Kapur Paya (*Dryobalanops rappa)*. However, sustainable forestry on rehabilitated peatland is not economically attractive at present, since the return on investment is so long (40-60 years) compared to the return on investment for oil palm (5-7 years). But of course, this is based solely on looking at returns for crops and not on all the services that intact and rehabilitated peatlands provide.

Possibilities for multi-cropping should be looked at, whereby the long term timber crop can be mixed in with crops which can give an economic return in a relatively short time, particularly for local communities.

Economic incentives are required for keeping peatlands intact or to rehabilitate degraded areas. This is where the international community can play a part. Intact peat swamp forest and rehabilitated areas should be good candidates for schemes such as reduced or avoided deforestation and avoided carbon emissions. A requirement is the benefits that intact peat swamp forest provide really have to be marketed properly. There seems to be little awareness of the huge carbon store in peat swamp forest, the carbon-sequestering ability and the cost-effectiveness of keeping such areas intact compared to other carbon storage / capture schemes.

Mission:

To sustain and restore, wetlands, their resources and biodiversity for future generations