RSPO MANUAL ON BEST MANAGEMENT PRACTICES (BMPs) FOR EXISTING OIL PALM CULTIVATION ON PEAT

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COVER IMAGE
Workers loading barges with oil palm fruits, which have been transported by water to save energy and enhance access.

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1.0 INTRODUCTION

1.1 INITIATION OF RSPO MANUAL FOR BEST MANAGEMENT PRACTICES

This Manual has been prepared in response to the decision by the RSPO General Assembly (GA) in NOVEMBER 2009 (see ANNEX 2 PAGE 186) to provide guidance to improve yields in existing oil palm cultivation on peat and to address issues related to GHG emissions, subsidence and other impacts that affect the potential sustainability of oil palm cultivation on peatlands.

This Manual has been prepared through a consultative process facilitated by the RSPO Peatland Working Group (PLWG) (see ANNEX 3 PAGE 187), which was established in APRIL 2010 in response to the above GA decision. The PLWG held six meetings in different parts of Malaysia and Indonesia during the period APRIL 2010 to SEPTEMBER 2011. The PLWG collated experiences from RSPO members and non-member companies, visited oil palm plantations and smallholders on peat as well as organized public stakeholder consultation fora in Sumatra, Peninsular Malaysia and Sarawak to gather input for the preparation of this Manual. Preparation of the main drafts was facilitated by Peter Lim of PT Bumitama Gunajaya Agro but amendments and contributions were received from a broad range of other PLWG members and external parties. Drafts were circulated for comment to a range of stakeholders. This Manual was finalized after 12 revisions to ensure balanced and practical views are taken into account.

1.2 PURPOSE OF BMP MANUAL AND BENEFITS OF ADOPTION

The objective of this Manual is to provide a set of practical guidelines for Best Management Practices (BMPs) that are important for enhancing the management of existing oil palm cultivation on tropical peat while at the same time reducing environmental impacts especially GHG emissions and subsidence. This BMP Manual is applicable to existing large plantations and also medium and small-scale cultivation of oil palm on peat.

This Manual draws on more than 30 years experience in SE Asia of cultivation of oil palm on peatlands as well as drawing on recent research on GHG emissions and water management. It also draws on and refers to existing national regulations and guidelines especially from Malaysia and Indonesia – the countries with the largest areas of oil palm cultivated on peatland.

This Manual is an initial step taken by RSPO to guide its members, particularly producers in responding to stakeholder concerns to promote the implementation of BMPs and reduce negative impacts related to oil palm cultivation on peat. It is also hoped that readers of this manual will better understand the constraints of oil palm cultivation on peat and the long term implications especially of subsidence, which will in many sites limit the potential long term life span of plantations. Implementation of BMPs will reduce subsidence but will not stop it, leading over time to long term drainability problems. Therefore in the medium to long term (depending on local hydrological circumstances), alternative uses will need to be identified for many of the areas now developed as plantations may need to be identified.

Although the existing cultivation of oil palms on tropical peat has brought about economic and social benefits in Indonesia and Malaysia, great precautions are still needed in existing plantations to minimize GHG emissions and potential impacts to the environment, especially if BMPs are not effectively implemented. The RSPO Principle on commitment for continual improvement should always be emphasized. It is also recognized that the smallholder sector will need more technical guidance and financial support to be able to implement BMPs effectively.

1.3 BACKGROUND OF OIL PALM CULTIVATION ON PEATLAND

Over the last 30 years, oil palm cultivation has rapidly expanded in SE Asia (particularly Indonesia and Malaysia) and currently covers about 12.5 million hectares. Initially oil palm cultivation focused on mineral soils and peat soils were considered less suitable – partly due to poor experience with initial cultivation. These problems were largely due to the lack of understanding of the structure and hydrology of these peatlands.

In the early 1960s, plantation crops such as rubber and subsequently oil palm were planted on peat soils. Again, success was limited due to the use of large drains to remove excess water. In 1986, the pioneering work of United Plantations in Peninsular Malaysia (Gurmit *et al.*, 1986) to introduce water control and nutritional management significantly increased the potential for successful cultivation of oil palms on peat.

In the past 20 years, a combination of development of new technologies for water management and agronomy for cultivating oil palm on peat as well as government planning decisions in some regions has led to the expansion of oil palm on peat. Currently it is estimated that there are about 2.4 million hectares of oil palm cultivated on peat representing about 20% of oil palm in the SE Asia region and covering about 10% of the region's peatlands. To date 666,038 ha of peatlands in Malaysia (Sarawak – 437,174 ha, Peninsular – 207,458 ha, Sabah – 21,406 ha) (Omar *et al.*, 2010) and about 1,710,000 ha in Indonesia (Sumatra – 1,400,000 ha and Kalimantan – 310,000 ha) (Agus *et al.*, 2011) have been developed for oil palm cultivation. For more details on distribution of peatlands in South East Asia and oil palm developments on peatland, as shown in ANNEX 4 PAGE 190.

Peat soils are diverse in physical and chemical properties and not all are productive and easy to manage. Considerable skill, planning and implementation of Best Management Practices (BMPs) as well as knowledge and understanding of peat are required to reduce some of the impacts caused by oil palm cultivation on peat while enhancing yields. Long term environmental considerations and social aspects need to be taken into account in peat-planting especially minimizing subsidence and reducing emissions of Greenhouse Gases (GHG).

Plantation companies with peatland development however reported that not all their peat estates are yielding equally. Especially low yields have been recorded on the more woody peat in Sarawak. The actual achieved FFB yields of prime age oil palms on deep peat are very contrasting, ranging from about 30 to less than 15 mt/ha/year. Data from the pioneers of oil palm cultivation on peatland, United Plantations, showed that their early plantings on deep peat during the 1960s yielded only an average of 12.9 mt/ha over a 12-year period (5TH to 16TH year of planting). The main factors affecting this high yield variation are peat type, land preparation, planting techniques, fertilization, water management as well as effective pest and disease control (Peter Lim, Pers. Comms.). Low yields are also experienced by smallholders (who often have little access to financial and technical resources) and the lack of BMP implementation. It is important to note that a proper drainage system with effective water management structures are crucial to maximize oil palm yield on peat and also to minimize GHG emissions and peat subsidence, which is vital for prolonging the economic life span of the developed peat.

It is generally understood that cultivating oil palm on peatland requires significantly more effort and associated costs in comparison to planting oil palm on mineral soils. Increased operational costs for oil palm cultivation on peatlands are a result of additional land preparation works, road maintenance and water management. The challenges for planting oil palm on peat have been highlighted by Tan Sri Datuk Dr Yusof Basiron, CEO of the Malaysian Palm Oil Council (MPOC), who said "The planting of oil palm on peat demands significantly more intense efforts in terms of higher costs and increased management inputs. It is not a planter's preference to plant oil palm on peat" (Liew, 2010).

1.4 POTENTIAL IMPACTS OF OIL PALM CULTIVATION ON PEATLAND

The cultivation of oil palms on peatland is not only a challenge from an agronomic perspective. There are also wide potential impacts that can result from the development of oil palms on peat. These impacts are often specific to the peatland environment or ecosystem. The range of potential social and environmental impacts specific to oil palm development on peatland includes:

- Soil subsidence
- Flooding
- Water shortage and pollution
- Fires and air pollution
- Habitat loss and biodiversity change
- Socioeconomics

See ANNEX 5 PAGE 194 for further information.

1.5 REGULATIONS & GUIDELINES RELATED TO OIL PALM CULTIVATION ON PEATLAND

The following are various regulations and guidelines related to oil palm cultivation on peatland. They consist of:

- RSPO Principles & Criteria (P&C), associated indictors and guidance from Indonesia, Malaysia and Papua New Guinea National Interpretation documents that cover oil palm cultivation on peatland and water management issues.
- Indonesian regulations
- Malaysian regulations

RSPO PRINCIPLES & CRITERIA (P&C)

Within RSPO's P&C there already exist some specific criteria and National Interpretation verifiers for cultivation on peatland. Therefore these provisions should fundamentally form the reference point or aspired standard of this Manual. Each P&C criterion already considers the relevant issues and key concerns, including legal obligations. See ANNEX 6 PAGE 196 for details of various national interpretations and guidance for the following P&C specifically relevant to peat as well as other P&C relevant to oil palm cultivation in general.

CRITERION 4.3
Practices minimise and control erosion and degradation of soils.

CRITERION 4.4
Practices maintain the quality and availability of surface and ground water.

CRITERION 5.1
Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continuous improvement.

CRITERION 5.6
Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.

INDONESIAN REGULATIONS

Developments of oil palm on peatlands in Indonesia need to take into consideration the following regulations from the Indonesian Government:

- Indonesia Forest Moratorium 2011: The Indonesian President made official the Indonesia Forest Moratorium on 20 MAY 2011. Under this moratorium, central and local governments are not allowed to issue new permits on primary forests and peatlands that are located in conservation areas, protected forest production forest (limited production forest, normal/permanent production forest, conversion production forest) areas and areas for other uses as stated in the indicative map attached to the regulation.

- Presidential Decree NO. 32/1990 and Ministry of Agriculture Decree No. 14/2009: These decrees prohibit the use of peatlands if the peat thickness is more than 3 metres or if the peatland is on conservation or protection forest land. Where existing plantation licenses or pending applications lie on peat soils with a depth greater than 3 metres, such licenses could be revoked under these provisions.

- Indonesian Sustainable Palm Oil (ISPO) requirements: Under the Ministry of Agriculture Decree NO. 19/2011, ISPO criteria specifically relevant to cultivation of oil palm on peatland are to be implemented:

  CRITERION 2.1.5
  Plantings on peatland – Planting oil palm on peatlands can be done by observing characteristics of peat so as to not cause damage to environmental functions

  CRITERION 3.6
  Mitigation of Greenhouse Gas Emissions (GHG) – Management of the plantation business must identify the source of GHG emissions.

MALAYSIAN REGULATIONS

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). Every State Government is also required to comply with these Enactments if they plan to develop a peatland site. 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. EIAs are a mandatory requirement for proposed development projects categorized as 'prescribed activities'.

See ANNEX 7 PAGE 201 for details.

1.6 CONTENTS OF THE MANUAL

The following is a summary of content in this Manual.

CHAPTER 1.0 INTRODUCTION

This chapter provides background information including the initiation of the Manual, purpose of the Manual along with benefits of BMP adoption as well as general background of oil palm cultivation on peatland focusing on Indonesia and Malaysia. This chapter also describes the potential environmental impacts as well as regulations and guidelines related to oil palm cultivation on peatland in the form of the RSPO's P&C including Indonesia, Malaysia and Papua New Guinea national interpretations as well as relevant Indonesian and Malaysian regulations.

CHAPTER 2.0 NATURE AND CHARACTERISTICS OF TROPICAL PEAT

This chapter provides basic information on the nature and characteristics of tropical peat including the following topics: definition, formation, distribution and classification of peat, peat depth, horizons and topography, physiochemical properties and fertility of drained peat. The impact of drainage in causing the subsidence of the peat surface is highlighted. The continuous lowering of the peat surface can cause areas that can initially be gravity drained, to become undrainable after several years of lowering the water table. This section provides some practical guidance on how to measure and to some extent reduce subsidence. A summary of other constraints of oil palm cultivation on peatland is also provided.

CHAPTER 3.0 BEST MANAGEMENT PRACTICES (BMPs)– OIL PALM CULTIVATION ON PEATLAND

This chapter provides practical guidance based on field experience and current knowledge on the following BMP topics to optimize oil palm cultivation on peat:

- Water management – effective water management is the key to high oil palm productivity on peat. Guidance is provided on maintenance of drainage systems, construction and maintenance of bunds, utilization of water management maps and management of water levels. Maintaining water level between 40-60 cm below the peat surface or 50-70 cm in the collection drains is emphasized.

- Fertilizer and nutrient management – next to water management, adequate and balanced fertilization is vital for high productivity of oil palm on peat. Guidance is provided on fertilization for immature and mature oil palms on peat.

- Integrated Pest and Disease Management – if not properly controlled, pest outbreaks can occur, resulting in economic losses due to reduction in yield and stand. Guidance is provided on cost-effective control of major pests such as termites, Tirathaba bunch moths, leaf-eating caterpillars, rats, rhinoceros beetles and Ganoderma management.

- Effective weed management on peat.

- Management of leaning and fallen palms – palm leaning is one of the major problems of planting oil palms on tropical peat. Guidance is provided on minimization of palm leaning and methods to rehabilitate fallen palms.

- Replanting practices – Guidance is provided on the need to do assessments prior to replanting, especially to assess future drainability, and also practices to reduce GHG emissions during replanting. Zero-burning concepts are emphasized.

- Nursery management – Good nursery practices with legitimate planting materials are required for effective replanting and high yield. Specific guidance on best nursery management for oil palm cultivation on peat is provided.

CHAPTER 4.0 BEST MANAGEMENT PRACTICES (BMPs)– OPERATIONAL ISSUES

This chapter provides practical guidance based on field experience and current knowledge on the following BMP topics: enhancing yield, transport systems (road, rail and water), labour and mechanization, training and field supervision.

CHAPTER 5.0 BEST MANAGEMENT PRACTICES (BMPs)– ENVIRONMENTAL AND SOCIAL ISSUES

This chapter highlights some practical guidance based on field experience and current knowledge on the following BMP topics: conservation, maintenance and rehabilitation of natural vegetation and river reserves / greenbelts, environmental management, fire prevention and control, minimization of Green House Gas (GHG) emissions from oil palm plantations, social and cultural issues, cooperation with local communities and occupational health and safety issues.

CHAPTER 6.0 BEST MANAGEMENT PRACTICES (BMPs)– RESEARCH & DEVELOPMENT, MONITORING AND DOCUMENTATION

This chapter focuses on practical guidance based on agronomic experience and practical knowledge on the following BMP topics: research and development needs on peat, monitoring, reporting and proper documentation of operating procedures.

CHAPTER 7.0 OIL PALM CULTIVATION BY SMALLHOLDERS ON PEATLAND

This chapter provides a brief description of the various types of oil palm smallholders (supported, independent and collective landowner schemes) cultivating oil palms on peat and main constraints encountered especially by independent smallholders without direct assistance from government or private companies. Suggestions on how to overcome some of these problems are highlighted.

2.0 NATURE AND CHARACTERISTICS OF TROPICAL PEAT

2.1 DEFINITION, FORMATION, DISTRIBUTION AND CLASSIFICATION OF PEAT

There are several definitions for peat and the most appropriate for tropical peat (modified from Soil Survey Staff, 2010) is:

Tropical peat soils (Histosols) are defined as organic soils with 65% or more organic matter and a depth of 50 cm or more.

They are characterized by woody fibers and in undrained conditions are saturated with water for 30 cumulative days or more during normal years.

Most tropical peat soils belong to the soil order Histosols and the sub-orders Fibrists and Hemists. Peat soils consist of partly decomposed biomass and develop when the rate of biomass production from adapted vegetation is greater than the rate of decomposition. The rate of decomposition is reduced due to the presence of a permanently high water table that prevents the aerobic decomposition of plant debris (Andriesse, 1988; Driessen, 1978).

In contrast to temperate and sub-arctic peat soils, which are mainly formed from Sphagnum mosses consisting of very fine fibres, tropical peat develops under forest vegetation and is derived from coarse, woody material. It is formed at a much faster rate (most peat in Southeast Asia is only about 4000 years old) and decompose more rapidly when exposed to aerobic conditions (Paramananthan, 2008). However, peat soils can vary greatly according to their genesis and hydrology. One major distinction is between ombrogenous and topogenous peat. Topogenous peat is usually smaller in area, shallower and in closer proximity to surrounding upland areas than ombrogenous peat.

Anderson (1961) studied the structure of the peat swamps in Sarawak by means of level surveys and borings to the substratum. In many systems there is a general rise in elevation of the peat in the areas in between adjacent rivers (see FIGURE 1 PAGE 18). It is important to note that these dome-shaped peatlands get their water solely from rain and not from groundwater. As a result, they are nutrient-poor or oligotrophic.

Domed-shaped peatlands may also have distinct vegetation types, which vary according to peat depth and nutrient status. The vegetation also influences the nature of the peat and the constraints for cultivation. Dominant peat forests based on studies in Sarawak are shown in TABLE 1. It is noted that plant species may differ in similar zonations elsewhere in the region.

TABLE 1

Dominant peat forest zones in well-developed peatlands in Sarawak (Source: Anderson, 1964).

Mixed swamp forest	A marginal zone within a river's flooding area. It is a mixed community and strongly associated with each other. Important species found in this area are *Gonystylus bancanus*, *Copaifera palustris* and *Shorea* species. This zone almost more or less resembles the mixed dipterocarp forest and is found on lower elevation and usually more fertile.
Alan forest	A zone with a single species, *Shorea albida* dominating the area. However, *Gonystylus bancanus* and other small trees are the most common associates of the *Shorea albida*. This also refers to forests on shoulders of peat domes and is generally not so fertile especially if the large buttress roots of the Alan batu species are not removed during land preparation.
Alan bunga forest	The highest stratum only belongs to *Shorea albida*. Strata B are almost non-existent. However, the lower regions to the forest floor are moderately filled by various species.
High pole forest	These communities are full of *Litsea palustris*, *Parastemon spicatum* and *Tristaniopsis* species.
Low pole forest	Narrow zones, almost similar to the high pole zone, but the trees are shorter and densely distributed. One of the most abundant species recorded in this zone is *Palaquim* species.
Padang Paya or Keruntum forest	Very open zone found on centre of peat dome area and least fertile. Common with *Cyperaceae*, herbs and other small trees.

2.2 PEAT DEPTH, HORIZONS AND TOPOGRAPHY

Under its natural state, peatlands generally have a high water table and are invariably waterlogged with woody components remaining intact under sustained anaerobic conditions. Once the peat is drained, the oxidation process sets in resulting in the decomposition and mineralization of the organic matter. Thus, it is common to see the soil profile of drained peat consisting of three horizons differentiated by sapric (mostly decomposed), hemic (partially decomposed) and fibric (raw, undecomposed). Deeper peats especially in Sarawak tend to be less decomposed (more woody), but as peatlands are drained and developed, decomposition increases. The thickness of these three horizons varies depending on the water table and cultivation practices. The sapric layers could extend deeper in drained peat.

Being close to coastal areas, the underlying substrata are usually marine clay (often sulphidic), riverine alluvium or sand. The classification of peat according to depth as shown in TABLE 2 is widely accepted (Lim, 1989).

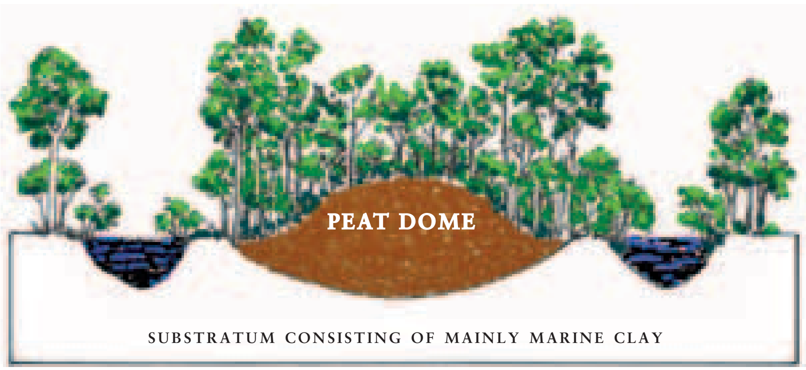

FIGURE 1
Schematic diagram of peat cross-section
(Source: M. J. Silvius, Wetlands International).
NOTE In reality, the slope is gentler.

TABLE 2
Classification of peat (according to depth phases).

CLASS	DEPTH (M)
SHALLOW	0.5 – 1.0
MODERATELY DEEP	1.0 – 3.0
DEEP	> 3.0

In Sarawak, the maximum peat depth of 20.7 m above mean sea level was recorded at Loagan Bunut National Park (Melling *et al.*, 2006) but in Riau, peat dome heights of 25 m have been measured at Pulau Padang (A. v. d. Eelaart, Euroconsult, pers comm.). The central raised part of the peat swamp is almost flat with a rise of less than half a meter per kilometer. This often gives the peat deposit a lenticular cross-section.

Tropical peat has a characteristic dome-shaped topography. Peat depth usually increases towards the centre of the basin. Most peat swamps are generally elevated 4–9 m above adjacent river courses. Surface slopes vary between 1–2 m per km (Melling and Ryusuke, 2002).

See FIGURE 1 opposite for an illustration of a typical peat cross-section.

2.3 PHYSIOCHEMICAL PROPERTIES AND FERTILITY OF DRAINED PEAT

PHYSICAL PROPERTIES

The physical properties of peat are those related to the colour, humification level, loss on ignition, bulk density/porosity and its water holding properties. These are generally summarized by Mohd Tayeb (2005) as follows:

- dark colour generally brown to very dark brown (depending on stage of decomposition);
- high organic matter content (> 65% loss on ignition value) including undecomposed to semi-decomposed woody materials in the forms of stumps, logs, branches and large roots;
- high water table and often inundated under its natural state, thus an anaerobic environment;
- high moisture content and water holding capacity of 15-30 times of their dry weight (Tay, 1969). This leads to high buoyancy and high pore volume leading to low bulk density (about 0.10 g/cm^3) and low soil bearing capacity;
- undergoes oxidation, shrinkage, consolidation and subsidence upon drainage;
- low bulk density (0.10-0.15 g/cm^3) of drained peat, resulting in the high porosity (85-90%) and soft ground condition. The infiltration rate is very high, ranging from 400-500 cm/hr (Lim, 2005a). High leaching of fertilizers is expected during rainy seasons.

CHEMICAL PROPERTIES

The chemical composition of peat is influenced by peat type. The older and thicker the organic horizon, the more impoverished are the surface layers. If the soil is regularly flooded, it has a higher amount of mineral content and is more fertile. The chemical properties of peat are described by Mohd Tayeb (2005) as follows:

- acidic in nature (pH 3-4);
- very low nutrient contents especially K, Cu and Zn;
- very low amounts of exchangeable bases thus having low percentage base saturation;
- high N but locked in the organic matter, thus its availability for plant uptake is rather low. The high C:N ratio coupled with the low pH result in low mineralization in peat (lower decomposition rate); and
- high cation-exchange capacity (CEC) contributed by organic acids such as carboxylic acid, phenolic acid and other organic acids.

The micronutrients Cu, Zn Mn and Fe in peat occur in different concentrations depending on the nature of the peat, its drainage status and its agricultural utilization.

The electrical conductivity values (which measure the salinity of the soil) are generally less than 1 mmhos/cm but may go up to more than 4 mmhos/cm in some areas near to the sea. Values up to 4.7 mmhos/cm have been recorded in Tanjung Karang area near to the coast and influenced by sea water (Ismail, 1984). Water sources with a salinity of more than 4 mmhos/cm is not suitable for oil palm cultivation due to reverse osmosis (Lim *et al.*, 2004).

PEAT FERTILITY

The fertility of drained peat is variable depending on the degree of woodiness, state of decomposition and physiochemical properties. Tropical peat is acidic (pH 3-4): the inherent Mg and Ca contents of peat are very high compared to K. The contents of essential micro-nutrients namely Cu, Zn and B are low (see TABLE 3). The total nitrogen content of drained peat is generally high for the first generation of cultivation on peat. With an organic carbon content of more than 40%, the C/N ratio is also high, affecting N mineralization in peat. The release of N in peat for palm growth is influenced by soil moisture, being more available under moist but not water-logged conditions.

TABLE 3
Generalized chemical properties of surface peat (0-50 cm).

CHEMICAL PROPERTIES	Lim, 2006	Melling *et al.*, 2006
	(Riau, Indonesia)	(Sarawak, Malaysia)
pH	3.7	3.7
Organic C (%)	41.1	45.4
Total N (%)	1.56	1.69
C/N ratio	26.3	26.9
Exch.Ca (cmol/kg)	6.68	0.76
Exch.Mg (cmol/kg)	9.55	1.01
Exch.K (cmol/kg)	0.61	0.19
CEC (cmol/kg)	70.8	41.4
Extr P (mg/kg)	120.0	21.4
Total Cu (mg/kg)	4.1	1.4
Total Zn (mg/kg)	28.0	17.1
Total B (mg/kg)	5.0	1.1
Total Al (mg/kg)	1.35	
Total Fe (mg/kg)	108.8	67.7

In addition to having data from fertilizer response studies, it is useful and pertinent that knowledge on factors influencing the inherent fertility of peat be known when drawing up the fertilizer programme for oil palm on the peat area to be developed. Adequate and balanced application of fertilizer nutrients to oil palm will not only ensure high oil palm productivity but also cost-effectiveness considering the current escalating fertilizer prices and higher manuring cost. Mohd Tayeb (2005) elaborated some factors influencing peat fertility as follows:

- position of area to be developed in the landscape (proximity to mineral soil, land formations, fertility of soils in the surrounding watershed);
- position in the peat swamp (raised central parts of ombrogenous peat swamp usually less fertile);
- nature of subsoil (mineralogy / nutrient content, presence of mineral soil layers, presence of potential acid sulphate soils under the peat layer, and
- degree of decomposition (fibric, hemic, sapric).

2.4 PEAT SUBSIDENCE

Under natural conditions, peat swamps are invariably water-logged with high water tables at or near the surface. To use peatland for oil palm cultivation, controlled drainage is required to remove excess water and lower the water table to a depth required by oil palm under best management practices, which is about 40-60 cm from the peat surface (water level of 50-70 cm in the collection drains).

An important effect of drainage is the subsidence of the peat surface. Subsidence is the result of consolidation, oxidation and shrinkage of the organic materials as a result of drainage. In tropical peatlands, biological oxidation is the main contributor to subsidence (Andriesse, 1988) with estimated long term contributions up to 90% (Stephens *et al.*, 1984; Hooijer *et al.*, 2012). These impacts cannot be stopped as long as the water table is below the peat surface (Tie, 2004). In general, the lower the water table, the faster the subsidence. However, water table depth is not the only control on subsidence as it has long been well known that peat oxidation is also strongly controlled by soil temperature and other factors (Stephens *et al.*, 1984; Andriesse, 1988). Substantial subsidence will therefore continue as peat oxidation cannot be stopped even at the highest water levels utilized in plantations.

The continuous lowering of the peat surface can cause areas that can initially be gravity drained, to become undrainable after several years of lowering the water table. Such areas may be widespread, especially in the coastal lowlands of SE Asia where tectonic movements over the last 8000 years have reduced the elevation of many coastal lowlands (east coast of Sumatra, coastal plains of Sarawak, west coast of West Malaysia) and through sea level rise, causing the base of up to 70% of peat domes to be located now below MWL of rivers and sea. This means that in the long term many oil palm plantations on peat may become prone to flooding and salt water intrusion (Andriesse, 1988). In order to reduce this problem and to postpone the loss of drainability, drainage needs to be minimized or stopped before the area becomes undrainable.

Subsidence also involves GHG emissions. The oxidation process described above as a result of drainage leads to CO_2 emissions of 35 to more than 80 tonnes of CO_2/ha/year (depending on peat type, drainage depth, soil temperature and other factors) and thus removal of the soil carbon resulting in subsidence. Therefore, minimization of drainage is important to reduce GHG emissions. However, even with an optimal drainage of 40-60 cm in the field, oil palm plantations will still have a significant carbon footprint of about 60 tonnes of CO_2/ha/year (derived from Page *et al.*, 2011, Hoojier *et al.*, 2011, Jauhiainen *et al.*, 2012). In general, maintaining a high water level as much as the oil palms can tolerate will help to reduce peat subsidence and CO_2 emissions.

The challenges to cultivating palms in peat soils have been documented by pioneers in this area, specifically United Plantations. In areas of deep peat (e.g. Sarawak, Malaysia) the challenge becomes more acute, while the required attention to good management of subsidence over the entire life-cycle is crucial to extend the life span of the plantation.

The rate of subsidence varies strongly depending on the peat type (stage of decomposition, bulk density and mineral content), drainage depth, rainfall conditions, soil temperature, vegetative cover and land management. The more fibric the peat, with lower bulk density and ash content, the higher the subsidence rate and the less the slowdown in subsidence in the long term. Data from Welch and Mohd Adnan (1989) studying the over-drained Western Johor Integrated Agricultural Development Project on the West coast of Johor, Malaysia revealed that the subsidence rates for 1974-1988 was 4.6 cm per year (see also Wosten *et al.*, 1997). A 17-year study of subsidence at the MPOB Research Station in Sessang, Sarawak (Othman *et al.*, 2009, Mohammed *et al.*, 2009 – See BOX 1 PAGE 30) showed that where BMPs were practiced (with an average water table of around 0.4 m) initial subsidence of 25 cm/year (excluding the period immediately after clearing drainage) reduced to a rate of 4-6 cm per year after 2 years. The subsidence rate over the years declined and stabilized after 15 years after drainage, at rates between 2.5 cm/yr in very shallow peat (less than 1.5 meters originally) and 4.3 cm/yr in deep peat (over 3 meters).

On the basis of comprehensive recent investigations in Sumatra on Acacia and oil palm plantations (at 218 monitoring locations) and literature reviews, Hooijer *et al.* (2012) concluded that an average subsidence rate around 5 cm/year applies to peatlands over 4 meters in depth in SE Asia after the first 5 years of drainage (during which subsidence total around 1.4 meters); this number applies to fibric and hemic peat with low mineral content at water depths around 0.7 meters that currently represent the best management observed in many plantations in Indonesia. In such deep peatlands, hardly any soil maturation is observed after the first 5 years, with bulk densities remaining constant, and no sign of a slowing down in subsidence rate after several decades (see FIGURE 2 PAGE 26).

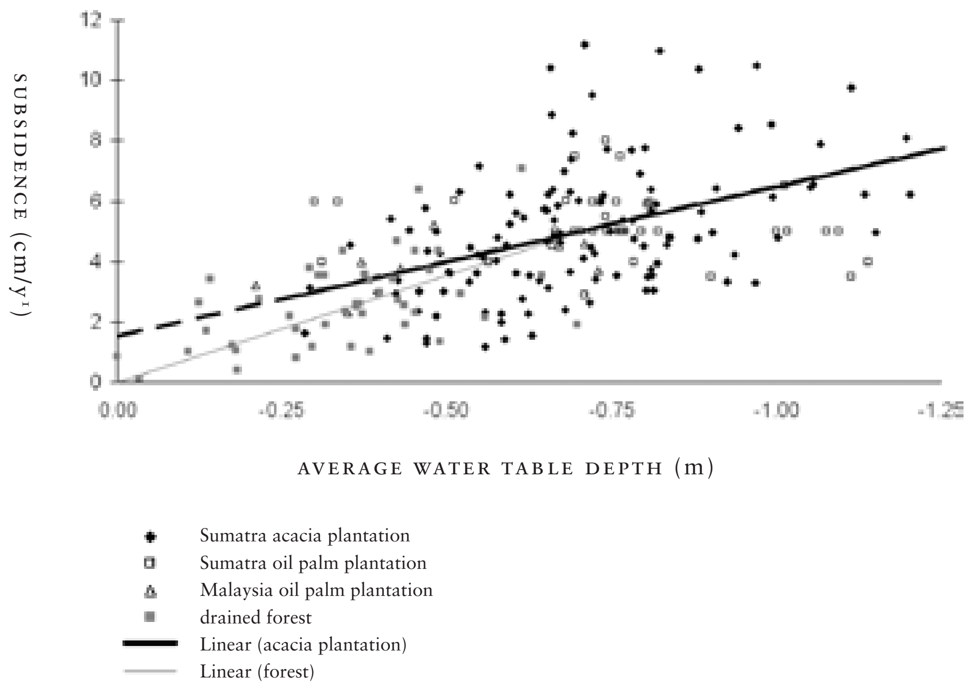

FIGURE 2
Subsidence rates measured at 218 locations over two years in *Acacia* plantations (6 years after initial drainage on average) and oil palm plantations (18 years after initial drainage) on fibric/hemic peat of over 4 meters in depth and with a bulk density below 0.1 g/cm^3 (from Hooijer *et al.*, 2012). The average water table depth as calculated over all locations is 0.7 m below the peat surface. Some measurements are in forest adjoining plantations that are affected by plantation drainage.

The most practical way of minimizing subsidence, once a plantation has been established on peat, is to maintain the water table as high as crop and field requirements permit. This is to enhance the long term cultivation of oil palm plantations on peat. Open burning during land preparation must be avoided as it will cause rapid and uneven subsidence and oxidation of the peat surface. By minimizing the rate of subsidence, the economic life span of a drained peat area can be prolonged for oil palm cultivation. With good management of water levels and compaction, CO_2 emissions and accidental peat fires can also be minimized. However, in the long term, the demise of the drainable peat soil layer is inevitable, and it is thus important – as part of Best Management Practice – to stop the drainage for oil palm cultivation well before undrainable conditions are reached and so minimize further loss or degradation. This is especially important in areas where the drainable peat layer is underlain by potential acid sulphate soil or is below (or may subside to below) the 5-year flood level.

Over-drainage (water table >60 cm from the peat surface or 70 cm in collection drains) will accelerate the rate of subsidence. In addition, burning and drying of the surface in areas with low vegetation cover can lead to irreversible drying of the organic colloids forming hard granules during prolonged dry seasons resulting in a physically and chemically poor growing medium. Maintaining a ground cover of natural vegetation e.g. *Nephrolepis biserrata* or moss will help to keep the surface peat moist and minimize irreversible drying.

MEASUREMENT OF PEAT SUBSIDENCE

The measurement of peat subsidence can be done by installing a vertical hollow iron pipe of about 8 cm external diameter into the peat. It is important to ensure that the subsidence pole is installed firmly into the mineral substratum. This is necessary for a sandy substratum and even more important with a soft clay substratum (entisol), the subsidence pole should be installed as deep as possible in the substratum. In addition, peat soils may shrink and slightly expand in relation to varying water content as a result of dry or wet periods.

An area of 2 m by 2 m around the subsidence pole should be securely fenced up to prevent disturbance that will lead to inaccurate readings. A subsidence pole should be installed at a rate of at least one and preferably two (for control) in each block of an estate (in representative locations). However, more subsidence poles are required to measure subsidence in plantations with varying peat qualities, depths and drainage circumstances. The peat surface level at the time of installation should be marked with non-erodable material.

There may be obstructions when installing the subsidence pole due to existing logs within the peat profile. Therefore, the exact position and depth for installing a subsidence pole has to be ascertained by using an auger to define the depth of the underlying mineral soil.

Readings of peat subsidence should be taken at least once a month. The water level in the collection drain or piezometer at time of reading needs to be recorded as well. It is noted that in a compilation of monthly peat subsidence, it is observed that the reading can be positive instead of negative especially during rainy seasons because the peat may periodically be expanding due to high water content. For this reason, amongst others, only subsidence records of at least 2 years can yield valid information.

FIGURE 3
Example of subsidence pole installed together with a piezometer. Peat subsidence over time in this site is clearly visible.

BOX 1

Case Study – Peat subsidence in shallow, mature (sapric) peat at PT TH Indo Plantations, Riau, Indonesia.

Measurements of peat subsidence in PT TH Indo Plantations started in 2008, about 10 years after drainage and development of the peat area for oil palm cultivation. Measurements of peat subsidence were done using the methodology elaborated above using subsidence poles (see FIGURE 4). The 2008-2010 annual subsidence data are shown in TABLE 4.

TABLE 4
Data of peat subsidence (cm/year) in mature (sapric) peat of 1-3 m depth from 2008 to 2010 at 8 different sites in PT TH Indo Plantations, Riau, Indonesia, with good water management systems.

	2008	2009	2010
SITE 1	0.60	0.48	0.50
SITE 2	1.65	1.40	1.60
SITE 3	1.40	0.60	1.90
SITE 4	0.90	2.00	1.70
SITE 5	2.50	1.30	1.30
SITE 6	0.90	0.10	0.80
SITE 7	0.50	1.45	2.40
SITE 8	0.65	1.00	0.30
AVERAGE	**1.14**	**1.04**	**1.31**

NOTE Water levels ranged between 30 and 75 cm from the peat surface. There may be swelling/shrinkage due to rainfall. Subsidence measurements were also taken 10 years after initial drainage so data does not show initial changes in subsidence, which are usually more drastic.

FIGURE 4
Example of subsidence pole installed in late 2007, 10 years after initial drainage.
NOTE It is advisable for the subsidence pole to be marked with non-erodable material indicating the initial peat surface height.

BOX 2

Case Study – Measurements of peat subsidence extracted from "Experiences in Peat Development for Oil Palm Planting in the MPOB Research Station at Sessang, Sarawak, Malaysia" (Othman *et al.*, 2009).

CHARACTERISTICS OF THE STUDY AREA

The study was carried out at MPOB's peat research station located at Sessang, Sarawak, which has an area totaling 1,000 ha of peatland. The area was previously a secondary forest of mixed peat swamp. Initially the peat depths ranged from 100 to 400 cm, consisting of undecomposed plant biomass (fibric peat material), while the nature of the mineral subsoil below the peat layer was non-sulphidic clay. Between 1990 and 2007, the station received high rainfall averaging 3487 mm annually with occasional dry months. Preliminary work to establish and set up the plantation began in the year 1991. It is important to note that the study area was cleared in 1991, 10 years before the current canal system was implemented in 2001.

PARAMETER MEASUREMENT

Changes in peat characteristics, such as peat depth, degree of peat decomposition, subsidence and bulk density were monitored and recorded over the period of 17 years after peat was drained. Field water table was measured using the lysimeter method, and data were summarized to monthly figures. The average bulk density of the peat was 0.14 g/cm^3 and 0.09 g/cm^3 for shallow and deep peat respectively at the start of plantation development.

2

PEAT SUBSIDENCE

An unavoidable effect of draining peatland for oil palm cultivation is the irreversible ground surface subsidence. Subsidence of drained peat can be divided into three components, namely consolidation, oxidation and shrinkage. The type of peat, degree of composition, depth of water table and ground vegetation are among the factors that influence the rate of subsidence.

The progress of subsidence for peat under oil palm cultivation at the MPOB Research Station, Sessang, is presented in FIGURE 5. Generally, the subsidence rate decreased with each year following land development, resulting in a total subsidence of 96.5 cm over 17 years, or an average of 5.7 cm/yr. A subsidence rate of 29 cm/yr was recorded during the first year of development and was mainly due to mechanical soil compaction using an excavator during the land preparation phase. During the second year after development, the subsidence rate decreased to 17 cm/yr, followed by 5-6 cm/yr over the next period of three to nine years after development. Thereafter, the subsidence rate was recorded at 2-4 cm/yr. The subsidence rate at the study area was relatively lower compared to previous reports and was mainly due to higher water table conditions.

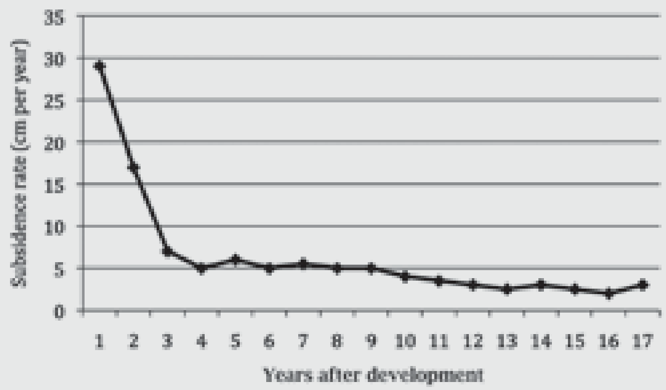

FIGURE 5
Progress of subsidence of the drained peat under oil palm cultivation at the MPOB Research Station, Sessang, Sarawak.

2.5 CONSTRAINTS OF OIL PALM CULTIVATION ON PEATLAND

In its natural state, some peat soils (depending on peat type) are less suitable for oil palm cultivation as it they do not provide adequate anchorage and nutrients for the palms. For improving management of existing plantations, these limitations must be addressed in order to enhance the productivity of the plantation and minimize its environmental impacts. It is relevant that prospective investors be made aware of the main constraints and their consequence to oil palm cultivation on peat (Mohd Tayeb, 2005).

The main constraints in the cultivation oil palm on tropical peat can be summarized as follows:

- Presence of elevated peat dome areas that have tendency of over-drainage, flooded patches that are difficult to drain by gravity and rapidly fluctuating water table pose great challenge to effective water management, which is important for high oil palm yields on peat.

- Peat subsidence upon drainage greatly affects palm anchorage and the economic life span of peat for oil palm cultivation. Continuous subsidence can cause some areas that can initially be gravity drained become undrainable after several years of oil palm cultivation. Intensive water management is needed to minimize the subsidence rate. Deep planting and compaction are required to reduce the palm leaning problem.

- The soft ground condition of peat greatly interferes with mechanization and increases the cost of road and drainage construction/maintenance. The initial cost of development on deep peat is therefore significantly higher compared to that on mineral soils.

- Peat has a low and imbalanced nutrient content. The K is very much lower compared to Mg and Ca content. This has an antagonistic effect on the K uptake by oil palm on peat. There is also problem with trace element fixation especially Cu and Zn, which is significantly influenced by peat type and water availability, being more serious under over-drained situation. Right timing of fertilizer applications to avoid rainy seasons and proper agronomic management are important for optimizing fertilizer-use efficiency on peat.

- The moist and woody nature of deep peat is very conducive for a number of important pests on oil palm especially termites, *Tirathaba* bunch moths and rhinoceros beetles. Weed growth is also more rapid on peat.

See CHAPTER 3.0 PAGE 37 for guidance in the form of BMPs to overcome some of the above constraints of cultivating oil palm on peatland.

3.0 BEST MANAGEMENT PRACTICES (BMPs) OIL PALM CULTIVATION ON PEATLAND

To mitigate the negative impacts of existing oil palm plantations on peat, Best Management Practices (BMPs) should be carried out. BMPs on peat can be defined as practices, which result in minimum GHG emissions and subsidence as well as environmental and social impacts while maintaining a high economic yield. In order for BMPs to be effective, good implementation, monitoring and documentation are essential. Where possible, BMPs should be measured and quantified.

3.1 WATER MANAGEMENT

Effective water management is the key to high oil palm productivity on peat. Good water availability and management is important for healthy palm growth and high yield. Too little or too much water in the palm rooting zone will adversely affect nutrient uptake and FFB production. Most palms' feeder roots are concentrated in the top 50 cm of the peat; therefore this zone must not be water-logged. For this reason, a peat basin must not have conflicting land-use, which requires differential water-levels. It is also important to note that water management is site specific and needs to consider wider implications on surrounding areas as well as to avoid undrainable situations, especially in areas where the mineral subsoil is below Mean Water Levels (MWL).

A good water management system for oil palm on peat is one that can effectively maintain a water-level of 50-70 cm (below the bank in collection drains) or 40-60 cm (groundwater piezometer reading) (see FIGURE 10A PAGE 46). It should be able to remove excess surface and sub-surface water quickly during wet seasons and retain water for as long as possible during dry spells. The moist peat surface at this water level will also help to minimize the risk of accidental peat fire. It is also advisable to cooperate with local communities when implementing a water management system as local knowledge on the subject can be invaluable. While coordinating water level management with local communities is important, it is noted that oil palm plantations should have the in-house proficiency to develop and implement good water management plans that also takes into account impacts on surroundings.

Such good water management can most easily be realized in regions that rarely suffer from prolonged drought periods; during which rainfall deficits occur (i.e. evapotranspiration exceeds rainfall). In drought-prone regions, water levels will necessarily be more variable in time and it can be inevitable for water levels to regularly drop below 0.6 meters below the peat surface. In such conditions, more efforts will be needed to store enough water in the wet season to reduce water table drop in the dry season, than are needed in regions where dry seasons are mild. From FIGURE 7 it is clear that the occurrence of drought is very rare in Sarawak but common in Central Kalimantan and South Sumatra where the rainfall regime is less favourable for maintaining water levels within narrow ranges. Lessons on water management in Sarawak, and of the impacts of below-target water levels, must therefore be modified before they can be applied in many regions in Indonesia where hydrological conditions are very different.

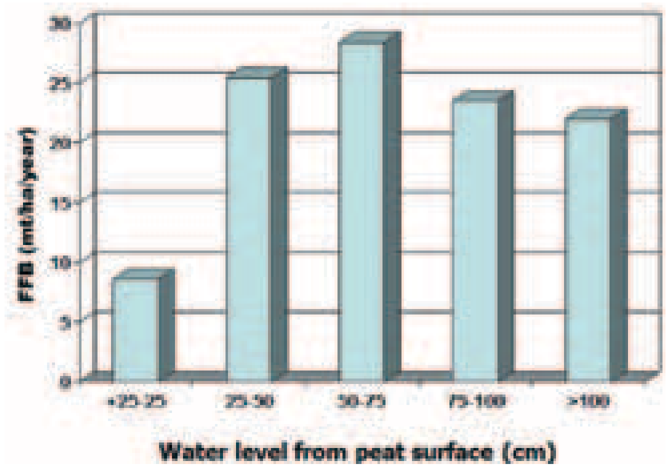

FIGURE 6
FFB yields (1998 planting) in relation to water levels in a peat estate in Riau, Sumatra, Indonesia.

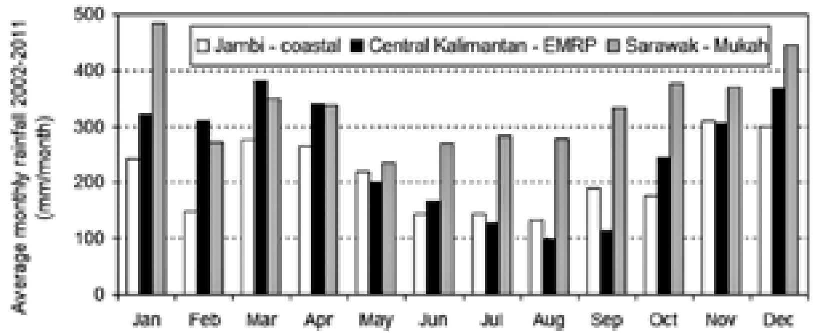

FIGURE 7
Average rainfall regime in three areas in SE Asia with extensive oil palm plantations on peatland, as determined from TRMM satellite data (Vernimmen *et al.*, 2012).

A well planned and executed drainage system with water control structures should be used for drainage and effective water management. Water-gates and/or weirs should be installed at strategic locations along the main and collection drains for effective control of the water table at an optimum level. Automatic flap-gates are usually installed at the main outlets, which are subjected to tidal variations. It is generally not recommended to install permanent water management structures (made of concrete) as subsidence will ruin the system. Use natural materials such as wood or sandbags for constructing weirs/stop-offs.

BOX 3 includes general guidance on drain construction extracted from "Guidelines for the development of a standard operating procedure for oil palm cultivation on peat" by MPOB for oil palm plantations in Malaysia. Experience elsewhere indicates that drainage density may need to be assessed on a site-by-site basis depending on rainfall, maturity of peat and other characteristics.

See FIGURE 8 PAGE 42 for an example of a controlled drainage system.

BOX 3

Guidance on drainage construction by MPOB (2011).

The types and orientation of drains include:
- Field drains – parallel to oil palm planting rows
- Collection drains – parallel to collection roads
- Main drains – perpendicular to collection drains

It is recommended that the density of field drains depends on the oil palm development stage:

Oil palm development stage	No. of oil palm rows between two parallel field drains
Immature (1 to 3 years old)	>8
Young mature (4 to 7 years old)	8
Fully mature (>8 years old)	4

It is recommended to have a shallow drain to get rid of excess water and to keep a high groundwater table.

There are 2 options for drain construction:

1 Placing the main and collection drains along the roadside:
   A. Has an advantage in the maintenance of the drains
   B. Has a disadvantage from a greater peat subsidence rate

2 Placing the drain in between two roads:
   A. Has an advantage in lowering the peat subsidence rate
   B. Has a disadvantage in the maintenance of the drains

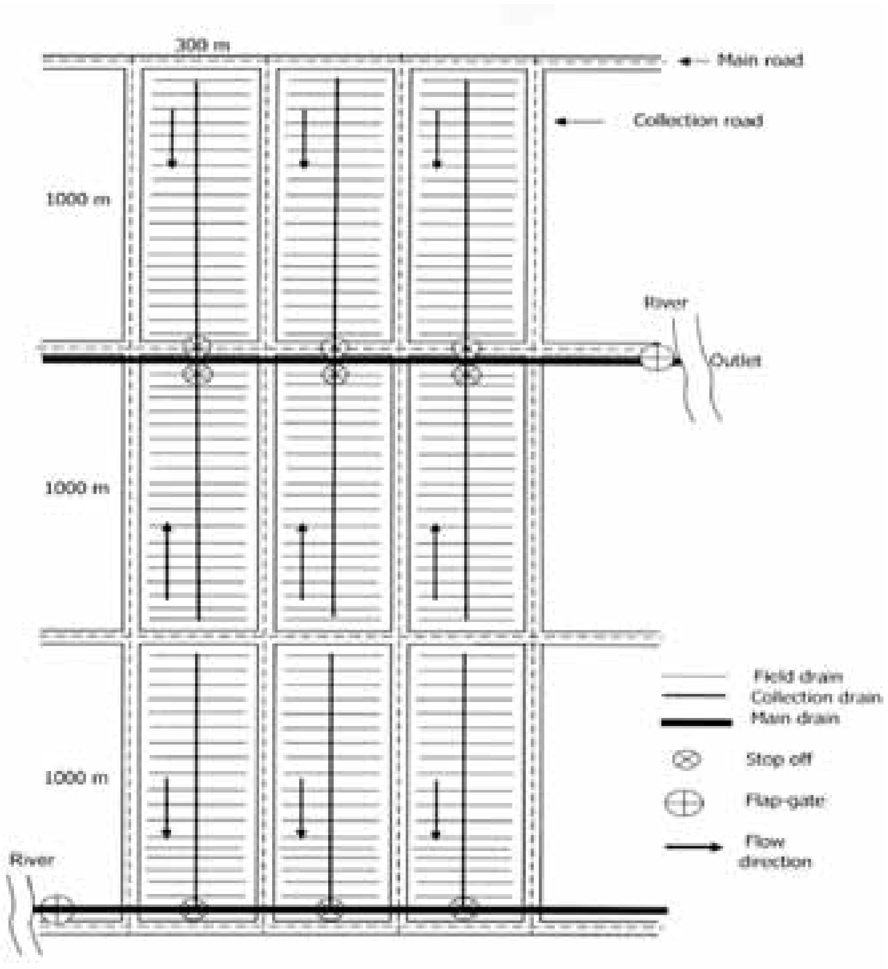

FIGURE 8
Example of controlled drainage system.

MAINTENANCE OF THE DRAINAGE SYSTEM

Drain maintenance must be carried out regularly or when required, to keep the drainage system working properly. Poor maintenance of the drainage system can be a cause of flooding in peat estates although it is often a consequence of subsidence relative to the surrounding landscape. Desilting of drains to required depths is best carried out prior to the rainy season. However, care needs to be taken to avoid cutting drains too deep in peat areas.

CONSTRUCTION AND MAINTENANCE OF BUNDS

Bunds are important protective structures in coastal areas to prevent the inflow of excess or saline water into the fields. Suitable bunding materials are loamy or clayey soils but these are often difficult to obtain in most peat areas. Clay soils used should not have sulphaquent pt potential acid sulphate soil (PASS) properties (see BOX 5 PAGE 98) as leaching of the acid from acid sulphate soils can have serious environmental impacts.

Bunds need to be checked and reinforced regularly especially before rainy seasons. This is to minimize bund breakage that will result in flooding and crop losses.

UTILIZATION OF WATER MANAGEMENT MAPS

For more effective supervision and timely actions, each peat estate should have a detailed water management map indicating the directions of water flow, flood-prone fields, locations of water-gates, stop-offs, water-level gauges, bunds, etc.

For higher efficiency in water management, it is important to have water management maps for the both dry and wet seasons. These maps should be calibrated every few years in relation to possible impacts on waterflow from subsidence. It should be noted that higher water levels (e.g. <40 cm from peat surface) may reduce yields but would reduce GHG emissions and subsidence as well as increase the lifespan of a plantation that could over time reach an undrainable situation or an acid sulphate soil.

MANAGEMENT OF WATER LEVELS

The optimum water level for high oil palm yield on peat is 50-70 cm (in collection drain) and 40-60 cm (groundwater piezometer reading) from the surface (see FIGURES 10A PAGE 46). Again, it is important to note that higher water levels would reduce GHG emissions and subsidence. However, if the water table is too high, fertilizer input will also go directly into the groundwater instead of being taken up by the oil palms. A flooded field will also hinder all estate operations and add to methane/nitrogen oxide emissions so that situation should be avoided (see FIGURE 11 PAGE 48)

FIGURE 9
Keeping the water level as high as possible reduces subsidence and risk of fire and maintains yield. High water levels also facilitate use of canals for transport.

FIGURE 10A
Optimal water level management at 50-70 cm (in collection drain) results in a yield potential of 25-30 mt FFB/ha/yr. It is important to ensure that this water level is present in all collection drains.

FIGURE 10B
Over-drainage in main drain in a peat dome area during dry seasons may result in high CO_2 emissions and subsidence rates as well as significantly reduced yields.

FIGURE 11
A flooded field will also hinder all estate operations and add to methane/nitrogen oxide emissions.

FIGURE 12
An example of a water control structure.

Weirs or water control structures with over-flows should be installed at strategic locations along the main and collection drains to achieve this water-level.

FIGURE 13
One weir installed at every 20 cm drop in water level to enable water retention along collection drains.

The number of weirs will depend on the topography. They are best installed at every 20 cm drop in elevation. Soil bags and logs can be used to construct such weirs.

FIGURE 14
Water level gauge for water level monitoring in collection drain.

Water-levels in peat can fluctuate rapidly especially during rainy or dry seasons. It is therefore important to carry out regular water level monitoring. This can be done by installing numbered water level gauges at strategic locations and at the entrances of collection drains behind each stop-off. Ensure that the level is set at zero on the planted peat surface. Negative values indicate water levels below the peat surface and positive values indicate flood levels. Readings are to be taken daily to monitor changes in water level in relation to rainfall. When the water level in a collection drain is less than 25 cm from the peat surface, take action for drainage and if it is lower than 65 cm from the peat surface, take action for water retention.

FIGURE 15
Example of piezometer for measuring groundwater levels.

To enable more precise water level control, a piezometer can be installed in the middle of each estate block. Normally the water level in the piezometer is about 10 cm higher than the water level in the collection drains.

It will be useful to have a full-time water management officer supported by a water management team in each peat estate for effective and timely control of water at optimum level. This person would also be responsible for operating the water-gates, regular checking of bund condition and inspection of water control structures for damage, blockages, etc.

The following is a case study detailing Sime Darby's experience with water management in their estates in Indonesia (see BOX 4 PAGE 58).

BOX 4

Case Study – Water Management Study PT Bhumireksa Nusa Sejati, Sumatera, Indonesia

INTRODUCTION

PT Bhumireksa Nusa Sejati (PT BNS) is a 25,000 hectares oil palm plantation in Sg. Guntung, Sumatera which is owned by Kumpulan Guthrie Berhad (now Sime Darby Bhd). The plantation is divided into five (5) estates: Teluk Bakau Estate (TBE), Nusa Lestari Estate (NLE), Nusa Perkasa Estate (NPE), Mandah Estate (MDE) and Rotan Semelur Estate (RSE). The entire area is peat and is networked by a grid of dual-purpose man-made canals as a mode of transportation and irrigation. Water input into these canals (which is at the northern-most point) comes from the tidal Guntung River. Effects of the tides on the water level in the canals are apparent up to about 6 km inland. As a result, in areas not affected by the tide, the water levels in canals vary significantly between dry and monsoon seasons. This is due to water being gained and lost through precipitation and evaporation respectively. Past experience revealed that inland canals ran dry and were non-navigable during dry seasons. However, during the monsoon season, the heavy rainfall caused these canals to flood. Such unfavorable conditions affected yields of the crop as well as logistics.

Thus a hydrology and water management study was commissioned in Bhumireksa Nusa Sejati in 2005/6. The objective of the study was to evaluate the hydrologic and hydraulic characteristics of the project area in relation to water navigation system of the existing canal. The study involved mainly field and hydrographic survey and investigation that include field data compilation and interpretation and hydraulic modeling exercise.

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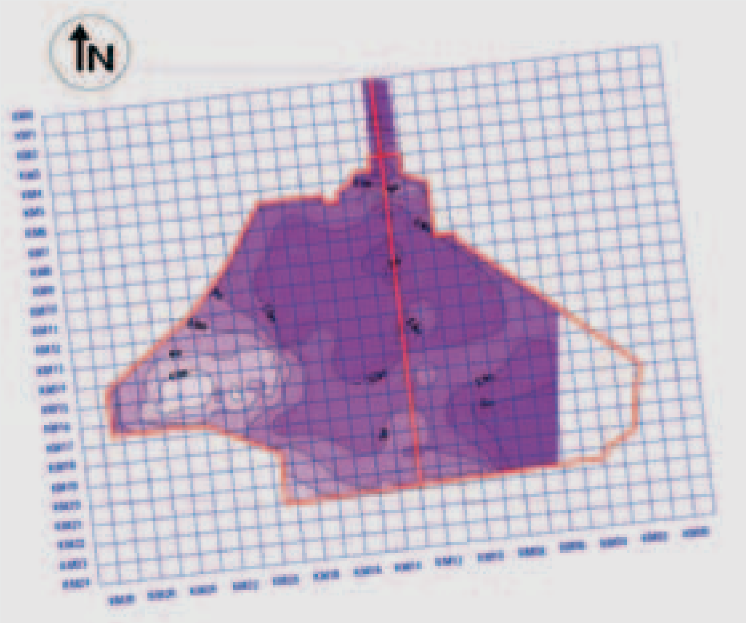
The major findings of the study were categorized under 3 issues:

A. Topography and peat depth configuration
B. Water and water balance analysis
C. Field demarcation system and canal water level control

AIM OF STUDY

The aim was to study and propose a water management system of the area to meet the followings conditions:

A. The depth of water level in the canals should be maintained so as to allow movements of vessels irrespective of the season.
B. The water table of the entire area should be maintained at 60-75 cm below the ground surface, as desired by the oil palm trees. [NOTE Current best management practice is to maintain water levels at 50-70 cm]
C. The water management system (water level control in the canals and water table control in the field) system should not cause saltwater intrusion into the area.



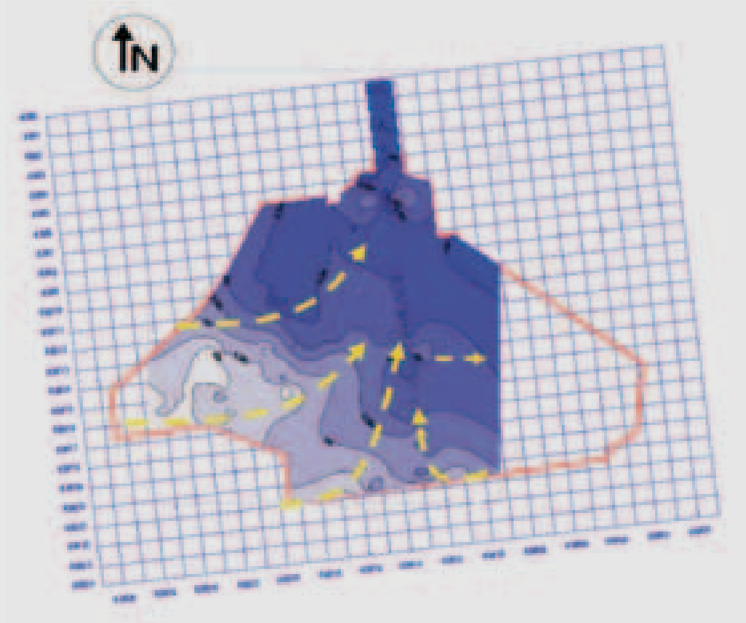


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FIGURE 16
Topography (above) and potential drain flows (above right) of project area.

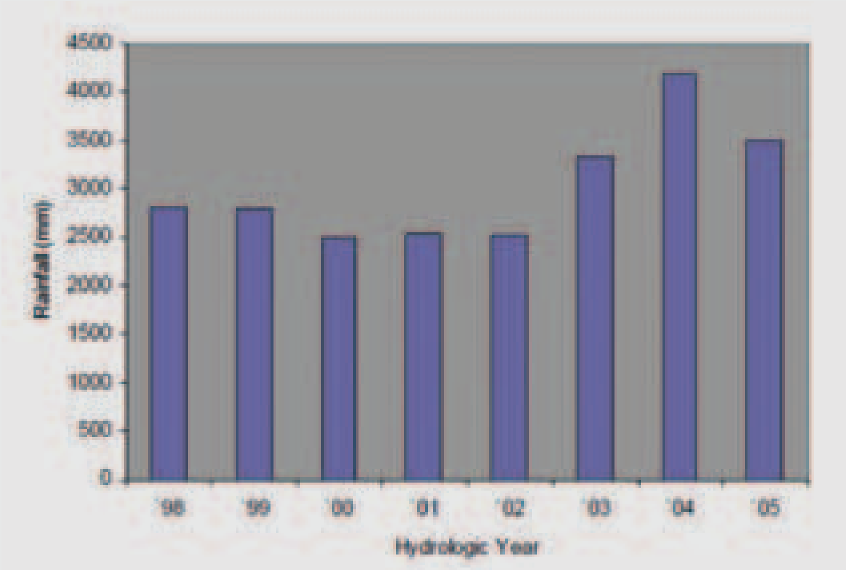
FINDINGS OF THE STUDY

Primary field data was collected between JULY and OCTOBER 2006. Data included topography of the areas adjacent to the canals, bathymetry, peat depths, canal flow and water quality. Topography and bathymetry were determined using Global Positioning Satellite (GPS) and echo-sounding equipments. Peat depths were measured at fifty points along the navigable canals using a standard peat auger. Standard river gauging procedures were used to determine water flow in the canals. Continuous water levels were also monitored using automatic loggers. Rainfall and water table data were obtained from the estate managers. Modeling of the observed data was performed using the HEC-RAS software.

The study area was relatively flat, with a difference of 2.5 m in elevation. Based on the norm water demand of oil palm trees and run-off parameters, hydrology analysis pertaining to water balance indicated that there was surplus when considering free flow in the canal without any obstruction. Two distinct flow conditions were observed along the canals. The discharge at the main outlet is 15 m^3/s during wet seasons and 3 m^3/s during dry seasons.

The topography of the project area was relatively flat with the potential drain flows shown above (FIGURE 16).

The annual rainfall pattern (1998-2005) and mean rainfall monthly pattern of the area studied are shown with FIGURE 17 PAGE 62.



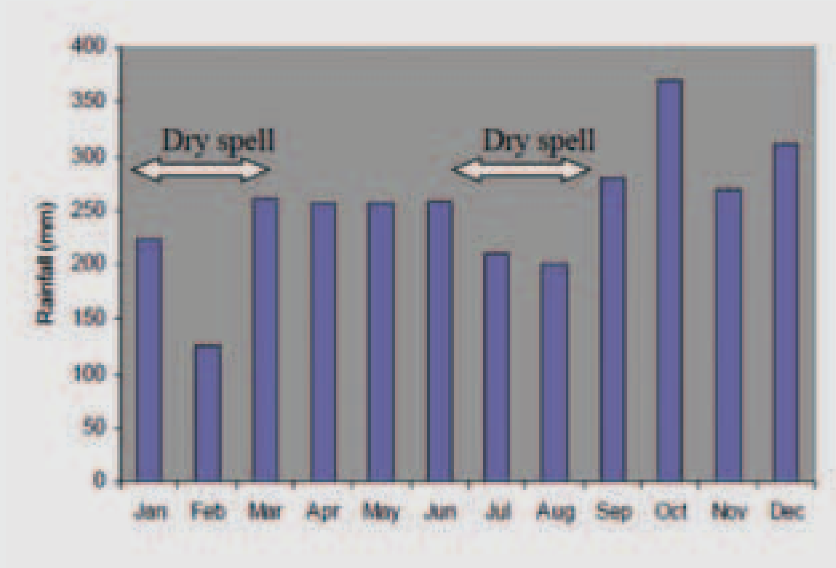


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FIGURE 17
Annual rainfall pattern (L) and mean rainfall monthly pattern (R) of the area studied.

Recommendations:

The demarcation of the area studied was based on three (3) options, namely, A, B and C. These options were adopted based on discussions with management. They included demarcation of the area into suitable sub-divisions, maintaining some of the existing structures and putting in place new water structures.

Considering the various topographic and hydraulic aspects of the area studied aided with computer modeling, the field layout in OPTION A (see FIGURE 18 PAGE 64) was the best to be adopted. Full implementation of OPTION A would achieve the following objectives.

- The water level in the entire canal (both main and secondary canals) is sufficient to ensure navigability throughout the year
- The water level of the ground surface is between 50 and 70 cm, i.e. an optimum condition for plant growth
- The possibility of flood occurring during heavy rainfall is minimal

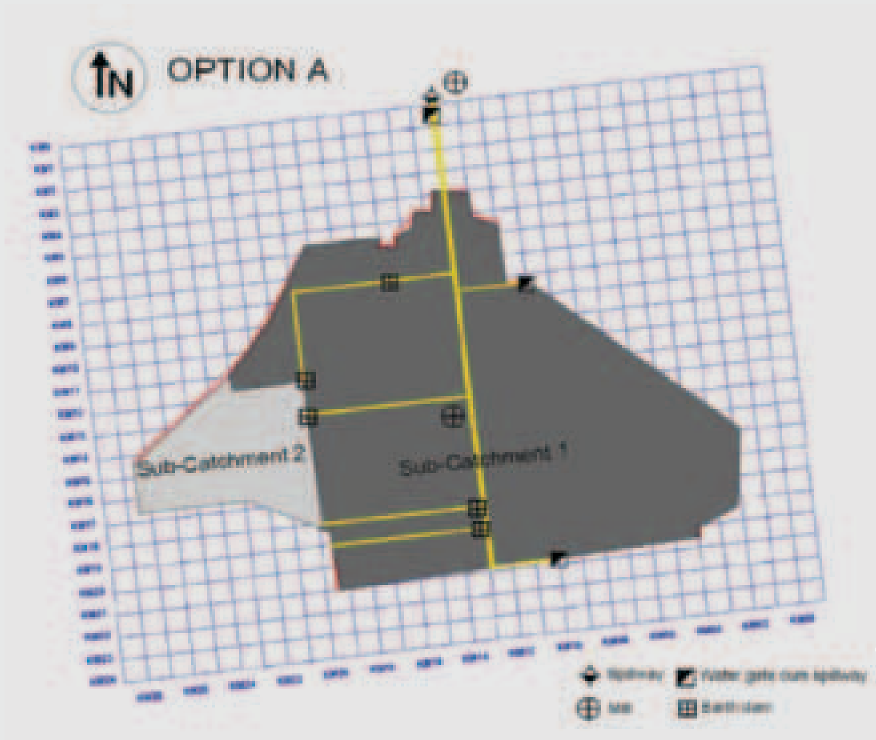

FIGURE 18
OPTION A field layout.

Nevertheless, it should also be noted that, while objectives (a) and (c) were highly achievable, objective (b) was subjected to the undulation of the ground surface.

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After due considerations of present conditions and existing water management practices OPTION A was recommended. When this option was in place, the water level in the entire canal (both main and secondary canals) was sufficient to ensure navigability throughout the year. At the same time, water level of the ground surface was between 50 and 70 cm, which is optimum for plant growth. Furthermore, the installation of the proposed scheme also alleviates flooding woes to the majority of the area. As with any design or schemes, flaws or weaknesses were inevitable and must be highlighted so that adequate and proper measures can be made or planned. Three significant weaknesses were anticipated. First, isolated topographically low lying areas could be flooded during the wet season, thus, additional flood protection bunds was required. Second, the collapse of hydraulic structures on peat soil is a common phenomenon, simply due to the settlement of soil and erosion. Hence, a continuous monitoring on the hydraulic structures with potential eroding areas must be carried out to alleviate this problem. Furthermore, effort should also be made to reduce canal flow velocity upon entering the spillway gate so as to reduce the erosive forces. Finally, since the water level in the whole proposed system is highly dependent on the water level at the spillway crest, a series of continuous water level monitoring stations (preferably equipped with data loggers) was established to record continuous water levels.

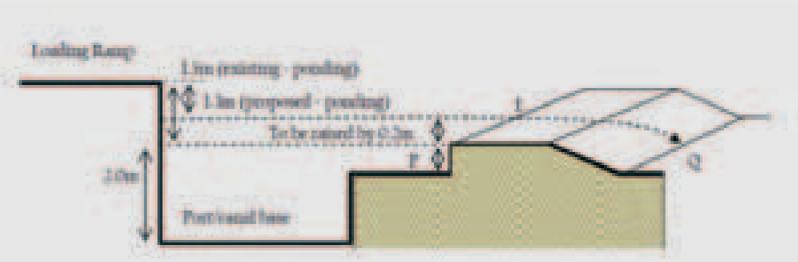

FIGURE 19
Alteration made to existing spillway crest (increasing the height to reduce over drainage).

CONCLUSION

A water management study was carried out at PT BNS. Appropriate and relevant primary field data was collected and acquired. From the three proposed options, OPTION A was recommended based on present conditions and water management practices. Full implementation of the proposed option would mean that the water level in the canals can be maintained at a level navigable by vessels. Furthermore, the proposed option also resulted in the water table of the entire area to be maintained at a level desired by the oil palm trees. With the aid of existing structures, construction of proposed water control structures also ensures that saltwater intrusion is kept at bay.

3.2 FERTILIZER AND NUTRIENT MANAGEMENT

Next to water management, adequate and balanced fertilization is vital for high productivity of oil palm on peat. Due to the high porosity and infiltration rate of peat, minimizing fertilizer leaching is vital for cost efficiency. This is especially important in areas with high and frequent rainfalls e.g. in Sarawak with 3000-5500 mm and 180-220 rain days per year. Under such circumstances, strict timing of fertilizer delivery and application to avoid high rainfall periods is important especially when applying B and K fertilizers, which are easily leachable in peat. In view of the escalating fertilizer prices, it is useful to maximize nutrient recycling especially through pruned fronds by placing them between the palms, just outside the palm circles. Wider use of bio-fertilizers especially those developed from the by-products of palm oil mills such decanter solid and composted empty fruit bunches is encouraged.

Peat is a decomposing medium with changing available nutrient content especially nitrogen, which is generally high in first generation peat. However due to the very high organic carbon content (>40%), the C/N ratio is high and this slows down mineralization rate. For relatively young plantings, the response to N is generally good (Manjit *et al.*, 2004). The mineralization and release of N in peat is also influenced by soil moisture, being more available under good moisture regime. The N fertilization on peat therefore needs to be well regulated with the K inputs, to avoid N/K imbalance problems such as the white-stripe symptom, which will affect FFB yield (Lim, 2005A). The emission of nitrous oxide, which is an aggressive greenhouse gas, on fertilized peatlands especially under wet conditions, is a significant GHG impact of oil palm plantations on peat. It is important to note that excessively high N inputs (more N provided than the plants will absorb) will lead to undesirable high nitrous oxide emissions. This can be avoided through better fertilizer management.

It is important to note that plantation companies with large scale planting of oil palm on peat are encouraged to carry out fertilizer trials to determine site-specific fertilizer requirements for their peat types and environmental conditions. Care should be taken to avoid over-application of fertilizers and season of application (i.e. rainy or dry weather) should be taken into consideration. A prescriptive range of fertilizer recommendations and leaf analyses are encouraged for smallholders and larger plantations respectively.

FERTILIZATION OF IMMATURE PALMS ON PEAT

The use of controlled fertilizer at time of planting is helpful in areas with labour shortage and to reduce leaching losses. Application of 300 g controlled release fertilizer (e.g. 17:8:9:3) and 500 g Rock Phosphate (RP)in the planting hole at time of planting, followed by surface application of 2.5 kg limestone dust on the palm circle gives healthy palm growth for about 10-11 months.

Liming of acidic peat at a rate of 2.5 kg of limestone dust per palm per year is best applied just outside the palm circles only during the first two years of planting to avoid excessive build-up of Ca, which may antagonize K uptake.

FERTILIZATION OF MATURE PALMS ON PEAT

When the palms come into maturity, fertilizer recommendation is based on leaf analysis done annually and trial results.

The K_2O:N ratio of fertilizers normally has to increase progressively from about 3.0 in the second year of planting to about 4.5 when the palms come into full maturity. Early results from a nutritional trial on peat in Riau indicated that application of K without N fertilizer gave lower FFB yield. High K rates (> 6 kg MOP/palm/year) have been shown to decrease oil to bunch ratio and also depress both Mg and B uptakes and will therefore affect yields (Mohd Hashim and Mohd Tarmizi, 2006).

The response to P on peat is usually not significant. Low input of about 0.5 kg Rock Phosphate (RP) per year is normally sufficient to maintain optimum leaf P status. High rates of RP application (>1.0 kg/palm/year) are not recommended as it was reported to reduce Cu and Zn uptake (Mohd Tayeb, 1999).

Straight fertilizers (Urea, MOP, RP, Borate, $CuSO_4$ and $ZnSO_4$) are normally used for mature palms (Lim, 2005A). High K inputs (4 to 6 kg MOP/palm/year), over 2-3 split-applications are needed for high yields on peat (Gurmit Singh, 1999 and Manjit *et al.*, 2004). It is important to time fertilizer applications during the drier seasons, to minimize losses due to leaching and periodic high water tables. The wider use of coated Urea to reduce volatilization losses and N_2O emission will be useful.

To ensure the qualities of delivered fertilizers are according to specifications, it is good practice to carry out samplings of delivered fertilizers for laboratory analysis of actual nutrient contents before field applications. Due to the importance of fertilizers for high yields and escalating fertilizer prices, it is essential to purchase them from reliable suppliers.

The availability of Cu and Zn is problematic in peat due to fixation by humic acid, fulvic acids and polyphenolic compounds present in peat.

The common symptoms of Cu deficiency is yellowish-orange discoloration of the lower fronds, reduced vegetative growth, smaller bunches and in severe cases, mid-crown chlorosis and premature desiccation of the lower fronds. This is especially severe during dry seasons and over-drainage conditions on high ground. For young palms on high ground suffering from severe Cu deficiency, fortnightly spraying of $CuSO_4$ solution at 15 g per 18 liters of water can be carried out until the new fronds turn green.

Lower frond desiccation may also be due to poor root development caused by presence of old tree stumps within the surface peat that interfere with adequate uptake of applied nutrients

Zn deficiency expressed as general yellowing of the canopy (peat yellow) is normally found on high ground with poor water management. For severe cases on young palms, fortnightly foliar spraying with $ZnSO_4$ at 80 g per 18 liters water is beneficial.

Borate application (80-120 g/palm/year) is especially important in the early stage of production. Inadequate borate will lead to leaf deformation symptoms (such as hooked leaf, blind leaf, crinkled leaf and shortening of the young fronds giving a flat top appearance), affecting light interception and photosynthesis. Inflorescence and bunch formation will be affected resulting in significant yield decline.

Due to the long carry distance on peat estates, good supervision is important to ensure that the first to the last palm get the same quantity of recommended fertilizers.

During times of low palm oil prices, if fertilizer cut-back is inevitable due to economic reason, it is better to reduce the rate per round rather than cutting down the number of application rounds per year. It is important to maintain a good balance of essential nutrients at all times. In this respect, timely fertilizer delivery and applications are important.

In periodically flooded fields with fluctuating water tables, application of Urea and MOP mixture in perforated plastic bags to simulate a slow release effect was able to reduce losses (Lim *et al.*, 2003). At 2 bags per palm placed at about 2 m from the palm base, this fertilizer protection technique was able to regulate fertilizer release for about 4-5 months. Supervision on the evenness of application using this fertilizer protection technique is more effective.

Tropical peat by nature is acidic (pH 3-4). With continuous application of fertilizers with acidic reaction especially MOP (KCl), the pH of the applied zone can dropped to below 3.5. Such low pH will invariably affect root development and availability of major macro-nutrients (N and K) and micro-nutrients (Cu, Zn and B) to oil palms.

Where available, bunch ash at 6 kg/palm/year applied on the outer zone of the palm circle, will be very beneficial for mature areas as it is a good source of K and can also significantly improve soil pH.

Application of empty fruit bunches (EFB) between the palm circles at 250 kg per palm per year in single layer, is beneficial. In a trial at Riau, EFB mulching increased pH of the surface peat from 3.2 to 5.4 and the soil exch. K from 0.20 to 8.38 cmol/kg (Lim, 2005A). EFB mulching may be considered in peat estates with good transportation and in-field distribution systems.

3.3 INTEGRATED PEST AND DISEASE MANAGEMENT

With planting of oil palms on large contiguous areas of peat, a number of pests have adapted themselves to the woody and moist environment. If not properly controlled, pest outbreaks can occur, resulting in economic losses due to reduction in yield and stand. Considerable costs and management inputs will be required to control these pests during outbreak situations. In essence, oil palms on peat and mineral soils encounter the same set of pests but on peatland, pests arrive at earlier stages and outbreaks occur more frequently so implementing regular monitoring/census and early warning/indicator systems are key.

To be cost-effective and environment-friendly in the control of major pests, Integrated Pest Management (IPM) on peat should be adopted (Lim, 2005B). IPM is defined as a pest management system that utilizes suitable techniques in a compatible manner and maintains the pest population at levels below those causing economic injury and crop losses. Good understanding of pest biology and ecology is needed in making the correct choice of physical, cultural, chemical and biological control methods. It is important to look for weaknesses in pest life cycles for targeting control.

In IPM, the amount of chemicals is reduced, to minimize the impact on beneficial and non-target organisms. Chemical treatments are only carried out by using selective pesticides at low rates and timely applications to ensure minimum impact on the biodiversity and environment. The key success factor in IPM is early detection by regular census and speedy treatment. In this respect, all peat estates should have permanent pest census teams. With effective implementation of IPM, expenditures on pest control on deep peat can be greatly reduced.

TERMITE CONTROL

Termites are a very important pest of oil palms planted on peat, causing death to numerous palms if not properly controlled. There are many species of termites found on peat. Most of termites are carrying out beneficial ecological functions of breaking down dead woody materials and converting them into organic matter while releasing nutrients to the palms. However, one species, *Coptotermes curvignathus* has been identified to attack oil palms planted on peat. Termites attack palms as early as seven to eight months after planting and infestations of immature plantings could reach 8-9 per cent with 3-5 per cent dead palms per year if not quickly treated (Lim and Silek, 2001). On mature areas, more than 50% of the palms can be killed by termites before age 10 years if not properly controlled. Negligence in termite control can lead to failure in a peat planting.

Palms infested by termites are characterized by the presence of fresh mudwork on the crown region and palm trunk, which are relatively easy to detect. The termites can be seen clearly when the mudwork is scraped off. The soldier termites of this species are very aggressive and bite fiercely when touched while simultaneously secreting a milky fluid.

Based on visual observations, the severity of termite attacks on palms can be classified into 3 stages namely:

INITIAL STAGE Presence of fresh mudwork on the frond bases, inflorescences, developing bunches and spear. At this stage, the spear and upper fronds are still green.

INTERMEDIATE STAGE Discoloration of the spear and the upper 2-3 young fronds turn to yellowish brown.

ADVANCED STAGE The spear and upper 3-4 fronds start to dry up, turning brownish. The spear becomes rotten and gradually collapses.

The termites attack the palms from the spear region downwards. This explains why termites build mudwork up the spear region. Termites kill palms in less than 2 months, by consuming the apical meristematic tissue. Infestation will spread to one or more neighbouring palms. The distribution pattern is clustered. New infestation spots indicate that termites also spread by swarming.

For effective termite control on oil palms planted on peat, an early warning system with monthly census on every palm (100 % census) and speedy treatment is recommended.

The recommended chemical for termite control is fipronil (5.0 % a.i.) at 2.5 ml product per 5 liters of water. Application volumes of the above recommended chemical solution:

Palms > 1 year – 5.0 liter/palm

Palms < 1 year – 2.5 liter/palm

Half the solution is to be sprayed using a knapsack sprayer on the basal region of the spear and crown while the other half is to be sprayed around the bole of the infested palm as a barrier. Where the mudwork is thick, slightly scrape it before spraying. The mudwork on the infested palms gradually dry up when the termites are killed. Application is to be repeated upon detection of reinfestation.

Delayed treatment will result in death of the infested palm, when the meristematic region is consumed by the termites. Optimum application of fipronil is important as over-application may agitate the termites and cause swarming and wider infestations.

Trials on termite baiting using hexaflumuron baits applied on the mudwork of infested palms seem promising but at the moment it is not cost-effective (Lim and Silek, 2001).

TIRATHABA BUNCH MOTH CONTROL

The bunch moth (*Tirathaba mundella*) is becoming one of the most important pests on oil palms planted on peat both in Indonesia and Sarawak. Poor sanitation, especially presence of unharvested rotten bunches on the palms and weedy field conditions, enhance infestations. More severe infestations are generally found on palms approaching maturity and young mature palms of 3 to 5 years. On tall palms > 5 m, infestations are normally lower.

The life-cycle of the pest is short, about 30 days (egg stage 4 days, larval stage 16 days and pupal stage 10 days), therefore spread is fast. The caterpillar of the last instar is about 2-3 cm and dark shiny brown to blackish in color. Once the caterpillars have infested a palm, female and male inflorescences and bunches at various stages of development are attacked. Normally the distal ends of fruitlets are eaten and about 5-10 % of the kernel can also be consumed. Average bunch weight is greatly reduced. Under serious attacks, bunches will not develop fully and may abort prematurely.

The caterpillars are active at night and are seldom seen during the day. Infested bunches are recognized by the non-glossy appearance and covered with frass (faeces) (see FIGURE 20). The faeces when fresh are moist and reddish brown in color and when old are brownish black and dry. The *Tirathaba* bunch moth can be effectively controlled using the Integrated Pest Management approach. Early detection, regular census, speedy treatment (when required) and sanitation measures are important to prevent outbreak situations. Tirathaba bunch moths may be regulated by natural predators, especially earwigs (*Chelisoches moris*) and *Kerengga* ants.

FIGURE 20
Tirathaba infestation on an oil palm showing fruit bunch covered with frass.

Oil palms on peat start to produce uneconomical bunches as early as 12 months after field planting. If these early small bunches are left unharvested, they become breeding sites for the moths. It is therefore important to carry out ablation from 12 to 18 months at monthly intervals and remove any rotten bunches to minimize proliferation of the pest (Lim, 2011). This practice is also useful to divert nutrients for better vegetative growth and give higher early yields.

For effective control of the *Tirathaba* bunch moth, early detection and regular census are important. Early detection of *Tirathaba* bunch moth damage is normally obtained by observing harvested bunches on FFB platforms during routine grading. When the infested bunches on the FFB platforms in a block is more than 5%, systematic census on 10% of palm population in the block (all palms in every 10^{TH} row) is carried out by a team of trained Pest and Disease (P&D) workers.

An infested bunch is identified by its non-glossy appearance and covered with frass (faeces) compared to a healthy one, which is shiny. Census must be carried out on the percentage of palms with symptoms of infestation and on the percentage of infested bunches on each infested palm. Three categories of infestation are as follows:

Categories of infestation	% palms infested	% bunches with infested symptoms	spray method
CATEGORY 1 – LOW	> 5-25	> 5-25	SELECTIVE
CATEGORY 2 – MODERATE	> 25-50	> 25-50	SELECTIVE
CATEGORY 3 – HIGH	> 50	> 50	BLANKET

Before spraying, all rotten bunches are to be harvested first. Ensure pruning is up-to-date as under-pruning will interfere with the effectiveness of spraying. During spraying, avoid spraying on the frond bases as this will reduce efficiency.

For palms less than 3 m in height, a 15 liter knapsack sprayer is used. For taller palms (> 3 m), use knapsack sprayers with an extended lance. Where there are scattered supplied palms with infested bunches, workers are to use separate 2-litre hand-sprayers for spraying the shorter palms.

For CATEGORY 1 and 2, spot spray infested palms and bunches selectively with *Bacillus thuringiensis (Bt)* at 1 g product/liter of water at 2-weekly intervals. Use relatively clean water with low suspended dirt. Avoid using old product stocks more than 1 year old. Target spraying on developing bunches and female flowers that have damage symptoms. Avoid spraying during rainy days. If it rains heavily after spraying, a repeated spray on the next day is required.

For CATEGORY 3, blanket spray all palms and bunches as above. Carry out sanitation of all badly infested and rotten bunches prior to spraying.

Good sanitation practices on mature palms are also important as an integral part of *Tirathaba* bunch moth management. All rotten aborted bunches and badly infested bunches on the palms, which attract the bunch moths, should be harvested and taken out of the field and left on road sides to desiccate. Weedy field conditions should be avoided. Negligence in carrying out regular census and speedy control of this pest can result in substantial crop losses.

The spraying of cypermethrin on infested bunches should be strongly discouraged as it will affect the population of the pollinating weevils and natural enemies such as earwigs (*Chelisoches moris*) that predate on the young *Tirathaba* caterpillars.

MANAGEMENT OF LEAF-EATING CATERPILLARS

Under normal conditions, leaf-eating insects are kept under control by natural enemies such as predators (e.g. predatory wasps), parasitoids, parasites, fungal and viral pathogens. Under conditions when natural control is inadequate, outbreaks can happen. Palms of all ages are susceptible to attack by leaf eating caterpillars, especially mature palms more than 5 years old when overlapping fronds speed up the spreading of caterpillars from palm to palm.

If the outbreaks are not kept under control, leaf eating caterpillars can cause severe defoliation. Defoliation during the mature phase has significant impacts on yield (Liau and Ahmad, 1995). For eight year old palms, crop losses of 50 per cent defoliation were estimated at about 30-40%. In another study on mature palms, moderate defoliation by bagworm (*Metisa plana*) resulted in crop losses of 33-40% (Basri, 1995).

These caterpillars feed through the lamina and cause holes on the leaves. These are easily noticed when viewed against a clear sky. In severe infestations, only the midribs are left and the fronds appear to be skeletonized.

The main species of leaf-eating caterpillars are:

- BAGWORMS – *Mahasena corbetti*, *Metisa planaa* and *Pteroma pendula*. They are called bagworms because they cover themselves with casings made of leaf tissues.
- NETTLE CATERPILLARS – *Darna trima*, *Setora nitens* and *Setothosea asigna*.
- HAIRY CATERPILLARS – *Dasychira spp*. and *Amathusia phidippus*.

Outbreaks of leaf-eating caterpillar infestations are monitored in 3 stages namely:

- Alert (early recognition of infestation signs is important as the pests can spread quickly, especially in mature areas).
- Identification of species involved and stages of development.
- Census to determine if the pest population levels have reached threshold values for chemical control.

Start census when symptoms such as feeding holes on leaves, presence of caterpillars are noticed beyond normal situations. Census palms at 1% (1 row in 10, 1 palm in 10) at 2-weekly intervals. The frond of each census palm is to be taken from the middle of the crown.

Threshold numbers for treatment:

- 10 per frond for smaller species e.g. *Metisa plana* and *Darna trima*.
- 5 per frond for larger species e.g. *Mahasena corbetti*.

Chemical treatment for control of leaf eating caterpillars to be carried out only when census figures are above threshold numbers (Lim, 2005B).

For young palms (1-6 years), spray 0.005% cypermethrin with knapsack sprayers at fortnightly intervals on the infested canopy until new infestations clear off. When mist-blowers are used, the concentration is increased to 0.01 %.

Ensure all the palms in an infested block are treated to minimize reinfestations. It is often necessary to first spray a buffer zone of 5-10 palms on the perimeter of the infested block to minimize spread to neighbouring uninfested blocks.

It will also be useful to coordinate with neighboring estates on treatment if they are also infested by this pest. For tall palms >8 years, trunk injection using monocrotophos, methamidophos or acephate is recommended. The hole is drilled using a power drill at 45° on the lower trunk (about 80 cm from the ground) with a diameter of 1.25 cm and depth of 15 cm. Plug the hole with a mud ball after introducing the chemical with a syringe.

Ensure all the palms in an infested block are treated to minimize reinfestation. Each injection lasts for about 4 weeks.

Post treatment censuses are needed to ensure that the pest is effectively controlled.

It will be useful to plant beneficial plants (especially *Cassia cobanensis*) on the road sides for biological control (see FIGURE 21). *Cassia cobanensis* establishes well on peat under non flooded condition. It grows into a bush of about 1 m height and start flowering and podding about 3-4 months after field planting. It can be propagated easily from seeds or cuttings for large scale planting. *Cassia cobanensis* produces nectar from flowers and leaf stipules throughout the year and is therefore effective in attracting predators and parasitoids for biological control of leaf-eating caterpillars especially bagworms.

Alternative hosts of bagworms e.g. *Acacia mangium* should not be planted in peat estates. Clean-clear weeding that reduces the population of natural enemies (predators and parasitoids) of leaf-eating caterpillars should be avoided as it may lead to outbreaks of nettle caterpillars and bagworms.

FIGURE 21
Planting *Cassia cobanensis* to attract natural enemies for biological control of leaf-eating caterpillars.
INSET Close-up of *Cassia cobanensis* flower.

RAT CONTROL

Rats are important vertebrate pests in oil palm plantations on peat. They cause damage in both mature and immature plantings. On mature palms, rats feed on loose fruits and developing fruit bunches. They also attack the inflorescences. Crop losses due to rat damage were estimated at 7-10% if not properly controlled (Liau, 1994).

For immature palms, rats chew on palm bases and consume the meristematic tissue, killing them in advanced cases. Rats also attack oil palm seedlings in nurseries, causing severe retardation or death to the seedlings.

Regular censuses on a block-by-block basis and baiting without delay (when required) are the key to successful rat control in oil palm plantations (Chung and Sim, 1994). This is because rats with access to good nutrition sources in oil palm plantations reproduce very rapidly.

The 3 main species of rats causing economic damage are:

- *Rattus tiomanicus* (Wood rat, white belly)
- *Rattus argentiventer* (Paddy field rat, grayish belly)
- *Rattus rattus diardii* (House rat, brown belly)

It is useful to carry out regular censuses based on fresh rat damage on palms or harvested bunches. For young palms, censuses should be carried out monthly in high infestation areas when their bases show signs of being chewed by rats.

Normally censuses are done on 10% palms (all palms in every 10TH row). For peat estates, ensure that palm rows beside stacked rows are equally censused as rats take shelter under the stacked rows. For young plantings on peat areas, monthly rat damage censuses on every palm (100 %) can be done together with monthly termite censuses.

Start baiting using anticoagulant baits when census results show more than 5 % fresh damage. Examples of first generation anticoagulants are warfarin and chlorophacinone and second generation anticoagulants are brodifacoum, bromadiolone and flocoumafen.

In new areas, start with 1ST generation baits as they are cheaper and safer for rat predators e.g. barn owls. Commence baiting block by block with date properly recorded. For the first campaign, start with 100 % baiting (1 bait/palm). Place bait at about 1 m from the palm base or between frond butts if weedy. Applied baits must be visible to be able to count the acceptance. Application of baits is to be timed after a harvesting round (if possible) to avoid the applied baits from being accidentally removed during loose fruit collection.

Replace taken baits at 4-5 day intervals (as it takes about 6-12 days to kill rats after consuming the poison). Stop baiting when acceptance (replacement) declines to below 20%. When bait acceptance is good but fresh damages continue, rat resistance to the 1st generation baits is suspected. In this case, switch to 2ND generation baits.

When the applied baits are not accepted, bait shyness is suspected. Bait shyness is due to poor ingredients in the baits, which are not attractive to the rats. It can also be due to poor bait quality due to long storage.

During baiting as a safety measure, workers coming in contact with rat baits should wear gloves. Cotton gloves are adequate. They must be washed regularly and destroyed by burning after the baiting campaign. To prevent misuse, gloves should only be issued to workers in the morning before baiting commences and collected back after the day's work for safe keeping.

All bait packaging materials such as plastic wrappers, wax papers and paper cartons, should be destroyed. Rat baits are perishable and must be handled with care during transport and storage. Poor handling e.g. sitting on the cartons or throwing them off vehicles may result in breaking up of baits into loose forms. Extreme heat will affect wax binding. Rat baits should not be stored for more than 6 months due to decline in quality and rat acceptance to the baits.

Where possible, use of barn owls (*Tyto alba*) for biological control can be practiced. In the use of barn owls for biological control of rats, nest boxes are provided at 1 unit per 5 to 10 hectares to encourage build-up of the owl population (Duckett and Karuppiah, 1990; Ho and Teh, 1997). However, it is unlikely that the owls will keep the rat population under control indefinitely. As such, intervention via baiting will still be necessary from time to time.

MANAGEMENT OF RHINOCEROS BEETLE

The rhinoceros beetle (*Oryctes rhinoceros*) is an important insect pest of immature oil palms on peat. The beetles breed in rotting woody materials where the grubs feed and develop in. In the Riau area, rhinoceros beetles in peat areas are often migratory from the nearby coconut plantations.

The use of aggregating pheromone integrated with chemical spraying is an effective IPM tool for monitoring and controlling rhinoceros beetles in immature and young mature oil palm fields.

The adult beetles feed on the basal region of spears and meristematic tissue. This causes symptoms such as new frond snapping, fan-shaped cut fronds, and dieback of spear and bore holes on the frond bases. If control measures are not applied quickly on immature palms, repeated attacks will lead to palm death, arising from direct damage to the meristematic tissue. Monthly census is important for newly planted palms in areas with high rhinoceros beetle population. On mature palms, severe attacks will result in reduction of leaf area and subsequently lead to pronounced male cycle and lower yields.

At low pest levels, carbofuran (3%) or carbosulphan (5%) may be applied to the spear region and base of new fronds at monthly intervals. Alternatively pheromone traps can be installed at every 200 m along canals, main drains, collection drains or roadsides of affected blocks. The height of trap needs to be about 1 m from the top of the oil palm canopy.

When the number of beetles trapped exceeds 10 beetles/ trap/ week, 2-weekly spraying of 0.06 % cypermethrin to the spears and new frond bases is recommended. It is important to ensure adequate wetting of the spear region, estimated about 200 ml solution per palm.

Effective control of beetles must also involve control of the potential breeding sites. Mechanical chipping and pulverization of trunk chips during replanting (Ho and Teh, 2004) is beneficial in reducing breeding sites. Palm oil mills should not store large heaps of EFB for too long. This is to ensure that the grubs will not go through their life cycle (about 5-6 months) to become adult beetles.

The use of biological control agents (*Baculovirus* and *Metarrhizium anisophiliae*) has been tested. Beetles captured using pheromone traps can be utilised for dissemination of the biological agent.

GANODERMA MANAGEMENT

Stem Rot caused by *Ganoderma boninense* and *Ganoderma zonatum* is a major disease of oil palm planted on peat (see FIGURE 22). On first generation oil palm from logged-over forests, normally *Ganoderma* infections are rare during the first 6-7 years after planting. Thereafter, disease incidence will increase especially in areas with low water levels >75 cm from the peat surface (Lim and Udin, 2010). The pattern of disease distribution by enlarging patches indicates that the disease is spread mainly by root contact from primary disease focal points or inoculum sources. The role of basidiospores in disease initiation and spread is still unclear (Hoong, 2007).

FIGURE 22
Basal Stem Rot (BSR) caused by *Ganoderma* infections.
INSET Close-up of *Ganoderma* fungi.

Appearance of fruiting bodies (basidiomata) and lesion cavities are usually seen on the exposed roots or basal region of infected palms, generally referred as Basal Stem Rot or BSR. However about 20-30% of the infected palms showed fruiting bodies and lesion cavities on the middle region of the palm trunks, termed as Middle Stem Rot or MSR.

There is currently no effective cure for *Ganoderma* infections in an existing stand. Preventive and ameliorative treatments, which are commonly carried out, showed various degrees of effectiveness. The use of a mycorrhizal products were tested on newly planted palms on deep peat, applied at 500 gm/point in the planting hole but its effect on controlling the disease is not conclusive (Lim, 2002). Trunk injection of infected mature palms using fungicide hexaconozole was reported to prolong life of *Ganoderma* infected palms (Idris, 2004). However its long term control is not conclusive.

Three to six monthly censuses of *Ganoderma* infections are recommended. For efficiency, estate workers like loose-fruit collectors and sprayers can be integrated to do these censuses. Infected palms should be quickly isolated using a 4 m by 4 m by 75 cm deep isolation trench around the infected palm (see FIGURE 23 PAGE 88). This is to minimize the spread to neighbouring healthy palms (Lim and Udin, 2010). It is recommended to use the soil from the trenches for mounding the base of the infected palm as the practice had been reported to prolong the productive life of the *Ganoderma* infected palm (Lim *et al.*, 1993; Ho and Khairuddin, 1997).

FIGURE 23
Isolation of *Ganoderma* infected palm using 4 m by 4 m by 75 cm deep isolation trench.

The strategy of more frequent censuses and speedy isolation of early infected palms is to keep *Ganoderma* infection levels to less than 15% till the end of the 20-25 year palm cycle on peat. At this infection level, the economic impact on FFB yield is minimal (Flood *et al.*, 2002). This is due to the compensatory effect of the remaining palms getting more sunlight.

On peat areas, it is important to maintain a water level of 50-75 cm from the peat surface to minimize *Ganoderma* infections and spread of this deadly disease on oil palms planted on peat.

During replanting, it will be useful to excavate the infected bole and root tissues as a sanitation measure. The sanitation pit should be at least 2 m by 2 m by 1 m deep. Planting of legume cover crops is not recommended as legume roots are known to harbor *Ganoderma* fungi. When the legume cover creeps to surrounding healthy palms, it may enhance spreading of this devastating disease.

More research to develop effective early detection methods utilizing molecular and electronic technologies is needed for more effective management of this deadly disease. Selection, breeding and cloning of high yielding *Ganoderma* tolerant palms for planting in susceptible peat areas or for supplying to diseased vacant patches in existing infected fields are an important research area.

3.4 WEED MANAGEMENT

The moist environment in peat favors luxuriant growth of weeds especially in areas of high rainfall such as in Sarawak (3,000-5,500 mm/year). However newly drained peat is relatively weed-free for about 6 months after land preparation.

With zero-burning, most of the early weed species are indigenous, mainly ferns (especially *Nephrolepis biserrata*, *Stenochlaena palustris, Dicranopteris linearis*), sedges (e.g. *Fimbristylis acuminata, Cyperus rotundus*) and woody species (e.g. *Uncaria spp., Macaranga spp., Melastoma malabathricum*) (Lim, 2003). Subsequently, other species are brought in by agricultural activities, road materials, wind and water e.g. *Mikania micrantha, Merremia spp., Mimosa pudica, Asystasia intrusa, Digitaria spp., Ischaemum muticum, Imperata cylindrica, Eleusine indica,* etc.

Uncaria spp. or "pancingan" is a fast spreading woody creeper in many peat estates. Slashing will lead to more rapid proliferation. If not properly managed, this noxious weed can cover an entire estate within a short time. The control is by searching for the basal main stems and brushing them with Garlon:Diesel (1:19).

High water table (less than 25 cm from the peat surface) and periodic flooding should be minimized as such conditions expedite proliferation of several weed species on peat especially *Uncaria spp.*.

Timely spraying of noxious weeds with selective herbicides to promote the growth of desirable ground cover is advocated to minimize the weed succession problem. The strategy is to keep the palm circles clean and interrows devoid of noxious weeds (especially *Lalang, Mikania micrantha, Ischaemum muticum,* etc.).

It is important to carry out weed control without delay on the harvesting paths and palm circles of 2.5 m radius, to ensure good accessibility and crop recovery especially loose fruit collection. Choice of spray equipment and herbicides must be based on cost-effectiveness and labour productivity as well as safety to workers and minimal impact to the environment. Herbicides that are quick acting and do not destroy the root system of soft weeds should be used. *Fimbristylis acuminata* with extensive surface root system is either encouraged or planted on peat roads to reduce erosion and peat degradation (Lim, 2002).

Clean-clear weeding that reduces the population of natural enemies (predators and parasitoids) against leaf-eating caterpillars should be avoided as it may lead to outbreaks of nettle caterpillars and bagworms.

In situation of zero-burning, woody growths especially on the stacked rows are problematic to control. Woody growths on the interrows can be controlled by brushing with Garlon:Diesel (1:19) on a 30 cm band on the basal stems. Flattening of stacked rows overgrown with woody growth can be done mechanically using a tracked excavator (e.g. Hitachi EX 200), followed by 1-2 rounds of herbicide spraying. Mechanical weed control is useful to enlarge the palm circles beside the stacked rows and for facilitating harvesting, pollination and reduction of the rat breeding sites.

Due to the fast weed growth in peat areas, any delay or neglect in weed control will lead to rapid deterioration of field conditions, especially in immature areas. Six to nine rounds of weeding per year are recommended for immature peat plantations (compared to 4-5 rounds for oil palm plantations on mineral soils). Weedy fields, especially palm circles, will lower the efficiency of important agro-management practices like harvesting, FFB evacuation, manuring, pest control and supervision.

3.5 LEANING AND FALLEN PALMS

Palm leaning is one of the major problems of planting oil palms on tropical peat (see FIGURE 24). Random leaning and in severe cases, fallen palms, are due mainly to peat subsidence. The low bulk density of peat (0.10-0.15 gm/cm^3 and the less extensive root system of oil palm planted in peat are also contributory factors to leaning and fallen palms. About 40-50% of the palms planted on peat can lean at various angles and directions at the age of about 7-8 years. The number of fallen palms increases thereafter due mainly to excessive root exposure, desiccation and breakage caused by the weight of the palms. Depending on the severity of leaning and fallen palms, a yield reduction of 10-30% can occur due to root damage and poorer interception of sunlight for photosynthesis. Different directions and degrees of palm leaning also interfere with harvesting due to differential palm height.

A practical approach to rehabilitate leaning and fallen palms is to carry out soil mounding to minimize root desiccation and promote new root development (see FIGURE 25). The soil for mounding the exposed roots of leaning palms should be taken from outside the palm circles in order to prevent damage to the surface feeder roots (Lim and Herry, 2010).

For severely leaning and rehabilitated fallen palms, it is important to have 2 palm circles; one for applications of fertilizers and one for harvesting and collection of harvested bunches and loose fruits.

Good water management to maintain the water level at 50-70 cm (from water level in collection drains) or 40-60 cm (groundwater piezometer reading) is crucial to minimize peat subsidence and reduce palm leaning.

FIGURE 24
Palm leaning caused mainly by peat subsidence.

FIGURE 25
Rehabilitated leaning palm after 2 years of soil mounding carried out on exposed roots.

3.6 REPLANTING PRACTICES

Replanting is normally carried after 20-25 years when yield is below economic level. However accelerated replanting may be required due to illegitimate planting materials or low productive stands caused by *Ganoderma* infections. Yield of second generation palms on peat is generally better than in the first generation palms as peat is more compact and better decomposed (Xaviar *et al.*, 2004).

ASSESSMENTS PRIOR TO REPLANTING

Assessments should be made prior to any replanting to estimate the potential benefits and costs including a drainability assessment to identify any issues relating to presence of shallow peat layers underlain with unsuitable/problem soils such as potential acid sulphate soils (see BOX 5 PAGE 98 and FIGURE 29 PAGE 101), sandy soils, etc. A key aspect of such assessments would be to identify and avoid replanting on those areas that are less productive and currently flood prone or will later be subject to flooding from the surrounding landscape. The assessment should assess the potential lifespan of the plantation in relation to subsidence impacts and future potential uses. Such assessments should involve proper hydrological and soil investigations as well as modeling of subsidence and potential flooding impacts. FIGURE 26 shows the measured and predicted long term subsidence rates over a 50-year period for SE Asia and USA. It also shows that long term subsidence of up to 4-5 m is possible especially for immature (fibric) peatlands.

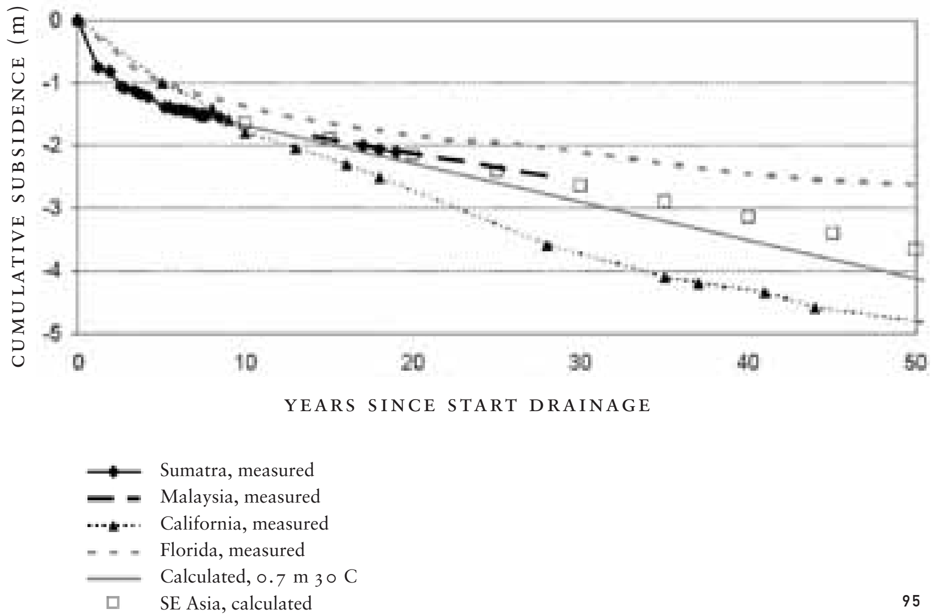

FIGURE 26
Average subsidence rates as measured at a larger number of drained peatland locations in Sumatra (Hooijer *et al.*, 2012), Malaysia (from Wosten *et al.*, 1997, based on DID Malaysia, 1996), Mildred Island in the California Sacramento Delta (Deverel and Leighton, 2010) and Florida Everglades. Also shown are long term calculated subsidence rates for SE Asia, applying both the relation determined for Florida Everglades (Stephens *et al.*, 1984), assuming water depth of 0.7 m and an average temperature of 30°C, and the relation found for SE Asia in Hooijer *et al.* (2012) (Source: Hooijer *et al.*, 2012).

ASSESSING THE DRAINAGE POTENTIAL

The drainage potential of the ombrogenous peat soils depends on gravity drainage towards the adjoining rivers. A minimal water level slope in the drainage system is required of about 20 cm/km canal length to enable sufficient drainage potential. Through continued subsidence peatlands may lose their potential for gravity drainage. Pump drainage is not an option for tropical peat soils as the costs for pumping of excess water are too high in tropical rain forest climates. Measurements of the actual topographical levels, including the depth to the mineral subsoil, are required to determine the drainage potential (van den Eelaart, 2005). These measurements should include the topographical levels of the water levels in the adjoining river during the peak of the wet season. Using modeling (Duflow) the drainage canal lay-out and its connection to the adjoining river, the actual drainage potential can be determined. The modeling should be created for the different land uses and its required groundwater level and should use the hydrological measurements and the expected daily rainfall, during the rainy season. Because the actual drainage potential might not be sustainable for the future, the Duflow modeling should be repeated based on the expected subsidence of the peat layers at respectively 10 years, 20 years and 40 years after reclamation. This Duflow modeling will provide the best estimates for the sustainability of the present or proposed land use on the ombrogenous peat domes.

Marginal drainable peat areas can be located using field data supplemented with Duflow modelling (van den Eelaart, 2005). To identify marginal drainable areas and to separate them from areas without drainage problems three land qualities are proposed to use for this purpose: 1) the assessment of the Potential Drainage Depth (for definition; see opposite), 2) the assessment of the Tidal Range and 3) the Mean Water Level. The latter two hydrological/ land qualities should be determined during the wet season in the adjoining river.

Areas without drainage problems will have a positive Potential Drainage Depth combined with a Tidal Range of more than 2.5 m in the adjoining river. Ombrogenous peat domes with a tidal range of less than 2.5 m in the adjoining river are considered marginal drainable areas that may have drainage problems for oil palm.

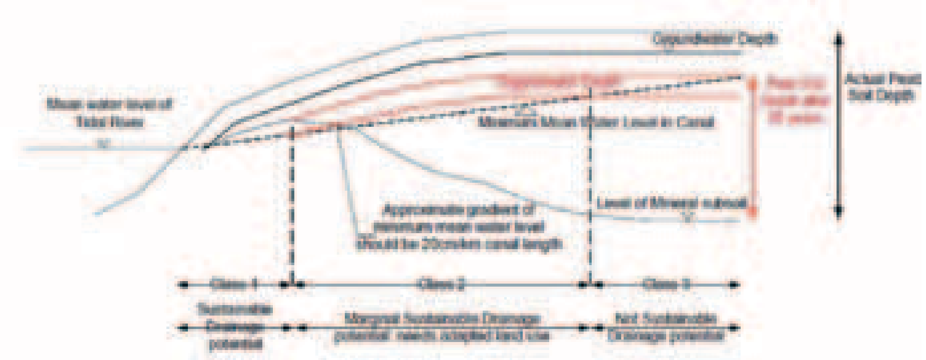

FIGURE 27
Example of assessment to determine drainability of peat soil after one plantation cycle (Source: van den Eelaart, 2005).

BOX 5

Problematic acid sulphate soils.

Acid sulphate soil (ASS) is the common name given to soils and sediments containing iron sulphides, the most common being pyrite. When exposed to air due to drainage or disturbance, these soils produce sulphuric acid, often releasing toxic quantities of iron, aluminium and heavy metals. They commonly occur in coastal wetlands as layers of recently deposited (within the past 10,000 years) mud and sand deposits especially in mangrove systems and are formed only in waterlogged conditions. A significant portion of coastal peatlands are underlain with such soils.

When ASS are exposed to air (that is, no longer in a waterlogged anaerobic state), the iron sulphides in the soil react with oxygen and water to produce a variety of iron compounds (including the yellow jarosite) and sulphuric acid. These compounds are detrimental to the environment. The generated acid also leads to the release of soluble forms of aluminium, which can then move into groundwater, drains and water bodies and has a negative impact on plants and aquatic life.

ASS are not always a problem. Under the anaerobic reducing conditions maintained by permanent groundwater, the iron sulfides are stable and the surrounding soil pH is often weakly acid to weakly alkaline. Such soils are called potential acid sulphate soils (PASS) as they have potential to produce sulphuric acid when disturbed or exposed to air. When PASS are disturbed or exposed to oxygen, the iron sulfides are oxidized to sulfuric acid and the soil becomes strongly acidic (usually below pH 4). These soils are then called actual acid sulfate soils (AASS) (that is, they are already acidic).

Acid sulphate soils are estimated to cover an area of about 2.2 million ha in Malaysia and Indonesia (Attanandana and Vachharotayan, 1986). In cases the potential acid sulphate soil is overlain with peat and the peat is drained and developed for an oil palm plantation – it is critical that the drainage ditches are not dug too deep or cut into the acid sulphate layer. If the acid sulphate layer below the peat is drained then the acidity will increase and toxic metals will be released. It is for this reason that the Indonesian Government through a ministerial decree in 2009 banned the development of oil palm on peat underlain by acid sulphate soils (see ANNEX 7 PAGE 201).

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For existing plantations on peat, which are underlain with potential acid sulphate soils, it is very important that only shallow drainage ditches are developed and they do not penetrate the acid sulphate layer. Over time the peat layer will be gradually lost due to oxidation and compaction and therefore by the end of the first or second generation the acid sulphate layer may be close to the surface. In such cases it is strongly recommended not to continue with the plantation – or to drain the area further – as in addition to the reduction in oil palm yield on the area affected, the acid and toxic runoff from the acid sulphate areas may contaminate other areas.

Experience from oil palm plantations cultivated on acid sulphate soils show that a drop in pH to below 3.0 is not uncommon and the oil palms will suffer hyperacidity symptoms and poor yields, with yield falling as low as 5 tonnes FFB/ha/yr.

Hew and Khoo (1970) found that liming was generally ineffective to control acidity in acid sulphate soils. Poon and Bloomfield (1977) then showed that by creating anaerobic conditions through high water tables - generation of acidity can be limited. Since inadequate drainage will give rise to flooded conditions which also adversely affect palm performance, a balance has to be struck between over and under drainage.

The prime requirement in the management of acid sulphate soils is that the water table should be maintained above the pyritic layer for as long as possible. This is again carried out using stops, weirs and watergates, their numbers are largely determined by the depth to pyriritic layer and slope of the land. Normally, the water table should maintained at between 45 to 60 cm from the soil surface, hence, the depth of field drains should not exceed 75 cm. Otherwise, there is a risk of accelerated oxidation of the pyritic layer during dry weather conditions (Poon, 1983).

Another important aspect in the management of shallow acid sulphate soils is to provide for periodic flushing of the drains to remove the accumulated toxic polyvalent ions such as Al^{3+} and the extremely acidic water (Poon, 1983). Therefore, during the wet season, all the water retention blocks and watergates are opened to allow flushing. One to two flushings during the wet season are usually adequate. Before the end of the wet season, the blocks and watergates are again closed to allow fresh water to build up to the required level.

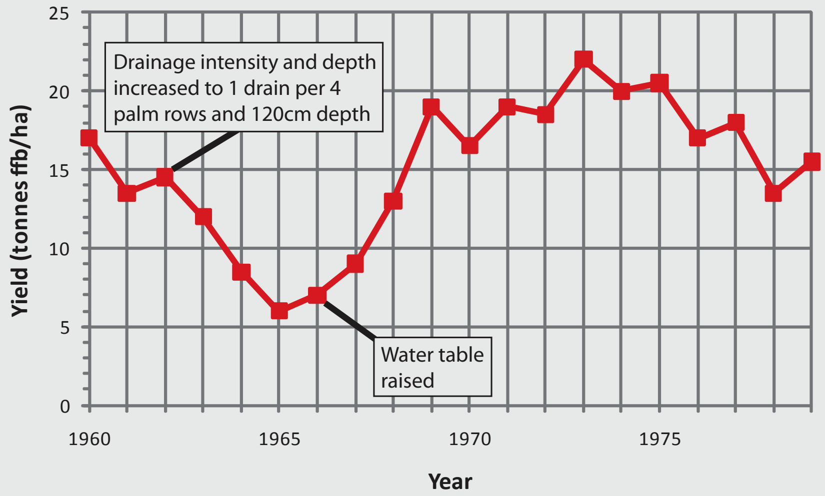

FIGURE 28
Effect of increased drainage and subsequent drainage of water table on yields of oil palm on severe acid sulphate soils (Source: Toh and Poon, 1982).

5

FIGURE 29
Acid sulphate soils.
INSET Pointing out trademark yellow markings of acid sulphate soils.

REPLANTING APPROACHES

If the assessment determines that the area is suitable for replanting, and replanting is done at the same planting density as before, the basic drainage system can be used and replanting cost will be lower. If additional drainage and water management structures are required, it is best to plan it before replanting.

During replanting, it is important to chip the trunks of the old stand to about 10 cm thick and heap them on the stacked rows at every 4 palm rows. This is to speed up decomposition to minimize breeding of the rhinoceros beetles. More importantly, is to excavate the palm boles and root tissue of *Ganoderma* infected palms. The size of the excavation needs to be 2 m by 2 m by 1 m deep. The infected palm boles and root tissues are cut into small pieces and placed on top of the stacked rows to desiccate in order to destroy the infective potential. The excavated cavities need to be filled by the spoil from the digging of collection drains, leveled and compacted.

The usual legume cover crop establishment on mineral soils may not be necessary on peat but there are still benefits of doing so. Establishing legume cover crops on infertile, very acidic peat soils can be challenging. It is recommended to maintain a natural cover of soft vegetation and mosses to conserve soil moisture (see FIGURE 30).

Using present planting materials – a density of 160 palms per ha on medium to deep peat is recommended, with 148/ha on shallow peat (MPOB, 2011).

REPLANTING – DEEP PLANTING AND COMPACTION

Pre-planting mechanical surface compaction and deep planting of seedlings (about 15 cm below the solid peat surface) are also important to minimize palm leaning and fallen palms (see FIGURES 31, 32 and 33 PAGE 103 TO 105). Good soil compaction is reported to reduce GHG emissions from peat (Witjaksana, 2011) as it increases capillary capacity and thus soil moisture content. Prevention of leaning by, for example compaction, will thus result in improved yield and reduced emissions.

FIGURE 30
To maintain soil moisture, it is recommended to maintain a natural cover of soft vegetation on the palm interrows.

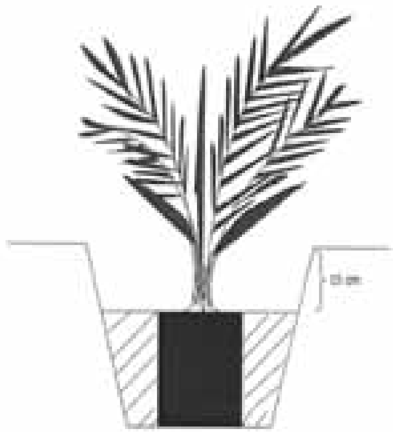

FIGURE 31
An illustration of deep planting on solid peat surface.

NOTE The seedling bole needs to be 15 cm below the compacted peat surface after planting. It is also important to ensure that the base of the planting hole be leveled and compacted by the worker before putting in the seedling for planting. To facilitate deep planting, useful to lower the water level in the collection drains to about 90 cm from the peat surface. About 1 month after planting is completed in a particular block, increase the water level in the fields back to the usual 50-70 cm from the peat surface.

FIGURE 32
A photo of deep planting on compacted peat surface.

FIGURE 33
A photo showing oil palms planted on peat soil treated with mechanical surface compaction.
INSET Photo of an adjacent area in the same estate planted with oil palms but without soil compaction. The problem of leaning palms is evident.

REDUCING EMISSIONS FROM REPLANTING

When replanting, care must be taken to minimize, where possible, disturbance of the soil as this may increase GHG emissions. Palm trunks should be chipped or applied directly to the plantations as surface mulch for reducing the direct impacts of rainfall and sunlight on the peat. Zero burning must be applied and measures taken to encourage rapid establishment of soft vegetation. In view of the new insights on optimal drainage levels, excessive deepening of drainage ditches should be avoided.

AFTER-USE PLANNING

In cases where assessments at the end of the plantation cycle (or even during the plantation cycle) have indicated that some portions of the plantation are not drainable or may soon become undrainable due to subsidence, or are underlain with acid sulphate soils or quartz sand it may be decided that these areas are unsuitable for continued operation as oil palm plantations. Rather than just abandon these areas it is important to consider appropriate after-use. The International Peat Society recently adopted objectives and proposed actions for after-use of peatlands (see BOX 6 PAGE 108)

Options for uses of peatland areas no longer cultivated for oil palm include the restoration of peat swamp forest or potential cultivation of other crops that can tolerate higher water table (e.g. wetland tree crops such as Jelutong *Dyera polyphylla* or Gelam *Melaleuca cajuputi*). Such tree species are indigenous to peatlands from south East Asia and are very suitable for cultivation on wet peat soils. Jelutong is a relatively fast-growing (growing to 60 m tall and a diameter of 2 metres) high-value forest tree. Its wood can be used for a range of wood products (furniture, paneling, veneer, pencils, matches, sculpture, boxes and crates, moulding, joinery, sliced veneer) as well as tapping for latex. The latex of the Jelutong tree is similar to rubber. Uses include chewing gum, high-end electrical insulation, as an ingredient in paints and as a primer for concrete.

Melaleuca cajuputi or Gelam is a fire tolerant indigenous swamp forest species in SE Asia. It is rapid growing and grows to a height of up to 20 m. It often occurs in peat swamp forest areas especially those that have been degraded or affected by fire. It is tolerant of acid sulphate soils and has been used in the rehabilitation of acid sulphate soils in the region especially in Vietnam. It has many uses. The wood can be used for construction piling in wet soils and also produces high value charcoal. The bark and fibre can be used to make paper. The oil distilled from the leaves is very valuable and is the main ingredient in tea tree oil and tiger balm and many other medicinal products.

Approaches and techniques for the rehabilitation of degraded or abandoned peatlands are described in further detail in the companion volume: BMP for management of natural vegetation and rehabilitation of degraded sites associated with oil palm cultivation on peat.

BOX 6

Importance of planning for after-use as stated in the Strategy for Responsible Management of Peatlands (SRPM) IPS 2010.

AFTER USE OF PEATLANDS

The Strategy for Responsible Management of Peatlands (SRPM) adopted by the International Peat Society (IPS, 2010) applies commonly agreed principles for the 'Wise Use of Peatlands' to management of all peatlands and provides objectives and actions for implementation.

The Wise Use of Peatlands for economic purposes requires planned after-use. There are several options for after-use of peatlands following economic use, including forestry, recreation and wildlife habitat and biodiversity provision (nature conservation). The choices available for after-use will depend on peatland type and former management as well as the condition of the 'used' peatland. In terms of after-use options, peatlands may be managed using rewetting, rehabilitation or restoration measures. The SRPM includes specific objectives and proposed action related to after use of peatlands as follows:

OBJECTIVES

1 Peatland rehabilitation or restoration should return degraded peatlands to conditions in which ecosystem functions are as close as possible to natural conditions within the constraints of practicality and at reasonable cost.
2 Efficient procedures should be adopted to ensure that peatlands are not simply abandoned in a degraded state when their economic use ceases. Procedures may include, for example, obligations to implement rehabilitation, restoration or other after-use plans, including contingency provisions.
3 Prevent further drainage and degradation of abandoned peatlands and target them for restoration with either government initiatives or as government projects with industry support.

6

ACTIONS

It is recommended to:

- Prepare mandatory after-use plans during the initial planning process of peatland management and in sufficient time for a wide range of opinions and options still to be incorporated.
- Identify the parties that will be responsible for the implementation of after-use plans during the planning process and ensure they have access to the required resources to achieve success.
- Ensure that when peatland use ceases, the landscape conditions are suitable for restoration and after use.
- Use the latest scientific knowledge of peatland ecosystem functions to derive acceptable and tested after-use management practices for the restoration of peatlands.
- Take into account stakeholder views on the after-use of peatlands as well as local peatland ownership issues in order to help ensure the sustainability of the measures taken.
- Monitor and review the implementation of after-use programmes over a realistic timescale and modify procedures if objectives are not being realised; consult stakeholders on their effectiveness, taking into account land ownership issues and traditional rights.

3.7 NURSERY MANAGEMENT

Good nursery practices are required for effective replanting. It is important to produce the best selected seedlings for high yields. For this reason nursery works should not be contracted out.

When using surface peat as the polybag filling material, it is important to ensure optimum fertilization and adequate watering. Correct applications of Cu and Zn fertilizers and in some cases foliar spraying of $FeSO_4$ (45-60 g per 15 liters water) are required to produce green and healthy seedlings.

Two stage nurseries (pre-nursery and main nursery) are used. Germinated seeds from identified legitimate seed suppliers should be used. In the pre-nursery, 15 cm by 23 cm polybags (500 gauge thickness) are used. For the main nursery 38 cm by 45 cm polybags of sufficient thickness (500 gauge) should be used and spaced at 90 cm by 90 cm triangular. It is vital to ensure proper culling of runts and only the best seedlings are planted out in peat estates.

During the pre-nursery stage (up to 3 months), two cullings should be carried at 1.5 and 3 months after planting, to remove abnormal seedlings or runts with the following characteristics; crinkled leaf, grass leaf, rolled leaf, stunted leaf, little leaf, twisted shoot and badly diseased seedlings.

During the main nursery stage, culling should be done at 6, 8 and 9 months for the following abnormal characters; erect habit with small stem base, juvenile and fused pinnae, narrow pinnae, limp and flaccid appearance, wide internodes, short internodes, retarded growth, fused tip, flat top and chimaera (partially yellow leaves). The final culling should be done not later than 10 months, after which the seedlings in the main nursery will be too crowded for effective culling.

The most suitable age of seedlings for field planting is between 10-12 months. Older materials (> 15 months) will experience greater transplanting shock due to root damage and excessive evapo-transpiration. For advanced planting materials, it is recommended to prune off the all older outer fronds leaving the spear, the youngest frond and 3-4 half cut fronds before field planting.

4.0 BEST MANAGEMENT PRACTICES (BMPs) OPERATIONAL ISSUES

4.1 ENHANCING YIELD

Low yielding oil palm plantations on peat can be due to a number of reasons specific to each location. The main reasons for low yield are:

- Poor water management with over-drained areas
- Inadequate manuring
- Inadequate labour
- Poor field supervision and management
- Poor pest control especially termites, leaf-eating caterpillars and Tirathaba bunch moths
- Poor planting materials
- Vacant points or abnormal palms (best to supply/replace before age of 5 years)

If the limiting factors are poor planting material, low productive stand and high *Ganoderma* infection, it is best to carry out accelerated replanting.

"A Review of Practices in the Development of Oil Palms on Peat Soils" by Golden Hope (now Sime Darby) discusses the limiting factors on oil palm yield and provides updated information on rectifying the problems faced in developing oil palm cultivation on peat soils in Sarawak. BOX 7 PAGE 114 provides a summary of recommendations. Relevant guidance is also provided in the form of BMPs in Chapters 3.0 to 6.0.

BOX 7

Limiting factors of oil palm cultivation on peat soils and recommendations for yield enhancement (Pupathy and Chang, 2003).

BACKGROUND INFORMATION

Golden Hope Plantations Bhd (now Sime Darby Bhd), had initiated Lavang Oil Palm Plantations Project near Bintulu, Sarawak, in 1996, covering an area of about 11,900 hectares. Out of this, about 3,820 ha i.e. 32% of the total area was developed for oil palm planting on peat. The soils in this region consist of mainly Merit Series, Bekenu Series and peat. A soil classification and suitability study in the Lavang Oil Palm Plantation Project revealed that about 67.6% of the area is dominated by mineral soils i.e. Merit and Bekenu series while the rest, approximately 32.4% of the area is classified as peat.

SOIL LIMITING FACTORS:

- pH – On shallow peat soils, a limiting factor is when the soil pH levels are below 3 (due to presence of acid sulphate substratum). It has been shown that very acidic conditions could limit the general growth of palms, presumably due to the poor growth of root and its metabolic activity. Trials on liming had shown that lime treatments between 2 kg and 4 kg/palm/year had suppressed cropping to the 4TH year of harvesting possibly due to Ca/K antagonism. Nevertheless the pH increased slowly and yield was better from the 7TH year onwards in the limed plots. Care should be taken not to over apply lime as it can adversely affect the uptake of K and micronutrients.

- Low micronutrient content – Peat soils are very deficient in micronutrients, especially copper (Cu) and zinc (Zn). Feeder roots play a big role in absorbing these nutrients from soils. However, absorption capacity of Cu and Zn elements are heavily fixed on complex organic compounds. Cu and Zn are usually applied at a range from of 100 g to 200 g/palm/year during the first year of field planting. The optimum leaf Cu concentration in frond 17 is 5-8 ppm meanwhile the optimum leaf Zn concentration in frond 17 is 15-20 ppm. The critical leaf Cu and Zn content of frond 17 is 3 and 12 ppm respectively. Correction of copper and zinc deficiencies is necessary to ensure better oil palm growth and yield on peat soils.

- Bulk density - Bulk density is the ratio of the mass to bulk or macroscopic volume of soil particles plus pore spaces in a sample. Bulk density is expressed in grams per cubic centimeter (g/cm^3). Bulk density testing was carried out on peat soils after a compaction of 4 runs, 6 runs and 9 runs. Generally bulk density for all peat samples were very low, ranging from 0.10 to 0.15 g/cm^3. Results also showed that the degree of bulk density increased with compaction. Yield on compacted plots was 30.57% higher than in non-compacted plots in the first year. However, the effect of compaction on yield declined over time. Actually the yield increase is manifested with increased bulk density due to compaction. An increased bulk density results in an increase of mass per unit volume of soil, which provides better contact with roots. Thus, palm performance was better as root proliferation and anchorage was increased with compaction.

PALM LIMITING FACTORS:

- Palm leaning – Leaning of palms on peat is largely attributed to peat shrinkage and subsidence. The situation is aggravated by the increasing weight of the palms as they grow older. There would be a two-year low cropping period with yield depression up to 30%, when palms suffering from leaning are trying to recover and growing upright again. Incidences of heavy leaning can be reduced through the use of right planting material and firmer anchorage of palm roots by increasing the bulk density of peat soils. It is reckoned that unidirectional leaning is tolerable for implementing mechanization on peat soils. Thus, attempts were made by the agronomists to achieve unidirectional leaning by means of forcing or planting at slanting position. Palm leaning could be a contributing factor in causing low harvester productivity. Leaning palms are subject to stress and tend to abort. In leaning palms, about half of the upper fronds are usually compressed as palms are in the progress of recovery for upright growth. Small size bunches were observed on leaning palms. In the other half portion of the palm, fronds tend to touch or come into contact with peat soil surface. Fronds in such positions could hinder the harvesting and loose fruit collection activities. The losses due to uncollected loose fruits are expected to be high.

- Palm canopy – Palm canopy on peats oils will be disturbed when palms are leaning, probably at the beginning of third year of field planting. Palms that suffer from leaning tend to have poor anchorage and end up leaning in different directions. Eventually, this situation will lead to inter-palm competition for light and nutrients and seriously hinder movements of harvester vehicles.

7

CLIMATIC LIMITING FACTORS:

- Rainfall - The total annual rainfall in Sarawak ranges from 3500-4000 mm. Therefore, nutrient losses due to leaching and surface runoff could be higher for peat soils that are porous in nature with poor nutrient retention capacity (especially for potassium, K). In view of this, higher dosage of K nutrient (up to 4 kg MOP/palm/year) was applied to the palms on peat in newly matured areas. Higher dosage of K application is required to maintain a proper K status in the palms and yield. The application of straight fertilizers (MOP and Urea) in perforated bags was a cost-effective and labour saving method for manuring your mature palms planted on deep peat soils. It is prudent, to consider such protective techniques to reduce fertilizer losses due to leaching and high rainfall in peat soils.

- Water management – During rainy seasons, a greater water flow is expected on peat soils and therefore a proper drainage system should be meticulously planned so that oil palm roots are not affected by reduced aeration in stagnant water. During periods of drought, water must be maintained to prevent irreversible drying of peat soils. Therefore, a water blocking system is required at strategic points along the collection drains to maintain the water level between 50 and 75 cm from the peat surface. It is also very important to maintain the optimum height of the water table to avoid any fire risk. There were past cases of flash floods due to back-flow of river water in Lavang Project. This is inevitable especially when peat soils are located in mostly low-lying and surrounding rivers. Selective bunding along the critical stretches of the riverbank is necessary to prevent back-flow of river water. Probably, frequent incidences of flash floods are also an indication that the mean water level of the river is above the mineral sub-soil level.

PEST AND DISEASES LIMITING FACTORS:

- Termite Infestation – Termite infestations are a major pest problem in oil palm plantings on peat. Censuses in the Lavang project revealed that cases of new termite infestation are below 2.5% of total area while casualties are less than 1%. Out of the several termite species found on peat soils, only *Coptotermes curvignathas* (*Rhinotermitidae: Coptotermitinae*) is found to attack oil palms. This species would secrete a milky fluid when they are challenged or under attack. This species would initially reach the spear region by building mud tunnels and then bore into the living meristemic tissues. Therefore, presence of mud work on spear region is a good indication of termite attack. Early detection of termite infestations and prompt action in controlling termite infestations will reduce the cases of palm damaged/death due to termite infestation. Censuses of all palms on a monthly basis should be carried out to identify the number of infested palms in the fields. A point-to-point plan of the termite-infested palms should be prepared and degree of infestation should be marked out in the plan. Areas with high termite infestation should be kept under close observation. Prophylactic measures were taken against termites to have an early control on pest infestations in the Lavang Project area. Fipronil (Regent) is used at the rate of 2.5 ml per 5 liters of water per palm as it has given longer lasting control.

- *Ganoderma* incidences - There is a strong relationship between major nutrients i.e. nitrogen, phosphorus and potassium and the basal stem rot of oil palm. Nitrogen (N) fertilizer significantly increased the incidences of *Ganoderma* and would pre-dispose oil palm to *Ganoderma* infection. Potassium (K) fertilizer significantly reduced the incidences of *Ganoderma*. As such, it may be possible to control the incidences of Ganoderma infection through fertilizer application management but more research needs to be done.

4.2 TRANSPORT SYSTEMS

Effective transport systems are often referred to as the backbone of any oil palm plantation operation. The following are descriptions of and guidance pertaining to various options available for plantations on peatlands. Roads transport is still regarded as the most important option although this can be supplemented by other modes like water transportation. It is important to note that the focus of this Manual is on existing plantations, which will already have developed a transport system. However, some guidance is provided for the actual construction/establishment of various transport systems in the event that estates envision restructuring their transport systems during replanting periods.

ROAD TRANSPORT

Road construction and maintenance is vital in all plantation operation while road density and quality are important components in construction. Mohd Tayeb (2005) provides some general guidelines for road construction/maintenance and is elaborated in this section. While it is relatively easy and cheap to construct roads on mineral soils, the opposite is true on peat. Roads are particularly difficult and expensive to construct, especially on deep peat and in Sarawak where sources of mineral soil and gravel stones to build road foundations and surfacing respectively are often not found in the vicinity of the plantation but instead have to be transported from other sources, sometimes located large distances away. This will have cost implications.

Construction of main and field roads on peat basically involve 3 main stages (Tahir *et al.*, 1996):

1. Build up road foundation with spoil from an adjacent drain with subsequent leveling
2. Raise up the road foundation with dumping of transported mineral soil with follow-up compaction
3. Surface road with gravel stones

A reliable but relatively more expensive road to construct on peat uses geotextile separators. Road construction involves leveling and land clearing. This is to ensure all protuberances and projections are removed prior to placing the geotextile to prevent damage. A layer of geotextile is laid down directly on graded ground before placing sandfill and crusher run surfacing (Zulkifli *et al.*, 1996; Steven and Chok, 1996).

For more details on guidance for maintaining roads/paths on peatland, see SECTION 4.3 PAGE 128 on Labor and Mechanization.

RAIL TRANSPORT

Main-line transport using the rail system had been attempted with varying degrees of success. Tradewinds Plantations had used the rail system on first generation peat in an estate near Mukah, Sarawak. The major problem is the variable peat subsidence that caused the rail line to be undulating. The wooden rail slippers are also attacked by termites and the overall maintenance cost was high.

FIGURE 34
Rail system in Tradewinds Plantations, Mukah, Sarawak.

WATER TRANSPORT

In peat areas where there are no suitable sources of road building materials but good natural water sources are available, especially during dry seasons, water transportation on peat can be considered. The existing drainage system can be modified for water transport by widening the main and collection drains.

COMPARTMENTALIZATION FOR WATER TRANSPORT

Compartmentalization or zoning an area with similar water levels will be required to facilitate water transport. This can be achieved by construction of stop-offs, bunding both sides of main and collection drains (when required) and water diversion at strategic locations. This has to be carefully planned and properly executed to be effective. Continuous water level monitoring and proper maintenance of the canals and water control structures are essential to ensure the success of the water transport system.

For more details on the implementation and maintenance of water transport systems, see BOXES 8 and 9 PAGE 122 & 124.

BOX 8

Case Study – Water transport system in PT TH Indo Plantations, Riau, Indonesia.

At PT TH Indo Plantations in Riau, there was no suitable source of road building material, which posed a great challenge for constructing a transportation and crop evacuation system within the project site.

A water transport system was developed for transporting fresh fruit bunches to palm oil mills. It also catered for general transport in the project area covering 80,000 ha. The main rivers that cut through the project site are Sungai Simpang Kanan and Sungei Simpang Kiri, forming part of the estate's water transport system.

The main problem faced with using water transportation in the 36 Tabung Haji peat estates, which form a large contiguous peat area of 70,000 ha, was the differential water levels since a network of water-gates and stop-offs were used to maintain a water level of 40-60 cm from the peat surface to optimize palm growth and performance. Compartmentalization or zoning areas with similar water levels were carried out to facilitate water transportation.

A system of main, boundary and secondary canals with water control structures (water-gates, stop-offs, bunds, underpass culverts or *gorong-gorong*, etc.) were used for controlled drainage and effective water management. Canal and drain dimensions are given in TABLE 5.

TABLE 5
Dimensions of canals and drains.

TYPES OF CANAL AND DRAIN	DIMENSIONS (m)		
	TOP WIDTH	DEPTH	BOTTOM WIDTH
MAIN CANAL	22.0	5.0	12.0
SEMI MAIN CANAL	9.0	4.0	6.0
BOUNDARY CANAL	8.0	6.0	4.0
SECONDARY CANAL	4.0	3.0	2.0
COLLECTION DRAIN	1.5	1.0	1.2

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The main canals were spaced at every 6 km, secondary canals every 500 m and collection drains at every 4-8 palm rows. With a block length of 1000 m, an average block size of 50 ha was obtained.

Lining and construction of the main and secondary canals should be carefully done. When constructing the collection drains (usually 1 to every 4-8 palm rows), it will be useful to place the spoil on the positions of the future harvesting paths rather than next to the collection drains to avoid back-filling which will result in higher maintenance costs.

Canal and drain maintenance including removal of aquatic weeds must be carried out regularly or when required, to keep the water transport cum drainage system working properly. Desilting to the required depth is best carried out during dry weather.

Another problem of the water transport system is the over-skipping at stop-offs by pontoons carrying the harvested fruit bunches to the palm oil mills as shown in FIGURE 35. This involves double or even multiple handlings of the harvested fruit bunches. This can be overcome by constructing smaller mills at major stop-offs where 2 water levels exist.

FIGURE 35
Water transport system for fresh fruit bunches to the palm oil mill using pontoons.

BOX 9

Case Study Harvesting and transportation of FFB in peats soils at PT Bhumireksa Nusa Sejati, Sumatera, Indonesia.

INTRODUCTION

PT Bhumireksa Nusa Sejati has land banks of about 25,000 hectares with a total planted area of about 20,000 hectares. With its total production volume increasing annually a process improvement was required to turn around the property to be profitable. A business framework to achieve excellence work culture has shown remarkable results since its inception in year 2004.

Historically the property was neglected for an extended period of time. The focus was on its operational efficiency in view of improving operational cost of production, work quality and minimized product losses. The property has a yield potential of >25 tons and with its huge hectarage and increasing crop volume over the years, a holistic approach was required to ensure targets are achieved and productivity maximized. Being 100% peat, the property is unique as compared to mineral areas where roads are not available to transport product to the mills.

Water ways remained as a back bone on the overall operational activities thus the previous transportation system is obsolete and was replaced immediately to ensure minimal crop losses. The old transport system involved manual handling of crops from collection points to mill reception area resulting huge crop losses in the waterways. After deliberations by team members, the new system known as Pontoon and Container system (P&C) was found effective. Undoubtedly the new transport mechanism reflects the excellence work culture as embraced by the company. In doing so, the Free Fatty Acid (FFA) level was curtailed to minimum since the turnaround time improved tremendously thus resulting in increased mill throughput. Labor reduction was substantial with minimum manual handling in loading and unloading activities in the estates and at the reception center.

The mechanisms of the old and new systems are shown for comparison.

9

THE OLD SYSTEM

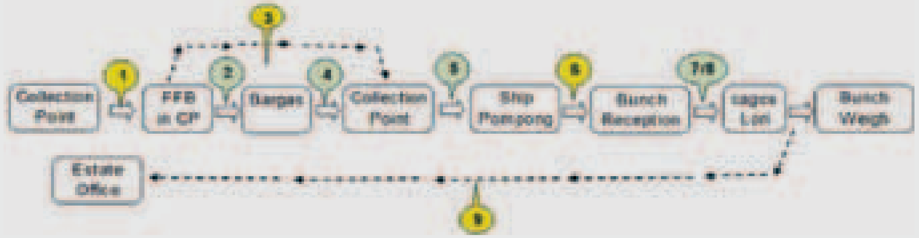

FIGURE 36
Schematic diagram showing the old FFB transportation system (from collection point to mill) using the contractor's ship (*pompong sewa*).
KEY 1- From main collection point to collection point, 2- Loading FFB from collection point to bargas, 3- From collection point to main collection point, 4- Unloading FFB from bargas to main collection point, 5- Loading FFB from main collection point to pompon, 6- Transportation to mill, 7- Queue at mill, 8- Loading FFB into cages, 9- Return from mill to main collection point

FIGURE 37
Series of photos showing the old system of FFB transportation. Bottom right photo shows significant losses of loose fruits.

THE NEW SYSTEM

The efficiency of the new system was evident from the time motion study conducted with minimal turnaround time, larger crop volume evacuated, cost reduction and less manpower required. Furthermore the significant impact is minimal crop loss especially the loose fruits in the canals as manual loading activities is ameliorated. The advantages of the Pontoons and Cages system (see FIGURE 38) were justifiable as stipulated in TABLE 6.

FIGURE 38
Series of photos showing the new system of FFB transportation. Clockwise from top left: FFB in cages being lifted out of a pontoon, cage being moved and positioned over a boiler cage and FFB emptied into the boiler cage.

TABLE 6
Comparison of turnaround time and manpower requirements for FFB transportation between old and new systems for FFB transportation.

	DESCRIPTION	OLD SYSTEM	NEW SYSTEM	IMPROVEMENT
1	FFB loading and turnaround time (time taken from CP to mill reception area)	20 hrs	12 hrs	40%
2	Loading/unloading FFB at estate collection point	1 hr	5.4 mins	91%
3	Loading/unloading FFB at mill km 0.0 (15 tons)	1 hr	19.8 mins 1 line 9.9 mins 2 lines	67% 84%
4	Transport cost including loading and unloading	Rp 26.74/kg	Rp 10.19/kg	62%
5	Manpower requirement	184 man-days	14 man-days	92%
6	Manpower requirement at over skips	92 man-days	10 man-days	89%
7	Manpower requirement at bunch reception area	90 man-days	4 man-days	96%
8	loose fruits losses 10% of 205,402 tons	10% 20,540 tons	nearing 0% nearing 0 ton	

4.3 LABOUR AND MECHANIZATION

Oil palm cultivation is labour intensive especially on peat areas. Labour shortage, especially skilled harvesters, is a major constraint now, not only in Malaysia but also in Indonesia. This has resulted in substantial crop losses.

To maintain a stable and productive workforce on peat estates, proper housing with basic amenities and satisfactory income are vital. Another area that can improve the labour shortage situation is mechanization.

MECHANIZATION

The relatively flat terrain of peat is advantageous for mechanization, especially in areas with labour shortage problems such as in Sarawak. The constraint however is the very soft ground conditions especially during rainy seasons and in areas with high water tables. Depending on the moisture content, the ground bearing capacity of deep peat is very low, between 0.1 to 2.2 kg/cm^2 (see FIGURE 39). The ground bearing capacity of peat decreases very sharply when the moisture content is higher than 300% (Lim, 2005A). MPOB (2011) provides specific guidance on mechanization for field maintenance (see BOX 10).

FIGURE 39
Operational problems encountered when ground bearing capacities of deep peat are exceeded.

BOX 10

Guidelines on mechanization for field maintenance on peatlands (MPOB, 2011).

MECHANIZATION FOR FIELD MAINTENANCE

Peat represents the extreme form of soft soils and has a very low ground-bearing capacity. Peat load-bearing capacity is defined as the maximum load that the peat can support before failing. It is often influenced by the water table and the presence of subsurface woody debris. Therefore, any prime mover/vehicle moving in peat areas must exert a low ground pressure on the soil. A larger ground contact area will have a smaller ground pressure, hence giving less load to the ground-bearing capacity. The use of machines is often restricted by the peat type and conditions, with deep undisturbed peat areas having a very low ground-bearing capacity.

Recommended machine specifications are as follows:

A. The wheels of the vehicle should be equipped with low ground pressure (LGP) tyres that are inflated at 5 psi. A multi-wheeled vehicle can also contribute to achieving a lower ground pressure
B. Tracked type vehicles exert low ground pressure and are the most suitable machines for peat areas but should have adequate ground clearance
C. A light-wheeled vehicle with a ground pressure of less than 0.35 kg/cm^2 can carry up to a 0.5 tonne load
D. The vehicle/machine should be equipped with a four-wheel drive (4WD) or an all-wheel drive system for better traction when needed
E. The machine should have an even distribution of weight to avoid sinking into the ground or being bogged down
F. A single-chassis machine will have better maneuverability compared with a trailer type
G. A machine having a high ground clearance will avoid obstacles
H. A machine having a skid attachment at the bottom will ensure better movement

Other suitable implements can be attached to the vehicle/prime mover for carrying out the following field activities:

A. Fertilizer application *
B. Weed management/herbicide spraying *
C. Pest and disease management
D. In-field collection of fresh fruit bunches (FFB)

The safety of workers is ensured during the operation of machines by following safety and health standards of the Department of Occupational Safety and Health (DOSH).

*It is noted that there will be generally more wastage (of agrochemicals) when mechanized spraying is employed.

To facilitate in-field transport especially for FFB evacuation, elevated mechanization paths of about 3.5 m width and 50 cm height can be constructed with a slight camber, on alternate palm rows during land preparation (see FIGURE 40). Elevated paths are useful for future mechanization and to minimize the effect of subsidence on the harvesting paths in the later stage.

Residual woody materials less than 15 cm diameter are used to strengthen the elevated paths. For construction before planting, accurate pre-lining of the planting rows, collection drains and stacking rows need to be carried out first.

As the palms get older, work rate on the construction of elevated paths is slower due to interference by the growing fronds. For planted areas, construction of elevated paths should be carried out not longer than 18 months after field planting.

FIGURE 40
Elevated path to facilitate mechanization.

In areas where there are insufficient woody materials, non-elevated but compacted paths of about 3 m width can be constructed on the existing harvesting paths. They are constructed by removing protruding stumps, filling surface cavities followed by 1-2 rounds of compaction using a track excavator. Path construction is usually carried out just before harvesting commences and must be well connected to the collection roads. Removal or chain-sawing of protruding stumps (especially those with sharp edges) on the mechanization paths is important, as puncturing of LGP tyres and snapping of rubber tracks have been reported (see FIGURE 41 PAGE 132).

Fimbristylis acuminata, a common weed on peat areas with extensive surface root systems, should be encouraged or planted on peat roads or mechanization paths to further strengthen the peat surface against rutting by moving vehicles.

A number of machines have been tested on both the elevated and non-elevated paths. With construction of elevated paths, mini-tractors and trailers with normal tyres can operate with minimal problems. On the non-elevated compacted paths, tracked carriers or mini-tractors and trailers with low ground pressure (LGP) tyres are more workable, especially during rainy seasons (see FIGURES 42 AND 43 PAGE 134).

FIGURE 41
Protruding stumps, if not removed, can pose various problems for oil palm cultivation on peat.

FIGURE 42
Low ground pressure (LGP) tyres on compacted path.

FIGURE 43
Tracked machine on soft ground.

4.4 TRAINING AND FIELD SUPERVISION

Technologies for oil palm cultivation on peat, especially deep peat, are increasingly available due to greater R&D efforts by both the private and public research organizations. New techniques for more effective pest control, early fire detection and control, safety measures and mechanization need to be disseminated quickly to all levels of personnel. This is best done through structured training programmes, from managers, senior assistants, assistants, field conductors, *mandores* to general workers.

Most large plantation companies in Malaysia and Indonesia now have their own in-house training centres to carry out training systematically and effectively. This is important to avoid making any serious mistakes during oil palm cultivation on peat, which is usually expensive to correct.

EFFECTIVE FIELD SUPERVISION

Due to the long carry distance and soggy ground conditions during rainy days in peat estates, stringent supervision by all levels of the estate management is vital to achieve higher efficiency, especially in fertilizer application, weeding, harvesting and FFB evacuation.

For optimum efficiency, each peat estate should not be sized more than 2000 ha. The area under a supervisory staff should not be more than 500 ha to achieve maximum yield, crop recovery and oil extraction. Due to the very dynamic nature of deep peat, short periods of neglect can lead to rapid deterioration in the yield and field conditions of peat estates.

FIGURE 44
A narrow strip of river reserve or greenbelt maintained with natural peat swamp vegetation by an oil palm plantation.

5.0 BEST MANAGEMENT PRACTICES (BMPs) ENVIRONMENTAL AND SOCIAL ISSUES

5.1 CONSERVATION, MAINTENANCE AND REHABILITATION OF NATURAL VEGETATION AND RIVER RESERVES

Tropical peat swamp forests are a critically endangered category of forested wetland characterized by deep layers of peat soil and waters in which a high diversity of plant and animal species are found with unique adaptation to their specific waterlogged and acidic conditions and do not occur in the other tropical forests of Asia. These unique forests play key roles 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 (Wetlands International – Malaysia, 2010).

River reserves or greenbelts are essentially the land adjacent to streams and rivers; a unique transitional area between aquatic and terrestrial habitats (see FIGURE 44). Although constituting only a small part of the landscape, river reserves/greenbelts that are intact and functional are important habitats for biodiversity and provide ecosystem services.

The following are the main reasons why peat swamp forests and river reserves/greenbelts within and adjacent to oil palm plantations need to be conserved, maintained and rehabilitated:

- WATER QUALITY IMPROVEMENT On-point sources of pollution, including run-off from plantations, introduce a variety of pollutants into the river system. These pollutants, which include sediments, nutrients, organic wastes, chemicals and metals, are difficult to control, measure and monitor. River reserves serve as buffers, which intercept non-point sources of pollution. In particular, riparian vegetation absorb the heavy metals and nutrients, trap sediments suspended in surface run-off and provide a habitat for micro-organisms that help break down the pollutants. In plantations where fertilizer, pesticides and herbicides are used, the maintenance of a vegetated river reserve of sufficient width is therefore extremely important to minimize the amount of these pollutants that enter the rivers.

- FLOOD MITIGATION Riparian vegetation increases surface and channel roughness, which serves to slow down surface water that enters the river and reduce flow rates within the river. This helps to slightly alleviate the magnitude and intensity of flooding downstream.

- HIGH CONSERVATION VALUE The concept of High Conservation Values (HCVs) was developed to provide a framework for identifying forest areas with special attributes that make them particularly valuable for biodiversity and/or local people. Peat swamp forests and river reserves form unique ecosystems and are valuable resources for local communities. By default, these areas would be defined as HCV areas. See FIGURE 44 PAGE 136 for an example of a map identifying HCV areas within an oil palm estate. Conservation and maintenance of HCVs are engrained in the RSPO P&C.

- ENDANGERED AND ENDEMIC SPECIES Peat swamp forests are home to many endangered and endemic species and subspecies, including enigmatic species such as Tiger (*Panthera tigris*), Sumatran Rhino (*Dicerorhinus sumatrensis*), Bornean Clouded Leopard (*Neofelis diardi borneensis*), Malayan Tapir (*Tapirus indicus*) and Proboscis Monkey (*Nasalis larvatus*) as well as less known endangered species such as the Storm's Stork (*Ciconia stormi*), False Gharial (*Tomistoma schlegelii*) and the Painted terrapin (*Batagur borneoensis*). The peat swamp forests of north Borneo represent a unique vegetation type characterized by the Alan tree (*Shorea albida*) as well as the valuable but endangered timber species Ramin (*Gonystylus bancanus*).

- WILDLIFE CORRIDOR AND BUFFER ZONE River reserves provide corridors for movement of wildlife and helps reduce incidences of human-wildlife conflict. Conservation of forested areas within the plantation and adjacent to a larger peat swamp landscape also provides buffer zones to minimize wildlife encroachment on plantation land.

- AQUIFER OR WATER CATCHMENT / RETENTION AREA During the dry season, peat swamps naturally remain waterlogged and this characteristic is important for maintaining natural ecosystems and water tables as well as mitigating floods.

- PREVENTION OF HYDROLOGICAL DISRUPTIONS TO ADJACENT PEAT SWAMP FORESTS Alteration of the natural ecosystem can lead to hydrological disturbances to the wider landscape. This in turn can lead to the destruction of adjacent habitats and increases in human-wildlife and social conflicts for the plantation.

- FIRE PREVENTION A major factor for peat fires is the drying out of peatland. Maintenance of river reserve and peat swamp vegetation allows these areas to retain water effectively and hence prevent fires from occurring.

- RIVERBANK STABILIZATION Riparian vegetation protects riverbanks from erosion or scouring caused by rain, water flow, etc. Erosion caused by removal of riparian vegetation results in sedimentation of the river which increases flood levels, as well as bank failure, which may bring about the need for expensive remediation measures such as dikes, levees and flood walls.

- FISHERIES Rivers of the peat swamps are home to the rare Arowana fish (*Scleropages formosus*) and a large number of other fishes. These fish have commercial values and are an important source of dietary protein for local communities.

Oil palm plantations have a role to play in identifying, managing and enhancing river reserves and peat swamp forests that are on and adjacent to their land. Preferably, these areas should be identified during initial stages of plantation development. These areas need to be conserved/managed and where necessary, rehabilitated. This activity during the initial stages is crucial to avoid extensive costs to rehabilitate cleared or planted (oil palm) river reserves/greenbelts and other areas unsuitable for oil palm or have high conservation value in the long run. For plantations that have already planted oil palms on river reserves, steps must be taken to restore these areas to its original state.

The following are examples of areas that are recommended to be identified, managed and enhanced as conservations areas within plantations on peatlands due to their high conservation value and/or unsuitability for planting oil palms:

- Peat dome (Padang Raya) areas (low moisture and fertility)
- Shoulder of dome (Alan Forest) areas
(large roots contained in peat)
- Undrainable areas
- Vital wildlife corridors (to avoid human-wildlife conflict)
- Remaining natural peat swamp forest areas and streams with endemic or endangered species or other HCV characteristics

FIGURE 45 is an example of actual mapping carried out by Sime Darby for Guthrie Peconina Indonesia (GPI) estate in Jambi, Sumatra, Indonesia, to identify High Conservation Values for their estates.

BOX 11 PAGE 142 explains and illustrates a practical example of efforts by an oil palm plantation to establish and manage conservation areas and wildlife corridors within their peatland estate.

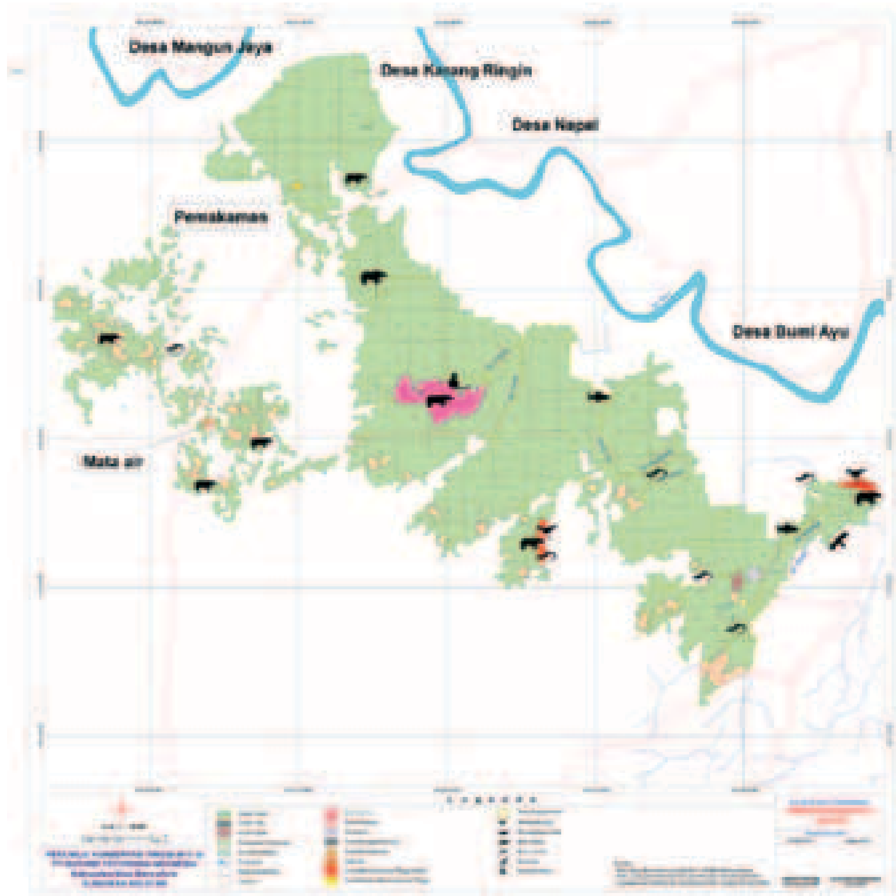

FIGURE 45
An example of mapping carried out by Sime Darby for Guthrie Peconina Indonesia (GPI) estate in Jambi, Sumatra, Indonesia, to identify High Conservation Values.
NOTE Areas marked in red on the map are areas identified as containing High Conservation Values. Areas of potential High Conservation Value, presence of wildlife, local community burial grounds and water sources are also indicated on the map.

BOX 11

Case Study Connecting conservation areas at PT Tolan Tiga Indonesia/ SIPEF Group.

After taking over a plantation under development on peat in North Sumatra, SIPEF Group identified two areas still reasonably forested to be kept as conservation areas. Given the relative small size of both areas (167 ha and 39 ha), and following consultation with HCV specialists, it was decided to connect the areas with a corridor of about 1.4 km in length (see FIGURE 46).

The objectives of the corridor are as follows :

- To increase habitat for wildlife as well as to facilitate movements and stabilize populations in a protected area
- To maintain and improve plant biodiversity, by increasing area available for re-growth and replanting of local species.

The corridor area had already been planted with oil palm for one year and blocks were orientated exactly in the direction of the corridor. It was decided to allocate the width of one block (300 meters) over the entire distance of the corridor for a total of about 44 ha. In the core area of 150 m width, young palms were removed and transplanted elsewhere. The buffer areas of 75 m on each side of the core area were left planted. In the buffer areas, pesticide applications will be reduced but otherwise, the palms will be managed normally.

The core area is being replanted with species such as *Alstonia pneumatophora* (pulai), *Palaqium spp.* (mayang), *Shorea spp.* (meranti merah and meranti batu), and *Callophylum spp.* (bintangur). Planting material was prepared in part on the estate and in part sourced from the local Forestry Services. Trees are planted at 5 x 5 meters to anticipate natural mortality.

After only a few months of installing the corridor, wildlife movements were already visible. The estate is monitoring survival rates of the trees.

FIGURE 46
A map showing conservation areas connected by a wildlife corridor established by SIPEF Group.

In terms of regulatory requirements for maintenance of conservation areas and river reserves, the Drainage and Irrigation Department (DID) Guidelines, Indonesian Law No. 41/1999 and Indonesian Sustainable Palm Oil (ISPO) Principles and Criteria provide some guidance for Malaysia and Indonesia:

Guidelines for developments involving rivers and river reserves (DID Malaysia)

TABLE 7
River reserve width requirements (DID Malaysia).

WIDTH OF WATERWAY	REQUIREMENTS FOR RIVER
RESERVE	
BETWEEN BANKS	WIDTH (BOTH BANKS)
>40 M	50 M
20M – 40 M	40 M
10M – 20 M	20 M
5M – 10 M	10 M
<5 M	5 M

Guidelines for developments in Indonesia involving rivers and other water sources (in accordance with Indonesian Law No. 41/1999 on Forestry) recognize the following protective zones:

1. 500 (five hundred) meters from the edge of water reservoir (dam) or lake
2. 200 (two hundred) meters from the edge of water spring and alongside the river in swampy area
3. 100 (one hundred) meters from the river (left and right banks)
4. 50 (fifty) meters from streams facing downstream (left and right banks)
5. Twice the depth of a cliff from the edge of a cliff
6. A coastal green belt with a width of 130 m times the average tidal range (in meters).

NOTE Since decentralization (and relegation of responsibilities to provinces and districts), interpretation and implementation of this legislation is left to regional/local government.

INDONESIAN SUSTAINABLE PALM OIL (ISPO) PRINCIPLES AND CRITERIA

ISPO CRITERION 3.5 Identification and protection of protected areas – Oil palm planters and millers should identify protected areas, which have the prime function to protect biodiversity, including natural and manmade resources as well as historical and culturally valuable areas. These areas should not to be planted with oil palm.

- INDICATORS
  1. Identified protected area is available
  2. Plantation map showing identified protected area is available
  3. Records of identification and distribution information of protected areas are kept

- GUIDANCE
  1. To do inventory on protected areas around the plantation
  2. Distribution of protected forest information to workers and surrounding community/farmers around the plantation

ISPO CRITERION 3.7 Conservation area with high potential for erosion – Oil palm planters and millers should conserve the land and avoid erosion according to rules and regulations.

ISPO CRITERION 3.8 Plantation in accordance with Presidential Decree No. 10/2011 – Postponement on oil palm plantation development to decrease green house gas (GHG) emissions through moratorium on new permits and improvements to the management of primary natural forests and peatlands.

- INDICATORS
  1. Moratorium on new permit included in indicative maps;
  2. Approved application by authorized institution on land permit is valid;
  3. Existing permits issued before the moratorium remain in effect.

- GUIDANCE
  1. Postponement on new permits related to the plantation are site permits and IUP;
  2. Postponement on new permits in accordance with indicative map for primary forests and peatlands, which exist in conservation forests, protected forests, production forests (limited production forests, regular production forests, converted production forests) and land for other uses;
  3. This regulation is not applicable for permits on released forest areas except for permits with principle agreement from the Ministry of Forestry;
  4. Postponement on the issuance of permits on land use rights (HGU, HGB, HP, etc.) including processed applications in provincial B committee;
  5. Moratorium on location permits, IUP and other land use rights for 2 (two) years effective from 20 MAY 2011 to 20 MAY 2013.

See BOX 16 (ANNEX 7 PAGE 204) for an explanation of abbreviations used in ISPO criteria.

Some oil palm plantations and members of RSPO have undertaken efforts to restore river reserves and greenbelts on their property. It is noted that further guidance as well as technical resources and incentive mechanisms are needed to ensure smallholder growers are able to be involved in any concerted effort to rehabilitate river reserves.

Despite the increase in efforts by plantations to conserve and restore river reserves/greenbelts along large rivers, the smaller tributaries and canals running through their plantations are commonly ignored and usually planted with oil palms right up to the banks. It is important to note that smaller tributaries and canals transport large amounts of sediments, suspended solids and agrochemicals to main rivers. In some instances river reserves along the small streams and canals are more important than river reserves along the main rivers. Due to the drainage patters in many estates, plantations drain into the small streams and canals rather than directly into the main rivers. To completely tackle the problem, river reserves along these smaller tributaries and canals need to be incorporated in overall efforts to conserve, maintain and rehabilitate river reserves and forested areas within and adjacent to plantations. At the very least, ferns and shrubs should be maintained for river/canal bank stabilization, minimization of erosion and reduction of agrochemical run-off.

Once river reserves/greenbelts are identified and demarcated, these areas need to be secured to prevent encroachment. Human activities like spraying of agro-chemicals, hunting, fishing, waste dumping, burning, etc. should be prohibited.

Refer to 'Manual on BMPs for Maintenance and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Tropical Peat' for specific guidance on maintaining and rehabilitating peat swamp forests and river reserves/greenbelts.

5.2 ENVIRONMENTAL MANAGEMENT

It is critical to incorporate a sensible environmental management plan to ensure that good environmental and waste management practices are adopted to conserve resources in the long term rather than allowing it to be exploited for short term gains.

Environmental legislation and audit systems in place in both Indonesia and Malaysia must be followed.

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). Every State Government is also required to comply with these Enactments. It seems this designation has been ignored in most EIAs for the development of peatlands. An 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).

In particular the recognition of an environmentally sensitive area within the HCV assessment and management should take due care and special attention in addressing peatland ecosystem sensitivities. Existing plantations on peat should do their utmost to at least restore zones in their plantations along rivers and streams to mitigate some of the HCV losses incurred as a result of their past plantation development.

Plantations on peat should carry out assessments of the potential lifespan of the plantation in view of subsidence related issues such as flooding, undrainability and potential infertile or acidic sub-soils. These assessments should define at least the final cut-off points at which subsidence level drainage should be stopped to ensure that areas will remain viable for rehabilitation and/or paludicultural use. Preferably drainage should stop well before that to enhance chances and options for rehabilitation and after use.

5.3 FIRE PREVENTION AND CONTROL

Peatland fires are a serious problem in Indonesia and Malaysia. The 'Manual for the Control of Fire in Peatland and Peatland Forest' published by Wetlands International – Indonesia Programme in DECEMBER 2005 elaborates on a variety of concepts and practical measures for the prevention and suppression of fire and also draws from field experience in handling of land and forest fires in the peatland areas of Kalimantan and Sumatera, Indonesia. The following are important elements quoted from this Manual (Wetlands International – Indonesia Programme, 2005B).

Fires occur not only on dry land but also on wetland areas such as peatland, particularly during the dry season when these areas dry out (especially when deforested and drained). Overcoming fire on drained and deforested peatland is extremely difficult, compared with fire in areas where there is no peat. The spread of ground fire in peatlands is difficult to detect because it can extend down to deeper levels or to more distant areas without being visible from the surface. On peatlands, if a fire is not quickly suppressed, or if it has already penetrated far into the peat layer, it will be difficult to extinguish. Moreover, the main obstacles to putting out fires are difficulties in obtaining large quantities of water nearby and gaining access to the site of the blaze. For these reasons, severe/extensive peatland fires can only be extinguished by natural means i.e. long consistent periods of heavy rain.

PLANTATION-SPECIFIC GUIDELINES

Plantation companies can help prevent peat fires by ensuring the following recommendations are in place and implemented:

- Zero Burning methods for land clearing/replanting
  Implementation of Zero Burning concepts greatly reduce the risk of fires occurring. See BOX 17 (ANNEX 8 PAGE 213) for details.
- Effective surveillance and monitoring
  In order for surveillance and monitoring of plantation activities to be effective, overall work needs to be broken down into smaller management units i.e. unit, block, sub block. The leader of each unit, block and sub block is responsible for the surveillance and monitoring of their area with regards to fire prevention. There should also be an intensive network of paths around estate blocks to facilitate surveillance and enable fire-fighting personnel and equipment to access areas of concern quickly. These paths can also function as fire breaks to prevent surface fires from spreading.
- Formation of land and peat forest fire suppression units
  It is important to develop an organizational structure to handle fire control in a plantation company. Overall leadership should be provided by the Head of the Fire Protection Division and this person has the overall responsibility for managing fires in the plantation and coordinating fire suppression activities. The following personnel should be in place to support the Head of Fire Protection Division:
  - Information Unit: develops and manages information related to fire danger
  - Special Fire-Fighting Unit: backs up the core fire-fighting units
  - Guard/Logistics Unit: mobilizes equipment and handles logistics
  - Sentry units: posted in places that are especially prone to fire
  - Core fire-fighting units (for each block): patrol units who have the task of surveillance over the whole block

For more details on fire prevention and suppression including specific guidance on techniques for suppression of land and forest fire in peatland areas as well as zero burning techniques, see ANNEX 8 PAGE 207.

5.4 MINIMIZATION OF GREEN HOUSE GAS (GHG) EMISSIONS FROM OIL PALM PLANTATIONS

The transformation of an intact peat swamp area to oil palm plantations leads to a release of carbon and greenhouse gasses to the atmosphere (De Vries *et al.*, 2010; Henson, 2009; Jeanicke *et al.*, 2008; Danielson *et al.*, 2008; Fragioni *et al.*, 2008; Rieley *et al.*, 2008; Gibbs *et al.*, 2008; Wosten and Ritzema, 2001; Hooijer *et al.*, 2010). When oil palm plantations are developed on peat, oxidation due to drainage, the possible increased fire frequency and carbon losses in the case that forest is cleared are the major sources of significant increases in greenhouse gas emissions. Page *et al.* (2011) reviewed a large number of assessments of GHG emissions from peatlands in SE Asia and concluded that the best available estimate of GHG emissions from oil palm plantations on peat was 86 tonnes of CO_2 per ha per year (annualized over 50 years) based on combined subsidence measurements and closed chamber measurements in the same plantation landscape.

Methane emissions from open water bodies such as drainage canals and ponds are likely to impact the methane balance. This may be significant since the water surface from drainage canals may account for us to 5% of the total area of a plantation on peatland. Nitrous oxide is primarily emitted from agricultural landscapes as a byproduct of nitrification and denitrification. In oil palm plantations, the application of fertilizers in particular accelerates the release of nitrous oxide and also of CO_2 (by catalyzing biological processes that result in oxidation). It is important to note that current sustainability measures in oil palm plantations on peatlands will only decrease emission source strengths, but will not stop peat carbon emissions, which with a drainage level of 40-60 cm will still be around 35-55 tonnes of CO_2 per ha per year.

Once a plantation is developed, maintaining the water table as high as practically possible (40-60 cm) and preventing fires will considerably reduce CO_2 emissions since oxidation and fires are the largest emission sources.

The following are areas where the oil palm sector can minimize GHG emissions on peat plantations:

WATER MANAGEMENT

In the case that a plantation is developed on peat, good water management is the key factor to keep greenhouse gas emissions as low as possible. Every cm of drainage causes an emission of around 0.91 tonnes of CO_2 per hectare annually. Flooding has to be avoided because this enhances the formation and emission of methane and reduces yields. This Manual recommends maintaining water levels in the field drains at 35-60 cm. However, if palms are immature, even water levels of 35-45 cm are sufficient to obtain high yields and this will reduce the greenhouse gas emissions further. For detailed guidance, see SECTION 3.1 PAGE 37.

FIRE PREVENTION

Burning of biomass for clearance and burning of drained peat in dry years is the second largest source of greenhouse gas emissions in peat swamp areas. Uncontrolled burning in peatlands can lead to an average emission of about 1000 tonnes of CO_2/ha. The implementation of zero burning and fire prevention measures will help to reduce emissions due to burning. Pulverization of old palms is a technique that is commonly used to clear old plantations for replanting. The pulverized material can be applied in the field for protection of the soil for drying and for fertilizing the soil, limiting carbon loss. In particular, it has been suggested to use high-tech field shredders/chippers/mulchers (for sample technology, see http://www.fae-ap.com.au/content.asp?L=3&idMen=317) to accelerate decomposition (and at the same time reduce incidences of oil palm-related diseases) during replanting. For detailed guidance, see ANNEX 8 PAGE 207.

SOIL COMPACTION

The compaction of the peat soil before planting has been reported to lead to lower CO_2 emissions compared to no compaction before planting of oil palms. The oxidation of the peat will be reduced due to the decreased porosity of the soil (Witjaksana, 2011). Maintenance of grasses, ferns, mosses (natural vegetation) and other soft vegetation on bare soil will add to the reduction of decomposition of the peat soil due to drainage by reducing the soil temperature and reducing the evaporation from the soil.

FERTILIZER PRACTICES

The use of 'coated' nitrogen fertilizer will help to reduce N_2O emissions. It is recommended to implement fertilizer practices that optimize N-fertilizer and maximize organic fertilizer use including composting and careful fertilizer application during rainy seasons. In addition, fertilizer can increase the breakdown of the peat soil by bacteria accelerating oxidation and subsidence. Reduction of fertilizer use can thus reduce the CO_2 emissions. For detailed guidance, see SECTION 3.2 PAGE 67.

CARBON STOCK

Carbon stocks can be maintained and increased through maintenance and rehabilitation of buffer zones and High Conservation Value Areas, planting other crops and optimal oil palm planting density. Conserving adjacent (or where appropriate, within plantation) forested areas will increase the carbon stock of the area. For further guidance, see SECTION 5.1 PAGE 137 and 'Manual on BMPs for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Tropical Peat'.

It is also recommended to implement IPM and pest/disease controls to maximize plantation productivity. Reductions in productivity (from crop losses due to pests and diseases) increase GHG emissions per unit of CPO. For detailed guidance, see SECTION 3.3 PAGE 71.

MILL PRACTICES

Implementing good mill practices like capturing methane, improving energy efficiency and production of fertilizer from POME and EFB (studies show that a 60-tonne capacity mill can provide 20% of an estate's fertilizer needs) can contribute to GHG emission reductions.

FUEL UTILIZATION

It is recommended to use renewable fuels wherever possible and maximize fuel savings by using water and rail transport systems. For detailed guidance, see SECTION 4.2 PAGE 119.

5.5 SOCIAL AND CULTURAL ISSUES

Satisfactory amenities lead to healthy and more productive workers. Proper housing, water and electricity supplies are basic needs. Clinics, shops, playgrounds and other supporting amenities will make a big difference in labour productivity and retention.

In areas where plantations operate, it is not uncommon in some cases for there to be prior users or owners of the land. Often those in the area include communities with either claims to tenure, use, territory or environmental services. In peatland areas, traditional communities and indigenous groups there are intrinsically tied to the land for a wide range and often essential uses. These can include ancestral lands, community forests, subsistence or low impact agriculture and relying on the area itself for natural resources. These resources include timber, sustenance and other Non-Timber Forest Products (NTFP). In addition peatland are also often maintained as natural water regulators preventing flooding and ensuring soil fertility.

There are often issues relating to Native Customary Rights (NCR) and land claims by natives both in Malaysia and Indonesia. These should be resolved peacefully by negotiation and sometimes, inevitably via conflict resolution methods and tools available. For oil palm plantations on peatlands, one risk from poor relations with local communities and not resolving conflicts at early stages may be higher chances of fire due to arson. BOX 12 PAGE 156 elaborates on various approaches to conflict resolution available.

Local communities may also be affected due to secondary impacts originating from plantations. Should water levels be disturbed to such a degree that downstream freshwater and coastal resources are threatened, then those dependent on these resources will face loss of livelihoods or increased risk to pollution.

Coastal and indigenous groups that have resided in peatland areas often rely almost exclusively on the resources provided by peatland areas. The close relationship with the peatlands often extend to include significant cultural sites, forest produce, fisheries, construction materials and fuel on a sustainable basis.

A culturally and socially successful plantation would be well aware of these issues and already establishing itself within the community as a partner and supporter of both economic development and rights of these communities. Plantations can drive important local growth and economic development (see SECTION 5.6 PAGE 161) in the area itself. The following are suggestions on how plantation companies can contribute to community socio-economic development through their (corporate) social responsibility:

- Capacity building and training
- Entrepreneurship support like setting up of sundry shops
- Provision of amenities like housing, utilities (water and electricity), clinics, schools, playgrounds, common halls for gatherings and wedding ceremonies, religious facilities like mosques and churches, etc.
- Employment of workers of all background, race or religion (equal opportunity employment)
- Subsidized transportation for employees to send children to school

For more details and examples of an oil palm plantation company's contributions and relationships with local communities, see BOX 13 PAGE 158.

BOX 12

Approaches to conflict resolution (adapted for the oil palm plantations sector from "Company–Led Approaches to Conflict Resolution in the Forest Sector" by Emma Wilson, 2009).

The paper offers examples of tools and approaches that are being employed by companies and non-industry players working closely with companies to address conflict-related issues. These include efforts by Aracruz Cellulose in Brazil to build dialogue with local indigenous groups in order to address a long-running dispute over land rights; the experience of APRIL in Indonesia in developing a land dispute resolution protocol based on the principles of FPIC; and the corporate strategies and tools employed by major companies such as Stora Enso, Mondi and Weyerhaueser.

The key conflict issue identified by most respondents was that of recognizing and negotiating rights to land and resources. For a company, this and other issues can be related in a broader sense to management of stakeholder relations. A range of mechanisms and flexible, locally tailored approaches are usually required to address conflicts. The following are key elements to successful conflict resolution:

RECOGNIZING RIGHTS

Conflicts frequently arise where the customary rights of existing land users are unclear or are not recognised. Such conflicts are usually the most serious, complex and difficult to address. In such cases a fundamental element of conflict resolution is the identification and clarification of the rights of local land users.

PARTICIPATORY MAPPING

An effective way to identify customary land rights is through participatory mapping exercises involving affected communities and other stakeholders. Ideally, companies should initiate such exercises and incorporate the practice into their ways of working. To date, participatory mapping has generally been initiated by NGOs in attempts to resolve conflicts and promote the rights of local users.

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STAKEHOLDER ENGAGEMENT

Getting stakeholder engagement right is of critical importance to oil palm plantation companies that are keen to secure their "social license to operate" in areas where local communities are present, and manage relations with other key stakeholders, including NGOs and government.

IMPACT ASSESSMENTS

Environmental and social impact assessments involve stakeholder engagement and are key requirements for RSPO certification. It is useful to note that how a stakeholder engagement process is conducted is more important than the fact of it taking place.

INTEGRATING CONFLICT MANAGEMENT INTO MANAGEMENT SYSTEMS

It is important for a company not only to listen to the needs and concerns of stakeholders, but also to address these needs and concerns – sometimes by adapting and amending company practices, and to provide feedback to stakeholders on the company response. In order for this to be effective, the company team that specializes in conflict management needs to be well integrated into the rest of the operations; ways of addressing disputes and conflicts need to be embedded into normal practice and need to be the responsibility of operational managers; conflict management needs to be part of the overall management system of the operation.

COMPANY GRIEVANCE MECHANISMS

Company grievance mechanisms constitute more than just a series of public meetings with local communities. They provide communities with appropriate channels of communication to make their concerns known to the company as they arise, and importantly they offer a formalized internal process within the company for addressing grievances.

RSPO has its own Grievance Process to address complaints made against RSPO members. Grievances are passed to the Grievance Panel, which is responsible for resolving the grievances, according to RSPO statutes and standards. Individual RSPO members are also expected to have their own functioning grievance or complaints mechanisms at the project site level to resolve disputes. There is also a Procedure for Complaints and Grievances relating to the performance of RSPO certification bodies.

BOX 13

Case Study Social and cultural issues relating to cultivation of oil palm on peat at PT TH Indo Plantations.

The total project area in Riau is 82,000 ha of which 70,000 ha has been planted with oil palm from 1997 to 2004. About 7% of the area is classified as shallow peat (0.5-1.0 m depth), 63% moderately deep peat (1-3 m depth) and 30% deep peat (>3 m depth).

Approximately 10,000 ha of peat forests along the 2 main rivers, namely Sungei Simpang Kanan and Sungei Simpang Kiri within the project site, were left uncleared to serve as green zone for conservation of biodiversity. Sago palms are growing naturally along the river banks and are harvested by the local community as additional sources of income.

During the early stage of development, the local community in the project area was not interested in plantation work on the peat estates. The Company had no choice but to recruit migrant workers from other parts of Indonesia especially Lombok, Java, Sumatra Utara and Nias. With proper selection, work agreement/ discipline, training and supervision, there were generally no major work related problems.

At later stages, the local community, seeing the progress of the migrant workers, became more interested in working for the Company. They were absorbed into the workforce where possible or employed by contractors of the Company as contract workers. With proper labor control and integration efforts by the Company, the different ethnic groups of various social and cultural backgrounds were able to co-exist harmoniously without conflict.

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The main means of transport to the project site is by motorized boats. Due to the distance of the project site from urban centres, costs of living, especially food items, are relatively high. The Company has helped to up set up sundry shops (*waserda*) in each estate and controlled prices of essential items where possible.

Provision of adequate amenities is the key to a healthy, happy and more productive workforce where most if not all, have considered their workplace as their *kampong* where they earn their livelihood. Proper housing, water and electricity supplies are basic needs provided in all estates and mills. Clinics, schools, playgrounds and other supporting amenities are in place to improve labour productivity and retention of workers, especially trained harvesters.

The religion of most local and migrant workers including staff is Islam with only a small minority of Christians. Mosques were built in all 24 estates and the main mill site.

To date the Company has set up 4 kindergartens, 7 primary schools and 2 secondary schools to provide education for the children of the employees and local community at subsidized rates (see FIGURE 47 PAGE 160).

FIGURE 47
A school set up by PT TH Indo Plantations for educating the children of estate workers and local community.

There are 12 clinics in the property providing free medical care for all staff and workers. The clinics also serve the local community around the estates.

There is a minimum wage for workers, which is fixed by the Local Government and reviewed upward every year. Each worker is also given monthly allowances for 1 wife and 3 children (max.) up to age 20 years, as well as rice allowances.

There were occasional incidences of thefts involving fuel and fertilizers. To minimize such incidences, security measures were strengthened in theft prone areas.

There have been some cases of land claim by natives but relatively minor compared to other parts of Indonesia with oil palm plantations, especially those developed on mineral soils. These are usually resolved peacefully by negotiation and some, inevitably by monetary compensation.

5.6 COOPERATION WITH LOCAL COMMUNITIES

It is often heard that many plantations find it extremely challenging in trying to recruit workers from their community area. The reasons often cited by plantations include the differences in expectations between many communities and the estate.

Often individuals in the community may be involved in part-time or casual work, such as seasonal labour. Such an arrangement is suited to many as it allows time for tending to their own land; often cultivated with cash crops like rubber or oil palm and fruit orchards.

Plantations may find benefit in extending community relations both in sophistication and cooperation. Thus far examples are rare of synergies between local communities and plantations. It is often that the parallel lives exist. The closest relations often heard are the selling of cash crops to plantation mills.

However plantations may find cost-benefits from increasing its sourcing of food with local content. Many communities often lack resources and capacity in entrepreneurial ventures. Plantations may be pivotal in raising capacity of communities in trade, tourism, marketing and agronomic practices.

Oil palms grown on peatland have also been documented as being especially challenging to manage, and the problems are highlighted in other sections here. Due to the increased intensity of managing palms in peat soils, resistance to even minor mechanization and challenging terrain plantations in peatland demand higher labour inputs. Each area of work may also be more challenging as opposed to plantations established in other soil types.

With this in mind (and recognizing the specific health and welfare concerns in peat areas) plantations need to anticipate and address human resource needs to maintain productivity. Measures to monitor potential disease prevalent to peat or water-logged areas should be prioritized.

Relevant sections of the Indonesian Sustainable Palm Oil (ISPO) Principles and Criteria are as follows:

PRINCIPLE 5: SOCIAL RESPONSIBILITY AND COMMUNITY

CRITERION 5.1 Social responsibility and social environment – Plantation managers should have a commitment to social and community development as well as development of local knowledge.

INDICATORS

1. Commitment to social responsibility and social environments in accordance with prevailing norms in local society available
2. Records of realization of commitments to social responsibility and social environments

GUIDANCE

1. Improving the quality of life and environment that benefits both the company itself, local communities and society in general
2. Participate in improving the welfare of the community through partnerships
3. Implement developments around the estate through various activities such as education, health, infrastructure, agriculture, small and micro enterprises, sports, arts, religion, socioeconomics, etc.

CRITERION 5.2 Empowerment of Indigenous Peoples/local communities – Plantation manager plays a role in increasing the welfare of indigenous peoples/local communities

INDICATORS

1. Have programs to increase the welfare of indigenous peoples
2. Have programs to preserve local knowledge
3. Records related to the realization of indigenous peoples programs available

GUIDANCE

1. Having a role in empowering indigenous peoples
2. Providing employment opportunities to indigenous peoples

5.7 OCCUPATIONAL HEALTH AND SAFETY ISSUES

Plantation activities are labor intensive and in some situations, regarded as being more difficult on peat than on mineral soil plantations. During rainy seasons, due to the presence of localized flooded patches, there could be more incidences of mosquito-related infectious diseases. Soggy fields and road conditions during wet seasons may also result in higher cases of accidents in the field. During dry seasons, good drinking and bathing water may be limiting in some peat estates, giving rise to related health problems.

It is therefore important to consult with estate employees/workers for promoting and creating safe work systems and environments in peat estates rather than just basing on prescriptive regulations.

There must be full commitment from the estate management to create a wider sense of accountability and responsibility. Regular health and safety audits are necessary to analyse the root cause of any accident. It is important to ensure the competency of operators handling estate machinery and road worthiness of tractors/machines used in peat estates. Care in the choice, storage and handling of pesticides as well as protective clothing must be taken into consideration.

Plantation healthcare and safety issues must be given adequate attention in peat plantations to reduce expenditures in curative treatments, sick pay and absenteeism. It is important to a have full-time health and safety officers to ensure occupational safety and health issues become a part of work culture in any peat estate.

6.0 BEST MANAGEMENT PRACTICES (BMPs) RESEARCH & DEVELOPMENT, MONITORING AND DOCUMENTATION

6.1 RESEARCH AND DEVELOPMENT

Research and development is vital for continual improvement of BMPs for oil palm cultivation on peatland, especially since this is a relatively new area of development for the oil palm sector.

The task of increasing productivity, efficiency and decreasing adverse impacts or slowing down adverse processes of oil palm plantations on tropical peat poses a great challenge to researchers and planters. Most large companies with substantial peat plantings e.g. United Plantations, Tradewinds Plantations and PT TH Indo Plantations have set up their own in-house Research and Advisory Departments to meet these needs. When engaging third-party agronomists for advisory services, it is important to select those with actual field experience on tropical peat.

More applied research is vital to enhance the potential of decreasing environmental impacts of oil palm cultivation on peat. Cost-effective innovations are continuously needed to meet the many challenges of oil palm cultivation on peatland. Planters with practical experience can also play a role in developing new peat technologies rather than just leaving it to agronomists and researchers.

RESEARCH AREAS

The following research areas are suggested to enhance yields and cost-effectiveness of cultivating oil palm on peat:

- Nutritional trials to establish the optimum nutrient ratios of N, K, and B for different stages of oil palm development on different types of peat
- Long term monitoring of physical and chemical changes of peat after development, including peat subsidence and changes in peat depth after drainage
- Assessment of plantation life span in view of subsidence related increasing flood risks, undrainability and the issue of exposure of infertile or acidic subsoils at the demise of the peat layer; identification of cut-off points and development of after use and rehabilitation plans
- Research on *Ganoderma* management on peat, to find early detection techniques. Selection and breeding of palm tolerant to *Ganoderma* BSR to be intensified
- Testing of different planting materials especially those with high yield but low height increment to minimize the palm leaning problem and good *Ganoderma* tolerance
- Techniques to minimize palm leaning problems on peat e.g. directional leaning
- More innovative drainage systems e.g. contour drainage
- Monitoring and decreasing GHG emissions on developed peat. Finding ways to minimize GHG emission is of high priority
- Conduct more density trials to fine-tune optimum planting densities on different peat types
- More R&D on mechanization on peat especially in-field evacuation of harvested fruit bunches

6.2 MONITORING AND REPORTING

By law, oil palm plantation companies are required to monitor and report on environmental and social impacts of their developments in the form of environmental and/or social management plans. This is especially important for cultivation on peatland, an environmentally sensitive ecosystem with complex hydrological regimes. BOX 14 provides details of these requirements in Malaysia.

BOX 14

Monitoring and reporting requirements in Malaysia.

In Sarawak, Malaysia, the local Authority NREB (Natural Resource and Environmental Board) requires peat estates to submit quarterly environmental reports covering waste management and analysis of water quality.

STRAPEAT-UNIMAS-NREB (2004) provides the following guidance on Environmental Management Plans (EMPs) as required by the EIA process in Malaysia. Identification of monitoring requirements is an important aspect of the EIA process where the project proponent should undertake during and after the establishment phase of development. These requirements ought to be developed as an EMP.

A monitoring program should generally identify:

- Type of monitoring required, for example, water quality and peat subsidence measurements
- Suitable locations of monitoring, ideally to be identified and marked on a map and the frequency of monitoring
- Methodologies used in samplings
- Types of measurements to be undertaken, for example, Ammoniacal-Nitrogen content

The monitoring requirements together with the mitigating measures are developed into an EMP. In general, the monitoring requirements together with the mitigating measures are developed into an EMP. EMPs ought to include the following:

- Management of ground water level
- Management of excessive discharge to minimize flood
- Control of peat fire
- Management of crops and pests
- Control of fertilizer leaching and chemical pollution
- Conservation of unique habitat and biodiversity
- Management of scheduled wastes and sewage
- Maintenance of road surface
- Environmental monitoring and auditing requirements
- Responsibilities and role of project proponent for the protection of the environment
- Conclusion and recommendations

Aside from regulatory requirements (keeping in mind the various overlaps), plantations companies are also encouraged to carry out monitoring and reporting for the purpose of minimizing GHG emissions as follows:

- Water levels – Levels to be maintained as high as practically possible (35-45 cm) for minimal oxidation
- Subsidence – Minimization of subsidence hence oxidation leads to GHG reductions. Monitoring should be done on a monthly basis or as frequent as practically possible
- Yields per hectare – Measurements should be taken at different blocks to ensure a clearer overall picture of the entire estate
- Fertilizer and pesticide inputs – Regular censuses should be carried out to determine and plan for optimum agrochemical inputs
- Weather – Rainfall, flood and other weather-related data should be collected as part of fire prevention measures as well as to support estate water and agrochemical management. On a macro level, Hot Spot Monitoring Systems using remote sensing by satellite can also provide useful climatic data
- Fuel utilization – To maximize fuel efficiency and GHG reductions

6.3 DOCUMENTATION OF OPERATING PROCEDURES

Documentation of BMPs and including this information in oil palm plantation companies' standard operating procedures is the key to effective implementation of these BMPs. This is in line with RSPO CRITERION 4.1 (Operating procedures are appropriately documented and consistently implemented and monitored) and CRITERION 8.1 (Growers and millers regularly monitor and review their activities and develop and implement action plans that allow demonstrable continuous improvement in key operations). This practice is also good for maintaining continuity in operations i.e. plantation staff changes will not affect operations.

7.0 OIL PALM CULTIVATION BY SMALLHOLDERS ON PEATLAND

Smallholder production has much to offer the future of the palm oil industry in terms of sustainability and credibility especially in Indonesia where about 40% of palm oil production are from the smallholder sector (holdings <25 ha).

According to Vermeulen and Goad (2006), at present, the main types of arrangements for smallholders are:

- SUPPORTED SMALLHOLDERS Growers who cultivate palm oil with the direct support of either government or the private sector. The basic concept is that the government agency or private plantation company provides technical assistance and inputs of seed stock, fertilisers and pesticides, on a loan basis, sometimes partially subsidized by government. There may be a verbal or written contract delineating the agreement and possibly including guarantees of sales, plus terms for calculating the mill price. Examples of supported smallholder schemes are nucleus-plasma (PIR) in Indonesia and the variety of land resettlement and rehabilitation schemes in Malaysia (RISDA, FELCRA, FELDA).
- INDEPENDENT SMALLHOLDERS Growers who cultivate palm oil without direct financial and technical assistance from government or private companies. They sell their crop to local mills either directly or through traders. In Malaysia, independent growers are proliferating as independent mills multiply and FELDA schemes mature towards less regulation and subsidy.
- COLLECTIVE LANDOWNER SCHEMES are another option for local communities who hold land title or recognised customary land rights. These are land leases or joint ventures, whereby local landowners rent out use rights of their land to a plantation company, or collect a share of profits based on the equity value of their land. This is not strictly a smallholder model, but can be an attractive alternative for local landowners. The mini-estate or Konsep Baru in Malaysia (Sabah and Sarawak) and Lease-lease-back schemes in Papua New Guinea are current models.

BOX 15 PAGE 175 provides an example profile on smallholders on peat in Indonesia.

Oil palm yields of small-holders on peat both in Indonesia and Malaysia are generally much lower than large plantations due mainly to poor land preparation and inadequate agronomic inputs, especially poor water management, inadequate/imbalanced fertilizer applications, improper pest and disease management and poor harvesting practices. Many smallholders have also use illegitimate planting materials with high dura contamination giving rise to lower FFB yield and oil extraction.

Coordination and cooperation is the key to effective implementation of BMPs for cultivation on oil palm on peatland for smallholders. For smallholders, implementation of vital components for cultivating oil palm on peat like water management, fertilizer management, pest and disease control and fire prevention, usually require a network for cooperation either with companies or amongst other smallholders. Local governments also have a role to play as coordinators. Implementation problems may be less inherent for scheme smallholders but independent smallholders usually require technical and financial support. In line with this, the Malaysian Palm Oil Board (MPOB) has initiated the establishment of a programme called *Pusat Tunjuk Ajar dan Nasihat* (TUNAS), which aims at spearheading the provision of extension services to independent oil palm smallholders. Initiatives such as TUNAS are important for facilitating transfer of technologies to smallholders. It is also important to note that in general, more research is needed on the topic of smallholder oil palm cultivation on peatland.

BOX 15

Profile on smallholders on peat, District Siak, Province Riau, Indonesia.

In Riau there are group of smallholders coordinated by the Farmers Cooperative that manage plantations on peat. Although management does not follow best management practices yet, they are open to assistance by any interested organizations.

These smallholders are located in Siak district in two sub districts, Bunga Raya and Pusako. They are coordinated by *Kelompok Tani* (farmers groups) under 7 cooperatives while their membership is about 1,140 head of families (total persons involved is about 4,560 persons with one family consisting of 4 persons). From this amount, 850 head of families or 2,200 ha, are preparing to be certified by RSPO (assisted by Yayasan ELANG, a local NGO).

The total land area is about 3,500 ha, all located in shallow peatland, very close to the Siak River. Reports by PTPN5 shows that the land is 30% inorganic, 70% shallow peat and is owned by smallholders. The plantation was developed by the local government with the objectives of overcoming poverty in the Siak area and giving opportunities to smallholders to have better lives. The project started in 2003 in Pusako district where smallholders owned the land while the government provided assistance to establish plantations. The establishment was contracted by the local government to government plantation PTPN5. The plantation was established, ditches developed and seeds sourced from Marihat (one of the original seed suppliers in Indonesia). The transfer of the plantation from PTPN5 to the smallholders was done in 2009.

Assessments of the site by the RSPO PLWG in 2011 indicated that although some BMPs were followed – the smallholders were following fertilizer regimes better suited for mineral soils and there were not adequate control structures in the drains to maintain appropriate water levels. It was clear from the visit that significant improvements could be made if further guidance on BMPs could be given to them.

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ANNEX I GLOSSARY & ABBREVIATIONS

AASS Actual acid sulfate soils
Aerobic Relating to, involving, or requiring free oxygen
AMDAL Analisis Mengenai Dampak Lingkungan (Environmental Impact Assessment, Indonesia)
Anaerobic Relating to living in the absence of free oxygen
APRIL Asia Pacific Resources International Holdings Limited
ASEAN Association of Southeast Asian Nations
ASS Acid sulphate soil
BAPPENAS Badan Perencanaan Pembangunan Nasional (National Planning Agency, Indonesia)
BMP Best management practise
BSR Basal stem rot
Bt Bacillus thuringiensis
CEC cation-exchange capacity
CPO Crude palm oil
DID Department of Irrigation and Drainage
DOSH Department of Occupational Safety and Health
Edaphic Related to or caused by particular soil conditions, as of texture or drainage, rather than by physiographic or climatic factors
EFB Empty fruit bunches
EIA Environmental impact assessment
EMP Environmental Management Plan
ESA Environmentally Sensitive Area
Euthrophication Characterized by an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes the shallow waters of oxygen
FDRS Fire Danger Rating System
FELCRA Federal Land Consolidation and Rehabilitation Authority (Kementerian Kemajuan Luar Bandar dan Wilayah, Malaysia)
FELDA Federal Land Development Authority (Lembaga Kemajuan Tanah Persekutuan, Malaysia)
FFA Free fatty acid
FFB Fresh fruit bunch
Fibric Organic soils that are least decomposed, and comprise intact fibers
FPIC Free Prior and Informed Consent
FSC Forest Stewardship Council
Fulvic acids Yellow to yellow-brown substances that are found in organic soils, soluble in water under all pH conditions and which may become suspended in water
GA General Assembly
GHG Greenhouse Gases
GPS Global Positioning Satellite
HEC-RAS Hydrologic Engineering Centers River Analysis System
Hemic Organic soils that are moderately decomposed with 1/3-2/3 intact fibre
HGU Hak Guna Usaha (Cultivation Rights Title, Indonesia)
HGB Hak Guna Bangunan (Right to Build, Indonesia)
High Conservation Value (HCV) HCV is a Forest Stewardship Council (FSC) forest management designation used to describe areas who meet criteria defined by the FSC Principles and Criteria of Forest Stewardship. Specifically, high conservation value are those that possess one or more of the following attributes:

1. Areas containing globally, regionally or nationally significant: concentrations of biodiversity values (e.g. endemism, endangered species)
2. Areas containing globally, regionally or nationally significant large landscape-level forests, contain 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. Areas that 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)

Histosols A worldwide soil type rich in organic matter, as peat (USDA Soil classification), especially prevalent in wet, poorly drained areas
HP Hak Pakai (Right of Use, Indonesia)
IPM Integrated Pest Management
IPS International Peat Society
ISPO Indonesian Sustainable Palm Oil
IUP Plantation Business License (Indonesia)
IUP–B Plantation Business Permit for Cultivation
IUP–P Plantation Business License for Processing
LGP Low ground pressure
Meristematic region The region on a plant where division of cells (and hence growth) occurs. For palm oil palm, the meristematic region is situated in the centre of the crown just below the growing point.
MoF Ministry of Forestry
MPOB Malaysian Palm Oil Board
MPOC Malaysian Palm Oil Council
MSR Middle Stem Rot
MWL Mean Water Levels
NCR Native Customary Rights
NPP National Physical Plan (Malaysia)
NTFP Non-Timber Forest Products
Oligotrophic Relatively low in plant nutrients and containing abundant oxygen in the deeper parts
Ombrogenous Describes a peat-forming vegetation community lying above ground water level: it is separated from the ground flora and the mineral soil, and is thus dependent on rain water for mineral nutrients. The resulting lack of dissolved bases gives strongly acidic conditions, and only specialized vegetation will grow. Ombrogenous peat is deep peat.
PA Protected Areas
PASS Potential acid sulphate soil
Pedohydrology Refers to an emerging scientific field formed from the intertwining branches of soil science and hydrology
Pinnae A part of a leaf of a fern or palm, corresponding to a leaflet in some flowering plants
PIR Pola Inti Rakyat (Nucleus plasma estate, Indonesia)
PLWG Peatland Working Group
PNG Papua New Guinea
Polyphenolic compounds A structural class of natural, synthetic, and semi-synthetic organic chemicals characterized by the presence of large multiples of phenol units (a class of chemical compounds consisting of a hydroxyl group (—OH) bonded directly to an aromatic hydrocarbon group)
POME Palm Oil Mill Effluent
P & C Principles & Criteria (RSPO)
P & D Pest and Disease
REDD+ reducing emissions from deforestation and degradation, sustainable management of forests and the enhancement of forest carbon stocks
RISDA Rubber Industry Smallholders Development Authority (Malaysia)
RP Rock Phosphate
RSPO Roundtable on Sustainable Palm Oil
R&D Research and Development
Sapric Organic soils that are most decomposed
SE Asia Southeast Asia
SOP Standard operating procedure
SRPM Strategy for Responsible Management of Peatlands
Topogenous Describes a wetland that develops as a result of a high local groundwater table caused by local relief such as a poorly drained basin or underlying impervious rock strata. In general, topogenous swamps tend to be either alkaline or neutral and thus do not preserve organic materials especially well. Topogenous peat is shallower peat.
TRMM Tropical Rainfall Measuring Mission
TUNAS Pusat Tunjuk Ajar dan Nasihat (Msia)
UKL/UPL Upaya Pengelolaan Lingkungan/ Upaya Pemantauan Lingkungan (Environmental Management and Monitoring Plan, Indonesia)

ANNEX 2

RESOLUTION ADOPTED AT 6TH RSPO GENERAL ASSEMBLY (2009)

Establishment of a working group to provide recommendations on how to deal with existing plantations on peatlands

BACKGROUND

Noting that peatlands are the most efficient and the largest terrestrial carbon store. Accounting for less than 3 % of the global land surface, they store more carbon than all terrestrial biomass and twice as much as all forest biomass;

Acknowledging that peatland ecosystems and their natural resources are under great threat as a result of large scale reclamation, deforestation and drainage, causing degradation and soil carbon oxidation;

Recalling that the RSPO established a Working Group to investigate and develop principles and criteria for greenhouse gas (GHG) emissions from land use change, and that this group failed to reach a consensus on the pertinent issue of how to deal with existing palm oil plantations on peat;

Recognizing that even the minimum estimates of CO_2 emissions from existing oil palm plantations on peatlands mean that palm oil from these plantations is not sustainable;

Further recognizing that besides GHG issues, in many cases palm oil plantations on peat in the long term may also result in significant on- and off-site hydrological impacts as a result of soil subsidence and reduced water retention capacity,

Wetlands International proposes the resolution set out below.

THE 6TH RSPO GENERAL ASSEMBLY GATHERED IN KUALA LUMPUR AGREES TO THE FOLLOWING:
A Committee will be established to explore and develop business models for optimizing sustainability of existing oil palm plantations on peatlands, including options for restoration and development of alternative economic uses.

By the 8TH RSPO in 2010:

1. The Executive Board will have developed the terms of reference for the Committee, and appointed its members;
2. The Committee will have developed business models for sustainable options for current oil palm plantations on peatlands. This will include exploring water management regimes appropriate to reduce emissions, mechanisms that facilitate restoration of peatlands and recommendations on after-use of plantation areas on peat.
3. Recommendations will be ready for presentation to the members of the 8TH RSPO 2010.

ANNEX 3

PEATLAND WORKING GROUP (PLWG)

Summary Terms of Reference for the RSPO Peatland Working Group (PLWG)

SCOPE OF WORK

The proposed objectives of the PLWG are to:

- A. OBJECTIVE 1 Identify the environmental and social impacts related to oil palm plantations on peatlands.
- B. OBJECTIVE 2 Identify best practices for managing oil palm plantations on peat soils in order to minimize GHG emissions and enhance sustainability.
- C. OBJECTIVE 3 Identify practical methodologies for assessing and monitoring carbon stocks and key GHG emissions from oil palm plantations established on peat soils
- D. OBJECTIVE 4 Evaluate options and constraints for the rehabilitation of degraded peatlands.

ACTIVITIES

It is proposed that the PLWG will work closely with and with the second RSPO Greenhouse Gas Working Group (GHG WG2), in order to provide specific information on oil palm plantations established on peatlands and make recommendations that would allow members to the RSPO to reduce emissions from existing plantations and mitigate potential future emissions from new plantations. The detailed tasks of the PLWG according to the four objectives are as follows:

1 Identify the environmental and social impacts related to oil palm plantations on peatlands.

- 1.1 Conduct a review of literature/other information sources to identify:
  - A. the environmental impacts of oil palm plantations on peatlands with focus on GHG, but including other issues (biodiversity etc)
  - B. social and economic impacts of oil palm plantations developed on peatlands
  - C. impacts of oil palm plantations on peatlands at a landscape level – e.g. impacting adjacent lands through drainage
- 1.2 Collate information on the current spatial extent of existing plantations established on peat soils, as well as the planned extent of future oil palm planting in peatland areas.
- 1.3 Collate information (and identify gaps) on the spatial extent of peatlands in main countries with oil palm on peatlands and stratify into appropriate categories including:
  - A. depth of peat; and,
  - B. the degree of existing land degradation (eg forest clearance, fires, overdrainage, subsidence etc)
- 1.4 Collate information on potential GHG emissions and other environmental impacts for a “business as usual” scenario for peatland development based on current practices and probable expansion under existing conditions.
- 1.5 Assess the long term effect of subsidence on the viability of oil palm cultivation on peat.

2 Identify best practices for managing oil palm plantations on peat soils in order to minimize GHG emissions and enhance sustainability.

- 2.1 Conduct review of literature/other information on best management practices for oil palm plantations on peat.
- 2.2 Compile/prepare case studies on best practices in oil palm plantations.
- 2.3 Organize field visits to a selection of oil palm plantations on peat with different management regimes.
- 2.4 Collate and compare current practices of peat management with other production systems on peat soils.
- 2.5 Develop best practice guidelines on oil palm plantations on peat.
- 2.6 Develop a strategy for promotion of best practices on peatlands.

3 Identify practical methodologies for assessing and monitoring carbon stocks and key GHG emissions from oil palm plantations established on peat soils

- 3.1 Compile information on practical methodologies to document and monitor carbon stocks and GHG flux from oil palm plantations on peat.
- 3.2 Work with GHG WG2 (Workstream 3) to develop practical procedures applicable in peatlands to estimate changes in GHG flux following enhanced management.

4 Evaluate options and constraints for the rehabilitation of degraded peatlands.

- 4.1 Collate information on the experience of rehabilitation of degraded peatlands.
- 4.2 Assess the changes in carbon stocks and flows (and flux of other GHG) that would occur from rehabilitated peatlands.
- 4.3 Compile information on potential of carbon finance and other mechanisms to avoid peatland degradation and support peatland rehabilitation
- 4.4 Identify options and constraints for rehabilitation or sustainable use of degraded peatlands, land cleared or earmarked for oil palm (but not planted) and after use of oil palm plantations
- 4.5 Evaluate the cost and feasibility of rewetting degraded/drained peatlands.

OUTPUTS

The main outputs of the Working Group are envisaged as follows:

- A. A review identifying the main environmental and social impacts related to oil palm plantations on peatlands.
- B. A guideline for best management practices (BMP) for oil palm plantations on peat in order to minimize to minimize GHG emissions and enhance sustainability.
- C. Identification of practical methodologies that can be adopted by RSPO members to assess and monitor key GHG emissions that originate from oil palm plantations established on peat soils.
- D. An evaluation of options and constraints for the rehabilitation of degraded peatlands Options for converting oil palm plantations on peat soils to alternative sustainable land-uses, including the restoration of peatlands.

PLWG MEMBERS

The following members of the PLWG participated in working group meetings and or provided specific inputs or references to support the work of the group. Affiliations were correct at the time of involvement in preparation of manual.

1	Faizal Parish	Global Environment Centre, GEC (Co-Chair)	Malaysia
2	Rosediana Suharto (Dr)	Indonesian Palm Oil Council, IPOC (Co-Chair)	Indonesia
3	Adrian Suharto	Neste Oil Singapore Pte Ltd	Singapore
4	Aljosja Hooijer (Dr)	Deltares, Delft Hydraulics	Netherlands
5	Arina Schrier-Uijl (Dr)	Wetlands International (Consultant)	Netherlands
6	Balu Perumal	Global Environment Centre, GEC	Malaysia
7	Bambang Hero Saharjo (Dr)	Sawit Watch/Bogor Agricultural University (IPB)	Indonesia
8	Cherie Tan	WWF International	Singapore
9	Chong Wei Kwang	HSBC Bank Malaysia Berhad	Malaysia
10	David Lee	Global Environment Centre, GEC	Malaysia
11	Fahmuddin Agus (Dr)	Indonesian Agency for Agricultural Research and Development	Indonesia
12	Franki Anthony	Sime Darby Plantations Sdn Bhd	Malaysia
13	Gusti Z Anshari (Dr)	Universitas Tanjungpura, UNTAN	Indonesia
14	Hasnol Othman	Malaysian Palm Oil Board, MPOB	Malaysia
15	Ivy Wong	WWF - Malaysia	Malaysia
16	Jean-Pierre Caliman	PT SMART	Indonesia
17	Jimmy Tan	Neste Oil Singapore Pte Ltd	Singapore
18	Marcel Silvius	Wetlands International	Netherlands
19	Mukesh Sharma (Dr)	Asian Agri	Indonesia
20	Olivier Tichit	SIPEF	Indonesia
21	Peter Lim Kim Huan (Dr)	PT Bumitama Gunajaya Agro	Indonesia
22	Pupathy Uthrapathy Thandapani	Sime Darby Plantations Sdn Bhd	Malaysia
23	Ruslan Abdullah (Dr)	Sime Darby Plantations Sdn Bhd	Indonesia
24	Si Siew Lim	Grassroots (Consultant)	Malaysia
25	Siti Norralakmam Yahya	Sime Darby Plantations Sdn Bhd	Malaysia
26	Sue Page (Dr)	University of Leicester	UK
27	Thomas Barano	WWF – Indonesia	Indonesia
28	Wim Giesen	Euroconsult/BMB Mott MacDonald	Netherlands

Meetings, site visits and stakeholder workshops held

- 22-23 APRIL 2010 1st meeting – Jakarta
- 22-24 SEPTEMBER 2010 2nd meeting – Kuala Lumpur
- 18-20 JANUARY 2011: 3rd meeting – Sibu
- 19-21 MAY 2011: 4th meeting – Pekanbaru, Riau
- 22-24 AUGUST 2011: 5th meeting – Kuala Lumpur
- 27-28 SEPTEMBER 2011: 6th meeting – Kuala Lumpur
- Site visits: Malaysia (Selangor and Sarawak) and Indonesia (Riau)
- Stakeholder workshops during JANUARY – AUGUST 2011 (200 participants): Sarawak, Riau and Kuala Lumpur

ANNEX 4

DISTRIBUTION OF PEATLANDS IN SOUTH EAST ASIA

The total peatland distribution in South East Asia is calculated at 27.2 million hectares or 271,991 km^2 (see TABLE 8). Indonesia alone has 22.5 million hectares, which is 12% of its land area and 83% of the South East Asian peatland area. FIGURE 48 below shows the distribution of lowland peat in Indonesia and Malaysia.

FIGURE 48
Map showing distribution of lowland peat in Indonesia and Malaysia (Source: SarVision, 2011).

The lowland peatlands of Indonesia are found mainly in Sumatra, Kalimantan and Papua. A large proportion of these peatlands consist of ombrogenous and topogenous peats close to the coasts of Sumatra, Kalimantan and Papua. According to Hooijer *et al.* (2010), it is estimated that 30.8% of Indonesia's peatlands occur in Sumatra, 25.9% in Kalimantan and 11.4% in Papua. For details, see TABLE 8.

TABLE 8
Estimation of lowland peat area in South East Asia (Hooijer *et al.*, 2010).

COUNTRY		LOWLAND PEAT AREA (km^2)
Indonesia		**225,234**
Kalimantan	**58,379**	
Central Kalimantan	30,951	
East Kalimantan	6,655	
West Kalimantan	17,569	
South Kalimantan	3,204	
Sumatra	**69,317**	
Aceh	2,613	
North Sumatra	3,467	
Riau	38,365	
Jambi	7,076	
South Sumatra	14,015	
West Sumatra	2,096	
Papua	**75,543**	
Other Indonesia	**21,995**	
Malaysia		**20,431**
Peninsular Malaysia	5,990	
Sabah	1,718	
Sarawak	12,723	
Brunei		**646**
Papua New Guinea		**25,680**
South East Asia		**271,991**

Estimates of major peat swamp forest areas are provided by Posa *et al.* (2011). The precise extent and condition of tropical peatlands is still unclear, as accurate delineation of peat soil is difficult and many areas have already been lost or degraded. Using published estimates from various sources, they calculated that a maximum of only 36.8% of the historical peat swamp forest area remains (see TABLE 9).

TABLE 9
Estimates of major peat swamp forest areas (in hectares) in SE Asia (Posa *et al.*, 2011).

REGION	INITIAL AREA	REMAINING	% REMAINING	PROTECTED	% PROTECTED
Indonesia	**15,351,600**	**5,724,600**	**37.3**	**1,514,400**	**9.9**
Sumatra	8,252,500	2,562,200	31.1	721,200	8.7
Kalimantan	6,787,600	3,160,600	46.6	763,200	11.2
Sulawesi	311,500	1,800	0.6	30,000	9.6
Malaysia	**2,730,500**	**882,000**	**32.3**	**142,800**	**5.2**
Peninsular	984,500	249,200	25.3	44,400	4.5
Sabah & Sarawak	1,746,000	632,800	36.2	98,400	5.6
Brunei	**104,000**	**87,300**	**83.9**	**21,800**	**21.0**
Thailand	**68,000**	**30,400**	**44.7**	**20,600**	**30.3**
SE Asia Total	**18,254,100**	**6,724,300**	**36.8**	**1,699,500**	**9.3**

Also Page *et al.* (2010) has published their best estimates of peat area, thickness and volume (see TABLE 10).

TABLE 10
Best estimates of peat area and mean thickness in tropical Southeast Asia (Page *et al.*, 2010).

COUNTRY	PEAT AREA (ha)	PEAT THICKNESS (m)
Indonesia	20,695,000	5.5
Brunei	90,900	7.0
Malaysia	2,588,900	7.0
Myanmar (Burma)	122,800	1.5
Papua New Guinea	1,098,600	2.5
Philippines	64,500	5.3
Thailand	63,800	1.0
Vietnam	53,300	0.5

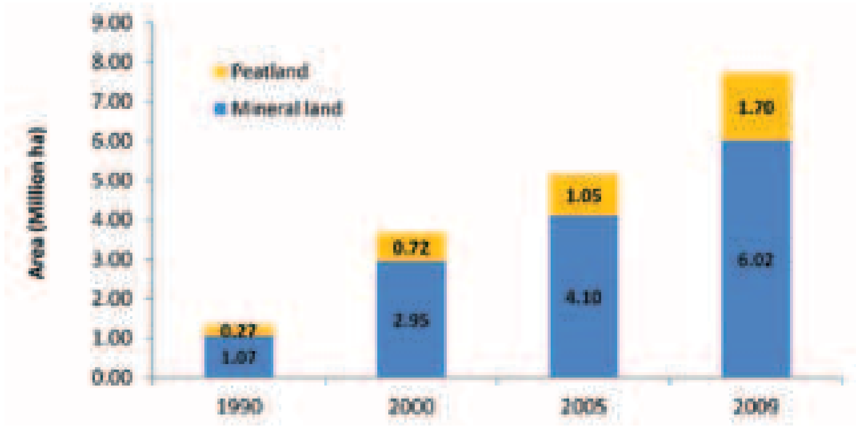
OIL PALM CULTIVATION ON PEATLAND IN INDONESIA AND MALAYSIA

The 2009 oil palm land use in Peninsula Malaysia, Sabah and Sarawak was determined using 2008-2009 satellite images (Omar *et al.*, 2010). The total area of oil palm detected in this study was 5 million hectares, of which 0.67 million hectares was on peat (see TABLE 11). This is about 13% of total oil palm hectarage in Malaysia. According to this study, by far most oil palm plantations on peat occurred in Sarawak; 0.44 million hectares, which is over 37%. A recent study by SarVision commissioned by Wetlands international (SarVision, 2011) using satellite images combined with soil maps and ground surveys, estimated that 41% of Sarawak's oil palm area was on peat.

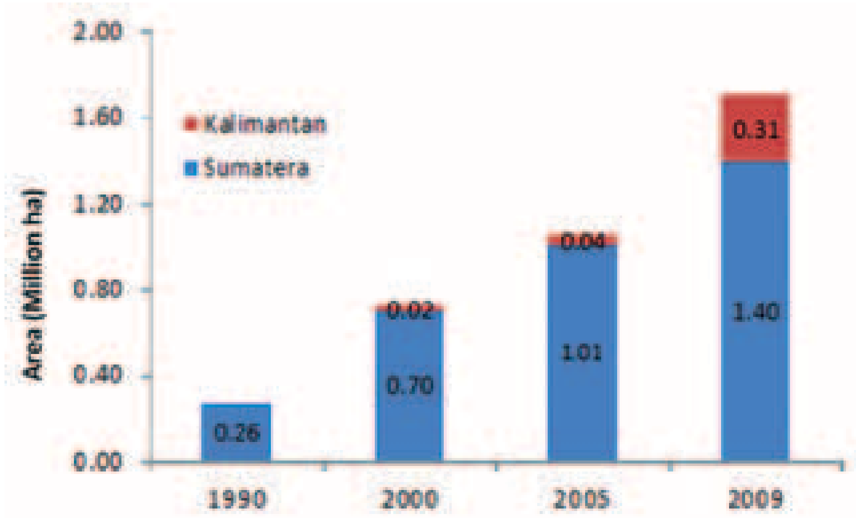
TABLE 11
Oil palm on peat in 2009 in Malaysia (Omar *et al.*, 2010).

REGION	OIL PALM (ha)	OIL PALM ON PEAT(ha)	(%)
Peninsular Malaysia	2,503,682	207,458	8.29
Sabah	1,340,317	21,406	1.60
Sarawak	1,167,173	437,174	37.45
Total	**5,011,172**	**666,038**	**13.29**

Currently, for Indonesia data availability is low, so it is not possible to get exact figures on oil palm plantations on peat. However, FIGURES 49 and 50 provide estimates of oil palm development on peat in Indonesia (especially Sumatra and Kalimantan) between 1990 and 2009 (Agus *et al.*, 2011).



FIGURES 49
Development of oil palm plantations in the three major islands (Sumatra, Kalimantan and Papua) of Indonesia on peatland and mineral soils between 1990 and 2009 (Source: Agus *et al.*, 2011).



FIGURES 50
Development of oil palm plantations in Sumatra and Kalimantan on peatland between 1990 and 2009 (Source: Agus *et al.*, 2011).

ANNEX 5

POTENTIAL IMPACTS OF OIL PALM CULTIVATION ON PEATLAND

The range of potential social and environmental impacts specific to oil palm development on peatland is given below (adapted from STRAPEAT-UNIMAS-NREB, 2004):

POTENTIAL IMPACTS OF OIL PALM CULTIVATION ON PEATLAND

PEAT SOILS

- Uneven peat compaction due to drainage and machinery movement
- Peat subsidence and peatland degradation due to uncontrolled drainage
- Irreversible drying of peat due to over draining and exposure of surface soils
- Fire hazard of desiccated peat
- Some soil erosion due to disturbance and exposure
- Acidification if in the presence of sulphidic layer below the peat (for shallow peat with potential acid sulphate soil substratum)

HYDROLOGY AND DRAINAGE

- Alteration of drainage pattern due to construction of drains, roads and perimeter bunds and land subsidence
- Reduction of water holding capacity due to loss of peat (from subsidence)
- Reduction of groundwater recharge and lowering of water level
- Changes in groundwater flow
- Disturbance of hydrological balance
- Reduction of ecological function of peatland – flow regulation and flow control
- Consequences of saline water intrusion in some cases
- Impact to adjacent farms (compatibility of crops due to different water table requirements) and peat swamp forest due to draw down effect of drainage

WATER RESOURCES AND QUALITY

- Impact to public water supply catchment due to reduction of catchment size and water holding volume
- Drainage impact of acidic water to river systems, which provide fish and drinking water for communities in the vicinity and downstream of the project area
- Drainage impact on mangrove swamps
- Degradation of surface and groundwater water quality by fertilizers (peat requires large amounts of nutrients to make the soil fit for growing crops) and other agrochemicals, and possible release of organic pollutants from the plantation
- Euthrophication of surface waters
- Long term pollution of local water supplies for settlements using river water

AIR QUALITY

- In some cases, impact from open burning and subterranean fire – air pollution due to open burning of the cleared vegetation, which may result in impacts like haze that may be difficult to control and can be propagated elsewhere

HABITAT LOSS AND BIODIVERSITY CHANGE

- Impacts that are inherent to the removal of the swamp and the peat – loss of genetic resources (loss of flora, fauna), destruction of habitat or habitat fragmentation, depletion in aquatic resources, loss or change of natural landscape, loss of productive function, loss of social function, impacts on flooding and local fisheries

SOCIOECONOMICS

- Possibility of land-use conflicts in adjacent areas with incompatible crops that require different drainage regimes
- Eradication of rural poverty, particularly through well-managed smallholder schemes

ANNEX 6

RELEVANT RSPO PRINCIPLES & CRITERIA AND NATIONAL INTERPRETATIONS (INDONESIA, MALAYSIA AND PAPUA NEW GUINEA)

The following are the RSPO P&C, associated indicators and guidance from Malaysia, Indonesia and Papua New Guinea National Interpretation documents that cover oil palm cultivation on peatland and water management issues.

CRITERION 2.1 There is compliance with all applicable local, national and ratified international laws and regulations.

Specifically includes adherence to regulations governing peatland management, which is almost always certain to be categorized in a special or sensitive environmental category.

CRITERION 4.2 Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield.

CRITERION 4.3 Practices minimise and control erosion and degradation of soils.

NATIONAL INTERPRETATION (MALAYSIA)
INDICATOR 4.3.4 Subsidence of peat soils should be minimised through an effective and documented water management programme. (Minor compliance)

Specific Guidance: Maintaining water table at a mean of 60 cm (within a range of 50-75 cm) below ground surface through a network of weirs, sandbags, etc. in fields and watergates at the discharge points of main drains.

NATIONAL INTERPRETATION (INDONESIA)
National Indicators (Minor):

- Maps of fragile soils must be available.
- A management strategy should exist for plantings on slopes above a certain limit (needs to be soil and climate specific).
- Presence of a road maintenance program.
- Subsidence of peat soils should be minimised under an effective and documented water management programme.

GUIDANCE Techniques that minimise soil erosion are well-known and should be adopted, wherever appropriate. This may include practices such as ground cover management, biomass recycling, terracing, and natural regeneration or restoration instead of replanting. For existing plantings on peat, water table should be maintained at a mean of 60 cm (within a range of 50-75 cm) below ground surface through a network of appropriate water control structures e.g. weirs, sandbags, etc. in fields, and Watergates at the discharge points of main drains (see also CRITERION 4.4 and 7.4).

NATIONAL INTERPRETATION (PAPUA NEW GUINEA)
INDICATOR 4.3.4 Subsidence of peat soils should be minimised under an effective and documented water management programme.

Guidance for independent smallholders: Independent smallholders can demonstrate that they have an understanding of the techniques required to minimise soil erosion and that these are being implemented. No plantings have been or will be established on peat soils of over 3 m depth. (Major compliance issue)

CRITERION 4.4 Practices maintain the quality and availability of surface and ground water.

NATIONAL INTERPRETATION (MALAYSIA)
INDICATOR 4.4.1 Protection of water courses and wetlands, including maintaining and restoring appropriate riparian buffer zones at or before replanting along all natural waterways within the estate. (Major compliance)

Specific Guidance: Riparian buffer zones: Reference to be made to relevant national regulations or guidelines from state authorities e.g. Department of Irrigation and Drainage (DID), whichever is more stringent.

INDICATOR 4.4.2 No construction of bunds/weirs/dams across the main rivers or waterways passing through an estate. (Major compliance)*

INDICATOR 4.4.3 Outgoing water into main natural waterways should be monitored at a frequency that reflects the estates and mills current activities which may have negative impacts (Cross reference to C 5.1 and 8.1). (Major compliance)

INDICATOR 4.4.4 Monitoring rainfall data for proper water management. (Minor compliance)

Specific Guidance: Data trended where possible over 3 years to look into resource utilization

INDICATOR 4.4.6 Water drainage into protected areas is avoided wherever possible. Appropriate mitigating measures will be implemented following consultation with relevant stakeholders. (Minor compliance)

INDICATOR 4.4.7 Evidence of water management plans. (Minor compliance)

Specific National Guidance for Smallholders and Small-growers: Scheme Managers should provide appropriate training for their participants on the importance of maintaining the quality and availability of surface and ground water. Independent smallholders can demonstrate that they understand the need to maintain the quality and availability of surface and ground water and these are being implemented. Small-growers should comply with INDICATORS 4.4.1, 4.4.2 and 4.4.6.

NATIONAL INTERPRETATION (INDONESIA)

National Indicator (Major): Protection of watercourses and wetlands, including maintaining and restoring appropriate riparian buffer zones at or before replanting.

National Indicator (Minor): An implemented water management plan

Guidance: Growers and millers should address the effects of their use of water and the effects of their activities on local water resources. The Water Management Plan may include:

- Taking account of the efficiency of use and renewability of sources.
- Ensuring that the use of water does not result in adverse impacts on other users.

* For cultivation of oil palm on peatlands, the construction of canals/ water ways are required. This indicator should exclude canals constructed by estates. Emphasis is also required on the need to take community and downstream users into consideration when planning and implementing these infrastructures.

CRITERION 4.5 Pests, diseases, weeds and invasive introduced species are effectively managed using appropriate Integrated Pest Management (IPM) techniques.

CRITERION 4.6 Agrochemicals are used in a way that does not endanger health or the environment. There is no prophylactic use of pesticides, except in specific situations identified in national Best Practice guidelines. Where agrochemicals are used that are categorised as World Health Organisation Type 1A or 1B, or are listed by the Stockholm or Rotterdam Conventions, growers are actively seeking to identify alternatives, and this is documented.

CRITERION 5.1 Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continuous improvement.

NATIONAL INTERPRETATION (INDONESIA)

National Indicator (Major):

- Documented impact assessment.
- Records of regular report on environmental management in accordance with relevant regulations.

National Indicator (Minor): Revisions to environmental management document if there are changes in companies operating areas or activities.

Guidance: Documented impact assessment is AMDAL for plantation area >3000 ha and UKL/UPL for plantation area <3000 ha. In view of the fact that development activities in general will alter the environment, it is important to pay due attention to environmental components having the following characteristics:

1. Environmental components for which the functions must be maintained, safeguarded and preserved, such as:
   - A. protection forests, conservation forests, and biosphere reserves
   - B. water resources
   - C. biological diversity
   - D. air quality
   - E. natural and cultural heritage
   - F. environment quality
   - G. environmentally-oriented cultural values

2. Environmental components which may undergo fundamental change(s), along with such change(s) as are considered important by the community in the area of the proposed business or activity, for instance:
   - A. land ownership and control
   - B. employment and business opportunities
   - C. living standards of the community
   - D. public health

AMDAL is Analisis Mengenai Dampak Lingkungan Hidup consisting of 3 (three) main documents; 1) Environmental Impact Assessment, 2) Environmental Management Plan, and 3) Environmental Monitoring Plan. The company must report periodically to related institution on environmental management and monitoring plan implementation. It is the responsibility of the companies to provide sufficient objective evidence to the audit team that the full requirements of an EIA are met for all aspects of plantation and mill operations, and captures all changes over time. Environmental impact assessment should cover the following activities where they are undertaken:

- Building new roads, processing mills or other infrastructure.
- Putting in drainage or irrigation systems.
- Replanting or expansion of planting area.
- Disposal of mill effluents (see CRITERION 4.4);
- Clearing of remaining natural vegetation.

Impact assessment may be a nonrestrictive format e.g. ISO 14001 EMS and/or EIA report incorporating elements spelt out in this criterion and raised through stakeholder consultation. Documented management action plans addressing issues raised from the above impact assessment, which is monitored annually. Effects on the environment can be identified on soil and water resources, air quality (see CRITERION 5.6), biodiversity and ecosystems, and people's amenities (see CRITERION 6.1 for social impacts), both on and offsite. Stakeholder consultation has a key role in identifying environmental impacts. The inclusion of consultation should result in improved processes to identify impacts and to develop any required mitigation measures. It is important that where activities, techniques or operations change over time, identifications of impacts, and any required mitigation, are updated as necessary.

CRITERION 5.2 The status of rare, threatened or endangered species and high conservation value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and their conservation taken into account in management plans and operations.

CRITERION 5.5 Use of fire for waste disposal and for preparing land for replanting is avoided except in specific situations, as identified in the ASEAN guidelines or other regional best practice.

NATIONAL INTERPRETATION (INDONESIA)

National Indicators (Major):

- Documented assessment where fire has been used for preparing land for replanting.
- Records of implementation of zero burning policy.
- Procedures and records of emergency responses to land burning (*Tanggap Darurat Kebakaran Lahan*)

National Indicators (Minor): Presence of appropriate fire extinguishers and facilities, depending on the risks assessment.

Guidance: Fire should be used only where an assessment has demonstrated that it is the most effective and least environmentally damaging option for minimising the risk of severe pest and disease outbreaks, and with evidence that fire-use is carefully controlled. Use of fire on peat soils should be prohibited.

NATIONAL INTERPRETATION (PAPUA NEW GUINEA)

Papua New Guinea (PNG) Guidance notes: Fire should be used only where an assessment has demonstrated that it is the most effective and least environmentally damaging option for minimising the risk of severe pest and disease outbreaks, and with evidence that fire-use is carefully controlled. Use of fire on peat soils should be avoided. Extension/training programmes for smallholders is necessary.

CRITERION 5.6 Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.

The specific reference for 5.6 is with emission of greenhouse gases during development or replanting of peat areas.

NATIONAL INTERPRETATION (MALAYSIA)

INDICATOR 5.6.3 Monitor and reduce peat subsidence rate through water table management (Within ranges specified in C 4.3). (Minor compliance)

Specific National Guidance for Smallholders and Small-growers: Scheme Managers should include an assessment of all polluting activities by their participants and develop abatement plan. Small-growers should be aware of their polluting activities and implement plans to reduce them. Not applicable to independent smallholders.

ANNEX 7

RELEVANT INDONESIAN AND MALAYSIAN REGULATIONS

INDONESIAN REGULATIONS

INDONESIA FOREST MORATORIUM 2011

The Indonesian President made official the Indonesia Forest Moratorium on 20 MAY 2011. Under this moratorium, central and local governments are not allowed to issue new permits on primary forests and peatlands that are located in conservation areas, protected forest production forest (limited production forest, normal/permanent production forest, conversion production forest) areas and areas for other uses as stated in the indicative map attached to the regulation (see FIGURE 51 PAGE 202).

The moratorium allows the following sectors to continue their activities:

1. All sectors that hold principal permit(s) from the Ministry of Forestry
2. Sectors that are vital to national development such as geothermal, fossil fuel and gas, electricity, rice paddy and sugar cane
3. Holders of renewable forest permits as long as permits are still valid
4. Ecosystems restoration

All related Ministers have to take action to support this regulation. As this regulation is related to the implementation of REDD+, a draft of REDD+ strategies have been issued and to follow it, a detailed indicative digital map consisting of 291 detailed maps has also been issued (see http://appgis.dephut.go.id/appgis/petamoratorium.html). In this draft, a REDD implementing agency with detailed tasks and functions is also explained.

The forest moratorium covers 64 million hectares. MoF data published in 2009 shows total natural primary forest area in Indonesia stands at 44.1 million hectares. Indonesia, based on a survey conducted by the National Development Planning Agency (BAPPENAS), has 21.07 million hectares of peatland. Total area included in the forest moratorium, therefore, can reach as high as 65.17 million hectares instead of 64 million hectares.

Presidential Instruction 10/2011 is not only concerned with the moratorium on the granting of new licenses to utilize natural primary forest and peatlands, but it will also provide time for the Government of Indonesia to solve regulatory conflicts that complicate the forest and land use planning and permit process. Better forest and land use management is critical to the achievement of both a 26 percent greenhouse gas emissions reduction and a doubling of palm oil production by 2020. The industry, therefore, expects the long term effect of a forest moratorium will be to create a more favorable investment climate for palm oil due to less legal uncertainty in the country's forest and land use licensing process.

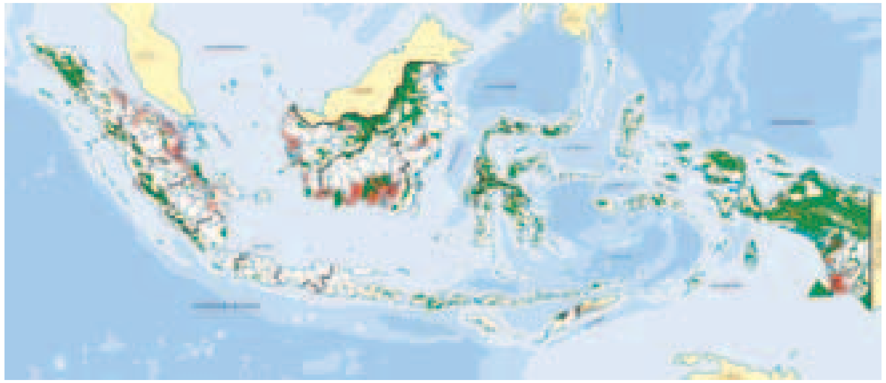


FIGURE 51
Indicative map showing moratorium areas. Green areas are primary, conservation, protection and production forests while red areas are peatlands.

PRESIDENTIAL DECREE NO. 32/1990 AND MINISTRY OF AGRICULTURE DECREE NO. 14/2009

These decrees prohibit the use of peatlands if the peat thickness is more than 3 metres or if the peatland is on conservation or protection forest land. Where existing plantation licenses or pending applications lie on peat soils with a depth greater than 3 metres, such licenses could be revoked under these provisions.

INDONESIAN SUSTAINABLE PALM OIL (ISPO) REQUIREMENTS

Under the Ministry of Agriculture Decree NO. 19/2011, the following ISPO criteria specifically relevant to cultivation of oil palm on peatland are to be implemented:

CRITERION 2.1.5 Plantings on peatland – Planting oil palm on peatlands can be done by observing characteristics of peat so as to not cause damage to environmental functions

INDICATORS

1. Available SOPs/work instructions for planting on peat soil and refer to the applicable regulations
2. Implementation of crop planting documented

GUIDANCE

SOPs or work instructions for planting should include:

- Planting is done on peatland with a depth <3 m and the proportion of planting includes 70% of the total acreage; mineral soil layer below the peat is not quartz sand or acid sulfate soil and peat soil is sapric
- Setting the number of palms and planting density in accordance with field conditions and best agricultural practices
- Implementation of cover crops
- Setting high ground water levels between 50-60 cm to inhibit carbon emissions from peatlands

CRITERION 3.6 Mitigation of Greenhouse Gas Emissions (GHG) – Management of the plantation business must identify the source of GHG emissions.

INDICATORS

1. Technical guidance/SOP for GHG Mitigation available
2. Inventory of GHG emissions sources available
3. Land use trajectory available
4. Records of GHG emission reductions available
5. Records of implementation of mitigations available

GUIDANCE

- Do an inventory of sources of GHG emissions
- Socialization efforts to reduce GHG emissions (methane capture, water management on peatland, proper fertilization, etc.) and calculation methods
- Utilization of solid wastes (fiber, shells, etc.) as boiler fuel and efficiency calculations of fossil fuel use
- Have evidence of land use at least 2 years prior to land clearing for plantation and evidence of cultivation.

BOX 16

Explanation of abbreviations used in ISPO Criteria.

Plantation Business License (IUP) is a written permission from the competent authority and should be owned by companies that do business with integrated plantation production and processing.

Plantation Business Permit for Cultivation (IUP-B) is a written permission from the competent authority and should be owned by a company that does the cultivation of a plantation (it has no processing unit).

Plantation Business License for Processing (IUP-P) is a written permission from the competent authorities and should be owned by a company that does business on plantation production and processing (at least 20% of the raw material must come from owned plantation).

Hak Guna Usaha (HGU) is the right to exploit State-owned land for agriculture, fishery or husbandry purposes for a period of up to 35 years with a possible 25 years extension. It could be renewed on the same land with similar HGU when the permit expires. HGU is given to an area of at least 5 (five) hectares and if it exceeds 25 (twenty five) hectares, it should use decent capital investment and good corporate techniques in accordance with the times.

Hak Guna Bangunan (HGB) is a right to establish and own buildings on land not privately owned with a period of 30 (thirty) years. At the request of rights-holders and keeping in mind the state building construction within this time period may be extended by 20 (twenty) years maximum.

Examination Committee for Soil B, hereinafter referred to Committee B is the committee in charge of ground checks in order to request completion, extension and renewal of HGU. B Committee members consists of various agencies of State and Acting Head of related BPN, local government district/municipality, Head Plantation Office, Head of Provincial Forestry Office, Head of Department of Animal Husbandry/Fishing, and Acting District Head of related BPN. Committee B's task is to examine the completeness of the HGU petition, research and review of physical soil, determine suitability for requested business, conduct an audit for HGU land applied for and give an opinion/judgment on the request as outlined in the Minutes of the Land Inspection.

Rights of Use (Hak Pakai) is the right to use State-owned or other land by public or private persons or entities for a definite period or occasionally for an indefinite period. This land right cannot be sold, exchanged or transferred unless explicitly provided in its grant or agreement. This right may be held by an Indonesian individual or entity, certain foreign individuals or a foreign legal entity with a representative office in Indonesia.

NATIONAL PHYSICAL PLAN (NPP)

The NPP states that Malaysia's Protected Areas (PA) network shall be enlarged to include a full representation of the diversity of natural ecosystems, particularly the lowland dipterocarp forests and wetlands. It also recommends that there shall be adequate buffer zones between ESA and agriculture development.

ENVIRONMENTAL IMPACT ASSESSMENTS (EIAS)

EIAs are a mandatory requirement for proposed development projects categorized as 'prescribed activities'. In exercise of the powers conferred by section 34A of the Environmental Quality Act 1974, the Minister, after consultation with the Environmental Quality Council, makes the following order. The activities as specified in the Schedule below (extracted list) are prescribed to be prescribed activities:

AGRICULTURE

A. Land development schemes covering an area of 500 hectares or more to bring forest land into agricultural production.
B. Agricultural programmes necessitating the resettlement of 100 families or more.
C. Development of agricultural estates covering an area of 500 hectares or more involving changes in types of agricultural use.

DRAINAGE AND IRRIGATION

A. Construction of dams and man-made lakes and artificial enlargement of lakes with surface areas of 200 hectares or more.
B. Drainage of wetland, wild-life habitat or of virgin forest covering an area of 100 hectares or more.
C. Irrigation schemes covering an area of 5,000 hectares or more.

STRAPEAT-UNIMAS-NREB (2004) provides the following guidance in terms of EIA compliance for potential peatland development particularly in Sarawak:

KEY ELEMENTS FOR BASELINE STUDY ON PEAT ECOSYSTEM

Past experience suggests that special focus should be given to:

- Establishing the geomorphological features, topographic profile and the peat depth in the project area
- Examining the drainability of the project area (especially for agricultural development projects); clearly demarcating undrainable deep peat areas that should not be developed
- Identifying all natural drainage systems in the area and their significance (as habitat for supporting aquatic life, saline intrusion/flood control, waterway access route, etc.)
- Inventorizing plant and animal species of scientific and conservation importance and estimation of above ground biomass that may need to be removed and disposed of
- Mapping the present land use, including those on NCR land and neighboring plantations (specifying the type of crops and their water management needs)
- Demarcating water catchment area
- Determining potential land ownership issues/conflicts

DRAINABILITY STUDY

The primary requisite for agriculture development in peat soil is its long term drainability on a sustainable basis, especially because peats in Sarawak are some of the deepest, low-lying and most expansive in the world. Thus drainability is the most significant factor affecting the potential of developing the peatland for any intended purposes. For this reason, detailed topographic surveys should be conducted to determine the drainability of the study area.

A peat soil area should only be economically drained if the mineral subsoil level is above the mean water level (MWL) in the nearby stream or river into which the drainage water will be discharged. If the mineral subsoil level is below the MWL, prolonged drainage and continual subsidence will render the ground surface almost at the same level with the river water level, thus making further drainage by gravity impossible. When this happens, the area will become water-logged, crop growth will be seriously affected, and the development will have to be abandoned.

Drainability studies are required for peat layers of more than 250 cm deep to ascertain either long term drainability could be sustained or to determine the underlying sub-soil level profile in relation to the MWL of the main river that serves as outlet for the main drainage system. Such profiling is important for the following reasons:

- It is more difficult to drain the area if the peat layer is deeper. However, this depends on the level of the mineral subsoil in relation to MWL
- The level of the underlying mineral soil should remain above the water level in the adjoining riverine system. The project area has better potential to be gravity drained if the level of the underlying subsoil is above the MWL. However, if the mineral subsoil is under the MWL, the area will be undrainable for significant periods, rendering cultivation impossible

ANNEX 8

FIRE PREVENTION AND CONTROL

FIRE PREVENTION

Peat fire control comprises three main activities:

1. To prevent peat fire from occurring
2. To extinguish peat fires rapidly while they are still small
3. To practice zero burning at all times

In order for peat fire control to be successful, a comprehensive control plan needs to be drawn up in advance. This plan will form the basis for carrying out prevention and suppression of peat fires.

Peat fire prevention is the most important activity in fire control and is work that must be carried out continuously and diligently. Fire prevention is the most economical way of minimizing damages and losses arising from fire, without having to use expensive equipment. A simple concept for preventing combustion from taking place is to remove one of the three components of the fire triangle (oxygen, heat source and fuel).

There are several strategies that can be used as a guide in efforts to prevent fire. These include:

WATER MANAGEMENT AND MONITORING

A major cause of peat fires can be attributed to the excessive drying of peatlands due to poor water management and over-drainage. Hence it is extremely important to ensure water in the plantation is managed effectively. A good water management system should also be able to remove excess surface and sub-surface water quickly during wet seasons and retain water for as long as possible during dry spells. Maintaining a moist peat surface will help to minimize the risk of accidental peat fire. Associated water management maps should also be utilized and drainage systems and water control structures well maintained, implemented and monitored. Care should be exercised to monitor and ensure water management activities within the plantation do not have adverse effects on adjacent peat swamp areas.

Water-levels in peat can fluctuate rapidly especially during rainy or dry seasons. It is therefore important to carry out regular water level monitoring. This can be done by installing water level gauges at strategic locations and at the entrances of collection drains behind each stop-off and numbered. It will be useful to have a full-time water management officer in each peat estate for effective and timely control of water at optimum level. This person would also be responsible for operating the water-gates, regular checking of bund condition and inspection of water control structures for damage, blockages, etc. There should also be coordination between the water management team and fire suppression units to jointly identify dry and fire-prone areas within the plantation.

FIRE INFORMATION SYSTEM APPROACH

One component in the success of fire prevention measures is a system for providing information about the possibility of fire breaking out, in which the information is distributed well to all relevant stakeholders, including those in the field. Conventionally, this information system is implemented through direct observations in the field (at locations prone to fire) and the use of maps and compasses. Today, with the help of modern technology (computers, telecommunications equipment and remote sensing), it is possible to develop a fire information system based on factors that affect the incidence of fire such as fuel conditions, climate conditions and fire behavior. Types of fire information systems:

1. EARLY WARNING SYSTEM developed using daily weather data as a basis for calculating the drought index. The drought index indicates the moisture deficiency level of the soil and land. Fire viewing towers are also an effective component of early warning systems.

2. FIRE DANGER RATING SYSTEM (FDRS) an early warning system concerning the probability of fire occurring or not. This system was developed on the basis of indicators that influence the incidence of fire. The Malaysian Meteorological Department (MMD) has been producing a FDRS for Southeast Asia on a daily basis since SEPTEMBER 2003. The Southeast FDRS was adopted from the Canadian FDRS developed by the Canadian Forest Service. Daily maps of the Southeast FDRS are available at: http://www.met.gov.my/index.php?option=com_content&task=view&id=4749&Itemid=1157&lang=english

FIRE SUPPRESSION

Fire suppression action should be taken as soon as possible when a peat fire occurs. The following strategies can be followed to ensure an effective fire suppression operation:

- HUMAN RESOURCES SUPPORT
  It is essential that various elements of the community, NGOs, institutions and relevant agencies be involved in fire suppression action, in view of the fact that fire-fighting requires considerable human resources.

- IDENTIFICATION AND MAPPING OF WATER SOURCES
  Water sources (surface water and ground water) in fire-prone land and peat areas need to be identified and mapped. Identification should be carried out during the dry season so that when fires occur, there is a high probability that sources identified earlier will still contain water.

- FUNDING SUPPORT
  The availability of an instant fund is essential. This fund can be used to provide food and drink for fire-fighters in the field, to mobilize the community to help in fire suppression activities, to acquire additional fire-fighting equipment and provide medical facilities for fire victims.

- SUPPORTING FACILITIES AND INFRASTRUCTURE
  Fire suppression activities must be supported by adequate facilities and infrastructure including:
  - Road network
  - Fire towers
  - Communications equipment
  - Telescopes and compasses
  - Transportation vehicles
  - Fire engines and boats (see FIGURES 52 and 53 PAGE 210)
  - Heavy equipment (bulldozers, tractors)
  - Other fire-fighting equipment such as fire beaters, axes, rakes, shovels, portable pumps
  - Protective gear and equipment for fire-fighters (fireproof suits, boots, helmets, gloves, torches, machetes, drinking flasks)
  - Emergency clinic, facilities for treating fire victims

- IDENTIFICATION OF SMOKE FREE ZONE
  It is necessary to identify smoke free areas where fire victims can be evacuated, because smoke from fires has a negative impact on health, causing upper respiratory infections, skin allergies, asthma, etc.

- ORGANIZATION OF FIRE-FIGHTING TEAMS
  It is essential that fire-fighting teams have an organizational structure so that each team member understands his/her role, task and responsibility when carrying out fire-suppression activities.

- STANDARD FIRE-FIGHTING PROCEDURES
  Fire-fighting involves the mobilization of all available people and equipment. Procedures must also cover information monitoring and preparations (before going to the site and at the site).

FIGURE 52
Close up example of fire boat used for fire suppression activities in oil palm plantations on peatland.

FIGURE 53
Field demonstration of water spraying for fire suppression.

SPECIFIC GUIDANCE ON TECHNIQUES FOR SUPPRESSION OF LAND AND FOREST FIRE IN PEATLAND AREAS:

1. Determine the direction in which the fire is spreading (this can be done by observation from a higher point or by climbing a tree)
2. If applicable, consider flooding the burning area by controlling water levels (i.e. adjusting weirs and water gates)
3. Before initiating fire suppression, a water-saturated transect is constructed to slow down the spread of the fire, acting as a non-permanent fire break
4. To prevent fire from jumping across, it is necessary to cut down dead trees, which are still standing upright (snags)
5. If there are no water sources in the area, boreholes must be sunk. If there water sources are far from the fire, water supply is obtained through a relay (using several water pumps)
6. Direct fire suppression should be done from the tail (back) or from the right and left sides of the fire. Do not attempt to fight the fire from the front (fire head) because this is extremely dangerous
7. In burnt areas, mopping up operations must first be carried out to clear the area of embers and ensure that the fire is well and truly out. This is done by spraying water on the surface of the burnt land
8. Fire-fighters must walk with great care, using 2m long planks to prevent them from sinking into holes left by the fire
9. Surface fire suppression is carried out by accurately directing a jet of water at the source of the blaze, using a pump
10. If the fire is in the tree crowns, direct suppression can be carried out with the help of heavy equipment such as aircraft, tractors and bulldozers
11. In cases of ground fire, especially in peatlands during the dry season, suppression is done using a peat spear, which has a hole at the end. The spear's nozzle is jabbed into the smoking ground until the peat fuel takes on the appearance of porridge, a sign that it is saturated with water. This ground piercing is continued until the fire has been extinguished
12. It is essential to extinguish all remnants of the fire, considering that such remnants, concealed beneath stumps and charred debris on peatlands, are often overlooked
13. The area of the fire should be inspected approximately one hour after the fire remnants have been extinguished, with the purpose of ensuring that the area is truly free from fire

ZERO BURNING ON PEATLAND

Zero burning is a policy adopted by the member countries of ASEAN to overcome the problem of transboundary haze pollution due to fire. For this purpose, ASEAN has prepared a manual to serve as a guide to implement the zero burning policy. Several important points regarding the techniques for preparing land without burning are quoted from this manual and given below (ASEAN Secretariat, 2003):

The zero burning technique is a method of land clearing whereby the existing plantation are felled, shredded, stacked and left in-situ to decompose naturally. It is noted that shredding felled oil palms is more difficult on peat soil compared to mineral soils due to the physical properties of peat so alternative technologies like industrial shredders are recommended.

Basic steps in Zero Burning techniques for replanting of oil palm:

1. Planning for replanting
2. Removal of *Ganoderma* diseased palms
3. Prelining
4. Planning and implementation of any new roads and drains
5. Felling and shredding/chipping
6. Stacking/windrowing
7. Lining, holding and planting of oil palm seedlings
8. Pulverization
9. Post-planting management

BOX 17

Guidelines for the Implementation of the ASEAN Policy on Zero Burning (ASEAN Secretariat, 2003).

THE ZERO BURNING TECHNIQUE FOR REPLANTING ON PEAT

Replanting on peat areas is more challenging from the operational as well as environmental perspectives. Peatlands in the tropics usually cover extensive areas and they perform vital hydrological and ecological functions for the entire landscape. In view of this, it is critical that comprehensive environmental impact assessments are conducted to ensure that the proposed replanting does not have significant adverse impact on the ecosystem.

Although the zero burning technique for peat areas would follow the same process of felling and stacking and planting of oil palm as that for replanting of oil palm on mineral soils, the inherent nature of peat would demand additional management inputs, particularly in respect of water management, land preparation and fertilization of the crop. Consequently, the cost of oil palm development on peat can be expected to be significantly higher than that for (Sarawak, Malaysia) areas on mineral soils.

Water Management

In their natural state, peat areas have a high water table and are often waterlogged. Effective water management holds the key to the successful development of oil palm on peat areas. An effective drainage system comprising main and subsidiary drains in a grid pattern that is integrated with the road system should have been put in place before zero burning operations commence. The intensity and dimensions of the drains would depend on the water level, land gradient and physical properties of the peat, particularly depth. The aim is to maintain a consistent water table level of between 50 and 75 cm below the soil surface.

Felling And Stacking

Felling using an excavator should be done soon after any construction of additional drains and roads. Bulldozers are not suitable for this operation on account of the soft ground conditions. Old palms should be pushed over and uprooted wherever possible, and the trunks cut into manageable size by chain saws. The residual palms and debris should be stacked at the intensity of one windrow for every two palm rows.

Soil Compaction

Planting of oil palms on areas that have not been adequately compacted would result in leaning of the palms and exposure of the roots. Additional compaction could be done by excavators about three to four weeks after any construction of additional subsidiary drains.

Holing And Planting Of Oil Palm

As peat areas are inherently less fertile, consideration should be given to planting palms at a higher density; for example at 160 palms per ha compared with 136-148 palms normally adopted for mineral soils. In view of soil subsistence, deep planting of oil palm seedlings is advisable. This is achieved by the 'hole within a hole' method whereby a large hole with a 1.5 m diameter is dug to 25-30 cm depth at the planting point, followed by making a smaller hole of about 40 cm diameter and depth, which will serve as the actual planting hole. Holing can be done mechanically using a puncher attached to the boom of an excavator. The puncher is an implement with a square top section and a conical bottom section to make the 'hole-in-hole'.