RSPO MANUAL ON BEST MANAGEMENT PRACTICES (BMPs)

FOR MANAGEMENT AND REHABILITATION OF NATURAL VEGETATION ASSOCIATED WITH OIL PALM CULTIVATION ON PEAT

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COVER IMAGE
Pristine peat swamp forest and lake system on Kampar Peninsular, Riau, Indonesia

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The statements, technical information and recommendations contained in this Manual are based on best practice and experience and have been prepared by the members of the RSPO Peatland Working Group (PLWG) established by decision of the RSPO General Assembly. The guidance in this Manual does not necessarily reflect the views of the RSPO Secretariat or any of the individual contributors, sponsors and supporters of the process. Every effort has been made to make this Manual as complete and accurate as possible. However there may be omissions or errors, both typographical and in content and over time the contents may become superseded. Therefore this text should be used as a guide and not the sole basis for management and rehabilitation natural vegetation associated with oil palm cultivation on peat. Implementation of these best practice guidance is voluntary and results will vary according to local situations. Neither RSPO nor the PLWG or any contributors or supporters of the process can be held liable for the results of application of the guidance.

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1.0 INTRODUCTION

1.1 INITIATION OF RSPO MANUAL FOR BEST MANAGEMENT PRACTICES

This manual has been prepared under the guidance of the RSPO Peatland Working Group (PLWG). The PLWG was established in 2010 based on a decision by the RSPO General Assembly in 2009 to explore and develop business models for optimizing sustainability of existing oil palm plantations on peatlands, including exploring water management regimes appropriate to reduce emissions, mechanisms that facilitate restoration of peatlands and recommendations on after-use of plantation areas on peat. Further details of the PLWG including scope and membership are given in ANNEX 2 PAGE 152. This Manual is dedicated to maintenance of existing natural vegetation in and adjacent to oil palm plantations on peat as well as rehabilitation of degraded peat sites deemed necessary to supplement the other main output of the PLWG, namely the 'RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat.'

1.2 PURPOSE OF BMP MANUAL AND BENEFITS OF ADOPTION

The objective of this Manual is to provide a set of practical guidance on Best Management Practices (BMPs) that are important for the rehabilitation and management of forested or degraded sites within existing oil palm plantations on peat or areas adjacent to them e.g. river reserves, High Conservation Value (HCV) areas or permanently undrainable patches after prolonged oil palm cultivation.

This Manual draws on experience of peatland management and rehabilitation in SE Asia. It also draws on and refers to existing national regulations and guidelines especially from Indonesia and Malaysia where there is extensive experience in peatland management and rehabilitation.

This Manual is part of the effort by RSPO and its members, particularly producers, in responding to stakeholder concerns to promote the implementation of Best Management Practices and contribute to sustainable peatland management as part of reducing the impacts of oil palm cultivation on peat.

It is noted that while it is possible with good water management measures to maintain peat swamp forest in good condition adjacent to oil palm plantations – restoration of degraded peatlands to its original pristine condition is almost impossible once an area has been cleared, drained and cultivated as much may be irreversibly changed in degraded peatlands (e.g. peat compaction and loss). In such cases, the objective should be to rehabilitate the degraded peat sites as much as practical towards its original state.

1.3 REASONS FOR MANAGEMENT AND REHABILITATION OF PEAT SWAMP FORESTS IN CONJUNCTION WITH OIL PALM CULTIVATION ON PEAT

Peatlands in SE Asia are naturally vegetated with peat swamp forests, which comprise a broad range of species with special adaptations for growing in peat conditions (especially high water levels, low bulk density, high acidity and limited nutrients). When oil palm plantations are developed in peatland areas the natural vegetation is normally cleared except in areas designated for conservation or deemed unsuitable for oil palm cultivation. In addition the rehabilitation of certain sites within a larger area of plantation may provide benefit for the estate, environment and local communities dependent on peatlands.

The following are specific reasons for management and rehabilitation of peat swamp forests in conjunction with oil palm cultivation on peat:

HIGH CONSERVATION VALUES (HCVs) WITHIN OR ADJACENT TO PLANTATION AREAS

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 form unique ecosystems and are valuable resources for local communities. By default, these areas would often be defined as HCV areas. Conservation and maintenance of HCVs are engrained in the RSPO P&C.

HCVs are defined as follows:
High Conservation Value Area (HCVA): The area necessary to maintain or enhance one or more High Conservation Values (HCVs):

- *HCV1. Areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species).*
- *HCV2. Areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.*
- *HCV3. Areas that are in or contain rare, threatened or endangered ecosystems.*
- *HCV4. Areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control).*
- *HCV5. Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).*
- *HCV6. Areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).*

See: 'The HCVF Toolkit' – available from www.hcvnetwork.org

WILDLIFE CORRIDORS

A wildlife corridor is an area of habitat connecting wildlife populations separated by human activities (such as roads, development, or agriculture). This allows an exchange of genetic material between populations, which may help prevent the negative effects of in-breeding and reduced genetic diversity that often occur within isolated populations. This may potentially moderate some of the worst effects of habitat fragmentation.

More importantly for oil palm plantations, systematic and planned maintenance of wildlife corridors within and adjacent to their estates provide corridors for the movement of wildlife and helps to reduce incidences of human-wildlife conflict. If not managed effectively, human-wildlife conflict can have enduring resource and cost implications for any oil palm plantation operating in areas with large animal populations, especially large mammals like elephants and tigers.

RIVER RESERVES OR BOUNDARY BUFFER ZONES

River reserves are essentially the land adjacent to streams and rivers; a unique transitional area between aquatic and terrestrial habitats. Although constituting only a small part of the landscape, river reserves that are intact and functional are important habitats for biodiversity and provide ecosystem services. In Indonesia, river reserves are formally recognized as 50-200 meter-wide green-belts (*jalur hijau*) zones adjacent to streams (50m), rivers (100m) and peat/swamp (200m). Malaysia requires 5-50m river reserves depending on the width of the waterway (see TABLE 1 PAGE 11 for details).

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

- WATER QUALITY IMPROVEMENT: Non-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 absorbs 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.
- 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.

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 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.

UNDRAINABLE AREAS WITHIN PLANTATIONS

Continuous peat subsidence can cause some areas that can initially be gravity drained to become undrainable after several years of oil palm cultivation. In addition, if the mineral subsoil is under the mean water level (MWL), the area will be undrainable for significant periods, rendering cultivation impossible. Such areas may be widespread, especially in the coastal lowlands of SE Asia where tectonic movements over the last 8,000 years have reduced the elevation of many coastal lowlands (e.g. east coast of Sumatra, southern coasts of Indonesian Borneo, coastal plains of Sarawak, west coast of West Malaysia), causing the base of many peat domes to be located now below MWL of rivers and sea. These areas should be clearly demarcated, not developed and if necessary, rehabilitated.

PREVENTION OF DISRUPTION OF HYDROLOGY OF ADJACENT PEAT SWAMP FOREST

Clearing and draining of land adjacent and hydrologically linked to peatland (e.g. edges of peat domes) can lead to hydrological changes and its subsequent degradation. This also often leads to increases in human-wildlife and social conflicts for the plantation involved.

FIRE PREVENTION

A major factor for peat fires is the drying out of peatland. Fires usually occur because of drainage being carried out for plantations (or other reasons). Uncontrolled drainage leads to desiccation and this significantly increases the risk of fire, especially if fire is used as a tool for clearing adjacent land. Maintenance of natural vegetation and appropriate ground water levels within river reserves and peat conservation areas may help prevent fires from occurring and spreading to the cultivated areas.

MANAGEMENT OF DISTURBANCE/ENCROACHMENT

Proper management of river reserves and plantation boundaries are crucial for preventing disturbance/encroachment by illegal settlers or squatters. This is a widespread problem in Indonesia and Malaysia.

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. Where plantations have been developed on the lower slopes of a peat dome – the subsurface flow, through the peat, of water from the top of the dome to the lower slopes, plays a key part in maintaining water levels in the plantation and hence preventing water shortages and associated yield reductions.

MAINTAINING AND INCREASING CARBON STOCK

As part of efforts to minimize greenhouse gas (GHG) emissions, it is recommended for oil palm plantations to increase their carbon stock. Carbon stocks can be increased through maintenance and rehabilitation of buffer zones and High Conservation Value areas. It is also recommended that oil palm plantations conserve adjacent (or where appropriate, within plantation) forested areas. Adoption by a plantation of an adjacent peat swamp forest area can reduce the net GHG emission profile and so can be a useful part of any GHG emission reduction strategy.

1.4 REGULATIONS AND GUIDELINES RELATED TO MANAGEMENT AND REHABILITATION OF PEAT SWAMP FORESTS

Peatland areas are generally identified and subjected to particularly stringent Environmental and Social Impact Assessments (EIA, SIA and SEIA). In addition, regulations in major producers like Indonesia and Malaysia demand adherence to planning laws, pollution regulations, riverine buffers, zero-burning laws and a host of other laws governing various aspects of the industry.

In terms of regulatory requirements for maintenance of conservation areas and river reserves, the Drainage and Irrigation Department (DID), 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)

TABLE 1
River reserve width requirements (DID Malaysia).

Width of waterway between banks	Requirements for river reserve width (both banks)
>40m	50m
20m – 40m	40m
10m – 20m	20m
5m – 10m	10m
<5m	5m

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 130m 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 of oil palm plantation development to decrease greenhouse 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 of new permits related to the plantation are site permits and IUP;
  2. Postponement of 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 of location permits, IUP and other land use rights for 2 (two) years effective from 20 MAY 2011 to 20 MAY 2013.

See BOX 1 PAGE 14 for an explanation of abbreviations used in ISPO criteria.

BOX 1

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 consist 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) are 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.

In addition, RSPO's Principles and Criteria for Sustainable Palm Oil relevant to this issue include:

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 5.2 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.

2.0 PEAT SWAMP FOREST ECOSYSTEMS

2.1 PEAT SWAMP FORESTS AND THEIR IMPORTANCE

Peat swamp forests are an important component of the world's wetlands and form the main wetland type in SE Asia – where they comprise more than 60% of the world's tropical peatlands. They also occur in West Africa and Latin America.

Peat swamp forests are unique habitats for fauna and flora, commonly with a high proportion of endemic species that give these areas global significance not only for unusual species but as a gene bank with untapped and even undiscovered resources for medicinal and other important human uses. They play an important part in stabilizing the ecosystem, particularly in the control of drainage, microclimate, water purification and soil formation. Coastal peat swamps act as a buffer between marine and freshwater systems, preventing excessive saline intrusion into coastal land and groundwater. Peat swamps often serve as a natural gene bank, preserving potentially useful varieties of plant species. At a global scale, the peat swamp forests contribute to the storage of atmospheric carbon that is an agent of global warming, helping to slow down that process. Peat swamp forest areas can also be very productive through the managed extraction of fish (see FIGURE 1 PAGE 18), timber and other non-timber forest products (see FIGURE 2 PAGE 18) (UNDP, 2006).

FIGURE 1
Fishery in peat swamp rivers is mainly for subsistence.

FIGURE 2
Non-Timber Forest Products (NTFP) – *Pandanus*, rattan, etc. for walls, baskets, etc.

Further details of benefits provided by intact peat swamp forests focusing on the provision of ecosystem services include:

FLOOD MITIGATION

Intact peat swamp forests can diminish peak flood flows mainly by reducing water velocity but also by providing a large area for storage of flood waters in terms of spatial area and, to a limited degree (dependent on how waterlogged the peat is already) through the water-holding capacity of the peat.

MAINTENANCE OF BASE FLOWS IN RIVERS

The water from floods held in peat swamps is released gradually over a long period. Intact peat swamps can contribute to maintaining the water level in rivers that run through them during dry periods.

PREVENTION OF SALINE WATER INTRUSION

Saline intrusion is related to base flows in rivers. By maintaining base flows in rivers, peat swamps can prevent the intrusion of saline water up rivers and maintain fresh groundwater in coastal areas. In placed where coastal peat swamp forests have been drained – saline intrusion has often increased, having a negative impact on water supply and agriculture.

SEDIMENT REMOVAL

When a peat swamp area is flooded, the reduction in water velocity associated with it spreading over a wide area, together with the retarding effects of vegetation, allows suspended sediments to settle. Water flowing back into rivers will then be largely sediment free. However, it is noted that this occurs mainly in peatlands along the rivers or in depressions.

NUTRIENT REMOVAL

Nutrients are often adsorbed onto the surfaces of suspended particles and deposited along with them. These nutrients are likely to be incorporated into biomass quite rapidly.

TOXICANT REMOVAL

Peat is very effective in binding metals. This largely accounts for the micronutrient deficiencies (such as copper) that are encountered when using peat soils for agriculture. Other metals (such as mercury and arsenic) are often bound in peat soils that are accumulated from waterborne and airborne sources over long periods. Some such metals are toxic in large quantities and peat acts as a store for them.

CARBON STORAGE AND CARBON SEQUESTRATION

Recognition of this function has gained in importance in recent years due to the implication of raised CO_2 levels in contributing to global warming. Large quantities of carbon are stored in tropical peat lands. Estimates suggest that up to 5,800 tonnes of carbon per hectare can be stored in a 10-meter deep peat swamp compared to 300-500 tonnes per hectare for other types of tropical forest.

Tropical peatlands, besides acting as stores of carbon, actively accumulate carbon in the form of peat. Because decomposition is incomplete, carbon is locked up in organic form in complex substances formed by incomplete decomposition. Drainage of peat swamps destroys this useful function and may contribute to global climate change through the release of CO_2 into the atmosphere.

2.2 CHARACTERISTICS OF SOILS IN PEAT SWAMP FORESTS

The soil in peat swamp forests is organic or peat soil (see FIGURE 3). The soil is derived from the accumulation of dead plants that are not decomposed due to the high water content, high acidity and low oxygen levels in the soil. Soil thickness varies, depending on the length of time of deposition of organic matter and damaging factors such as wild fires. Most coastal ombrogenous peat along the east coast of Sumatra and south coast of Kalimantan has been formed in the past 6,000-10,000 years and often has a maximum depth in the range of 6-12 meters.

FIGURE 3
Peat soil in forest area showing high density of tree roots.

2.3 FORMATION AND ROLE OF WATER IN PEAT SWAMP FORESTS

Tropical lowland peat swamps are generally primarily rain-fed. They have their origins in the topographic conditions that lead to semi-permanent waterlogging. Under natural conditions, they are formed by the accumulation of vegetative matter, which is deposited in the waterlogged soils faster than it can decay. Hydrology is an important (if not the most important) factor in the formation and functioning of peat swamp ecosystems. The hydrology of a peat swamp depends on the climate, topographic conditions, natural subsoil, and drainage base. Any changes in the hydrology, especially those from the introduction of drainage, will often have irreversible effects on the functioning of these fragile ecosystems. A better understanding of the hydrology of peat swamps will make it possible to manage them in a more sustainable way. FIGURE 4 illustrates the formation of peat swamp forests as well the role of water in this process.

Water is vital for the survival of the peat swamps forests. Water, whether in terms of quantity (water level) or quality, affects the survival and growth of plants. A water level higher than the pneumatophores of the plants disrupts the respiratory and air exchange process of the trees. On the other hand, too low a water level causes organic soil to become dry and prone to damage by wild fires and subsidence. The result will be the loss of plants which have adapted to the natural water regime in the peat swamp forest.

Good management of peat swamp forests requires identification of the proper water level for the peat swamps. This is also important for maintaining the water balance of the overall peat swamp landscape as adjacent areas may be affected by water management activities in one area.

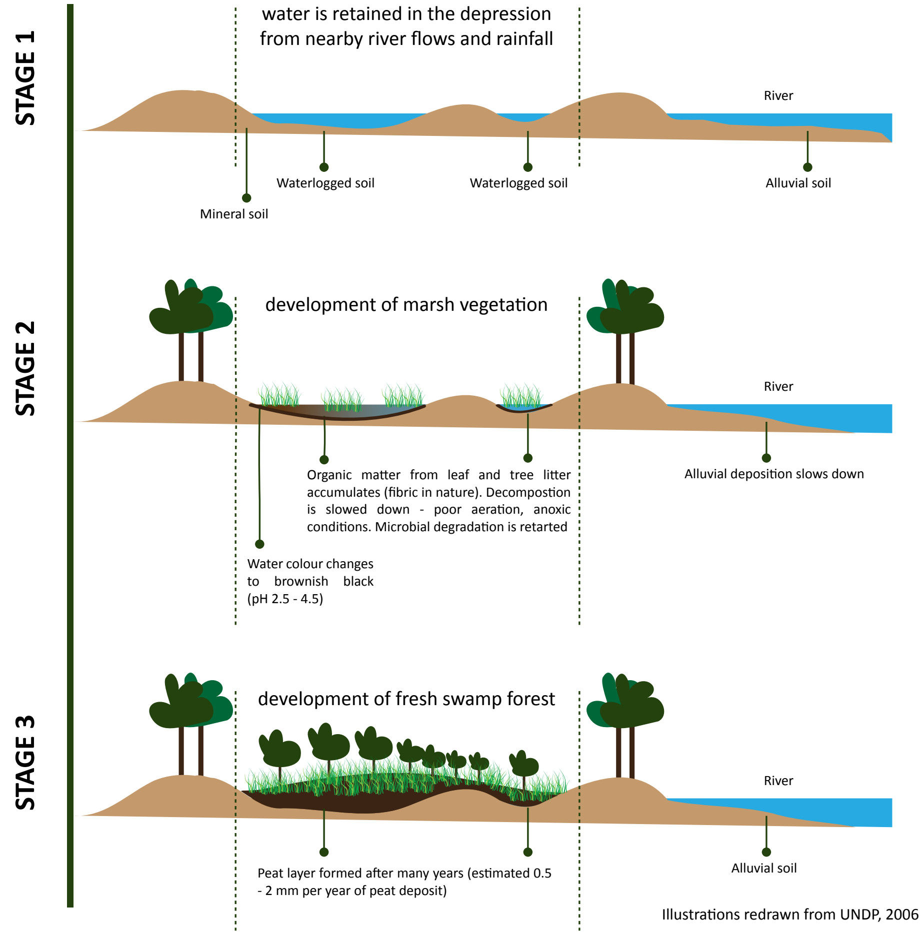

FIGURE 4
Illustration of formation process for peat swamp forests and the role of water (Source: UNDP, 2006).

2.4 PLANT COMMUNITIES IN PEAT SWAMP FORESTS

Plant communities in peat swamp forests possess special plant properties, particularly the root systems, which differ from those of other plant communities. Plants in peat swamps have developed their root systems to survive in the peat soil, where there is extremely high water content. The plants have produced special roots in the form of buttress, which is rather large in size, and stilt roots. Because of the long periods of high water level in the soil, plants have developed pneumatophores emerging from the water (see FIGURE 5), resulting in differing shapes and sizes of roots. For example, pin-shaped roots belong to *Stemonurus secundiflorus*, *Korthalsia laciniosa* and *Eleiodoxa conferta*. Curved noose-shaped roots belong to *Xylopia fusca* and *Calophyllum sclerophyllum*. Knee-shaped roots belong to *Ganua motleyana*, *Campmnosperma coriaceum* and *Alstonia spathulata*. Finally inverted Y-shaped roots belong to *Elaeocarpus macrocerus*.

FIGURE 5
Many species of trees in peat swamp forests display pneumatophores.

Peat swamp forests have diverse plant species. For example in Thailand, more than 470 species and 109 families have been recorded in peat swamp forests (Chamlong, Chawalit and Wiwat, 1991). In Kalimantan, Indonesia, 310 species and 78 families of plants have been recorded in the peat swamp forests (Simbolon and Mirmanto, 1999).

2.5 ANIMALS IN PEAT SWAMP FORESTS

Peat swamp forests are found to have a high biodiversity value for both plant and animal species. In Borneo, these forests are home to wildlife including gibbons, orangutans, and crocodiles. In particular the riverbanks of the swamps are important habitats for the Crab-eating Macaque (*Macaca fascicularis*) and the Silvered Leaf Monkey (*Trachypithecus cristatus*) and are the main habitat of Borneo's unique and endangered Proboscis Monkey (*Nasalis larvatus*), which can swim well in the rivers, and the Borneo Roundleaf Bat (*Hipposideros doriae*). Peat swamp forests are also key habitat for orang utans (*Pongo pygmaeus*, especially in Kalimantan. There are two birds endemic to the peat forests, the Javan White-eye (*Zosterops flavus*) and the Hook-billed Bulbul (*Setornis criniger*) while more than 200 species of birds have been recorded in Tanjung Puting National Park in Kalimantan, Indonesia. Sebastian (2002) provides an assessment of the status of the mammal and bird fauna of both W and E Malaysian Peat Swamp Forest (PSF) habitats. Of the 57 mammal and 237 bird species recorded in PSF, 51% and 27% respectively are listed as globally threatened species.

Peat swamp forests have long been regarded as a species-poor ecosystem with low productivity, low faunal diversity and few endemics (Johnson, 1967), an assumption contradicted by the many endemic and highly stenotopic (restricted) species discovered in recent years (e.g. Kottelat & Lim, 1994; Kottelat & Ng, 1994). Up to 15% of the known freshwater fish species in Malaysia are associated with peat swamps, with more than 80 stenotopic blackwater fish species, representing more than 20% of this specialized fauna, discovered only in the last 20 years (Ng *et al.* 1994).

Peat swamps also harbor a significant number of miniature fish species. The smallest fish in the world is *Paedocypris progenetica* a member of a new genus of paedomorphic cyprinid fish from highly acidic blackwater peat swamps in Southeast Asia. It is the smallest fish and vertebrate known, with the smallest mature female measuring a mere 7.9mm long. Of the 47 miniature fishes in Asian freshwaters listed by Kottelat & Vidthayanon (1993), 27 inhabit swamps, of which 11 live in peat swamps. Since then, new discoveries have brought the total up to 20 named miniature peat swamp species and more are not yet formally described. In peat swamps, miniature fishes survive droughts in shallow pools, burrows of other animals, or in the soil, and small size is a considerable advantage when the water level falls. Even in very dry periods, the peat acts as a buffer and retains isolated pools of clean and cold water. In high domes, the waterlogged peat often releases permanent creeks. The permanent presence of water in this loose soil ensures stability of the peat swamp habitat. This stability must have allowed the survival and favored the evolution of strictly stenotopic species, among them many miniatures.

In addition, the peat swamps are home to the rare hairy nosed otter, the endangered false gharial (*Tomistoma schlegelii*) and a range of waterbird and crocodile species. The North Selangor PSF is one of the most well studied areas, from which 48 peat swamp fishes have been recorded (Ng *et al.*, 1992, 1994). These include rare species from genera such as *Encheloclarias*, *Bihunichthys*, *Betta* and *Parosphromenus* (Ng & Lim 1993; Ng & Kottelat, 1992, 1994). Far from being a depauperate ecosystem, peat swamps possess an interesting fish fauna, which is diverse and unique, and many of the species have narrow niches and restricted ranges.

FIGURE 6
Betta livida – an endemic peat swamp forest fighting fish from North Selangor Peat Swamp forest Malaysia (Source: Stefan van der Voort).

NOTE Shortly after its first discovery in 1992, the site where it was found was turned into a pineapple plantation, which then failed and was converted to an oil palm plantation.

FIGURE 7
Paedocypris progenetica – the world's smallest vertebrate animal – a recently described fish species found in peat swamp forests in Sumatra in 2005 (Source: H. H. Tan).

FIGURE 8
Betta uberis – an endangered endemic fish that lives in small blackwater rivers of peat swamp forests in Borneo.

2.6 ZONATION OF PEAT SWAMP FOREST ECOSYSTEMS

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

Anderson (1961) also found that Tropical Lowland Peat Swamp Forests show conspicuous changes in vegetation types from its periphery to the center of each domed-shaped peat swamp. Anderson, who studied these swamps in Sarawak, Malaysia and adjacent Brunei on the island of Borneo, had used the term "Phasic Community" (PC) to designate a dominant vegetation zone. Anderson recognized six distinct Phasic Communities or zones on the basis of their floristic composition and structure of the vegetation in each zone:

- TYPE 1 Mixed swamp forest; the *Gonystylus-Dactyloclados-Neoscortechinia* association (see FIGURE 10 PAGE 35);
- TYPE 2 Alan forest; the *Shorea albidida-Gonystylus-Stemonurus* association;
- TYPE 3 Alan Bunga forest; the *Shorea albida* consociation;
- TYPE 4 Padang Alan forest; the *Shorea albida-Litsea-Parastemon* association;
- TYPE 5 the *Tristania-Parastemon-Palaquium* association; and
- TYPE 6 Padang keruntum; the *Combretocvarpus-Dactylocladus* association.

NOTE This particular zonation is rarely seen outside of Sarawak. Zonation occurs at all sites but this differs from region to region.

They were numbered PC1 at the periphery to PC6 in the center of the Peat Swamp. See FIGURE 9 PAGE 34 for an illustration of the lateral zonations of peat swamp forests and ANNEX 1 PAGE 150 (Glossary) for a detailed description of the phasic communities mentioned above, both provided by Anderson (1961).

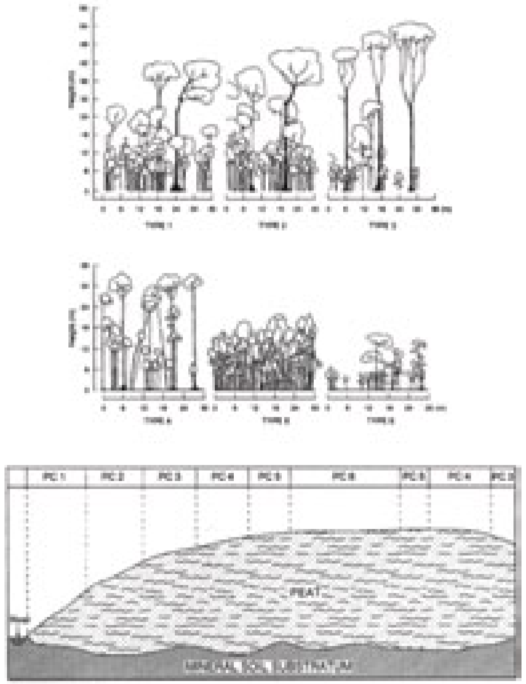

FIGURE 9
Lateral zonations of vegetation in the six phasic communities (Source: Anderson, 1961).

In spite of studies being undertaken over the last 70 years since the work of Buwalda (1940) relatively little is known about the ecology of the Peat Swamp Forests in Southeast Asia. Perhaps the most comprehensive and best known study of the ecology of the Tropical Lowland Peat Swamp Forest was carried out by Anderson over a period of ten years in the 1950s (Anderson, 1961, 1963 and 1983). Anderson recorded 253 tree species (including 40 small trees which rarely exceed 5-10m in height in the Tropical Lowland Peat Swamp Forest. Many of these species recorded by Anderson are also found in other forest types outside peat swamp forest especially many of the species, which are largely confined to the periphery of the Tropical Lowland Peat Swamp Forest, also occur in the Lowland Dipterocarp Forest. On the other hand, the species that are present in the forests located in the center of the peat dome are mainly those that are found on the poorer soils, frequently podzols of the heath forest (Anderson, 1963).

FIGURE 10
Mixed peat swamp forest in Brunei found on relatively shallow peat at margins of domes where species richness is high and are flooded at times by nutrient-rich river water.

2.7 CARBON STORAGE IN PEAT SWAMP FORESTS

Peatlands are major carbon stores. Parish *et al.* (2007) reported that peatlands globally cover 400 million hectares and store more than 550 GtC or 30% of all global soil carbon equivalent to twice the carbon stored in the combined biomass of all the world's forests. Tropical peatlands cover about 44 million hectares and store about 89 billion tonnes of carbon (GtC) with an estimated 68.5 GtC in SE Asia (Page *et al.* 2011). C. Neuzil (1997) estimated that the annual carbon accumulation rate in Indonesian peatlands ranges between 0.59-1.18t C/ha/yr, which is much higher than the accumulation rates in temperate or boreal zones, which ranges between 0.2-1t/ha/yr. Suzuki *et al.* (1999) measured net sequestration of 5.3t C/ha/yr in primary peat swamp forest in To-Daeng, Thailand, in a typical wet year. However, if disturbed by drainage and burning, the carbon is released into the atmosphere as CO_2 contributing to the greenhouse effect.

Current carbon emissions from drained and fire-affected peatlands in Southeast Asia have been estimated to be between 355-855 Million tonnes (Mt) CO_2/year from drainage-related peat decomposition (Hooijer *et al.*, 2010) and 300-600Mt CO_2/yr from peat fires (Coowenberg *et al.*, 2009, Page *et al.*, 2002; van der Werf *et al.*, 2008). Losses on this scale contribute significantly to atmospheric carbon loading and anthropogenic climate change processes (Page *et al.*, 2011).

2.8 DEGRADATION OF PEAT SWAMP FORESTS

The main causes of degradation of peat swamp forests associated with the development of oil palm plantations include: drainage, fire, land clearing and fragmentation. These are described in further detail below.

POTENTIAL IMPACTS OF OIL PALM CULTIVATION ON PEAT SWAMP FORESTS

The cultivation of oil palms on peatland is not only a significant 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:

- Hydrology and drainage
- Water resources and quality
- Fires and air quality
- Habitat loss and biodiversity change
- Socioeconomics

DRAINAGE

Drainage is an essential starting step for oil palm cultivation and cultivation of most crops known at present on peatland, and remains the unique and most critical management issue for oil palm plantations in peatland. The expected role of drainage in negatively impacting peat is immense if water management at plantation level causes rapid or otherwise a non-natural deterioration or degradation of peat.

The potential impacts from drainage and subsequent changes to the natural regime would often result in changes to the area itself. Subsidence and the associated oxidation or releases of CO_2 as a result of lowering water levels are important environmental impacts. The subsidence can then enhance the frequency of flooding and also increase saline intrusion in coastal areas. Drainage within the plantation area can affect significant portions of the peat dome as drainage can impact water levels over 1 km away from the drain – depending on the drainage depth and flow rates.

FIRE

One of the most serious risks to peat swamp forests in SE Asia comes from fire. More than 4 million ha of forest in the region have been destroyed by fire on the past 15 years.

The use and risk of fire in plantations on peat, is discussed in the associated 'RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat.' On the subject of rehabilitation and fire threat, it should be highlighted that natural vegetation in disturbed or pioneer forests are greatly vulnerable and possess less ability to further rehabilitate due to the already disturbed nature of the site. Therefore fire presents a major potential threat to peat swamp forests owing to the increased susceptibility of disturbed or degraded peat forests (see FIGURE 11).

FIGURE 11
Degraded peatlands next to plantations are susceptible to fire (Photo taken adjacent to Klias Forest Reserve, Sabah, Malaysia).

UNSUSTAINABLE EXTRACTION OF TIMBER AND OTHER FOREST PRODUCTS

Typically infrastructure and access to a peatland area may be improved as a result of the establishment of a plantation. The need to ensure good transport (whether ground or water) for the palm oil crop means that access for local people to the edges of remaining peat swamp forest increases significantly.

This presents an opportunity for either opportunistic or externally driven illegal actions including illegal logging (which further increases the risk of fires), poaching, unlicensed fisheries, destructive fishing or other extraction of forest products without due permission. The presence of communities adjacent or within plantations often adds complexity to ensuring sustainable and fair use of forest resources.

LAND CLEARING/ENCROACHMENT

Due to the sensitivity of peat forest ecosystems, irreversibility of impacts and inter-connectedness of an entire peat area land clearing is another major threat resulting from the vastly improved infrastructure and access to peat forest that plantations bring.

An often cited problem associated with the establishment of plantations is improved access to outsiders and displaced local communities. This in turn allows for easier poaching of forest resources, including illegal logging, land clearing for agriculture and fires.

FRAGMENTATION

Fragmentation of a forest complex due to logging, infrastructure, mining and plantation development is a critical factor in the decline of forests. With the higher inter-dependence and linkage of peatland forest species to their unique and specific roles the barrier or alteration (e.g. drainage) of one part will adversely affect a wider area.

The threat of fragmentation to an entire peat dome covering large tracts of peatland forest are magnified due to its unique hydrology and consequent flora and fauna. Fragmentation may also exacerbate or create water level changes that are ultimately fatal to the entire peatland area.

Oil palm plantations operating on peatlands usually require extensive water management systems consisting of water gates, canals and bunds. Construction of these infrastructures can inadvertently lead to fragmentation.

LAND CONFLICTS

Peat forests are often found along coastal or near coastal areas. Based on the examples of Indonesia and Malaysia, different groups of indigenous peoples and other communities may have inhabited the forests, cultivated crops, extracted various forest resources, depended on them for water supply or are directly dependent for downstream fisheries or fishing. One example includes the Proto-Malay group of *Jakun* people on the Peninsular Malaysia coastal areas. Therefore the threat posed from disruption of the role of peat forests may well lead to conflicts over land. Similarly, overlapping claims for traditional *adat* peat swamp forests in Sumatra and Kalimantan may lead to issues regarding land rights.

The potential problems include competing priorities of downstream communities who are dependent on the peat forests for various functions as well as those who inhabit peat areas or have traditional or customary claims to part or the entire forest.

3.0 MANAGEMENT OF EXISTING PEAT SWAMP FOREST AREAS IN OR ADJACENT TO OIL PALM PLANTATIONS

The conservation and appropriate management of existing peat swamp forest areas in or adjacent to oil palm plantations is crucial to avoid the impacts of degradation mentioned previously, as well as saving the time and resources required to rehabilitate these areas if they are later degraded.

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:

- Areas of intact peat swamp forest with high conservation value
- Peat dome areas (*kubah gambut*, Padang Raya)(with low moisture and fertility)
- Edges/shoulders of dome (in Sarawak with Alan Forest) areas (with often large roots contained in peat)
- Undrainable areas
- Wildlife corridors (to avoid human-wildlife conflict)
- In Indonesia – areas of peat deeper than 3m (in line with Indonesian regulations)
- In Indonesia – areas of peat underlain with potential acid sulphate soils or infertile quartz sands (where development is not permitted according to Indonesian regulations)
- River corridors

3.1 MANAGEMENT OF NATURAL HYDROLOGICAL REGIME

The proper management of the hydrological regime is critical to the success of any conservation or rehabilitation measures on peat. There should not be any artificial drainage in peat swamp forest areas identified for conservation as this will ultimately lead to degradation and/or loss of peat. In these areas on the edges of peat domes, drainage should be very strictly limited because the effects of drainage will spread to the dome. Therefore, if required only species that do not require any drainage should be used in rehabilitation programmes, and the emphasis should be on hydrological restoration prior or at least parallel to replanting programmes.

SYSTEMATIC BLOCKING OF CANALS AND DITCHES

One activity that greatly impacts adjacent areas during the development of oil palm plantations on peatlands is the uncontrolled digging of canals and ditches in these areas. This often occurs during the logging phase, as timber may be extracted via canals. These peatland canals and ditches typically exit into one or more rivers. When these canals and ditches are constructed haphazardly, large amounts of soil (fresh litter and peat) are intentionally or unintentionally discarded into rivers. This leads to changes in river morphology and water quality. Subsequently, this will have detrimental effects on aquatic life and biodiversity as well as the communities that depend on these resources. Uncontrolled drainage via ditches and canals also result in the drying of peatland, leaving the peat vulnerable to fire as well as subsidence of the peat.

In some situations, oil palm plantations may wish to restore the hydrology of peatland ecosystems in and adjacent to their plantations through the systematic blocking of ditches and canals (see FIGURE 12). By building blocks and dams, water and retention levels of peatlands can be increased and hopefully restored. 'A Guide to the Blocking of Canals and Ditches in Conjunction with the Community' published by Wetlands International – Indonesia Programme in 2005 elaborates on methods of repairing the condition and hydrology of peatlands via blocking of canals and ditches. The following are important elements quoted from this Manual (Wetlands International – Indonesia Programme, 2005A):

FIGURE 12
Dam constructed to systematically block a former logging canal to restore peat swamp water levels.

The blocking of ditches and canals is a physical intervention that is multidisciplinary in nature. Prior to blocking, it is necessary to carry out a number of scientific studies covering soil characteristics, limnology, hydrology, vegetation and socio-cultural characteristics, amongst others.

GENERAL RECOMMENDATIONS FOR CANAL AND DITCH BLOCKING

1. Survey the location and status of canals/ditches: to map the bio-physical conditions of the canal/ditch and socioeconomic impacts on surrounding communities. Blocking activities should be socialized to the local community and government. This involves clarifying the goals and usage of the blocked canals/ditches.

2. Blocking technique: Blocking activities should start at the upstream side of the ditch/canal, working downstream. Distance between blocks should be minimized to allow more effective retention of water. Preparation and mobilization of materials to the blocking site should be carried out at the end of the rainy season (or the beginning of the dry season). Construction of dams during the rainy season is difficult and requires additional labor. Large dams (more than 5m wide) have an increased risk of damage due to erosion of the peat layer on the sides and under the block.

3. Monitoring and maintenance of dams: Physical condition of blocks should be monitored at a minimum of once per month. Damaged or leaking blocks must be repaired immediately.

FURTHER RECOMMENDATIONS FOR CANAL AND DITCH BLOCKING

The following canal blocking strategies were developed based on the unique characteristics of peatlands:

- Low bearing capacity, thus the dams should not create much head difference (difference between upstream and downstream water level in the canal);
- High permeability of the peat, thus dams cannot store much water, they mainly act as an extra barrier to flow (water retarders increasing flow resistance);
- Canals may also be used for navigation/transport by the local population. Therefore consensus should be reached with the local people as to which canals can be considered inactive and thus can be blocked, and which canals remain active and therefore should not be blocked. Failure to reach consensus can result in ineffectiveness of the dam structures. (Budiman and Wosten, 2009).

When constructing dams, the following aspects need to be considered:

- A cascade of dams is proposed to avoid too much head difference over the dam. Experience and computer simulations with an unsteady-state simulation model show that head differences in the relatively small drains with an average width of 2m and an average depth of 1m, should be at a maximum of 0.25m.
- Construction of a cascade of relatively simple dams with relatively short distances between the dams (for instance 300-500m) also reduces water velocity in the drains. In turn this limited water velocity stimulates sedimentation of mineral and organic particles on the upstream part of the dam while it also reduces erosion of the drains as well as of the dam.
- The blocking is best started at the upstream part of the canal to avoid too much discharge and thereby gradually decreasing the pressure on the dams constructed further downstream in the canals.
- Indigenous materials i.e. *Melaleuca* (*gelam*) poles, peat or soil bags etc. are used to avoid excess load/weight. The principle behind this is that the ongoing consolidation of the peat layer under these structures should be approximately equal to the total unavoidable subsidence of the surrounding area. The practical consequence of this principle is that the overburden pressure should be very low (e.g. for a water table of 0.25m, the overburden pressure should not exceed about 1kPa or 100kg/m^2).
- Use of locally available material has the clear advantage that it is practical and inexpensive as no new construction material needs to be transported to the dam building site.
- Dams are designed in such a way that vegetation can easily re-grow thereby encouraging nature to take over with time. As indigenous materials i.e. peat above the groundwater level will oxidize and even *gelam* poles have a limited lifetime when they are not permanently water saturated, vegetation growth on the dam and in the blocked canal sections should be stimulated to ensure more permanent clogging up of the drainage system.
- The ultimate aim of a canal blocking system is to fill-in the drain with original peat forming vegetation thereby restoring the resistance to water flow in the peat swamp forest to its original value of approximately 30m/day. However this process takes a long time (more than 20 years) (Budiman and Wosten, 2009).

It should be noted that canal blocking is fraught with difficulties and at best it is moderately successful. A much better and cheaper alternative is to avoid the need for dam construction in the first place, i.e. avoid canal and ditch construction in forested areas wherever possible.

BOX 2

Practical canal blocking experiences in Central Kalimantan (Euroconsult Mott MacDonald *et al.*, 2008A).

INTRODUCTION

In Kalimantan as well as in other deep peat areas with similar conditions, several mainly non-government organizations have been active in blocking canals in order to raise the groundwater level and to rehabilitate the peat areas. This section gives an overview and evaluation of activities over the past few years in Central Kalimantan mainly in the Ex-Mega Rice Project (PLG) area. The information is based on interviews with members of the organizations involved, field observations, and a study of monitoring data and reports. Field visits were undertaken to collect specific information about the channel blocks and to evaluate their conditions and effectiveness in early 2008. The visits included the northwestern part of Block A (Wetlands' dams), Block C (CIMTROP dams) and the Sebangau National Park (WWF structures). The main conclusions regarding each of the three areas are given below. It is noted that most of the larger canal blocks are all variants of the box dam, consisting of rows of wooden poles driven across the canal into the bed, with the space in between the rows filled up with soil bags.

CIMTROP

The northern part of Block C and the northeastern part of the Sebangau National Park, both deep peat areas, are research locations of CIMTROP. Since 2004 nine block structures have been built in the main canals with widths of up to 20m and another 50 smaller dams in secondary canals. The design and construction uses local expertise, labor, materials and equipment. The structures are rather light. Construction costs are in the order of Rp. 25 million (US$2,500) per block. Several blocks were washed away in the rainy season. The actual lifetime of the blocks is short and they need to be replaced every 2-3 years. There are experiments to consolidate the blocking structures by means of vegetation.

2

CCFPI/CKPP/WETLANDS INTERNATIONAL

Wetlands International carried out peat conservation activities under the CCFPI Project (in partnership with Wildlife Habitat Canada and Global Environment Centre) and later under the CKPP project in the north-west of Block A. The area is situated north of Mantangai, between the Kapuas and Mantangai rivers. Since 2004, twenty-six canal blocks have been built with widths varying from 15 to 30m. The design of the structures is based on structural analyses, local experience and expertise. A local contractor built the structures in cooperation with the local community. Most of the materials were imported from outside the immediate area.

The structures are more robust than the CIMTROP structures. Piles are deeper and the dam body is wider. The canal flow is supposed to partly seep through the structures, and partly flow over the structure. Provisions to divert peak flows over the adjacent land have been added as well. In the later CKPP designs, the middle section of the dam is narrowed and equipped with wooden planks to facilitate pulling small boats over the dam, and so avoids people digging ditches for boat passage around the dam. The narrowing however generally tends to weaken the dam. Average costs are in the order of Rp. 100 million (US$10,000) per structure. The expected lifetime is about 5 years, due to the use of timber, which degrades over time. Geo-textile has been used to limit seepage losses but after one year, many of the sheets were already torn. Vegetation is planted around the structure in an effort to let "nature take over" and gradually over-grow the canal.

WWF

WWF built four blocking structures with widths of up to 15m, and sixteen small dams, in the Sebangau National Park. The soils vary from shallow peat close to the Sebangau River to deep peat further inland. The design of the structures is similar to those constructed by Wetlands International. A contractor built the larger block structures and the local community built the smaller ones. All materials were imported from outside the area.

PUBLIC WORKS DEPARTMENT (PU)

PU has not built any blocking structures in the peat conservation areas, but they are constructing many water control structures in the canals of the developed areas. The structures are mostly in the tertiary canals, 4 to 6m wide, and made of concrete, masonry or a combination of both. Some tests with fiberglass structures are ongoing. The structures serve to control rather than block canal flows, and are equipped with gates (i.e. stop logs, flap-gates or sliding gates). Without extensive bottom and side slope protection, seepage often develops below or besides the structure, and head differences of more than half to one meter can rarely be maintained for long periods, even though soils are predominantly (soft) clayey. Depending on their size, costs of the structures range from Rp. 50 to 150 million (US$5-15,000). The structures are built by contractors. The large water control structures built in some of the primary canals by the PLG project are mostly heavily damaged and beyond repair. Nevertheless, the remaining concrete foundations could possibly be incorporated in future blocking structures.

EVALUATION AND LESSONS LEARNED

Valuable experience has been gained from past canal blocking efforts in Central Kalimantan, especially regarding the design of the blocks and how to construct these. Most of the structures are effective to create a water step, or head difference, in the canal, and they have been built with minimum material imported from outside the region. With the limited means available to the organizations who built them, much has been achieved. However, the large PLG canals were built by an enormous operation involving many large construction companies with dozens of heavy equipment and huge budgets.

The following conclusions and lessons learned are drawn from the Central Kalimantan experience.

- While effective to raise upstream canal water-levels, the effect on overall landscape groundwater levels is likely to be small in view of the fact that the canals have "eaten themselves into the land" and are now situated in small depressions. Nevertheless, raising the canal water is important to prevent further drops of the groundwater tables and reduce fires.
- The effect of each block extends only a few kilometers upstream, depending on the created head difference and the canal gradient. To raise the water-levels along an entire canal many more blocks with small head differences would be required.
- With the limited means available, it is tempting to try to create blocks with a big head difference to maximize the effect of the block. However, the bigger the head difference, the bigger the water pressure on the dam and the higher the seepage flows through or around the dam. With the materials and construction methods at hand, head differences of more than half a meter prove difficult to maintain.
- The Wetlands International built dams, especially the earlier CCFPI dams, appear to be the strongest, although also the most expensive. The later CKPP design is likely weakened by the narrower section in the middle of the dam. The structures should be deeply embedded in preferably the mineral subsoil to avoid instability.
- The expected lifetime of the dams is about 5 years. In many cases there is little sign of nature taking over by re-growth or sedimentation in the upstream canal, and new dams will soon need to be built. To promote re-growth in the canal, dam building may have to be combined with partial infilling of the upstream canal and planting of (water tolerant) tree species.
- Water flows over the dams damage the dam crests. The overflowing water takes away dam fill material and creates flow paths through the dam below the crest, hence reducing the head difference and effectiveness of the dam and threatening to further damage the dam.
- Seepage and piping through as well as below and around the dam is a serious threat and calls for small head differences over the dam, and long dam bodies. Dam fill material should preferably be clayey soil.
- The dams require regular inspection and a maintenance organization capable of reacting quickly to repair small damage before such damage becomes bigger.
- Involvement of the local people in planning, design and construction of the blocks is important to gain their support, but is no guarantee that the dams will be safe from human intervention. Small bypass channels should be considered for dams in canals that are frequently used for transportation of goods or people. Planks provided for pulling boats over a lower section of the dam proved not very long-lasting. Providing alternative livelihoods for the local population could decrease their dependency on forest resources, but this is at best only a solution in the long term.

Experience from outside the region largely confirms the above conclusions. Small head differences over the dams and a large number of dams are essential to effectively raise water levels and to act as a safety precaution in case one or more of the dams fail.

For further technical details and guidelines on designing blocking strategies and structures as well as implementation, refer to "Guideline for Canal Blocking Design in the Ex-Mega Rice Project Area in Central Kalimantan (Technical Guideline No. 4) – Master Plan for the Conservation and Development of the Ex-Mega Rice Project Area in Central Kalimantan" (Euroconsult *et al.*, 2008a).

FIGURE 13
Small ditch blocked with peat dam.

FIGURE 14
Small ditch blocked with sandbags and soil.

FIGURE 15
Successive ditch blocks made of wood and soil bags in a medium-width canal in Central Kalimantan.

AVOIDING ELEVATED WATER LEVELS

Avoiding water levels which are too high are as important as avoiding water levels which are too low. Peat swamp forest trees breathe through their roots. Although some species have extensive prop or stilt roots and others have pneumatophores to help them breathe in partly flooded environments – most tree species in peat swamp forest cannot survive permanent inundation. Therefore in developing infrastructure such as roads or bunds in and adjacent to the plantations it is important that this does not lead to water levels higher than normal. As a guide, the water level in most peat swamp forests is normally just below the peat surface (allowing the presence of a shallow, oxygenated layer for the tree roots) and only above the surface following heavy rain or in areas which are affected by flooding from adjacent river systems.

FIGURE 16
Peat swamp forest trees killed by elevated water levels caused by back-flooding of the forest as a result of the construction of adjacent bund with no culverts between the forest and agricultural land.

FIGURE 17
Peat swamp forest killed by elevated water levels above the peat surface.

3.2 PREVENTION AND CONTROL OF FIRE

As mentioned previously, fire constitutes a major threat to peatlands. This fact has triggered added scrutiny from governments in Indonesia and Malaysia (as examples) for any type of development in peatland. This is especially true of plantation development, and the regulations surrounding fire prevention from government is matched by the emphasis and implementation of zero-burn management guidelines by plantation companies. For more details, refer to the Guidelines for the Implementation of the ASEAN Policy on Zero Burning (ASEAN, 2003).

FIGURE 18
Burnt forest adjacent to land developed for oil palm plantations.

FIGURE 19
Fires in peat swamp forest burn not only the vegetation, but also the peat layer below the trees.

GUIDELINES FOR FIRE PREVENTION

Plantations can help prevent peat fires in the plantations and adjacent peat swamp forest 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.
- Effective surveillance and monitoring: There should also be an intensive network of paths around estate blocks, especially those in close proximity to peat swamp forest areas, 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

Fires may often enter a peatland from areas outside (but adjacent to) plantations especially from areas with local communities or small holders.

In the case of HCV and riverine buffer areas within peatland plantations as well as peatland areas adjacent to the plantation – the drainage of the adjacent plantation may also drain these sites making them more vulnerable to fire. In addition the surface vegetation and the large amounts of accumulated litter make such areas more susceptible to fire than plantation areas that have little litter and are normally more compacted or consolidated with less fire-prone vegetation cover.

In order to prevent fire problems in such areas – the following measures are needed:

- Maintenance of high water levels (drainage of no more than 20cm below the soil surface) by use of high level perimeter drains in which water is maintained at or near the surface
- Blocking of any ditches or canals cutting through the forest areas.
- Regular patrolling of HCV, river buffers and adjacent peatland areas to check for land clearings, drainage or other activities that could lead to fires
- Rapid response units for fire control within and adjacent to the plantation
- Dialogue and cooperation with local communities to discourage use of fire and to enhance protection of intact peatland areas

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 and any adjacent forest areas 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.

FIGURE 20
Plantation perimeter drain maintained with low water level may lead to drainage of adjacent peat swamp forest thus increasing fire risk.

FIGURE 21
High water level in canal between the peat swamp forest and oil palm plantation prevents drainage of the forest edge and minimizes the risk of fire (but water should not be too high – i.e. not covering the peat surface).

FIRE DANGER RATING SYSTEM

One aspect 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 to all relevant stakeholders, including those in the field. 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. One key fire information systems is the Fire Danger Rating System (FDRS):

Fire Danger Rating System (FDRS) – an early warning system concerning the risk of fire occurring. This system was developed on the basis of indicators that influence the incidence of fire. The FDRS is a system that monitors forest/vegetation fires risk and supplies information that assists in fire management. The products of FDRS can be used to predict fire behavior and can be used as a guide to land managers and policy-makers to take actions to protect life, property and the environment.

The meteorological variables used (temperature, relative humidity, rainfall, wind speed) are those measured at meteorological stations throughout the Southeast Asia region that are made available on the Global Telecommunication System (GTS). Spatial Analysis is carried out using the ArcView software.

Six indices are produced with associated maps as follows:

A. Fine Fuel Moisture Code (FFMC) an indicator of the risk of bush or grass fires
B. Duff Moisture Code (DMC) an indicator of the risk of fires burning in upper peat layers and drained peatlands
C. Drought Code (DC) an indicator of the risk of fire burning in deep peat layers or un-drained peatlands
D. Build up Index (BUI) – a combined index on the vulnerabilities of grasslands, forest and peatlands
E. Initial Spread Index (ISI) – an indicator of the likelihood of rapid spread of fire (e.g. as a result of strong winds)
F. Fire Weather Index (FWI) – an overall indicator of the risk of fire

Fire danger levels are shown as low, moderate, high and extreme. A high index means that there is a high risk of fires starting and becoming established. However for the fires to actually start they will need an ignition source – such as a land clearing fire or discarded cigarette – before the area will burn. As long as there is no ignition source – the fires will not burn. FDRS maps can therefore provide guidance on where to deploy personnel and resources to undertake fire prevention and monitoring activities. Once a fire starts the indices can show how quickly a fire may spread and how difficult it may be to control.

The Malaysian Meteorological Department (MMD) has been producing a FDRS for Southeast Asia on a daily basis since SEPTEMBER 2003. The Southeast FDRS was adapted from the Canadian FDRS developed by the Canadian Forest Service. A more detailed FDRS for Malaysia is also prepared by MMD. The Indonesian Meteorological agency also produces its own FDRS.

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

The FDRS maps are also available as an overlay for Google Earth – which enables the location of high risk areas to be easily pinpointed in relation to roads, rivers, forests and other features. A sample FDRS map is shown in FIGURE 22 PAGE 67.

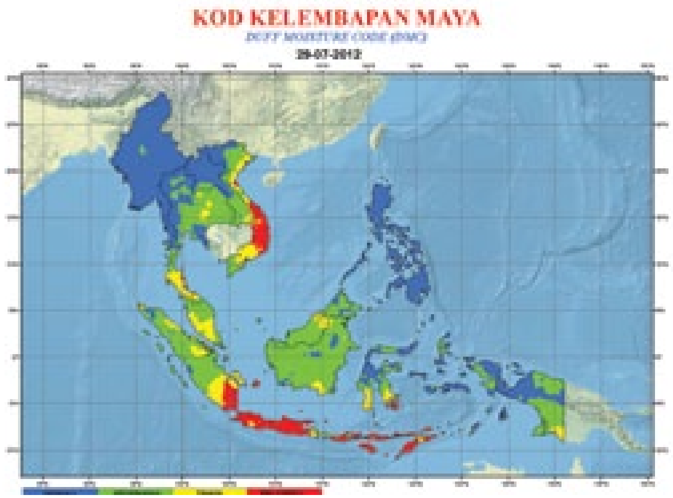

FIGURE 22
Series of images of FDRS Maps for Fine Fuel Moisture Code, Duff Moisture Code and Fire Weather Index for SE Asia.

FIRE SUPPRESSION

Where fire is used or breaks out in a plantation, adjacent or nearby peat swamp forest areas become extremely vulnerable due to the nature of fires in peatlands. The 'Manual for the Control of Fire in Peatland and Peatland Forest' (Wetlands International – Indonesia Programme, 2005B) 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 peatland and forest fires in the peatland areas of Kalimantan and Sumatra, Indonesia. The following are important elements quoted from this Manual

Overcoming fire on 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. In 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 often only be extinguished by natural means i.e. long consistent periods of heavy rain or artificial measures which raise the water level to the surface.

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 the plantation management together with various elements of the community, NGOs, institutions and relevant agencies are 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 peatland 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:
  - Fire towers
  - Communications equipment
  - Telescopes and compasses
  - Transportation
  - Fire engines and boats
  - 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, etc.)
  - Emergency clinic, facilities for treating fire victims
- 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.

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) or pumping water from nearby water sources.
3. Before initiating fire suppression, a water-saturated transect is made to slow down the spread of the fire, acting as a non-permanent fire break
4. 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)
5. Fire-fighters must walk with great care in burnt peat areas, to reduce risk of them sinking into holes left by the fire
6. Specialized equipment such as a peat spear, which is a one to two meter long nozzle for fire hoses with a large number of holes in the last 50cm before the tip. The spear is jabbed into the smoking ground and water is sprayed through it into the smoldering soil layers below ground. Water is sprayed 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
7. 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
8. The area of the fire should be inspected both several hours after and one to three days after the fire remnants have been extinguished, with the purpose of ensuring that the area is truly free from fire

3.3 MANAGEMENT OF EXTRACTIVE USES

Extractive uses include the activities of local communities and indigenous peoples with legitimate claims to areas within or adjacent to plantations. These areas may include peat swamp forests and associated resources including non-forest timber products (NFTPs) and fisheries. Management of access to peat swamp forests by local communities; minimizing impacts to peat forest ecology and ensuring sustainable use of resources; and avoiding use of fire; are the priority issues to be tackled. Management plans for existing peat swamp forest areas should cover these aspects and appropriate operating procedures need to be in place to sustainably manage any potential extractive uses. Illegal logging needs to be curbed as much as possible, as this will only exacerbate fire risk since logging leads to forest and peat desiccation and in turn, provides more readily flammable fuel on the ground. Any management strategy for such resources should be developed in a participatory way with local communities and also with the involvement of relevant local government agencies.

3.4 AVOIDING FRAGMENTATION

Peat swamp forests are perfect examples of the inter-connected nature of forest ecosystems. The inter-dependence of the entire ecosystem makes peat swamp forests especially vulnerable to a collapse from fragmentation. Subdividing the peat swamp forest in to smaller units makes the units more vulnerable to fire and degradation. Small areas of forest may be inadequate to enable large mammals such as tigers to survive as they normally have a home range of 6,000-40,000 ha (Priatna *et al.*, 2012).

Identification of peat swamp forest areas to be conserved/managed needs to take this factor into consideration. Areas that provide connectivity/ecological links between larger landscapes of peat swamp forests should be prioritized. The size of the area should also be adequate to ensure the long-term ecological survival of the peat swamp forest. These corridors will also provide safe passage to wildlife and hence prevent potential human-wildlife conflicts in the future. In peatland areas, corridors are recommended to be at least 500m to 1km wide to reduce edge effects and provide for undisturbed movement of wildlife.

Special attention should be given to any establishment of canals, weirs (water gates), bunds and access roads constructed by oil palm plantations. Water management is crucial for oil palm cultivation but can also have adverse effects on the hydrology of adjacent areas if uncontrolled or not managed properly. This infrastructure may also lead to fragmentation of the peat swamp forest landscape in general.

4.0 REHABILITATION OF PEAT SWAMP FORESTS IN DEGRADED SITES

4.1 ADDRESSING THE ROOT CAUSE OF DEGRADATION

Understanding the root causes of degradation requires careful and honest assessment of the role or impact of various actors in the area that have an impact on the peat swamp forest. Often plantations operate in a landscape with alternating types of land uses in peatland areas. By taking a landscape approach to planning, it may be possible to reduce the impact of the plantations and prevent fragmentation of remaining forest areas. However such work needs collective action as well as the support and participation from a broad range of stakeholders including plantations.

Understanding root causes of degradation may require the participation of various stakeholders in the area, including community representatives, other industries (forestry, mining, fish farming, etc.), downstream users, other plantations and the government. This presents a potentially impossible task for a single actor like a plantation to take on. However without the participation of all stakeholders, plantations can still acquire significant information to derive at some root causes of degradation. Planning with participation from local NGOs and stakeholders, can produce information on both root causes as well as identify actions that a plantation can take to contribute towards the overall health of the peat swamp forest area.

The range of factors leading to degradation can change over time. In Berbak National Park, for example, (see BOX 3) a range of factors were identified as affecting peat swamp forest in 2001. In 2004, the main cause of degradation was found to be the widespread illegal logging in the national park both by a logging company with a concession adjacent to the national park and by a transmigration village located adjacent to the park. To cover up illegal activities, fires were lit, which further added to the damage (Giesen, 2004). Subsequently a major cause of degradation in the park was the conversion and drainage of large areas adjacent to the National Park to oil palm. The drainage for the oil palm led over time to significant changes in the hydrology of the park system as subsurface water flows were diverted to rivers outside the park – decreasing the water level in the park and increasing vulnerability to fires.

BOX 3

Causes of Peat Swamp Forest degradation in Berbak National Park, Indonesia in 2001.

General assessments of the Berbak National Park in Indonesia according to Wetlands International– Indonesia Programme (2001) revealed that the main threats and causes of peat swamp forest degradation were:

- Forest fires, caused by:
  - Transmigrants excavating drainage canals and lowering water tables
  - Small fires (e.g. for cooking) getting out of control
  - Fishermen clearing sites for fishing
  - Farmers preparing sites for cultivation and uncontrolled use of fires
- Illegal logging – Mainly in the logging concessions outside the proposed Berbak-Sembilang national park
- Unsustainable use of resources – Especially *jelutung*, and *nipa* leaves
- Poaching – Mainly of saltwater crocodiles (*Crocodylus porosus*), false gharials (*Tomistoma schlegelii*), monitor lizards (especially *Varanus salvator*), snakes (Elephant-trunk snake *Acrochordus javanicus*, Sunbeam snake *Xenopeltis unicolor*, Reticulated python (*Python reticulatus*) and the occasional stork (Milky Stork *Mycteria cinerea*, Lesser Adjutant *Leptoptilos javanicus*)
- Land conversion
- Unclear boundaries
- Insufficient patrol system and law enforcement
- Use of cyanide for fishing

In Central Kalimantan – the degradation of the peat swamp forests was driven by the development of a 1.5 million ha rice production scheme (the so-called Mega Rice Project) in 1996-97. This involved the construction of 4,600 km of so-called irrigation canals through the peat swamp forest with the expectation that they would carry irrigation water into the forest area from rivers. Unfortunately they acted as drains and drained all the water out of the peat domes. In the 1997-98 El Nino – more than 500,000 ha of the peat swamp forest burnt. In 1998 the project was officially abandoned as it was realized that the area was almost totally unsuitable for growing rice. However for most years since 1998, between 100,000-200,000 ha of the area has burnt as a result of the increased vulnerability as a result of the abandoned drainage canals. Work was initiated on a pilot scale in 2003 (under the Climate change Forest and peatlands in Indonesia project) to block the abandoned canals using local materials and community action. This has raised water levels, addressing the root causes of degradation leading to a reduction on peatland and forest fires and enhanced regeneration of the forest areas. This approach has been expanded under other projects and now has been adopted by the Indonesian Government.

It can be expected that each degraded site will present its own set of complex root causes of degradation and can be a combination of any of the above examples listed. Once root causes are determined, it is important that management plans are drawn up and appropriate actions taken to address these problems. Monitoring should also be carried out to track progress and determine any corrective actions needed.

4.2 GUIDING PRINCIPLES FOR REHABILITATION

Guiding principles for the rehabilitation of peat swamp forests in Central Kalimantan specifically for the ex-Mega Rice project area (Euroconsult MMD *et al.*, 2009) include:

1. **SOCIOECONOMICS**
Local communities should be the key stakeholder involved in replanting, restoration and rehabilitation programmes. Where possible, useful species should be incorporated in the programmes. These useful species are to be:

- those producing Non-Timber Forest Products (NTFPs) in conservation areas where conservation is the main option and where this does not affect biodiversity, and
- species producing timber, species producing NTFPs, and multi-purpose trees (timber plus NTFPs)

Local communities should be given legal access and user rights to the NTFPs and there should be a binding benefit sharing agreement (e.g. between Forestry Department and local communities) for harvesting of timber species. Local communities and other stakeholders are to be involved in the planning and decision-making stages if restoration or rehabilitation is to be successful.

2. **BENEFICIAL SPECIES**
The focus of replanting should be on species that:

- provide NTFPs (such as *jelutung*, *gemor* and *tengkawang*) rather than timber species (such as *belangiran*, *ramin* and *geronggang*); this should closely involve local communities; or
- are important as food species for key wildlife such as orangutan, gibbon and hornbills

3. DRAINAGE

There should not be any artificial drainage in conservation areas as this will ultimately lead to loss of peat. In areas on the edges of peat domes, drainage should be very strictly limited because the effects of drainage will spread to the dome. Therefore, only species that do not require any drainage should be used in rehabilitation programmes, and the emphasis should be on hydrological restoration prior or at least parallel to replanting programmes.

4. BIODIVERSITY

Increase diversity in number of species used in peat swamp forest rehabilitation and restoration programmes as much as possible, as this will:

- Enhance overall biodiversity and increase/restore the biodiversity function of the peat swamp forest system
- Reduce the pest threat, as pests are more inclined to attack monocultures

NOTE this means that smallholders are more likely to be involved in the programmes, as commercial plantations prefer large scale approaches that require monocultures. A higher diversity of species utilized will spread livelihood risks, as pests and diseases are less likely to take hold, and sources of income are spread more throughout the year.

5. EXOTIC TREE SPECIES

Only indigenous species should be used in rehabilitation programmes and the use of exotics should not be allowed.

Setting up any structures for rehabilitation should also utilize indigenous materials i.e. *gelam* poles and peat etc. to avoid excess load/weight. The basic principle behind this is the ongoing consolidation of the peat layer under these structures should be approximately equal to the total unavoidable subsidence of the surrounding area. The practical consequence of this principle is so that the overburden pressure will be very low (e.g. for a water table of 0.25m, the overburden pressure should not exceed about 1 kPa or 100 kg/m^2) (Budiman and Wosten, 2009).

6. COSTS

The overall budget required for rehabilitation is likely to be substantial. Therefore, rehabilitation programmes must opt for the most cost-effective solutions – the end result must of course be successful rehabilitation, as this should not be compromised.

7. MEASURING SUCCESS

Many past programmes have measured their impacts and rate of success on the number of planted seedlings or the hectares of degraded land that has been replanted. However, these are only input-related criteria, and it is much more important to assess success on the real impact (medium to long-term) of rehabilitation. Implementers should therefore not only be held accountable for use of funds for planting trees and hectarage covered, but be responsible for survival of tracts of replanted peat swamp forests. This means that monitoring and maintenance of replanted areas should be part and parcel of every rehabilitation programme and form the basis of measuring the rate of success.

In addition and from a management point of view, the following key principles for peat swamp rehabilitation projects are recommended (Euroconsult *et al.*, 2008B):

1. **ADAPTIVE MANAGEMENT**
   It is neither possible nor desirable to provide a "blue-print" for implementation of plans. During implementation, lessons will be learned as to what works and what does not and these lessons should be included in future planning. Adaptive management promotes a process of "learning by doing" and integrates planning and design with ongoing monitoring, assessment and evaluation.

2. **ADOPTION OF AN INTEGRATED APPROACH**
   Implementation of plans will be complex and will involve a large number of sectors – each with its own interests and responsibilities. A major challenge will be to integrate and harmonize these needs so as to reduce any conflicts and to maximize synergies.

3. **PLANNING AND IMPLEMENTATION AT A LANDSCAPE ECOSYSTEM SCALE**
   The different parts of the landscape should not be considered in isolation but integral components of a complex landscape mosaic, with each part having effects on its neighbors. The rehabilitation and revitalization program needs to take a resource-based approach to lowland management.

4. **MEANINGFUL INVOLVEMENT OF COMMUNITIES**
   Communities in the project area should be aware of and have a voice and role in planning for their environment and the development of their respective areas. Feedback from local communities is essential to measure the effectiveness (or not) of interventions and will serve to constantly improve planning and future actions.

4.3 PLANNING FOR PEAT SWAMP FOREST REHABILITATION PROJECTS

The stages of degradation need to be identified for the area to be rehabilitated as this will allow for a better assessment of the situation in the field, better matching of species selected for replanting and a selection of more appropriate interventions in general (Euroconsult Mott MacDonald *et al.* 2009). Systematic fieldwork is required to develop a degradation typology for the area. Fieldwork should involve recording species composition, vegetation structure (including seedlings, saplings, trees) and densities, but also other parameters such as peat depth and maturity, light intensity, nutrient availability, site hydrology and fire history.

Once this information is gathered, intervention types required such as the following can be determined:

A. none required, for example in areas already regenerating naturally or in areas that are a lost cause (e.g. former peat areas that have become deep lakes),

B. assisted natural regeneration (e.g. hydrological rehabilitation <see SECTION 3.1 page 44>, prevention of fires <see SECTION 3.2 page 58>), or

C. active rehabilitation (see CHAPTER 5 page 105)

MAPPING DEGRADATION

Mapping of the area needs to be at the level of detail (and recent enough) to allow recognition and delineation of the various stages of degradation at a landscape level. The mapping should recognize units that require rehabilitation, assisted regeneration, natural regeneration and those that do not require any intervention. See FIGURES 23 and 24 page 82 & 83 for examples of degradation and site condition mapping.

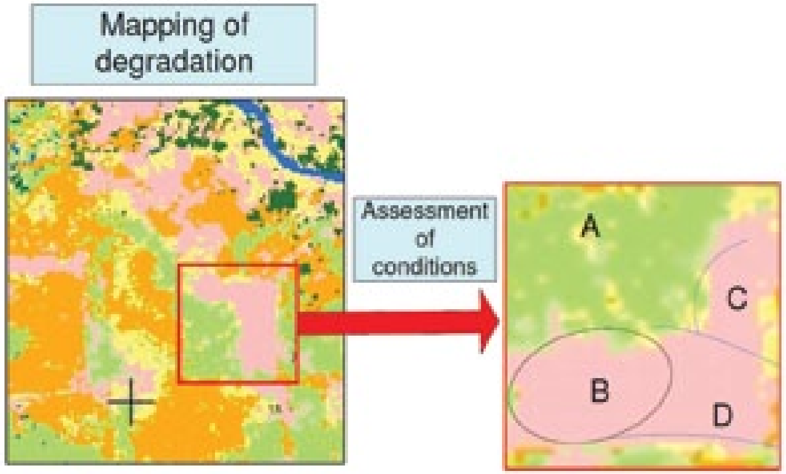

FIGURE 23
Example of mapping degradation and site conditions (Source: Euroconsult MMD *et al.*, 2009). Area marked "A" shows an area with deeply (1.5 m) flooded peat (2x burnt, 1.5 m of peat has disappeared); areas marked "B" shows an area with moderately deep flooding (1 m), 1x burnt, 1 m of peat has disappeared; area marked "C" shows an area that is shallowly flooded (0.5 m), 1x burnt, 0.5 m of peat has disappeared; area marked "D" is similar to "C" but with riverine influence (nutrients, current and some erosion).

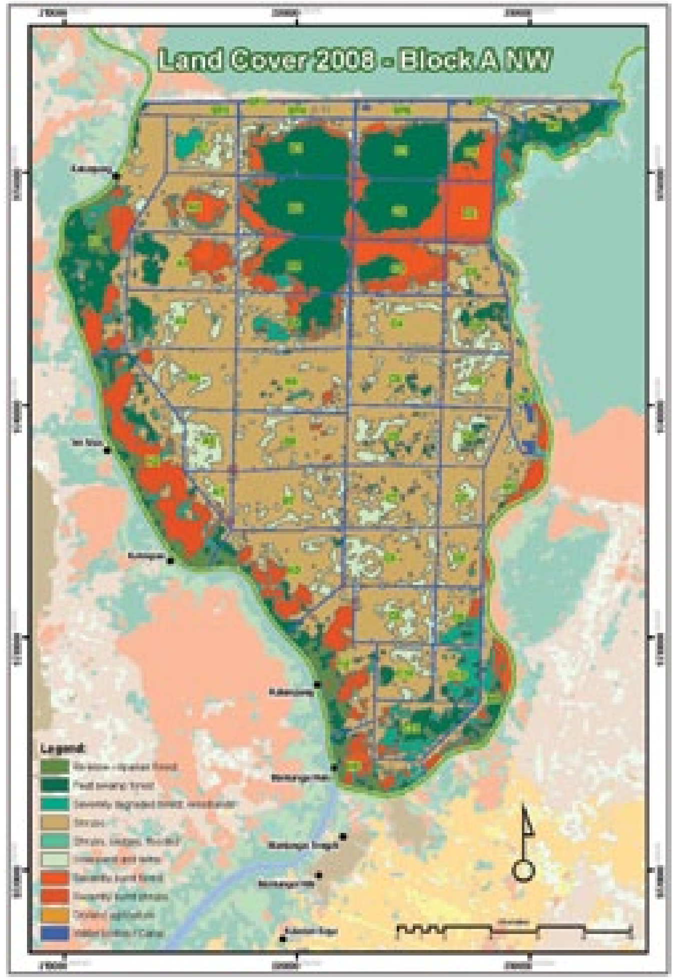

FIGURE 24
Sample land cover map from the Ex-Mega Rice Project in Central Kalimantan showing riverine forest, peat swamp forest, severely degraded forest, shrubs, grassland, recently burnt and agriculture areas as well as location of canals and water bodies (Source: Euroconsult Mott MacDonald and Deltares | Delft Hydraulics, 2009).

CANAL SELECTION

Selection of canals for closure to increase and maintain water levels is very important during mapping. Canal blocking is best commenced in the upstream part of canals to avoid excess discharge and thereby gradually decreasing pressure on dams constructed further downstream in the canals.

RAPID SURVEY OF SITE CONDITIONS

Rapid surveys will be required in addition to mapping, to assess site conditions, and determine the possible causes of degradation (see SECTION 4.1 PAGE 73). This will result in a further refining of information available about a site, so that the intervention can target what is required.

Physiochemical conditions need to be rapidly surveyed in each mapped intervention unit and this may result in a further refinement of the map, or at least a better understanding of the conditions at a given site. Parameters that need to be assessed include:

- water depth/availability, flooding depth/duration, distance from river bank,
- micro-topography (hillocks and depressions: what is the range, height and elevation),
- exposure (to sunlight; depends on existing tree/shrub cover, height and density),
- peat depth and maturity,
- occurrence, depth and pyrite concentration of Potential Acid Sulphate (PAS) soils,
- nutrient-availability and pH of each of the mapped units.

It is also good practice to take inventory of existing plants and incorporate this information into rehabilitation plans. For more details, refer also to Euroconsult Mott MacDonald and Deltares | Delft Hydraulics (2009).

BOX 4

Example of planning and mapping for peat swamp forest rehabilitation projects from the Ex-Mega Rice Project Area in Central Kalimantan.

FIGURE 25 PAGE 86 is a map developed and used as part of the peatland rehabilitation plan for one of the planting blocks within the Ex-Mega Rice Area in Central Kalimantan. These planning maps are vital to the successful implementation of any peat swamp forest rehabilitation project.

Earlier field surveys revealed that while areas with remaining peat swamp forest do not require replanting, vast areas of shrub land, burnt shrub land and sedge-grass-fern vegetation may require 100% replanting with peat swamp forest tree species. This includes shrub land that already has some small trees although replanting these areas could include species of more mature peat swamp forests if these can be shaded. Patches of severely degraded peat swamp forests were estimated to require 30-50% replanting, while burnt peat swamp forests required an average of 50% replanting as trees often remained in patches in the latter areas. The areas targeted for replanting according to these planting regimes (0%, 30-50%, 50% and 100%) are indicated in FIGURE 25 PAGE 86.

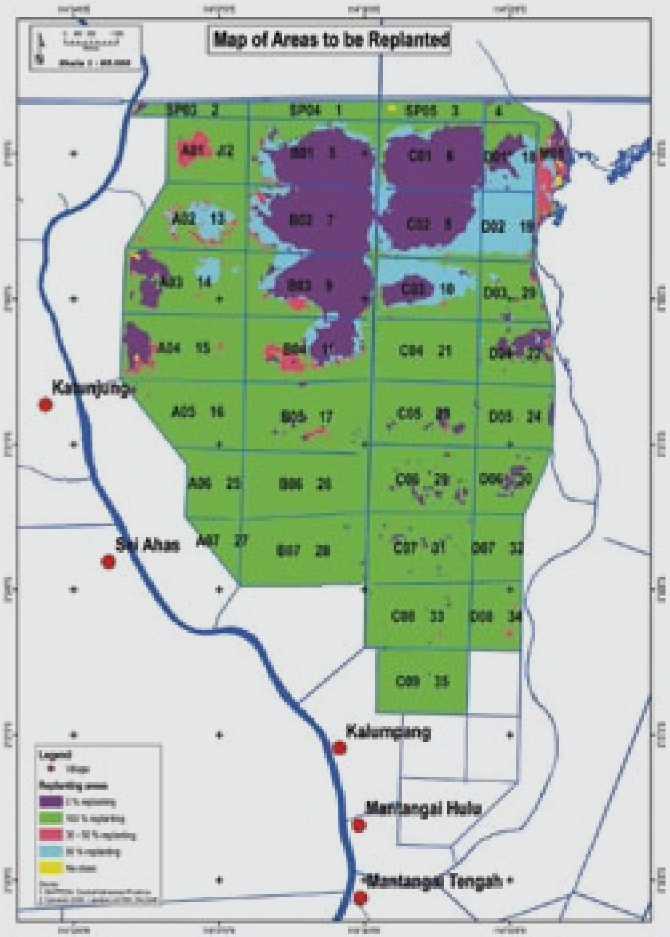

FIGURE 25
Sample map showing areas to be replanted as part of the peatland rehabilitation plan for one of the planting blocks within the Ex-Mega Rice Area in Central Kalimantan (Source: Euroconsult Mott MacDonald and Deltares | Delft Hydraulics, 2009).

4.4 ESTABLISHMENT OF AN APPROPRIATE HYDROLOGICAL REGIME

Restoring hydrological functioning should be the first consideration in peat swamp forest rehabilitation. It is estimated that hydrology is the single most important environmental factor (50 percent relative importance) in controlling plant community structure (Graf, 2009). The hydrological regime is the most important factor in the establishment and maintenance of peat swamp forest types and processes. Hydrology greatly affects chemical and physical properties such as nutrient availability, soil salinity, sediment properties, pH and the degree of anoxia. Water inputs, if any, are a major source of nutrients. Restoring the hydrological regime is necessary for the establishment of target vegetation and nutrient cycling. A number of techniques used to restore wetland hydrology are outlined below:

- Blocking drainage ditches is an important step in restoring wetland hydrology. This simple step will retain surface water and elevate the ground water level (see SECTION 3.1 PAGE 44). Blocking of canals with multiple dams can be considered successful if blocked canal sections also hold water during the dry season
- Berms or bunds, hold surface water and precipitation on site
- Berms, bunds, terracing and polders hold surface water and precipitation on site
- The use of mulch or nurse plants increases the moisture level of the microclimate on the peat surface by increasing the relative humidity near the surface and decreasing the evaporation loss compared to a bare peat site

It is not possible to create a universal formula for restoring the hydrology of peat swamp forests affected by disturbances. Each site has site-specific factors, which should be taken into consideration when rehabilitation strategies are being considered. It is generally recommended that hydrological regimes should be restored to natural/original conditions prior to any disturbances (assessments can be done on healthy adjacent peat swamp forest areas to determine this) to ensure the long term ecological survival of the project area.

4.5 IDENTIFICATION OF SUITABLE SPECIES FOR REHABILITATION

The selection of (woody) species for peat swamp forest rehabilitation should in the first place be guided by the suitability of the species for the conditions of the site that is to be rehabilitated. Certain peat swamp forest tree species appear to be more characteristic of deep peat while others occur on peat of shallower depth, while other species again seem to occur along the range of peat depths (Page and Waldes, 2005; TABLE 2).

TABLE 2
Main peatland tree species and ecological zoning.

NOTE Principal tree species occurring in three peat swamp forest communities on peat of increasing depth across a peatland dome in the Sebangau catchment, Central Kalimantan (adapted from Page and Waldes, 2005).

Principal tree species	Mixed swamp forest at the edge of the peat dome	Low pole forest nearer to the centre of the peat dome	Tall interior forest on the central peatland dome
Palaquium ridleyi	x		
Calophyllum hosei	x		
Mesua sp.	x		
Mezzettia parviflora	x		x
Combretocarpus rotundatus	x	x	
Syzygium sp.		x	
Tristaniopsis obovata		x	
Shorea teysmanniana		x	x
Palaquium leiocarpum			x
Stemonurus secundiflorus			x
Neoscortechinia kingii	x		x
Palaquium cochlearifolium	x		x

Depending on the degree of degradation, conditions may differ considerably from the original peat swamp forest conditions, and this should be given due consideration. Former peat swamp forest areas that have been drained will be a lot drier than in the original state, while areas that have been subjected to (repeated) burning may also be subject to prolonged and/or deep flooding. Also, most degraded sites are also (much) less shaded than in the original peat swamp forest state. On the whole, species used for reforestation of degraded areas will usually have to be able to cope with: i) more exposure to direct sunlight, ii) desiccation in the dry months, and iii) some degree of flooding in the wet season. Many species of mature peat swamp forests will therefore not be suitable for replanting of degraded peatland, and the choice of species should during initial planting focus largely on those with a broad ecological tolerance, such as pioneer species (see TABLE 3 PAGE 91).

RIGHT: TABLE 3

Pioneer/secondary peat swamp forest species in Sumatra and Kalimantan, Indonesia. Sources: van der Laan (1925), Giesen (1990), Bodegom et al. (1999), Kessler (2000), Giesen (2004), van Eijk & Leenman (2004) and Giesen (2008).

#	Family	Species	Local name
1	Anacardiaceae	*Campnosperma coriacea*	terentang
2	Anacardiaceae	*Campnosperma macrophylla*	terentang
3	Anacardiaceae	*Gluta renghas*	rengas
4	Anacardiaceae	*Gluta wallichii*	rengas manuk
5	Anisophylleaceae	*Combretocarpus rotundatus*	tumih, parapat, tanah tanah
6	Apocynaceae	*Alstonia pneumatophora*	pulai
7	Apocynaceae	*Dyera polyphylla*	pantong, jelutung
8	Arecaceae	*Licuala paludosa*	
9	Arecaceae	*Nenga pumila*	
10	Arecaceae	*Pholidocarpus sumatranus*	
11	Caesalpiniaceae	*Koompassia malaccensis*	kempas merah
12	Dipterocarpaceae	*Shorea balangeran*	belangiran
13	Ebenaceae	*Diospyros siamang*	eang
14	Elaeocarpaceae	*Elaeocarpus petiolatus*	
15	Euphorbiaceae	*Austrobuxus nitidus*	
16	Euphorbiaceae	*Glochidion rubrum*	
17	Euphorbiaceae	*Macaranga amissa*	
18	Euphorbiaceae	*Macaranga pruinosa*	mahang
19	Euphorbiaceae	*Mallotus muticus*	perupuk
20	Euphorbiaceae	*Mallotus sumatranus*	
21	Euphorbiaceae	*Pimilodendron griffithianum*	
22	Hypericaceae	*Cratoxylum arborescens*	geronggang
23	Hypericaceae	*Cratoxylum formosum*	popakan
24	Hypericaceae	*Cratoxylum glaucum*	bentaleng
25	Icacinaceae	*Stemonurus scorpioides*	pasir pasir
26	Lauraceae	*Actinodaphne macrophylla*	
27	Lecythidaceae	*Barringtonia macrostachya*	
28	Lecythidaceae	*Barringtonia racemosa*	
29	Leeaceae	*Elaeocarpus petiolatus*	
30	Melastomataceae	*Melastoma malabathricum*	senduduk
31	Melastomataceae	*Pternandra galeata*	
32	Mimosaceae	*Archidendron clypearia*	
33	Moraceae	*Artocarpus gomeziana*	
34	Moraceae	*Ficus deltoidea*	ara
35	Moraceae	*Ficus virens*	
36	Myristicaceae	*Knema laytericia*	pirawas
37	Myrtaceae	*Eugenia spicata*	ubah, kayu lalas
38	Myrtaceae	*Melaleuca cajuputi*	gelam
39	Myrtaceae	*Syzygium cerina*	
40	Myrtaceae	*Syzygium zippeliana*	
41	Pandanaceae	*Pandanus helicopus*	rasau
42	Rubiaceae	*Neolamarckia cadamba*	bengkal
43	Rubiaceae	*Timonius salicifolius*	
44	Rutaceae	*Melicope accedens*	
45	Theaceae	*Ploiarium alternifolium*	asam-asam
46	Ulmaceae	*Trema cannabina*	
47	Ulmaceae	*Trema orientalis*	landuhung

Many of the trials and peat swamp forest reforestation attempts to date have failed because the species used were unsuitable for the conditions at the specific location. TABLE 4 gives an overview of the species tried to date in Southeast Asia, and the degree of success. As the degree of dryness and flooding can vary considerably (e.g. at various distances from a canal or burn scar), local conditions must be accurately mapped beforehand to guide species selection.

TABLE 4
Species used in restoration trials in Southeast Asia (adapted from Giesen, 2008).

#	Species	Family	Locations/ countries	Performance
1	*Alstonia spathulata*	Apocynaceae	Jambi	•
2	*Anisoptera marginata*	Dipterocarpaceae	Malaysia	•
3	*Baccaurea bracteata*	Euphorbiaceae	Thailand	•
4	*Calophyllum ferrugineum*	Guttiferae	Malaysia	o
5	*Combretocarpus rotundatus*	Rhizophoraceae	Jambi	•
6	*Dialium patens*	Leguminosae	Thailand	o
7	*Diospyros evena*	Ebenaceae	Kalimantan	•
8	*Durio carinatus*	Bombacaceae	Jambi	o
9	*Dyera (lowii) polyphylla*	Apocynaceae	Jambi, Malaysia	•/o
10	*Eugenia kunstleri*	Myrtaceae	Thailand	•
11	*Ganua motleyana*	Sapotaceae	Thailand, Malaysia	•
	(syn. *Madhuca motleyana*)			
12	*Gluta wallichii*	Anacardiaceae	Jambi	•
13	*Gonystylus bancanus*	Thymelidaceae	Jambi, Malaysia,	•
			Kalimantan	•
14	*Hibiscus sp.*	Malvaceae	Riau	•
15	*Litsea johorensis*	Lauraceae	Thailand	o
16	*Macaranga hypoleuca*	Euphorbiaceae	Riau	•
17	*Macaranga pruinosa*	Euphorbiaceae	Thailand, Malaysia	•/•
18	*Melaleuca cajuputi*	Myrtaceae	Thailand, Vietnam	•
19	*Palaquium sp.*	Sapotaceae	Jambi, Kalimantan	•
20	*Peronema canescens*	Verbenaceae	Kalimantan	o
21	*Polyalthia glauca*	Annonaceae	Thailand	•
22	*Shorea balageran*	Dipterocarpaceae	Kalimantan	•
23	*Shorea pauciflora*	Dipterocarpaceae	Jambi	•
24	*Shorea pinanga*	Dipterocarpaceae	Kalimantan	o
25	*Shorea platycarpa*	Dipterocarpaceae	Malaysia	•
26	*Shorea seminis*	Dipterocarpaceae	Kalimantan	o
27	*Stemonurus secundiflorus*	Icacinaceae	Thailand	o
28	*Syzygium oblatum*	Myrtaceae	Thailand	•
	(syn. *Eugenia oblata*)			
29	*Tetramerista glabra*	Theaceae	Jambi	o

• = good to very good (or >50% survival) o = poor to fair (or <50% survival)

Based on field experience and several surveys in Central Kalimantan, Giesen (2008) provides a preliminary list of species that have potential for peat swamp restoration attempts, allocating these into four different flooding regimes:

1. Deepwater areas (deeply flooded for long periods),
2. Deeply flooded areas (frequently deeply flooded areas),
3. Moderately flooded areas (regularly, shallowly flooded areas), and
4. Rarely flooded areas

For each of these flooding types, a suite of potentially suitable species is listed (TABLE 5 PAGE 94). The same suite can also be used for channel blocking programmes, with type 1 being equivalent to deep-sided channels, type 2 partially in filled channels, type 3 largely in filled channels, and type 4 completely in filled channels. Over time, these types will naturally evolve from one into another. Studies in peat swamp forests show that deeper peat layers largely consist of *Pandanus* roots and stems, indicating that infilling of deeper waters may be an initial stage in natural peat formation in at least some areas. In deeply flooded former peat swamp forest areas, a similar succession may be attempted. In type 4, once pioneer species have established a canopy, shade tolerant or requiring species can be planted as well, hastening the succession towards mixed peat swamp.

TABLE 5

Peat swamp forest species suitable for rehabilitation programmes under various flooding regimes (adapted from Giesen, 2008).

#	Green canal blocking	PSF Restoration	Engineering species (i.e. also suitable for channel blocking programmes)	Species	Local name
1	Steep sided canals	PSF area deeply flooded during long period	GROUP 1: deep water • *Hanguana malayana* • *Pandanus helicopus*	• *Hanguana malayana* • *Hypolytrum nemorum* • *Pandanus helicopus*	• Bakung • rasau
2	Sloping sides (eroded or back filled) of canals	Frequently, deeply flooded PSF areas	GROUP 2: deeply flooded • *Combretocarpus rotundatus* • *Lepironia articulata*	• *Combretocarpus rotundatus* • *Lepironia articulata* • *Mallotus sumatranus* • *Morinda philippensis* • *Psychotria montensis* • *Stenochlaena palustris*	• tumih • purun • perupuk • kiapak
3	Largely in-filled canals, with shallow pools	Regularly (shallowly) flooded PSF areas	GROUP 3: moderately flooded • *Cratoxylum glaucescens* • *Ploiarium alternifolium* • *Shorea balangeran*	• *Blechnum indicum* • *Cratoxylum glaucescens* • *Ploiarium alternifolium* • *Shorea balangeran* • *Stenochlaena palustris*	 • gerongang • asam-asam • belangeran/ kahui • kiapak
4	Infilled canals	Flooding rare or absent in these PSF areas	GROUP 4: rarely flooded • *Alstonia spathulata* • *Dyera polyphylla*	• *Alstonia spatulata* • *Blechnum indicum* • *Dyera polyphyla* • *Macaranga sp.* • *Stenochlaena palustris*	• pulai • jelutung/ patung • mahang • kiapak
	As above, with shade trees	As above, with shade trees	GROUP 4B: rarely flooded shade required	• *Alseodaphne coriacea* • *Baccaurea bracteata* • *Dialium patens* • *Diospyros evena* • *Durio carinatus* • *Ganua motleyana* • *Gonystylus bancanus* • *Patonema canescens* • *Shorea pinanga* • *Syzygium spp.* • *Tetramerista glabra*	• gemor • rambai • uring pake • durian hutan • ramin • punak

Once a suite of suitable species (i.e. species suited to the conditions of a site) have been selected, species selection can further be guided by guiding principles 2 *Selection of beneficial species* and 5 *Avoiding use of exotic species* (see SECTION 5.2 PAGE 112). Beneficial species should be utilized where possible when the degraded areas that are being rehabilitated are located near villages, or belong to a particular community. The focus should not only be on timber species, as has often been the case to date, but on species that provide Non-Timber Forest Products (NTFPs). A preliminary list of potentially beneficial species – both for timber and NTFPs – is included in TABLE 6 PAGE 96. It should be remembered that restoration of peatland hydrology is one of the key guiding principles (see SECTION 4.4 PAGE 87), and that exotic species that require drainage are incompatible with this principle in areas on margins of peat domes.

TABLE 6

Peat swamp forest species suitable for timber and NFTPs.

#	Family	Species	Local name	Timber	NTFP
1	Anacardiaceae	*Mangifera havilandii*	resak rawa	+	
2	Anisophyllaceae	*Combretocarpus rotundatus*	tumih	+	fuelwood
3	Apocynaceae	*Alstonia spathulata*	pulai	+	
4	Apocynaceae	*Dyera polyphylla*	jelutong	+	latex
5	Araucariaceae	*Agathis borneensis*		++	
6	Bombacaceae	*Durio carinatus*	durian hutan	+	edible fruit
7	Dipterocarpaceae	*Dipterocarpus verrucosus*	karuing	+	
8	Dipterocarpaceae	*Dryabalanops sp.*	kapur naga	+	
9	Dipterocarpaceae	*Hopea sp.*	lentang bangkirai	+	
10	Dipterocarpaceae	*Shorea balangeran*	belangiran	++	
11	Dipterocarpaceae	*Shorea leprosula*	lentang	+	
12	Dipterocarpaceae	*Shorea parvifolia*	meranti batu	+	
13	Dipterocarpaceae	*Shorea rubra*	meranti bahandang	+	
14	Dipterocarpaceae	*Shorea smithiana*	lentang mahambung	+	
15	Dipterocarpaceae	*Shorea uliginosa*	lentang bajai	+	
16	Dipterocarpaceae	various species*	tengkawang	++	ilipe nuts
17	Euphorbiaceae	*Bacaurea bracteata*	rambai		edible fruits
18	Guttiferae	*Callophyllum grandiflorum*	bintangur	+	
19	Guttiferae	*Garcinia spp.*	manggis hutan	+	edible fruits
20	Hypericaceae	*Cratoxylum sp.*	gerunggang	+	
21	Lauraceae	*Alseodaphne coriacea*	gemor		bark for mosquito coils
22	Myrtaceae	*Melaleuca cajuputi* [1]	gelam	+	fuelwood, oil, honey
23	Myrtaceae	*Tristaniopsis maingayi*	palawan/ balawan	+	
24	Podocarpaceae	*Dacrydium pectinatum*	alau	++	
25	Sapotaceae	*Ganua motleyana* [1]	katiau	+	
26	Sapotaceae	*Palaquium rostratum*	nyatu/ nyatuh		latex
27	Sapotaceae	*Palaquium leiocarpum*	jangkang		latex
28	Theaceae	*Ploiarium alternifolium*	asam-asam		edible young leaves
29	Thymelaceae	*Gonystylus bancanus*	ramin	++	

NOTES

+ Good timber species
++ Excellent, valuable timber species

* Needs to be surveyed; *tengkawang* is produced and marketed in West Kalimantan, and specialists consider that peat swamp forest dipterocarp species probably also include a number of species producing Ilipe nuts.

1 *Melaleuca cajuputi* is often incorrectly recorded as *Melaleuca leucadendron* or *M. leucadendra* and *Ganua motleyana* is often incorrectly recorded as *Madhuca motleyana*.

FIGURE 26
Jelutung seedlings at a nursery.

There are also several palm species that can be easily planted on peat e.g. red pinang palm (*Crytostachys renda*), salak hutan (*Salacca magnifica*), Sago palm and some species of wild pandan.

PLANNING FOR SUCCESSION

Rehabilitation planting programmes should take a succession-based approach, first utilizing pioneer species with a broad ecological tolerance, later adding climax species/species of mature/mixed peat swamp forests if this is appropriate. The latter would be appropriate if, for example, the aim is to increase the density of certain beneficial species characteristic of mature peat swamp forests, or if the aim is to increase biodiversity value if the area is adjacent, near or forms part of a conservation area.

Studies of succession in peat usually show a historic transition from either a freshwater swamp (with *Pandanus*) or mangrove to a mixed peat swamp forest. In terms of coping with increased flooding in degraded peat (e.g. after subsidence or loss of peat after fires), the approach would be to mimic the historic succession and start once again with very flood tolerant species such as *Pandanus helicopus*. Once a location becomes shallower or partially infilled, species that have some flood tolerance such as *Combretocarpus rotundatus* can be added. Possible suites of species with differing flood tolerance are listed in TABLE 5 PAGE 94.

As peat accumulates over time, a particular site may develop a mixed peat swamp forest. Although containing less biodiversity than lowland dipterocarp forests, mixed peat swamp forests can attain a canopy height of 35-40 meters and include anywhere from 30-130 tree species at a given location (Giesen, 2004).

Light conditions in peatland vegetation also vary over time. In degraded conditions, light conditions will be harsh and shade requiring species more common in mature peat swamp forests will not flourish. In pole forest, light penetration is greater than in mixed/mature peat swamp forests, and once again light conditions may be more harsh and contribute to unfavorable conditions for certain species. Little is known about light requirements of peat swamp forest tree species, but one may assume that pioneer species have a high tolerance, while species that occur only in mature-mixed peat swamp forests are likely to be less tolerant.

4.6 ENCOURAGING NATURAL REGENERATION

The basic principle behind encouraging natural regeneration is to assist nature to grow its own new plants by removing constraints. Native plants normally self-seed and re-grow new seedlings by themselves. This is called natural regeneration and it is the normal process in a healthy swamp. It is the most natural method and gives the best results in terms of biodiversity. Natural regeneration is usually the low input option. Plantations can assist this process by removing elements that threaten existing native vegetation. This involves controlling inappropriate weeds, putting up fences/barriers to protect the area or changing drainage techniques (see SECTION 4.4 PAGE 87). Maintenance should not be required unless weeds prevent the regeneration of native species, in which case weed control becomes necessary.

Inventories of existing plants and ecological surveys of the project area during the planning stage will provide information on whether encouraging natural regeneration will suffice to rehabilitate the area. If not, enrichment planting and/or active replanting (see SECTION 4.7 PAGE 102) will be necessary.

It is also important to identify the barriers or the factors that impede recruitment and regeneration processes. These include identification of factors like seeds, dispersal patterns and establishment limitations. Various approaches to overcome these limitations are illustrated in FIGURES 27 and 28.

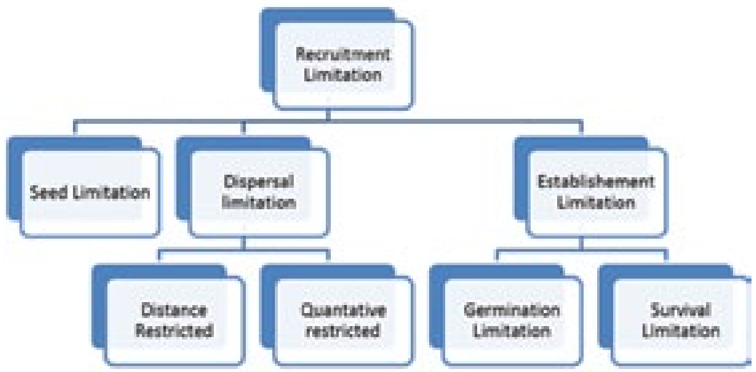

FIGURE 27
Factors that may limit regeneration of peat swamp forests.

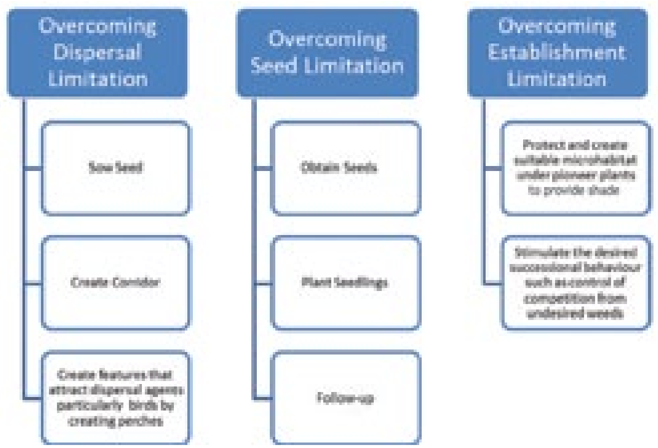

FIGURE 28
Approaches to overcome primary limitations.

4.7 ENRICHMENT PLANTING/REPLANTING

Enrichment planting or active replanting may be necessary depending on the degree of degradation of the peat swamp forest area. If natural regeneration is not possible or insufficient, enrichment planting can be a useful intervention to assist rehabilitation. Suitable species types for enrichment planting will depend on the stage of succession currently in progress. If pioneer species are well established, shade tolerant or requiring species can be planted, hastening the succession towards a mixed peat swamp. If the area has been completely cleared or repeatedly burned, it may be necessary to implement a full-fledged peat swamp forest rehabilitation program. Detailed guidance on implementing such a program is provided in CHAPTER 5 PAGE 105. It is useful to note that government research units are sometimes able to provide ready-to-plant material that is available in reasonable quantities and cost (see BOX 5 for an example of an offer in Indonesia).

BOX 5

Example of seedling offer in Indonesia.

The following offer was provided by *Koperasi Pegawai Negeri Sylva Balai Penelitian Kehutanan Aek Nauli* (Address: *Kampus Kehutanan Aek Nauli*, Km 10.5, Sibaganding, Parapat, Indonesia) to an oil palm plantation company.

TABLE 7
Available seedlings for peat swamp forest rehabilitation.

#	Type	Specifications	Stock	Price per seedling (Rp)
1	Meranti Batu	30cm height	20,000 seedlings	1.600,-
2	Meranti Merah	20cm height	10,000 seedlings	1.600,-
3	Bintangur	20cm height	40,000 seedlings	1.600,-
4	Pulai	30cm height	2,000 seedlings	1.800,-
5	Mayang	50cm height	20,000 seedlings	1.600,-
6	Aren	2-3 leaves	15,000 seedlings	4.000,-

NOTE
1. For seedling types numbered 1-5, the recommended spacing for planting is 3m x 3m.
2. For seedling type number 6, the recommended spacing for planting is 6m x 6m.
3. Prices above are as of JUNE 2011.

5.0 IMPLEMENTING PEAT SWAMP FOREST REHABILITATION

The following detailed guidance on replanting activities in peat swamp forests is mainly adapted from the 'Manual on Peat Swamp Forest Rehabilitation and Planning in Thailand' (Nuyim, 2005). For more information, see also "Guidelines for the Rehabilitation of Degraded Peat Swamp Forests in Central Kalimantan" (Giesen and van der Meer, 2009).

5.1 SEED STOCK COLLECTION AND DEVELOPMENT OF NURSERIES FOR PEAT SWAMP SEEDLINGS

INTRODUCTION

The choice of seedling is one of the major factors that determine the success or failure of reforestation efforts. Healthy, strong and proper-sized seedlings, when planted, are able to survive and grow into large trees. On the other hand, unhealthy seedlings will not survive – making it a waste of resources in terms of the preparation and additional time required for replacement planting. Poor planning during the preparation of seedlings may also result in shortage of seedlings for replanting for a particular year, causing a great loss to the rehabilitation program. Leaving the prepared plots vacant without planting any seedlings will always give rise to the speedy growth of weeds, especially in the rich soil of the peat swamp forests with adequate water supply and proper sunlight. These weeds will dominate the prepared plots. Within a period of 3 to 4 months, the plots will return to their former state, as it was before preparation work was carried out. To carry out replacement planting, the plots have to be prepared all over again.

PLANNING FOR SEEDLING PREPARATION

Planning to ensure an adequate supply of quality seedlings requires planners to be well-informed of the types of seedlings to be used for planting. Requirements include the planners' prior knowledge about the quantity of seedlings required for planting and replacement planting, size and height of seedlings suitable for planting, time for planting, as well as planting patterns and conditions. In addition, good planning for quality seedlings requires the planners to make additional plans for collecting seeds, determining seed sources and the collection season. Certain seeds have to be sought from distant areas. Planning for the production of seedlings of wild plant species requires more attention than the preparation of fruit tree seedlings or seedlings of economic species. Seedlings of fruit trees and economic plants are commonly found and can be acquired from other sources too. Wild plant seedlings are cultivated by only a few nurseries.

FIGURE 29
To supplement wild seed supplies, wild seedlings can be collected.

SELECTING PLOTS FOR SEEDLING NURSERY

A critical criterion for selecting a suitable plot for a seedling nursery is that the plot should be located on flat land outside the peat swamp forest, or the plot area must not be waterlogged. Such a plot provides convenience in carrying out nursery work. Another factor to be considered is that the area must have easy access to water all year round, whether from the peat swamp or other natural sources such as marshes, canals or wells. Utilizing tap water would be too costly. If possible, a temporary water storage tank should be built and connected to the water source using a pipe. The size of the pipe can be varied depending on the distance from the tank to the water source. The use of a good quality water pump makes the temporary storage tank unnecessary. More importantly, the plots for the seedling nursery should be accessible to vehicles all year round and equipped with electricity. In addition, labor should be easily available in the area. The plot for the seedling nursery should have soil with sandy loam. If necessary, sand can be put on top of the soil to prevent the nursery plot from being soggy.

CONSTRUCTION OF NURSERY HOUSE AND SEEDLING NURSERY

After selecting the site for a seedling nursery, another criterion would be whether there is adequate shade and sunlight for the seedlings. Sunlight is an important factor in regulating growth and promoting the health of plants. Sunlight should be able to penetrate all seedling storage areas, and at least 50% of the open spaces. Seedlings that lack exposure to sunlight grow very tall and young branches break easily. Afterwards, grasses are weeded and pests are removed. Then, the area must be leveled and the nursery house is built on the space. Large and strong poles should be used for building the nursery house. Once poles are piled into the ground, bamboo stalks or metal pipes should be placed on the top ends of the poles. Once the bamboo stalks or metal pipes are connected to the top ends of all poles, a shading plastic panel is attached on top of these stalks or pipes. Each roll of shading plastic panel can be connected to another by manual sewing with nylon thread of metal wire. Depending on the color of these plastic panels, the shading capacity ranges from 30% to 50% to 70%. For nursing or seedlings, a 50% shading panel is applied.

A seedling nursery bed can be built using cement bricks into a structure that looks like an open box. The bed is filled with sandy loam or crushed coconut fiber. This is for sowing seeds.

FIGURE 30
Example of nursery set up for a peat rehabilitation project.

ESTABLISHMENT OF WATER PROVISION

A temporary water tank should be constructed in forest nurseries. Piping should be joined with the temporary water tank. The diameter of the pipe should be reduced according to distance from the tank to the pipe network. There are also other methods of water provision such as the use of a good quality water pump rather than a temporary water tank, and through inexpensive sprinkler systems, which can provide significant labor savings.

SOWING SEEDS AND REPLANTING SEEDLINGS

Most seeds of plant species in the peat swamp forests are rather large (with the exception of certain plants such as *Melaleuca cajuputi* and *Fagraea racemosa*). Large seeds are easier to sow than small ones. The seeds must first be sown in prepared seed pans. Seeds should be distributed evenly in the pan and not too close together. Fine sand is topped on the seeds and watering is carried out in the mornings and afternoons, using a watering can with a fine hose. If the sown seeds are small, the seedling pan should be covered with a transparent plastic sheet to prevent raindrops from dispersing the seeds. A label should be attached to the pan, stating the date of sowing and the plant species. The information should be recorded in a logbook. After the seeds germinate, the young seedlings are then transplanted into polythene bags filled with pot soil. It should be noted that seedlings from small seeds should be allowed to grow at least one inch tall before they can be selected for transplanting. For the purpose of maximizing genetic diversity, seeds should be collected from good plant stocks and seeds from different stocks should be mixed when sowing to help lessen inbreeding among plants from the same stock.

Certain seeds are difficult to acquire or are only available in small quantities. A good idea would be to cultivate plant stocks in natural forests or in prepared plots. Stocking plots should be properly managed so that required seeds are produced and gathered. It is found that almost all seedlings naturally grown in the wild can be transplanted into polythene bags and nursed with high survival and growth rates.

PREPARATION OF POLYTHENE BAGS

Polythene bags used for peat swamp forest seedlings need to be generally large and taller than the highest water levels. Water levels beyond the crown of the seedlings often result in seedling deaths. However, seedlings may survive even though the base of the seedlings was underwater for a period as long as 18 months (Nuyim, 2003). It should be noted that transferring seedlings to planting sites can be rather difficult and especially cumbersome with large bags. Therefore, it is advisable to use polythene bags of mixed sizes.

FIGURE 31
Putting wildlings in polythene bags.

SOIL USED FOR FILLING POLYTHENE BAGS

Trees and seedlings growing in peat swamps thrive well on organic soil. Top soil from outside peat swamp areas mixed with rice husk and manure can also be used for cultivating seedlings in polythene bags. These seedlings may grow faster than those grown in bags filled with organic soil.

To acquire organic soil, one has to wait for the soil to become dry as it is difficult to dig for soil under wet conditions. Before filling the bags, workers have to pick out gravel, stones and pieces of leaves and branches. The soil is then mixed well with rice husks and manure, filled in the bags, compressed and put in rows. Storing blocks should have a space of 30cm at both ends in order for nursery workers to do weeding and watering.

NURTURING SEEDLINGS

Seedlings should be watered thoroughly twice a day, in the mornings and afternoons. Weeding should be done once a month. Bags with seedlings should be moved once every three months to prevent the roots of the seedlings from penetrating into the ground. Height grading should be carried out so that all seedlings are exposed to sunlight and shorter seedlings are not suppressed. These procedures will help accelerate growth and make it more convenient for selecting seedlings for planting. Tall seedlings should be planted first.

Nursery workers should also look out for diseases and pests. If pests are found, the seedlings should be sprayed with chemicals. If there is a need for accelerating the growth of seedlings for planting, they should be treated with urea fertilizer – with a formula consisting of one handful of urea dissolved with 5 litres of water. One month before the planting season, the shading panel should be taken out so that all seedlings are fully exposed to sunlight, thus promoting the hardening of the seedlings. If it is not possible to take out the shading panel, all seedling bags should be brought out into the open to areas close to the main road. This will help to harden the seedlings, accustom them to real planting conditions and also easier for transportation to planting plots.

5.2 PREPARATION OF CULTIVATION PLOTS AND PLANTING OF SEEDLINGS

INTRODUCTION

Procedures and practices in the preparation of cultivation plots, planting and nurturing of the plantation are very important. The success of replanting and rehabilitation depends mostly on the work done during these stages. Different cultivating locations require different treatments.

SITE SURVEY FOR PREPARATION OF REHABILITATION AREA

After the site for the plantation has been decided upon, the first stage is for the person/s responsible for planting to survey the plots. A preliminary survey should be made to collect basic information on the area, such as location, boundary, site history, distribution of plant and weed species, and signs of wild fires and domesticated animals. Surveyors should make recommendations and present the baseline data to their superiors for consideration. Before starting the operation, a thorough survey should be made to designate the exact location of the plot. Planning should be done for the temporary walkway, digging ditches, firebreak, calculation of the number of seedlings required and other necessary preparations. Measurements should be taken of the boundary and boundary posts should be erected to prevent encroachment. The planting location should be plotted on a map with a scale of 1:50,000. A more detailed map showing planting plots should be drawn on a letter-size paper (A4) with a scale of 1:500 to 1:5,000 depending on the sizes of the planting areas. The map should include details about the permanent physical features of the landscape such as roads and canals as well as other details. A preliminary survey provides surveyors with information on suitable plant species to be cultivated and the quantity required for planting. An area with large trees already growing should be planted with species that do not need much sunlight. Similarly, a waterlogged area should be planted with tall seedlings and the species should be well-suited for growth in the water.

PREPARATION OF REHABILITATION AREAS

Clearing of the area for planting and rehabilitation of the peat swamp forests require weeding of certain plants such as *Scleria sumatrensis*, *Blechnum indicum* and *Stenochlaena palustris*. This must be done in a cautious way so as not to damage the seedlings growing along with the weeds. Most of the seedlings are difficult to locate because they are overgrown by weeds. Workers should use machetes or sickles to cut the weeds as close to the ground as possible. Cutting only the upper parts of the weeds will allow the remainder of the plant to rapidly regrow, making it difficult for the seedlings to survive. The practice of burning to clear the weeds should not be allowed.

FIGURE 32
Preparation of rehabilitation area.

The bases of the replanted seedlings must be buried. In order for the seedlings to be able to outgrow the weeds, it is recommended that the seedlings to be planted should be more than one meter tall. But cutting the weeds close to the ground requires a lot of labor and a specific technique. Firstly, the workers have to slash the weeds vertically to cut the parts that cover other plants. Secondly, they have to cut the weeds horizontally, as close to the ground as possible. The cut weeds are then broken into small pieces and stepped on to level the cut pieces on the ground surface. This complicated procedure makes the preparation cost for planting in the peat swamp forest higher than that for other types of forests. Climbing weeds on large, naturally occurring trees should be cut and pulled down to allow the trees to grow freely. Extended and cumbersome crowns of original trees should be pruned to allow sunlight to reach newly planted seedlings. Seedlings exposed to more sunlight grow better. About 10 workers are required to clear a half-hectare area in one day. In areas where weeds do not grow too densely, workers can use grass cutting machines for the preparation of the planting plots.

CONSTRUCTION OF TEMPORARY WALKWAY TO ACCESS PLANTING PLOTS

Because peat swamp forests are waterlogged and peat soil is loose and very sodden, the movements of laborers, tools or seedlings into the planting site is rather difficult. For a planting area of more than 8 ha, or if it is necessary to enter the planting site often, there may be a need to construct a temporary walkway to the site. Bamboo poles and fallen tree branches are laid on the ground to make the walkway.

POLING FOR PLANTING AND PLANTING SPACE

Very few studies have been carried out to determine the appropriate planting space for peat swamp forests; therefore, there has not been any specific formula for the space. Setting the proper planting space between trees is important because this will determine the operating cost. Planting space also dictates the number of seedlings required for planting. The number of seedlings dictates the number of positioning poles and pits to be dug for planting. A narrow space between trees means a larger number of seedlings are required, and a higher operating cost per ha as a result. The space between trees is determined by the crown size. For example, *Compnosperma coriaceum* has an extended crown. A planting space of 2 x 4 meters results in cramping of the crowns within 4 years. For the same planting space, it will take 15 years for the crowns of *Calophyllum sclerophyllum* to cram. Therefore, the planting space of each plant species differs. On average, the most appropriate number of seedlings to be planted in the peat swamp forests is 1,250 seedlings per hectare. Planting of the seedlings should preferably not be fixed in a straight line or in a row.

The advantage of poling the planting spot is that it makes it easier to notice the site to be planted. A seedling is set beside each pole before planting. By tying the seedling to the pole, the pole also serves as the support for the seedling to grow upright. Also, the pole is an indicator for the location of the planted seedling. This makes it convenient for workers to find the location of the seedling when they want to do weeding. The poles make it easy for the workers to survey the seedlings for growth, survival or replacement planting. In economic plantations where seedlings are planted in rows, it is necessary to use planting poles. Planting poles or stakes may be made from bamboo (which can last for 2-3 years) or from Johnson grass or *Arundo donax* obtained (which can last for 6 months).

FIGURE 33
Planted sapling with bamboo pole.

PREPARATION OF PLANTING PITS AND PLANTING

Good planting pits are essential for the survival of seedlings. They should be at the same level as the original soil. Topping the weeds with organic soil can be a problem when the water level recedes. The organic soil becomes dry, the roots of the plants become dehydrated and the plants eventually die. Growing certain plant species on a small soil mound at an elevated level above the water surface may result in a significantly better growth rate than growing at normal ground level. These plants include *Eugenia kunstleri*, *Eugenia oblata*, *Baccaurea bracteata*, and *Decaspermum fruitcosum*.

In certain areas, (which may be waterlogged because of subsidence, fire, or changes in natural drainage) limited or temporary drainage may be applied instead of constructing mounds. Both of these techniques share the same principle, i.e. mounds allow the roots of the seedlings to grow in soil above the water level, whereas drainage lowers the water level in the soil so that the roots are not in the water. For large-scale planting, drainage is a more convenient and less costly technique. But this brings with it the risk subsidence and fire.

The dry season is a good time for making mounds because the water level in the peat swamp is low. The plantation manager or chief often mobilizes the workforce to build mounds for the whole plantation during this season. The seedlings are planted early in the rainy reason. Such a practice differs from planting methods in other forests where the seedlings are planted immediately after making the planting holes or pits.

In planting the seedlings, use a knife to cut the polythene bag and remove it. Make a planting hole of the right size with a stick. Carefully put the seedling into the hole; do not cause the soil covering the roots of the seedling to break. After that, cover and compress the base of the seedling with the soil. If there are weeds around the planting hole, remove the weeds first. Tie the seedling to the planting pole at 70% of the seedling height above the ground. This will help the seedling to grow upright. When tying the string, tie one end loosely to the seedling to allow it to grow freely and tie the other end tightly to the pole to prevent it from falling to the base. Removed polythene bags should be disposed outside the plantation to keep the environment clean and prevent wild animals from accidentally ingesting them as the bags may be mistaken for something edible. Before planting the next seedling, scoop water from around the planting hole and pour it onto the base of the newly planted seedling.

As for planting at the ground level, use a machete to weed the chosen location. In order to grow trees in a straight line, it is important to be consistent in making a lead hole, either to the left or to the right of the planting pole, so that the rows of the grown trees will be in straight lines. The next step is to remove the polythene bag from the seedling, and carefully put the soil-covered seedling into the prepared hole (see FIGURE 34). Similarly, tie one end of the string loosely to the seedling and the other end tightly to the planting pole to prevent slanting of the trunk. Water the seedling the same way as was done in the mound method.

Most seedlings of species from the peat swamp forests grow slowly. Depending on site conditions, fertilizer applications may be necessary. It has been suggested to use 100g of controlled release fertilizer (15% N: 15% P_2O_5: 15% K_2O) in each planting hole.

FIGURE 34
Removing polythene bag from seedling to be planted.

To ensure that no planting poles are missed during the planting process, the seedlings should be planted in a row starting from the edge of one side of the planting area toward the opposite end.

SEEDLING TRANSPORTATION

The transporting of seedlings is a procedure that needs special attention. The well-prepared seedlings can be damaged while being transported due to lack of knowledge and proper attention in handling on the part of the handlers. Healthy seedlings may have dried or leaf abscission and broken roots. It should be noted that transporting seedlings takes a short time but it may affect the seedlings that have been prepared for a long time. Another point worth noting regarding transporting of seedlings is time. Seedlings should be transported from the nursery to the planting area in the shortest time possible. A logistic plan should be mapped out carefully to avoid delay in transportation. The proper handling technique is to put seedlings into large plastic bags with straps. The plastic bags are then loaded on a truck; careful layering the seedlings on top of each other is permitted. Upon reaching the site, the bags are unloaded and transported to the planting area – carried by hand, on shoulders or by boat. A plastic shading panel is required to cover the seedlings when being transported by truck. This is meant to prevent the leaves from being damaged by the force of strong wind while the vehicle is moving. Without a shading panel, the seedlings being transported may suffer leaf abscission, which requires months for recovery. In transporting large plants of Palmae species, it is recommended that all the leaves are tied together before beginning the journey. This handling technique will prevent the seedlings from being disturbed. It should be noted that at every stage of seedling transportation, only the plastic bags should be handled, not the seedlings. Touching the seedlings may cause the covered soil at the base to break off, an action which may result in the death of the seedlings. For redistribution at the planting site, the seedlings may be transported by trailer, boat or on foot.

FIGURE 35
Transportation of seedlings at the planting site.

5.3 MAINTAINING OF PLANTS

REPLACEMENT PLANTING

The first month of field planting is crucial to determine the survival of the planted seedlings. This means that under normal climate conditions and without pests or diseases, most seedlings that survive the first month can grow further to become large trees. Major reasons for seedlings not being able to survive after one month are: they are unhealthy; damaged by the planting procedure; not properly planted by the planters; or the soil is not suitable. Seedlings wither if dehydrated, or the leaves will fall when submerged in the water and eventually the seedlings will die. Symptoms of dying can be seen within 2 or 3 days for certain plants, whereas for others it takes time for the signs to surface. In order for the replaced seedlings to grow along with the original seedlings, it is advisable to carry out the replacement planting as soon as possible after a seedling is found dead. For large scale planting, it is rather impractical and costly to make a survey of the newly planted area every day. Therefore, replacement planting should be carried out one month after the first planting of the seedlings.

A certain number of seedlings should be set aside for replacement and these seedlings should be nurtured in the nursery to grow along with the ones already planted. Using the reserved seedlings of the same lot for replacement is a good idea, because the original seedlings and the replaced seedlings will be growing at almost the same height. This has the advantage of helping to prevent the replaced seedlings from being dominated or overshadowed by the originally planted seedlings. By moving the seedlings in the polythene bags twice a year, it is possible to prevent the roots of the seedlings stored in the nursery from penetrating into the ground. If the roots are firmly established in the ground, it would be harmful to prick off the seedlings for replanting. The nurtured seedlings are suitable for replacement planting in the second and third year. The success of reforestation depends significantly on natural factors, particularly the climate. Regular rainfall provides water required by the plants, resulting in a high rate of survival. On the other hand, a drought often results in a low survival rate for the plants. Replacement planting in favorable climate for three consecutive years will make reforestation more successful.

WEEDING THE PLANTING PLOTS

A Randomized Block Design (RBD) experimental weeding scheme involving 20 plots of *Macaranga pruinosa* was conducted in Thailand (Nuyim, 2003). The experiment involved five blocks of the plants, each consisting of 5 plots. Weeding was carried out in the following manner. The 1ST plot was weeded once a month; the 2ND plot twice a month, the 3RD plot every six months. Weeding was not applied to the 4TH plot. This experiment was conducted over five years. By taking the plant's growth rate and weeding cost into account, it was found that weeding twice a month was the most optimum practice (Nuyim, 1995). The peat swamp forest has adequate water and sunlight, which promotes the growth of certain weeds such as *Blechnum indicum*, *Stenochlaena palustris*, and some types of *Scleria sumatrensis*. Weeds will dominate the area if weeding is not done for 2-3 months and the condition of the area will return to a similar state as the pre-weeding period. Weeds are one of the major problems in planting and rehabilitating peat swamp forests.

In weeding areas where there are fairly large sized trees, the use of a hand-held grass cutting machine makes weeding 3 times faster than cutting with a machete. The cutting blade should be thick and the grass cutter should wear a protective mask to prevent any cut material from getting into the eyes. In the case where the seedlings are still small, aged 1-2 years old, grass cutting machines are not suitable. Grass cutting machines are also not suitable where trees in the rehabilitating area are not grown in a row or straight line. This is because the blades may cut or damage the young trees easily. In this case, it is suitable to use a machete to cut the weeds instead. Spraying the weeds with chemical herbicides should be strictly avoided to prevent the water in the peat swamp from being contaminated with the chemical – a disaster for the environment and a hazard for both fauna and flora.

FIRE-PREVENTION, MAKING FIREBREAKS AND EXTINGUISHING WILD FIRES

Most peat swamp forests are degraded. The major cause of degradation of primary forests is wildfire. Dry peat becomes easily flammable when dried. This is the reason why it is easy for wild fires to break out but difficult to extinguish in the peat swamp forests. Fires also burn both above and below the ground's surface. The fire above the ground may be put out but the one underground may still burn or smolder. When the fire spreads to a large area causing fires at different points, aggravated by a very low water level, extinguishing the fires through human intervention will be almost futile, although it may be possible to simply delay the spreading of the fire. A complete extinguishing of the fire can be done through filling the peat soil with water. However, using water pumps to raise the water level in the planting area to put out underground fires is a long and very costly procedure. Wild fires often break out during the dry season when the water level in the peat swamp forests is low. The only occasion where it is feasible to use water pumps is when there is a large reservoir next to the peat swamp forest. Ultimately, prevention is the best strategy to manage fires in peat swamp forests.

PEST AND DISEASE CONTROL

Problems of disease and insect infestation in peat swamp rehabilitation pilot projects in South East Asia have not been severe. This may be because of the planting strategy where mixed species are planted in the same plots. Such practice helps to prevent insects and diseases from affecting the plants. In addition, as most of the rehabilitation areas are of small scale and isolated, there is less risk of severe attacks by insects or diseases. However, care should be taken to monitor potential infestations by insect and rodents from adjacent oil palm plantations.

Some diseases and insect pests, which affect the plants during the planting stage, are rotten roots in the seedlings in the nurseries and early field plantings, termites devouring the bark of *Melaleuca cajuputi* seedlings and grasshopper damage on young leaves of *Metroxylon sagu* seedlings. Although diseases and insects may have a low risk, it is important to be aware of the potential threats from diseases and insects, and to conduct studies on their effects.

5.4 EVALUATION OF REHABILITATED AREAS AND THE SETTING UP OF VEGETATION GROWTH STUDY PLOTS

EVALUATING THE SURVIVAL OF SEEDLINGS

To evaluate seedling survival, a survey should be carried out immediately after weeding. In evaluating the seedlings, evaluators simply walk along the planting plots in a systematic pattern for an area equivalent to 10% of the total planting area. Record the survival and death rates of each plant species. The record can be used in the calculation of the number of seedlings required for replacement planting.

SETTING UP OF PLANT GROWTH STUDY PLOTS

Study plots for examining the growth of plants are useful and essential. The information acquired from the study plots can be used for evaluation of rehabilitation project and for identification of plant species suitable for planting in specific areas. The information acquired can also be used to determine the selection and improvement of the plant species to be used for the following year's planting. Technical information can be disseminated through lectures and publications to agencies or individuals interested in peat swamp plantations.

FIGURE 36
Tagging and monitoring of planted saplings.

A plot for studying plant growth should be a permanent plot of 40 x 40 meters. Each rehabilitation project area should have at least 4 study plots, sited at different locations in the project area. Each plant in the plot is labeled with an identification number. The trunk size and crown height of each plant are measured. The trunk size is measured at 20 centimeters above the ground. A mark with red paint is made around the measurement point on the trunk. When the plant grows taller, measure the trunk at 1.3 meters above the ground. Repeat the measurement every year. A plan should be mapped out before collecting the data; all necessary tools such as notebooks should be prepared beforehand. Other information that should be collected includes a description of general surroundings, flowering and fruiting period, and diseases and insects found. To obtain reliable data on water, surveyors should install a water gauge and measure the water level monthly.

6.0 RESEARCH AND DEVELOPMENT NEEDS

Tropical peatland rehabilitation is a relatively new field and thus, additional research and development is needed. The Government of Indonesia and Royal Netherlands Embassy (2009) recommended the following topics for further study for the rehabilitation of peat swamp forests in Central Kalimantan:

PHYSIOCHEMICAL TOPICS

- Dams – where to put them and when
- Species that can tolerate flooding/drought – especially root structure
- Loss of peat – rates and problems
- Site characteristics for peat
- Monitoring of hydrology – for at least a year
- Species in relation to peat depth and maturity
- Data needed for carbon crediting
- Light – species that can tolerate higher levels
- Criteria for land use and level of degradation

BIOLOGICAL TOPICS

- Plant species in relation to with peat characteristics
- Identifying species that can tolerate flooding
- Creating permanent plots to learn about biodiversity
- Identifying which local species are appropriate for each (type of) site
- Learning about the phenology of tree species and thus seed distribution
- *Gemur* and other potential NTFP species – finding the skills to mass-produce
- Identifying plant species that can cope with high light levels
- Learning more about the symbiotic species with trees (*mycorrhizae*, Nitrogen-fixing, etc.)
- Improving and learning about present silviculture techniques

PEOPLE-ORIENTED TOPICS

- Valuation study of NTFPs
- Local perceptions regarding restoration
- Integration agro-fisheries and forestry
- Providing incentive models, improving livelihood, and finances
- How to manage NTFPs, including after harvesting (collection, storage, process, selling)
- Gain understanding of the dependence of local people on NTFPs/ ethnobotany and ethnoecology study; identify which NTFP species are best for local people (finance, yields, etc.)
- Learning and incorporating local knowledge
- Developing methods and documenting community participation
- Developing agroforestry systems

7.0 PARTNERSHIP MECHANISMS INVOLVING LOCAL COMMUNITIES, GOVERNMENT, NGOs AND INCENTIVES

Oil palm plantations have demonstrated clear leadership and excellence in breeding and producing healthy plants, nurturing them and ensuring their survival. With many oil palm plantations operating nurseries successfully, they would be a perfect partner for the establishment of tree nurseries to raise peat forest species for reforestation or rehabilitation nurseries.

This provides a distinct advantage for rehabilitation of degraded peatlands. Experience from NGOs in this area suggests that rehabilitation work requires wider support, direct commitment from key players (i.e. local government, communities and the commercial sector).

To ensure the success of the rehabilitation project, wider participation and involvement of stakeholders is crucial in the following:

1. The establishment of an area where rehabilitation can occur in as close to optimal conditions as possible (i.e. minimize fire threat, encroachment, conversion, etc.).

2. Providing management of the area and rehabilitation process (i.e. monitoring, water table management, other inputs, etc.).

3. Long-term protection from conversion or unsustainable exploitation of the rehabilitated area.

During the establishment of a peat swamp forest rehabilitation area, the role of the oil palm plantation includes nursery work, mapping and planting. Local community support is necessary for identifying key sites, generating local support and in enrichment planting. Government and NGOs can play important roles in helping to minimize threats to the area by monitoring and enforcement. In cases where significant areas are being identified for rehabilitation, government plays a crucial role in providing incentives like land-swaps to degraded lands.

In the management and maintenance of the rehabilitated area itself, plantations again play critical roles in monitoring various parameters like plant health, diversity and water levels. The role of government becomes wider now as the need for protecting the area from erosive factors like negative upstream activities increases. Local community support for sustainable activities that do not jeopardize the area is also important. This would extend well into the long-term outlook as government planning should be cognizant of the need for integrating wider land use and economic development with sustainability.

See BOX 6 PAGE 134 for a case study on the rehabilitation of Raja Musa Forest Reserve in Malaysia by the Selangor State Forest Department and local NGO, Global Environment Centre.

BOX 6

Case study – Rehabilitation of Raja Musa Forest Reserve, Selangor, Peninsular Malaysia.

FIGURE 37
Tree planting for peat swamp forest rehabilitation at Raja Musa Forest Reserve, Selangor, Malaysia.

6

BACKGROUND

The North Selangor Peat Swamp Forest (NSPSF) is the largest remaining peat swamp forest complex in Selangor. It is divided into the Raja Musa (RMFR) and Sg. Karang Forest Reserves (SKFR) with a total area of approximately 76,000ha. Some 1,000ha in the RMFR have been illegally drained and burned for agriculture activities. In 2008, the Selangor State Forestry Department (SFD) and Global Environment Centre (GEC) established a partnership to rehabilitate this area through improvement of water management and replanting of seedlings in collaboration with other partners and communities.

A total of more than 40 partners have helped to block drainage canals, prevent fires, encourage natural regeneration and plant seedlings in the forest. In addition, the Raja Musa Rehabilitation Programme also focuses on capacity building, raising awareness and demonstrating community-based reforestation exercises to rapidly re-establish the forest and restore its biodiversity.

RMFR was gazetted in 1990. Prior to its gazettement, the area was part of Stateland forest and was intensively subjected to logging since 1950s with little control and supervision from the State government agencies. As a consequence, the condition of the forest is heavily disturbed and the RMFR currently supports tree species with small to medium sized crowns, typically reaching 30 meters tall. Emergent trees are scattered throughout the area. *Kempas* (*Koompassia malaccensis*), *Kedongdong* (*Santiria* spp.), *Kelat* (*Syzygium* spp.) (see FIGURE 38 PAGE 136) and Durian (*Durio carinatus*) (see FIGURE 39 PAGE 137) are the dominant tree species within the forest. Ramin (*Gonystylus bancanus*) (see FIGURE 40 PAGE 138), which was a common species in the peat swamp forest and highly prized timber species, is now very rare. Part of the north-east corner of RMFR is known for its high water table and is dominated by palms and *pandanus*.

FIGURE 38
Two-year old *Kelat Paya* (*Syzygium cerinum*) seedlings in a nursery.

FIGURE 39
Durian (*Durio carinatus*).

FIGURE 40
Ramin (*Gonystylus bancanus*).

FOREST FIRES AND ENCROACHMENT

Past surveys and studies showed that there is a correlation between heavily drained and degraded forest areas and fires in the NSPSF. Fires in NSPSF are most frequent during prolonged dry spells. Deliberate burning as part of land clearing for agriculture outside the Forest Reserve causes most fires in the NSPSF. Other causes are related to illegal encroachment activities e.g. hunting and general negligence in controlling campfires, cooking and smoking. In many cases, areas that were destroyed by forest fires were rapidly encroached-upon by people most of whom are involved in agriculture activities. Assessments made in 2008 showed that many people developing land inside the forest reserve were not poor local community members but residents of towns who had purchased lots from illegal land development syndicates.

Subsequently, a special paper detailing the encroachment activities in RMFR and its adverse effects on the sustainability of forest areas in the state was tabled to the present Selangor State Government. Based on the paper, about 470 plots were cleared of cultivation in the site in December 2008 and these areas have now been subjected for forest rehabilitation activities.

FOREST REHABILITATION PROGRAMME

As the first steps towards forest rehabilitation in NSPSF, the Selangor State Forestry Department has blocked old logging and drainage canals; 850 blocks in all, but requires proper and systematic maintenance to prevent water leakage and subsequent drying of the peat swamp forest, which have led to several forest fire incidences. To avoid the forest fire incidences, the Selangor Forestry Department has also increased patrolling and enforcement activities along the forest reserve boundary. Many of these areas have been left to recover naturally after undergoing major hydrological restoration. Some heavily degraded sites were rehabilitated by adopting the following measures:

- Planting of fast growing tree species in grassland/scrubland areas
- Enrichment planting and/or thinning and removal of non-timber species in heavily degraded areas

To date the SFD tree planting programme has focused on heavily burned and degraded forest compartments with a history of human encroachment. A series of tree planting programmes have been carried out in collaboration with NGOs, local interest groups, other government agencies, private sector, students from schools and higher learning institutions (mostly from Klang Valley) and involving the local communities from nearby villages surrounding the RMFR.

In total about 80ha of degraded peat swamp forest has been planted with 55,000 tree seedlings. The seedlings consists of three main species; namely, Mahang (*Macaranga pruinosa*) and Tenggek Burung (*Melicope lunu-ankenda*) – which makes up 84% of the planting, Mersawa Paya (*Anisoptera marginata*) – 6%, and the balance 10% with Ramin (*Gonystylus bancanus*). From monthly monitoring of the growth of planted seedlings, it was noted that Mahang and Tenggek burung (secondary forest species) performed much better than the other two timber species. Trial planting using Kelat Paya (*Syzygium cerinum*) has also yield positive results.

Usually, the tree seedlings (of about 1 meter in height) were systematically planted in lines with a distance of 6m x 6m apart – mainly in open grass fields or scrubland. So far, no fertilizer has been applied to the growing plants but planting treatments (e.g. weeding and replacement of dead seedlings) were conducted quarterly.

FINDINGS AND CONSTRAINTS

Financial and human resources

The availability of sufficient financial resources is very crucial for successful implementation of forest rehabilitation programmes. Initial costs related to securing the perimeter of RMFR and hydrological restoration was absorbed by the SFD. Later activities in relation to tree planting were supported by GEC either through regional project funding or enticing local corporate sponsorship. In 2010, a formal arrangement, in the form of memorandum of understanding was signed between SFD and GEC. This has enabled GEC to secure longer term finance from two companies Bridgestone Tyre Sales Malaysia Sdn. Bhd. and HSBC Bank Berhad. Support has also been provided through the EU supported SEApeat Project especially for community and stakeholder engagement.

Availability of seedlings

The procurement of large numbers of suitable seedlings was urgently required for the rehabilitation of RMFR as the area to be rehabilitated is quite extensive (ca. 864ha). SFD is already experiencing difficulties in getting adequate supply to sustain the current planting activities and if the problem is not addressed immediately, it will affect on-going rehabilitation programmes. Current supply for seedlings for the tree planting activities comes from a community nursery based in Sungai Buloh.

Several other peat swamp species commonly found growing in open areas with degraded peat were identified by GEC team during field assessments. Information on the characteristics and planting of these species e.g. *Alstonia spathulata, Campnosperma coriacea Cratoxylum glaucescens, Ploiarium alternifolium* are available in Nuyim (2005) and are suggested for future planting trials at RMFR.

Preparation for planting and clearing of weeds

Large areas within RMFR's planting site are covered by dense vegetation in the form of grasses like *Lalang* (*Imperata cylindrica*) and shrubs mainly dominated by *Kemunting* (*Melastoma malabathricum*). Clearing this dense vegetation in the degraded peat swamp area is the first step in the preparation of the planting area and this requires a lot of labor and can be very time consuming. Therefore, preparation costs for planting in degraded peat swamp areas can cost at least RM500/ha. Furthermore, these areas are also prone to fire during dry seasons.

Tree planting activities

Planting of young seedlings (as was the case in previous planting events) in such areas evidently resulted in heavy mortality and surviving plant seedlings can be suppressed by the over-grown vegetation and become difficult to locate. In this case, weeding will be required of certain plants such as *Rumput purun* (*Scleria sumatranensis*), *Paku resam* (*Blechnum indicum*) and *Paku midin* (*Stenochlaena palustris*). It is therefore advisable that in order for seedlings to out-grow weeds, seedlings should be more than one meter tall during planting. Similarly, a waterlogged area should be planted with tall seedlings that are well-suited for growth in high water table areas.

Very few studies have been carried out to determine the appropriate planting space for peat swamp forests. Setting proper planting space between trees is important because this determines operating costs. Planting space also dictates the number of seedlings required for planting. For the planting area, a 6m x 6m distance between trees was established with the option of introducing other species in between. The advantage of poling planting spots is to make it easier for workers to notice pits that are to be planted. Using bamboo poles for planting is most practical because it can last 2-3 years and is relatively cheap.

As peat swamp forests are waterlogged and peat soil is loose and very sodden, the movements of volunteers/laborers and transportation of tools or seedlings to the planting site can be difficult. Some people may face discouragement because they have to wade waist-deep into the peat and water in order to access the planting sites. Constructed walkways and make-shift bridges can provide more convenient access to planting sites.

As part of rehabilitation strategy, it is suggested that planting activities take note of the ecological succession of vegetation types in the following orders:

1. Open grassland ⟶ Shrubland ⟶ Secondary forest ⟶ Regenerating forest
2. Water dispersed ⟶ Wind dispersed ⟶ Bird dispersed ⟶ Small mammal dispersed

Accordingly, planting should only consider plant species that are common/native to the area and is found in abundance. The latter is to ensure sufficient planting stocks for mass planting.

In general, it is helpful for both planting activities and selection of species for planting to enhance and support the natural succession and selection process. To do it in any other way will only result in higher mortality rates of the planted seedlings.

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ANNEX I GLOSSARY

Bulk density It is defined as the mass of many particles of the material divided by the total volume they occupy. The bulk density of soil depends greatly on the mineral make up of soil and the degree of compaction. The density of quartz is around 2.65g/cm³ but the bulk density of a mineral soil is normally about half that density, between 1.0 and 1.6g/cm³. Soils high in organics and some friable clay may have a bulk density well below 1g/cm³

Dipterocarp Chiefly tropical Asian trees with two-winged fruits; yield valuable woods and aromatic oils and resins.

Ecology The science of the relationships between organisms and their environments.

High Conservation Value (HCV)
High conservation value (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, refugia); and/or large landscape-level areas where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance
2. Areas that are in or contain rare, threatened or endangered ecosystems
3. Areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control)
4. Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health) and/or critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities)

Phasic Communities Much work has been done by Anderson (1963) on the floristics of the peat swamps of Sarawak and Brunei. In the domed peat swamps, Anderson described six phasic communities (PC1-6) of plants proceeding from the edge to the centre of the dome. Anderson described them as phasic communities because pollen analysis of bore samples on a peat dome just west of Marudi indicated that the change in vegetation up the dome was paralled by the same sequence of vegetation types with depth of peat; i.e. a succession in time. The features of each community are described briefly here:

PC1: Mixed peat swamp forest
This community occurs on shallow peat at the periphery of the peat domes and on shallow peat. This is the most species rich of the communities, although lower in species than mixed dipterocarp forest. The canopy is uneven and 40-45m high. Prominent tree species are *Dyera lowii, Alstonia pneumatophora, Parishia* sp., *Palaquium* sp., *Diospryros evena, Combretocarpus rotandatus, Dactylocladus stenostachys, Gonystylus bancanus* and *Lophopetalum multinervium*. The ground layer varies greatly – in wetter areas, *Eleiodoxa conferta* forms thickets whilst where the canopy has been opened, *Pandanus andersoni* becomes common.

PC2: Alan batu forest
The composition of this community seems to be very similar to that of PC1, with the exception of the appearance of very tall (to 60m) individuals of *Shorea albida* (alan). These are stag-headed and have hollow trunks and are considered excellent timber, being classed as a medium hardwood.

PC3: Alan bunga forest
The entire canopy is composed of *Shorea albida* at a height of 50-60m. The stems of alan bunga are solid, although the timber is considered not as good as that of alan batu.

PC4: Padang alan forest
There is a closed canopy of 35-40m high composed mainly of *Shorea albida*. The forest is much more pole-like than the preceding communities.

PC5: Padang paya
This is a much lower type of forest, with a canopy of 15-20m high. The trees are small in girth and the forest very dense. The dominant trees are *Tristaniopsis* spp., *Parastemon* sp., and *Palaquium* spp. *Shorea albida* is more or less absent.

PC6: Padang keruntum
This community is markedly different from the preceding ones in that it is very open and strictly speaking would not be classed as a forest type. It is found on the central bog plain of the most highly developed zones. *Combretocarpus rotandatus* (keruntum) is the only species that can be called a tree and does not rise above 15m. in height. *Dactylocladus stenostachys* is present, but is more shrub-like than tree-like. Plants which obtain nutrients from sources other than the soil water are common, such as myrmecophytes and *Nepenthes* spp. The appearance is very xeromorphic.

It is worth noting that PC5 and 6 only occur in the Baram/Belait peat swamps in the Marudi area. In other areas of Sarawak, PC1-4 only are found.

The major trends in the stature of the forest along the peat dome are thought to be concerned mainly with decreasing fertility, increased incidence of periods of water stress and problems with uptake of water very high in leached plant defensive compounds.

Pneumatophores These are specialized aerial roots that enable plants to breathe air in habitats that have waterlogged soil. The roots may grow down from the stem, or up from typical roots. The surface of these roots is covered with lenticels, which take up air into spongy tissue, which in turn uses osmotic pathways to spread oxygen throughout the plant as needed.

Podzols Soil that is characterized by an upper dark organic zone overlying a white to gray zone formed by leaching, overlying a reddish-orange zone formed by the deposition of iron oxide, alumina, and organic matter.

ANNEX 2

PEATLAND WORKING GROUP (PLWG)

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

SCOPE OF WORK

The objectives of the PLWG were 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

The PLWG worked closely 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 (e.g. 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 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 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 including options for converting oil palm plantations on peat soils to alternative sustainable land-uses, including the restoration of peatlands.

MEETINGS, SITE VISITS AND STAKEHOLDER WORKSHOPS HELD

- 22-23 APRIL 2010 1[st] meeting – Jakarta
- 22-24 SEPTEMBER 2010 2[nd] meeting – Kuala Lumpur
- 18-20 JANUARY 2011: 3[rd] meeting – Sibu
- 19-21 MAY 2011: 4[th] meeting – Pekanbaru, Riau
- 22-24 AUGUST 2011: 5[th] meeting – Kuala Lumpur
- 27-28 SEPTEMBER 2011: 6[th] 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

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.

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 (Dr)	Wetlands International, WI – Netherlands (Consultant)	Netherlands
6	Balu Perumal	Global Environment Centre, GEC	Malaysia
7	Bambang Saharjo (Dr)	Sawit Watch/Science Panel	Indonesia
8	Cherie Tan	WWF	Singapore
9	Chong Wei Kwang	HSBC Bank Malaysia Berhad	Malaysia
10	David Lee	Global Environment Centre GEC	Malaysia
11	Fahmuddin Agus (Dr)	Indonesian Soil Research Institute	Indonesia
12	Franki Anthony	Sime Darby Plantations Berhad	Malaysia
13	Gurmit Singh (Dr)	United Plantations	Malaysia
14	Gusti Z Anshari (Dr)	Universitas Tanjungpura, UNTAN	Indonesia
15	Hasnol Othman	Malaysian Palm Oil Board, MPOB	Malaysia
16	Ivy Wong	WWF - Malaysia	Malaysia
17	Jean-Pierre Caliman	PT SMART	Indonesia
18	Jimmy Tan	Neste Oil - Singapore	Singapore
19	Marcel Silvius	Wetlands International, WI – Netherlands	Netherlands
20	Mukesh Sharma (Dr)	Asian Agri	Indonesia
21	Olivier Tichit	SIPEF	Indonesia
22	Paramananthan A/L Selliah (Dr)	Param Agricultural Soil Surveys (M) Sdn. Bhd.	Malaysia
23	Peter Lim Kim Huan (Dr)	PT Bumitama Gunajaya Agro	Indonesia
24	Pupathy Uthrapathy Thandapani	Sime Darby Plantations Berhad	Malaysia
25	Ruslan Abdullah (Dr)	Sime Darby Plantations Berhad	Indonesia
26	Si Siew Lim	Grassroots (Consultant)	Malaysia
27	Siti Norralakmam Yahya	Sime Darby Plantations Berhad	Malaysia
28	Sue Page (Dr)	University of Leicester	UK
29	Thomas Barano	WWF - Indonesia	Indonesia