SUMMARY:

RSPO MANUAL ON BEST MANAGEMENT PRACTICES (BMPs)

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

RSPO

Roundtable on Sustainable Palm Oil

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Authors:
Faizal Parish
Si Siew Lim
Balu Perumal
Wim Giesen

Summary prepared by:
Si Siew Lim

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Authors:
Faizal Parish
Si Siew Lim
Balu Perumal
Wim Giesen

Summary prepared by:
Si Siew Lim

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Yap Ni Yan

Please direct all inquiries to
RSPO Secretariat Sdn Bhd
Unit A-37-1, Menara UOA Bangsar
No. 5 Jalan Bangsar Utama 1
59000 Kuala Lumpur
Malaysia

rspo@rspo.org
http://www.rspo.org/

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1.0: INTRODUCTION

The need for an 'RSPO Manual on Best Management Practices (BMP) for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Peat' was included in the work plan of the RSPO Peatland Working Group (PLWG) after it was established in 2009. This Manual is dedicated to maintenance and rehabilitation of peat swamp vegetation in and around oil palm plantations on peat. It supplements the 'RSPO Manual on Best Management Practices (BMP) for Cultivation of Oil Palm on Tropical Peat.'

The objective of this Manual is to provide practical guidelines for BMPs that are important for the rehabilitation and management of degraded peat sites within existing oil palm plantations on peat or areas adjacent to them e.g. permanently undrainable patches after prolonged oil palm cultivation and logged over river reserves and HCV areas.

This Manual draws on experience of peatlands rehabilitation in Southeast Asia. It also draws on and refers to existing national regulations and guidelines especially from Indonesia and Malaysia where there are ongoing peat rehabilitation initiatives.

It is noted that restoration of degraded peatlands to its original pristine condition is almost impossible given that much is irreversibly changed in degraded peatlands (e.g. peat compaction and loss) and so the best strategy is to conserve peatland vegetation in its natural form at the time of plantation development.

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

The challenges attributed to peatland cultivation of palms (as opposed to ideal soil-types) are also linked to many social and environmental problems in surrounding peatlands, waters and forests. It should also be noted that the rehabilitation of certain sites within a larger area of plantation may provide benefit for the estate, environment and communities that are dependent on peatlands. The following are specific reasons for management and rehabilitation of peat swamp forests in conjunction with oil palm cultivation on peat:

- presence of High Conservation Values (HCVs) within or adjacent to plantation areas,
- importance of wildlife corridors,
- importance of river reserves or boundary buffer zones,
- undrainable areas within plantations,
- prevention of disruption of hydrology of adjacent peat swamp forest,
- fire prevention,
- management of disturbance/encroachment, and
- presence of water catchment/retention areas and for increasing carbon stocks.

2.0: PEAT SWAMP FOREST ECOSYSTEMS

PEAT SWAMP FORESTS AND THEIR IMPORTANCE

Peat swamp forests are unique habitats for fauna and flora, commonly with a high proportion of endemic species that give these areas worldwide 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. At a global scale the peat swamp forests contribute to the storage of atmospheric carbon that is an agent of global warming, helping to regulate climate change and contribute to the cooling of the planet. Peat swamp forests can also be very productive through the managed extraction of fish, timber and other non-timber forest products (UNDP, 2006).

Further benefits provided by intact peat swamp forests focusing on the provision of ecosystem services include flood mitigation, maintenance of base flows in rivers, prevention of saline water intrusion, sediment removal, nutrient and toxicant removal as well as carbon store and sequestration.

CHARACTERISTICS OF SOILS IN PEAT SWAMP FORESTS

The soil in peat swamp forests is organic or peat soil. The soil is derived from the accumulation of dead plants that are not decomposed due to the high water content and low oxygen levels in the soil. Soil thickness varies, depending on the length of time of deposition of organic matters 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.

As for the properties of organic soil in peat swamps, it is found that the peat soil in SE Asia is of a low bulk density of 1.3-1.6g/ml. The color of peat swamp soil varies with the depth of the soil, from dark gray to dark reddish brown. The soil is categorized as slightly decomposed fibric soil. It is highly acidic, with a pH level of 4.4 for the top soil and 4.2 for the subsoil. The soil also has a low conductivity of 0.2-0.7dS/m. As for nutrients in the soil, most nutrients are found not more than 25cm from the surface (Nuyim, 2005).

FORMATION AND ROLE OF WATER IN PEAT SWAMP FORESTS

Tropical lowland peat swamps are generally completely 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 vegetation, which is deposited on 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 have often 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 1*** 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.

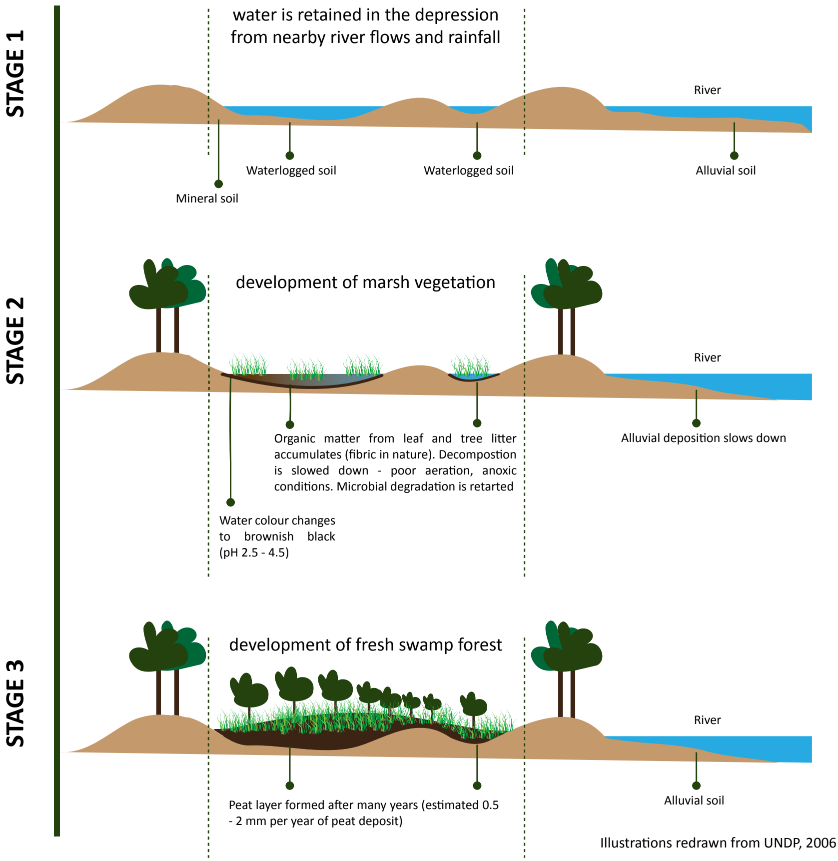

Figure 1: Illustration of formation process for peat swamp forests and the role of water.

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 a buttress, which may be 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, 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*, *Campnosperma coriaceum* and *Alstonia spathulata*. Finally inverted Y-shaped roots belong to *Elaeocarpus macrocerus*.

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

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 Lead 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 West and East 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).

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.

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* (*Eleiodoxa 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.

ECOLOGY OF TROPICAL LOWLAND PEAT SWAMP FORESTS

In spite of the work of Buwalda (1940) little was known about the ecology of the Peat Swamp Forests in Southeast Asia. Perhaps the most comprehensive and best known study of the ecology of the Tropical Lowland Peat Swamp Forest was carried out by Anderson over a period of ten years in the 1950s (Anderson, 1961, 1963 and 1983). Anderson recorded 253 tree species (including 40 small trees which rarely exceed 5-10 meters in height in the Tropical Lowland Peat Swamp Forest. Many of these species recorded by Anderson are also found in other forest types outside peat swamp forest. It is also significant to point out that many of the species, which are largely confined to the periphery of the Tropical Lowland Peat Swamp Forest, also occur in the Lowland Dipterocarp Forest. On the other hand, the species that are present in the forests located in the centre of the swamps are mainly those that are found on the poorer soils, frequently podzols of the heath forest (Anderson, 1963). The Tropical Lowland Peat Swamp Forests show conspicuous changes in vegetation types from its periphery to the centre of each domed-shaped peat swamp (Buwalda, 1940; Anderson 1961). Anderson who studied these swamps in Sarawak, Malaysia and adjacent Brunei on the island of Borneo had used the term "Phasic Community" (PC) to designate a dominant vegetation zone. Anderson recognized six distinct Phasic Communities or zones on the basis of their floristic composition and structure of the vegetation in each zone:

- Type 1: Mixed swamp forest; the *Gonystylus-Dactyloclados-Neoscortechinia* association;
- Type 2: Alan forest; the Shorea *albida-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 *Combretocarpus-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 2*** for an illustration of the lateral zonations of peat swamp forests.

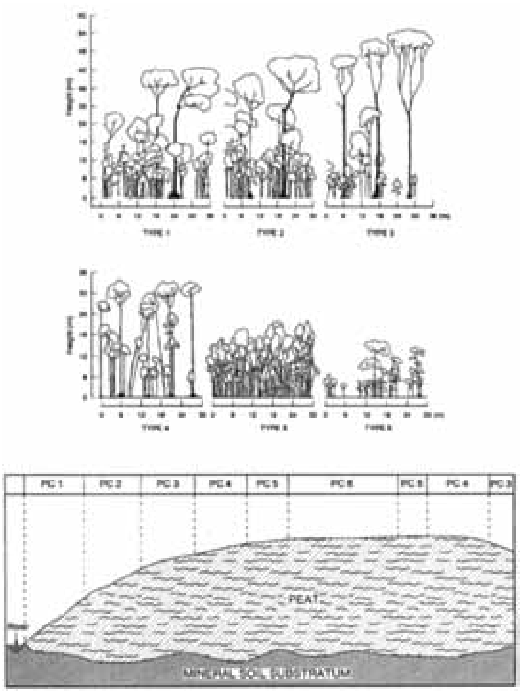

Figure 2: Lateral zonations of vegetation in the six phasic communities (Source: Anderson, 1961).

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 550Gt C 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 40 million hectares and store about 70Gt C. Murdiyarso and Suryadiputra (2003) estimated that Indonesian peatlands store about 46Gt C. Neuzil (1997) estimated that the annual carbon accumulation rate in Indonesian peatlands ranges between 0.59-1.18t C/hectare/year, which is much higher than the accumulation rates in temperate or boreal zones, which ranges between 0.2-1t/hectare/year. Suzuki *et al.* (1999) measured net sequestration of 5.3t C/hectare/year 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. Hirano *et al.* (2007) found a net emission of 6t C/hectare/year in drained peat swamp forest in Central Kalimantan, Indonesia, during the dry El Niño year of 2002, although this loss was nearly halved in wet years due to a higher water table.

Current carbon emissions from drained and fire-affected peatlands in Southeast Asia have been estimated to be of the order of about 360 million t C/year: about 170Mt C/year from drainage-related peat decomposition (Hooijer *et al.*, 2006) and 190Mt C/year from peat fires (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).

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) (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 – area 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 in not permitted according to Indonesian regulations)
- River corridors

MANAGEMENT OF NATURAL HYDROLOGICAL REGIME

The proper management of the hydrological regime is critical to the success of any conservation of 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 when 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 3***). By building blocks and dams, water and retention levels of peatlands can be increased and hopefully restored.

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.

Figure 3: Dam constructed to systematically block a former logging canal to restore peat swamp water levels.

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.

PREVENTION AND CONTROL OF FIRE

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.

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:
    - o *Information Unit:* develops and manages information related to fire danger.
    - o *Special Fire-Fighting Unit:* backs up the core fire-fighting units.
    - o *Guard/Logistics Unit:* mobilizes equipment and handles logistics.
    - o *Sentry units:* posted in places that are especially prone to fire.
    - o *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.

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 system 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.

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, 2005) elaborates on a variety of concepts and practical measures for the prevention and suppression of fire and also draws from field experience in handling of 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:
    - o Fire towers
    - o Communications equipment
    - o Telescopes and compasses
    - o Transportation
    - o Fire engines and boats
    - o Heavy equipment (bulldozers, tractors)
    - o Other fire-fighting equipment such as fire beaters, axes, rakes, shovels, portable pumps
    - o Protective gear and equipment for fire-fighters (fireproof suits, boots, helmets, gloves, torches, machetes, etc.)
    - o 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.

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.

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 hectares (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 500 meters to 1 kilometer wide to reduce edge effects and provide 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

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 identify root causes of degradation. Logical-framework analyses (for example) 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.

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.

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 Mott MacDonald *et al.*, 2009) include:

- Engaging local communities
- Selecting Beneficial species
- Controlling Drainage
- Enhancing Biodiversity
- Restricting Exotic tree species
- Balancing costs
- Measuring success

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, prevention of fires), or
c) active rehabilitation

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. 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.
- 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.

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).

#	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 (syn. Madhuca motleyana)*	Sapotaceae	Thailand, Malaysia	•
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 (syn. Eugenia oblata)*	Myrtaceae	Thailand	•
29	*Tetramerista glabra*	Theaceae	Jambi	o

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

Table 1: Species used in restoration trials in Southeast Asia (adapted from Giesen, 2008).

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 1*** 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.

If the suitable species recommended above are not readily available or other constraints are encountered, it is suggested to focus on the following main species for peatland rehabilitation due to their availability and high success rate:

- *Macaranga* spp.
- *Pulai* (*Alstonia* spp.)
- *Jelutung* (see ***Figure 4***)
- *Melaleuca* (*Gelam*)
- *Beringin*

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

Figure 4: Jelutung seedlings at a nursery.

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 restoring natural or near natural water levels. 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 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.

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. 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.

5.0: IMPLEMENTING PEAT SWAMP FOREST REHABILITATION

Understanding the root causes of degradation requires careful and honest 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).

SEED STOCK COLLECTION AND DEVELOPMENT OF NURSERIES FOR PEAT SWAMP SEEDLINGS

The choice of seedlings is one of the major factors that determines 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

Figure 5: To supplement wild seed supplies, wild seedlings can be collected.

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.

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; and 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 preferably equipped with electricity. In addition, labor should be easily available in the area. The plot for the seedling nursery should preferably 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. The nursery plot should be cleared and, 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 6: 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 7: 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.

PREPARATION OF CULTIVATION PLOTS AND PLANTING OF SEEDLINGS

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 8: 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 hectares, 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 hectare 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 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 9: 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

Figure 10: Removing polythene bag from seedling to be planted.

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.

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.

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 100 grams of controlled release fertilizer (15% N: 15% P_2O_5: 15% K_2O) in each planting hole.

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

Figure 11: Transportation of seedlings at the planting site.

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.

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.

FIRE-PREVENTION 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

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.

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

Figure 12: Tagging and monitoring of planted saplings.

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.

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: 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.

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

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