

**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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1.0 INTRODUCTION

1.1 DEVELOPMENT OF THE RSPO MANUAL FOR BEST MANAGEMENT PRACTICES ON PEATLANDS

This Manual was initially prepared under the guidance of the Roundtable for Sustainable Palm Oil (RSPO) Peatland Working Group (PLWG) which was established in 2010 in response to an RSPO General Assembly 2009 decision. This Manual has now been modified in 2018 to incorporate new data, information, methods, and research and development by the second PLWG (PLWG-2) formed in March 2017. The scope and membership of PLWG 2 can be seen in Annex 2. This Manual is focused on the maintenance of existing natural vegetation in and adjacent to oil palm plantations on peat as well as rehabilitation of degraded peatland areas. This complements the 'RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat' initially prepared in 2011-12 and also revised in 2018.

1.2 PURPOSE OF BMP MANUAL AND BENEFITS OF ADOPTION

The objective of this Manual is to provide a set of practical guidance on BMPs that are important for the rehabilitation and management of forested or degraded sites within or adjacent to existing oil palm plantations on peat including riparian reserves, High Conservation Value (HCV), High Carbon Stock (HCS) areas and/or peatland set aside or conservation areas. It also provides guidance for the rehabilitation of sites where oil palm has been phased out as a result of drainability assessments or for other reasons.

This Manual draws on experiences of peatland management and rehabilitation by RSPO members and other organisations mainly in Southeast Asia, but to a limited extent in Africa and Latin America. It also 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 BMPs and contribute to sustainable peatland management as part of reducing the impacts of oil palm cultivation on peat.

While it may be possible to maintain peat swamp forests adjacent to oil palm plantation in good condition with good water management and fire prevention measures, restoration of degraded and drained peatlands to its original pristine condition is almost impossible. In such cases, the objective should be to rehabilitate the degraded peat sites as much as practical towards its original condition.

These guidelines are also key to guide compliance with the RSPO P&C. The RSPO P&C 2013 and 2018 include significant requirements for the conservation and rehabilitation of peatlands in and around oil palm plantations. These guidelines provide practical guidance to RSPO member companies to maintain and enhance peatland conservation areas and meet key targets for sustainable oil palm production.

1.3 REASONS FOR MANAGEMENT AND REHABILITATION OF PEAT SWAMP FORESTS

Tropical lowland peatlands in Southeast Asia, Central and Western Africa and the Amazon Basin are naturally vegetated with peat swamp forests, which comprise species which are adapted to high water levels and high acidity conditions. 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. The rehabilitation of certain sites within a larger area of plantation may provide benefits to the estate, environment and local communities.

The following are specific reasons for management and rehabilitation of peat swamp forests (PSFs) associated with oil palm cultivation on peat:

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

The concept of HCVs was developed to provide a framework for identifying areas with special attributes that make them particularly valuable for biodiversity and/or local people. PSFs are 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 Principles and Criteria (P&C).

HCVs are defined as follows:

High Conservation Value Area (HCVA): The area necessary to maintain or enhance one or more HCVs and there are 6 types of HCVs as seen below.

- **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). Establishment and maintenance of wildlife corridors 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 help 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, and primates such as orang utan and gibbons.

RIPARIAN 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, riparian reserves that are intact and functional are important habitats for biodiversity and provide ecosystem services. In Indonesia, riparian 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 wide river reserves depending on the width of the waterway (see **Table 1-1** for details).

The following are the main reasons why riparian 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 include sediments, nutrients, organic wastes, chemicals and metals. 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 growers have a role to play in identifying, managing and enhancing river reserves and PSFs 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 were initially able to 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 may be undrainable for significant periods, rendering cultivation impossible. Such areas may be widespread, especially in the coastal lowlands of Southeast 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 Peninsular Malaysia), causing the base of many peatlands to be located now below MWL of rivers and sea. These areas should be clearly demarcated, not developed and if possible, rehabilitated.

AREAS PREDICTED TO FACE FUTURE DRAINAGE PROBLEMS

In accordance with RSPO P&C (P&C 2013 - Indicator 4.3.4 and P&C 2018 - Indicator 7.7.5), prior to replanting on peat, it is necessary to undertake a drainability assessment – so determine the long term viability of drainage of the plantation. This assessment should be guided by the RSPO Drainability Assessment Procedure (2018). The result of the assessment may indicate if the oil palm can be replanted or if the area needs to be converted to other more water tolerant crops or rehabilitated as a natural ecosystem. In the latter case this Manual can provide further guidance.

PREVENTION OF HYDROLOGY DISRUPTION AT ADJACENT PEAT SWAMP FOREST

Hydrology function is contiguous for peatlands. Clearing and draining the land adjacent to a PSF (e.g. edges of peat domes) can lead to hydrological changes and subsequent degradation in the adjacent land. The effects from drainage often go beyond plantation boundary, impacting between 500m to two kilometers depending on the drainage intensity and hydrological conductivity of the peatlands, thus potentially impacting the nearby PSFs.

FIRE PREVENTION

A major factor for peat fires is the drying out of peatlands. Fire risk is enhanced as a result of the drainage system in the plantations. 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 the riparian reserves and peat conservation areas may help prevent fires from occurring and spreading to the cultivated areas.

MANAGEMENT OF DISTURBANCE/ENCROACHMENT

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

MAINTAINING AND INCREASING CARBON STOCK

As part of the efforts to minimize greenhouse gas (GHG) emissions, it is recommended for oil palm plantations to maintain and increase their carbon stock in conservation or rehabilitation areas. Carbon stock can be conserved and increased through maintenance and rehabilitation of buffer zones and HCV areas. It is

also recommended that oil palm plantations conserve adjacent (or where appropriate, within the plantation) forested areas. Adoption by a plantation of an adjacent PSF area can reduce the net GHG emission profile and so can be a useful part of any GHG emission reduction strategy. In line with an impact mitigation hierarchy a company should first and foremost avoid impacts and emissions, then minimize impacts (including restoration on-site and other actions), and lastly provide offsets for remaining unavoidable impacts.

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.

RSPO has developed a separate *RSPO Manual on Best Management Practices (BMPs) for the Management and Rehabilitation of Riparian Reserves* in 2017 (see Box 1).

BOX 1

RSPO Manual on Best Management Practices (BMPs) for the Management and Rehabilitation of Riparian Reserves (2017)

Conservation of natural vegetation within and alongside natural waterways is a compliance requirement for RSPO certified oil palm plantations (Principle 4.4), which is also a legal requirement in many countries.

Natural vegetation should be protected inside riparian reserves (also called river reserves or riparian buffer zones), along all natural waterways – rivers, streams, lakes and springs – within and along the boundary of RSPO certified oil palm plantations.

Key environmental benefits of riparian reserves include water quality protection, bank stabilisation, flood protection, carbon storage and sequestration and biodiversity conservation. Hence, properly managed riparian reserves could generate significant benefits from the conservation of natural vegetation for oil palm companies, besides maintaining good relationships with local communities.

Specific guidance about which waterways would require riparian reserves and how wide such reserves need to be vary from country to country. National guidelines are outlined with appropriate national interpretations at the RSPO website (www.rspo.org).

In the absence of national guidelines, RSPO requires riparian reserves to be established along all natural waterways >1m wide. More detailed guidance on riparian reserve size, location and vegetation type is outlined in Chapter 2 of this Manual.

Riparian habitats are also required to be protected as High Conservation Value Areas (HCVAs), typically under HCV4, as areas which provide “basic ecosystem services in critical situations, including protection of water catchments and control of erosion of vulnerable soils and slopes”. Riparian reserve habitats should therefore be maintained and/or enhanced as part of the HCV management plans for oil palm plantations (Principle 5.2).

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

GUIDELINES FOR DEVELOPMENTS INVOLVING RIVERS AND RIVER RESERVES

MALAYSIA

Malaysia through DID developed guidelines to identifying width of waterway to be conserved (Table 1-1).

Table 1-1: 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

MALAYSIA SUSTAINABLE PALM OIL (MSPO) PRINCIPLES AND CRITERIA

Malaysia's government had introduced Malaysia Sustainable Palm Oil (MSPO) Standard in 2013. Certification for both plantations and smallholders is targeted to be completed by 31 December 2019. MSPO requirement for maintenance of conservation areas and river reserves include the following criteria under:

Criterion 4.5.5 Natural water resources

The management shall establish a water management plan to maintain the quality and availability of natural water resources (surface and ground water). The water management plan may include:

- Assessment of water usage and sources of supply;
- Monitoring of outgoing water which may have negative impacts into the natural waterways at a frequency that reflects the estate's current activities;
- Ways to optimize water and nutrient usage to reduce wastage (e.g. having in place systems for re-use, night application, maintenance of equipment to reduce leakage, collection of rainwater, etc.);
- Protection of water courses and wetlands, including maintaining and restoring appropriate riparian buffer zones at or before planting or replanting, along all natural waterways within the estate;
- Where natural vegetation in riparian areas has been removed, a plan with a timetable for restoration shall be established and implemented;
- Where bore well is being used for water supply, the level of the ground water table should be measured at least annually.

INDONESIA

LAW NO.41/1999 ON FORESTRY

Recognised the following protective zones:

- 500 (five hundred) meters from the edge of water reservoir (dam) or lake
- 200 (two hundred) meters from the edge of water spring and alongside the river in swampy area
- 100 (one hundred) meters from the river (left and right banks)
- 50 (fifty) meters from streams facing downstream (left and right banks)

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 be planted with oil palm.

• INDICATORS

- Identified protected area is available
- Plantation map showing identified protected area is available

- iii. Records of identification and distribution information of protected areas are kept
- GUIDANCE
 - i. To do inventory on protected areas around the plantation
 - ii. 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
 - i. Moratorium on new permit included in indicative maps;
 - ii. Approved application by authorized institution on land permit is valid;
 - iii. Existing permits issued before the moratorium remain in effect.
- GUIDANCE
 - i. Postponement of new permits related to the plantation are site permits and IUP;
 - ii. 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);
 - iii. This regulation is not applicable for permits on released forest areas except for permits with principle agreement from the Ministry of Forestry (now Ministry of Environment and Forestry);
 - iv. Postponement on the issuance of permits on land use rights (HGU, HGB, HP, etc.) including processed applications in provincial B committee;
 - v. Moratorium of location permits, IUP and other land use rights for 2 (two) years effective from 20 May 2011. Third extension was given in May 2017 to give authorities more time to pin down regulations on forest use (by November 2016, the government's forest moratorium covered an area of more than 66 million hectares).

PRESIDENTIAL DECESS ON PROTECTION AND MANAGEMENT OF PEATLAND ECOSYSTEMS

PP 71/2014 which was revised as PP 57/2016 in December 2016 sets out the requirements for protection and management of peatland ecosystems in Indonesia. This regulation regulates land use and drainage in peatland areas, sets a maximum draining limit for the peatland water table at 0.4 m below the ground surface; and makes it illegal for both companies and local communities to burn peatland prior to development.

Under the regulation, there are sub-regulations formed to specifically guide the oil palm companies as follows:

- i. P.14/MENLHK/SETJEN/KUM.1/2/2017 on Procedures of inventory and determination of peatland ecosystem function
- ii. P.15/MENLHK/SETJEN/KUM.1/2/2017 on Procedures of ground water table measurement at designated point in peatland ecosystem
- iii. P.16/MENLHK/SETJEN/KUM.1/2/2017 on Technical guidelines on restoration of peatland ecosystem function
- iv. SK129/MENLHK/SETJEN/PKL.0/2/2017 on Determination of maps for national peatland hydrological unit
- v. SK.130/MENLHK/SETJEN/PKL.0/2/2017 on Determination of maps for national peatland ecosystem function

In addition, RSPO's P&C 2013 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 HCV 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.

RSPO P&C 2018 consolidated specific guidance on peatland into Criteria 7.7 as follows:
[To be added after approval by RSPO GA 2018]

DEMOCRATIC REPUBLIC OF CONGO

Based on the HCV National Interpretation of the Democratic Republic of Congo (DRC), the protection zone is determined from river and springs (see Table 1-2).

Table 1-2: Protection zone for water body in DRC

Size of water body	Size of protection zone
Width >10m	50m from each bank
Springs	150m in each direction

PAPUA NEW GUINEA (PNG)

In PNG, riparian reserve buffer zones should be maintained and/or rehabilitated as per the PNG logging code of practice at the time of planting or replanting (Table 1-3).

Table 1-3: Riparian reserve as per PNG logging code of practices

Watercourse definitions in PNG include the following: Permanent water courses	Have water flowing for part or all of the year for most years. The stream beds have no vegetation growing on them, and may consist of water-washed sand, silt, stone, gravel or exposed bed rock materials. Class 1 Stream bed width = >5m Class 2 Stream bed width = <5m and >1m
Non-permanent water courses or drainage channels	Are usually stable, non-incised depressions which carry surface water during times of high rainfall. The beds are comprised of soil and are usually covered with leaf litter and vegetation.
Swamps	Have surface water present for 6 months of the year.
Stream buffer zone starting point adjacent to the stream	Delineation of the buffer zone should start where the vegetation was 10m high or higher*.

2.0 PEAT SWAMP FOREST ECOSYSTEMS

2.1 FUNCTION AND VALUES OF PEAT SWAMP FORESTS

Peat swamp forests (PSFs) are an important component of the world's wetlands and form the main wetland type in Southeast Asia – where they comprise more than 50% of the world's tropical peatlands. They also occur in West and Central Africa and Latin America.

PSFs are habitats for fauna and flora that are highly adapted to the acidic water and waterlogged condition. Commonly with a high proportion of endemic species that give these areas global significance and act as a gene bank with undiscovered resources for medicinal and other important human uses.

They play a major part in regulating water in the ecosystem. They serve as fresh water reservoir, to stabilise water level and reduce peak-flow. Coastal peat swamps act as a buffer between marine and freshwater systems, preventing saline water intrusion into the coastal land and groundwater. Peat swamps often serve as a natural gene bank, preserving potentially useful varieties of plant and animal species. At a global scale, the PSFs contribute to the storage of atmospheric carbon that is an agent of global warming, helping to slow down that process. PSF areas can also be very productive through the managed extraction of fish (see Figure 2-1), timber and other non-timber forest products (see Figure 2-2) (UNDP, 2006).



Figure 2-1: Fishery in peat swamp rivers is mainly for subsistence.



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

Further details of benefits provided by intact PSFs focusing on the provision of ecosystem services include:

FLOOD MITIGATION

Intact PSFs 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 water intrusion is related to base flows in the rivers. By maintaining base flows in the rivers, peat swamps can prevent the intrusion of saline water up to rivers and maintain fresh groundwater in coastal areas. In places where the coastal PSFs have been drained – saline water 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.

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

Peatlands are major carbon stores. Parish *et al.* (2007) reported that peatlands globally cover 400 million hectares and store more than 550 giga tonnes of carbon (GtC) or 30% of all global soil carbon equivalents to twice the carbon stored in the combined biomass of all the world's forests. Tropical peatlands cover about 60 million hectares (ha) and store about 89 billion tonnes of carbon (GtC) with an estimated 68.5 GtC in Southeast Asia (Page *et al.* 2011).

Large quantities of carbon are stored in tropical peatlands. 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.

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 PSF in To-Daeng, Thailand, in a typical wet year.

Since peatlands store large amounts of carbon – their degradation releases carbon. Current carbon emissions from drained and fire-affected peatlands in Southeast Asia have been estimated to be between 355-855 million tonnes (Mt) CO₂/year from drainage-related peat decomposition (Hooijer *et al.*, 2010) and 300-600Mt CO₂/yr from peat fires (Couwenberg *et al.*, 2009, van der Werf *et al.*, 2008, Page *et al.*, 2002). Losses on this scale contribute significantly to atmospheric carbon loading and anthropogenic climate change processes (Page *et al.*, 2011).

2.2 CHARACTERISTICS OF PEAT SWAMP FORESTS

OMBROTROPHIC DOMED PEATLANDS

Many tropical peatlands have a dome-shaped topography. Peat depth and elevation usually increase towards the center of the peatland. Most peat swamps are generally elevated 4–9 m above adjacent river courses but some old domes are up to 20m thick. Surface slopes vary between 1–2 m per km (Melling and Ryusuke, 2002). See Figure 2-3 for an illustration of a typical peat cross-section of a domed peatland.



Figure 2-3: Schematic diagram of peat cross-section (Source: M. J. Silvius, Wetlands International)

BASIN PEAT

Some tropical peatland occurs in lake basins and valley bottoms in which case there may be more input of mineral content at least in the edge of the system. Depending on the conditions this peat type may also develop a dome formation in the centre see Figure 2-4.

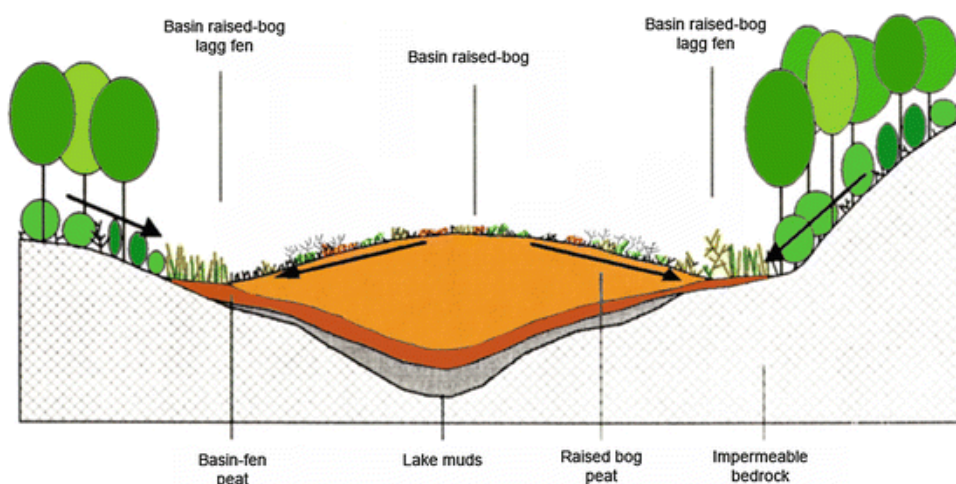


Figure 2-4: Basin peat (source The Wetlands Book)

2.3 FORMATION AND ROLE OF WATER IN PEAT SWAMP FORESTS

Tropical lowland peat swamps are 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 2-5 illustrates the formation of PSFs as well as the role of water in this process.

Water is vital for the survival of the PSFs. 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 dry and oxidize and prone to damage by wild fires and subsidence. The result will be the loss of soil and peat swamp vegetation which have adapted to the natural water regime.

Good management of the PSFs requires identification of proper water level that naturally fluctuates around the surface, 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 Sarawak, the peat domes serve as reservoirs of water for coastal areas. Otherwise, these areas would suffer water shortages during droughts (Sawal, 2004).

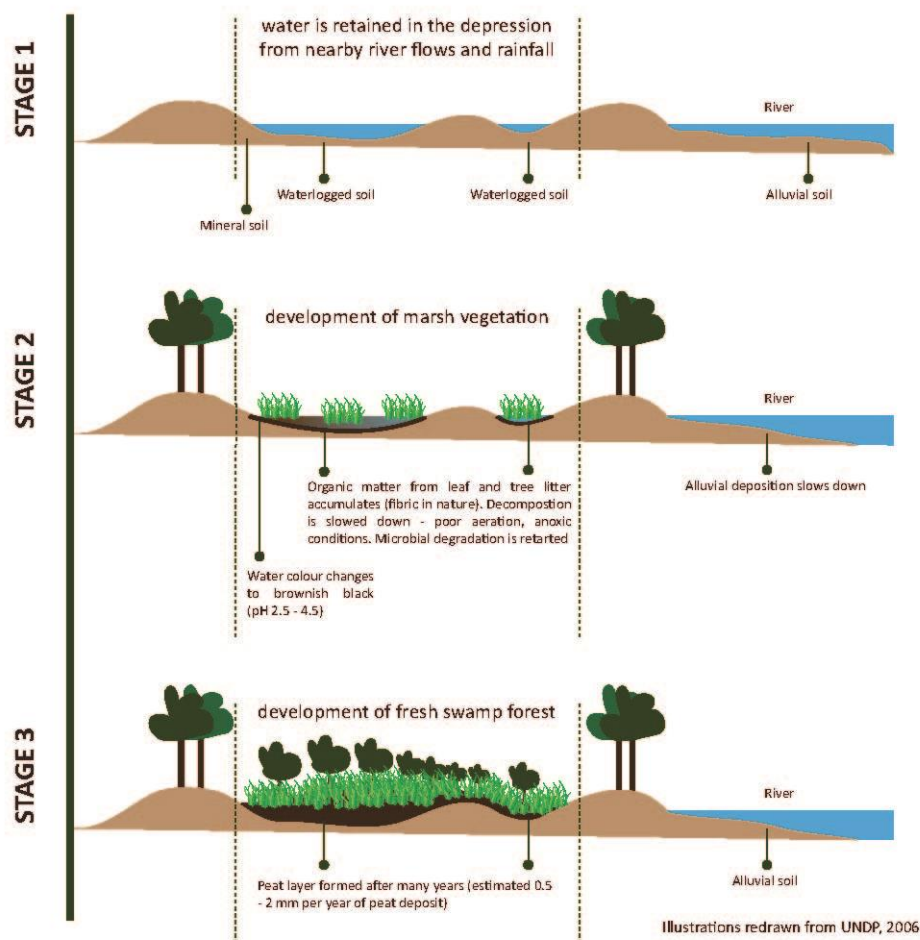


Figure 2-5: Illustration of formation process for peat swamp forests and the role of water (Source: UNDP, 2006).

2.4 FLORA IN PEAT SWAMP FORESTS

PSFs have diverse plant species. The numbers, types and species can vary between sites – but well developed sites may have up to 250 tree species or 500 plant species. For example in Thailand, more than 470 species and 109 families have been recorded in the PSFs (Chamlong, Chawalit and Wiwat, 1991). In Kalimantan, Indonesia, 310 species and 78 families of plants were recorded in the PSFs (Simbolon and Mirmanto, 1999). Perhaps the most comprehensive and best known study of the ecology of the tropical lowland PSF 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 PSF. Recently, 312 plant species were recorded in the In the Katingan-Mantaya peat swamp in Central Kalimantan.

A few species are endemic to PSF, of which including: Ramin (*Gonystylus bancanus*), *Shorea platycarpa*, *Shorea uliginosa*, *Durio carinatus*, *Cyrtostachys renda*. Trees in PSF tend to develop buttresses and stilt roots to provide stability and anchorage in waterlogged condition. Because of the long periods of high water level, many of the tree species have pneumatophores, a protruding root above the water surface which functions as breathing roots (Figure 2-6 and Figure 2-7).



Figure 2-6: Example of buttress, stilt root and pneumatophores which enable breathing of the tree at different water levels.



Figure 2-7: Peat swamp forest dominated by *Shorea albida* in Brunei Darussalam

2.5 FAUNA IN PEAT SWAMP FORESTS

MAMMALS

PSFs are found to have a high biodiversity value for both plant and animal species (Figure 2-8). In particular the riverbanks of the swamps are important habitats for the Crab-eating Macaque (*Macaca fascicularis*), Silvered Leaf Monkey (*Trachypithecus cristatus*), Borneo's unique and endangered Proboscis Monkey (*Nasalis larvatus*), which can swim well in the rivers and the Borneo Roundleaf Bat (*Hipposideros doriae*). The PSFs are also key habitat for orang utans (*Pongo pygmaeus*), tiger (*Panthera tigris*) and elephant (*Elephas maximus*). In addition, the PSFs are home to the rare hairy nosed otter (*Lutra sumatrana*). In the Katingan-Mantaya peat swamp in Central Kalimantan, 77 species of mammal are found.



Figure 2-8: Mammals found living within the tropical PSFs (clockwise from top left - Sun bear, Tapir, Orang Utan and Tiger)

BIRDS

There are two bird species known to be endemic to PSFs in SE Asia, 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 and a similar amount in the Katingan-Mantaya peat swamp, both in Kalimantan, Indonesia. Sebastian (2002) provides an assessment of the status of the mammal and bird species of both West and East Malaysian PSF habitats; of the 57 mammal and 237 bird species recorded in the PSFs, 51% and 27% respectively are listed as globally threatened species.

FISH

PSFs have long been regarded as a species-poor ecosystem with low productivity, low faunal diversity and few endemics (Johnson, 1967), an assumption contradicted by 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 the Katingan-Mantaya peat swamp 110 species of fish are known.

Peat swamps also harbour a significant number of miniature fish species. The smallest fish in the world is *Paedocypris progenetica*, a member of a new genus of pedomorphic 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 the PSFs, 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 favoured the evolution of strictly stenotopic species, among them many miniatures.

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 2-9 to Figure 2-11).



Figure 2-9: *Betta livida* – an endemic PSF fighting fish from North Selangor PSF, 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 2-10: *Paedocypris progenetica* – the world's smallest vertebrate animal – a recently described fish species found in PSF in Sumatra in 2005 (Source: H. H. Tan).



Figure 2-11: *Betta uberris* – an endangered endemic fish that lives in small blackwater rivers of PSFs 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 PSF 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.

Anderson (1961) also found that the tropical lowland PSFs 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 recognised six distinct PC or zones on the basis of their floristic composition and structure of the vegetation in each zone:

- **Type 1:** Mixed swamp forest; the *Gonystylus-Dactylocladus-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 2-12** for an illustration of the lateral zonations of PSFs.

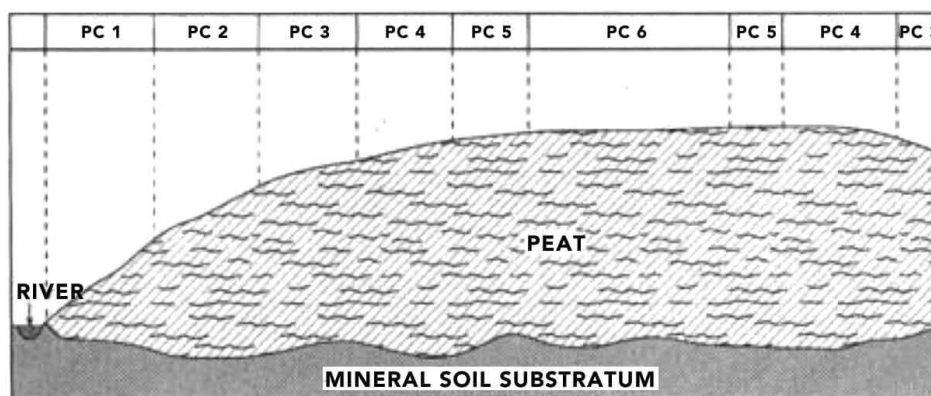
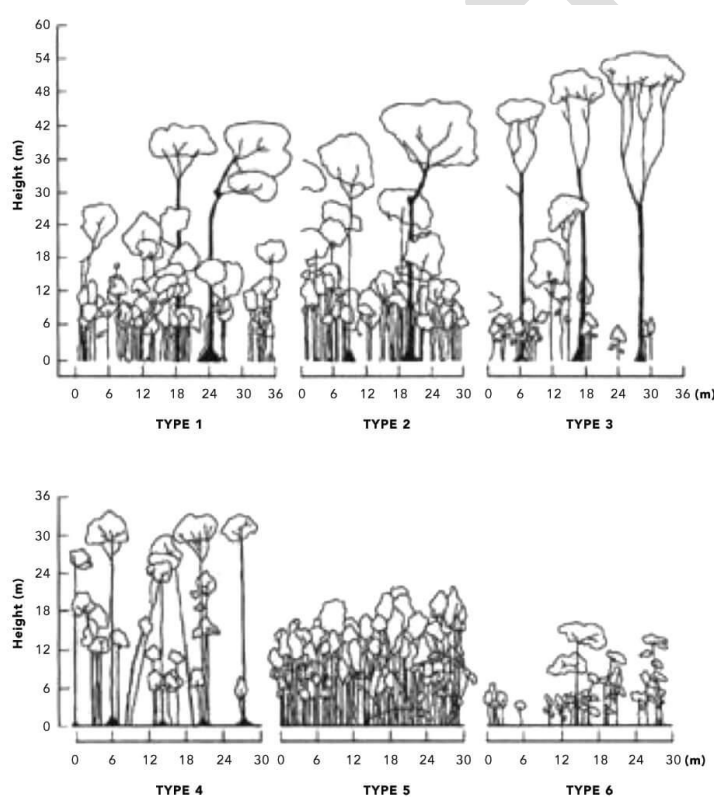


Figure 2-12: Lateral zonations of vegetation in the six phasic communities (Source: Anderson, 1961).

2.7 DEGRADATION OF PEAT SWAMP FORESTS

In Southeast Asia however, 90% of the PSFs are degraded by logging, drainage and fire and millions of hectares are currently managed for industrial plantations including palm oil and pulp wood. In total, industrial plantations cover 4.3 million ha (27%) of the peatlands in Peninsular Malaysia, Sumatra and Borneo, the main peatland-areas in Indonesia and Malaysia. The great majority of industrial plantations are oil palm plantations (73%) while practically all the rest (26%) are pulp wood plantations (Miettinen *et al.*, 2016¹). In Malaysia in 2018, it is estimated that over 1 million ha of the peatlands are under oil palm cultivation. In Indonesia, over 2 million hectares of peatlands are planted with oil palm. Both oil palm and pulp wood cultivation requires peatland drainage of which causing major decline of biodiversity, huge GHG emissions, major fires and smog, and land subsidence that in the long term make these areas prone to flooding and no longer productive for agriculture.

HYDROLOGY AND DRAINAGE

Drainage is an essential starting step for oil palm/ most crops cultivation on peatland. However, drainages disrupt the hydrology functions of the peatland ecosystem, which often lead to negative impacts beyond the estate boundary, as the hydrology is contiguous. Over-drainage usually causes more serious impact but controlled drainage system would still have impacts on the adjacent peatland. Drainage within the plantation area can affect significant portions of the peat dome, as drainage can impact water levels up to two km away from the drain – depending on the drainage depth, flow rates and hydrological conductivity of the peat.

SUBSIDENCE AND FLOOD RISK

Subsidence is the lowering of the soil surface as the result of physical compression of the peat and loss of carbon due to oxidation and erosion. Peat soils comprise 10% accumulated organic materials and 90% of water. When drained, the peat oxidizes and all peat above the drainage level will eventually be lost. Subsidence and the related flood risk is a well-known and inevitable phenomenon in all places in the world where lowland peatlands have been converted to drainage-dependent land-uses. Examples include the UK (Somerset), USA (Sacramento Delta, Everglades), northern Germany, Denmark and the Netherlands where a large part of the highly populated western part of the country is situated below sea level as a result of the soil subsidence.

In Indonesia (namely Sumatra and Kalimantan) and Malaysia, many of the PSFs have been drained for oil palm or pulp wood plantations. Research results show that in the first five years after drainage, peatland subsidence is typically 1 to 2 m. In subsequent years, this stabilizes to a constant 3 to 5 cm/year, resulting in a subsidence of 2-3 m in 25 years and 4-5 m within 100 years (Hooijer et al 2012, Jauhiainen et al. 2012).

FIRE

One of the most serious risks to remaining PSFs in Southeast Asia comes from fire. In July-September 2015 more than 100,000 fires occurred in Indonesia, burning approximately 2.6 million ha of plantations, forests and peatlands throughout Sumatra, Kalimantan and Papua regions. In what the Guardian called “the year’s worst environmental disaster”, an estimated 1.75 billion tonnes of carbon dioxide equivalent was released in just a few months, more than Germany’s or Japan’s total annual emissions. Daily emissions during the peak weeks of the fires exceeded the daily fossil fuel emissions of the entire USA economy. The fires created a smoke and haze crisis affecting all of Southeast Asia, triggering national emergencies across Indonesia and into Singapore, Malaysia and other countries, resulting in diplomatic tensions between Indonesia and its neighbouring countries. The human cost was terrible: 19 people died during the fires and more than 500,000 cases of respiratory tract infections were reported at the time of the fires. It is estimated that the fires led to more than 100,000 premature deaths in the region. A public health study estimated that 91,600 people in Indonesia, 6,500 in Malaysia and 2,200 in Singapore may have died prematurely in 2015 because of exposure to fine particle pollution. The study said those figures were nearly 2.7 times higher than the estimated deaths linked to the previous fire and haze crisis in 2006. Long term impacts are unpredictable, but a study of the effects of the 1998 haze crisis on foetal, infant and child mortality showed that the air pollution led to 15,600

¹Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990
Jukka Miettinen *, Chenghua Shi, Soo Chin Liew

fewer children in Indonesia. The haze crisis caused schools to close around the region and shut down air transport. Damage to the Indonesian economy was calculated at around US\$ 16 billion (IDR 221 trillion), equivalent to 1.9 percent of Indonesia's gross domestic product (GDP). Fires have always been part of land management in the tropics and beyond because fire is the cheapest way to prepare land for planting.

Drained peatlands are susceptible to fire as dry peat is highly inflammable. The magnitude of industrial-scale plantations led to large areas of drained peatland. In combination with natural and climate change induced droughts, these provide the fuel for catastrophic fires. As peatland burns with low oxygen levels and hence burns incompletely it leads to thick haze formation. Thus development of large plantations has become the major driver of fires and led to haze episodes of disastrous proportions.



Figure 2-13: Degraded peatlands next to plantations are susceptible to fire (Photo taken adjacent to Klias Forest Reserve, Sabah, Malaysia).

ENCROACHMENT/ UNSUSTAINABLE EXTRACTION OF TIMBER AND NTFP

Typically infrastructure and access to a peatland area may be improved as a result of the establishment of 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 PSF increases significantly.

This presents an opportunity for either opportunistic or externally driven illegal actions including 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 the forest resources.

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

The conservation and management of existing peat swamp forest (PSF) areas in or adjacent to oil palm plantations is crucial to avoid the impacts of degradation as mentioned in Chapter 2, 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 conservation areas within plantations on peatlands:

- Areas of intact PSF
- Riverine vegetation and areas in prescribed riparian buffer zones
- Buffer zone adjacent to intact PSF
- Central portion of peat dome area (*kubah gambut*, Padang Raya)
- Edges/shoulders of dome (in Sarawak with Alan Forest) areas (close to drainage base hence flooding risks)
- Areas that cannot be drained using gravity or areas identified through drainability assessment as facing future gravity drainage constraints
- Wildlife corridors (to avoid human-wildlife conflict and conserve biodiversity)
- In Indonesia –
 - a. Areas of peat identified as being in the conservation zone of the peatland hydrological unit (PHU) or Kawasan Hidrologis Gambut (KHG) – i.e. areas covering at least 30% of each KHG, areas of importance for biodiversity conservation and all areas deeper than 3m (in line with Indonesian regulations – PP71/2014 and PP57/2016)
 - b. Areas of peat underlain with potential acid sulphate soils or infertile quartz sands (where development is not permitted according to Indonesian regulations)
 - c. areas identified as protection forest (*hutan lindung*)
- In Malaysia – areas specified as Environmentally Sensitive Areas (ESA) Class 1 or 2.

3.1 REWETTING AND REVEGETATION 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 the PSF areas identified for conservation as this will ultimately lead to degradation and/or loss of peat. In the areas bordering PSF, the water table should be maintained as high as possible to minimize the effects of drainage from the plantation area into the PSF (off-side impacts). If replanting is required as part of rehabilitation, only indigenous PSF plant species that are tolerant to high water tables and do not require any drainage should be used. The emphasis should be on hydrological restoration prior to or at least in parallel to any 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 digging of canals and ditches in these areas. This often occurs during the timber removal or land clearing phases, as timber may be extracted via canals and water tables may also be artificially lowered to allow access for heavy machinery. These peatland canals and ditches typically exit into main canals or 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. But the primary concern is that drainage via ditches and canals also results in the drying of the peatland, leaving the peat vulnerable to fire as well as subsidence of the peat. Drainage of oil palm plantations on peat also impact adjacent PSF due to the high hydrological conductivity of the water in the peat soil.

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 3-1). 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 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 Guide (Wetlands International – Indonesia Programme, 2005a):



Figure 3-1: Dam constructed to systematically block a former logging canal to restore peat swamp water levels.

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 socio-economic 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 and decrease the velocity and head difference (the water level difference at each dam). 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 the use of a computer simulations with an unsteady-state simulation model show that head differences in relatively small drains with an average width of 2m and an average depth of 1m, should be a maximum of 25cm height difference.
- 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. should be 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 25cm,, the overburden pressure should not exceed about 1,000 Pascals (kPa) or 100kg/m²).
- Use of locally available material has the clear advantage of not only being practical and inexpensive but also means no new construction material needs to be transported to the dam building site.
- Considering the amount of dams needed to effectively conserve the remaining PSF, it is recommended to use wood sparingly to avoid deforestation and consider compacted peat dams or soil bag dams first as they use least wood.
- Dams should be 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 PSF 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 includes experience in Canal Blocking in Central Kalimantan, Indonesia.

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 between 2000-2008 in Central Kalimantan mainly in the Ex-Mega Rice Project (Proyek Pengembangan Lahan Gambut, 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 north-western part of Block A (Wetlands International 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 north-eastern 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, labour, materials and equipment. The structures are rather light. Construction costs are in the order of Indonesian Rupiah (IDR) 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.

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 IDR 100 million (US\$10,000) per structure. The expected lifetime is about 5-8 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 IDR 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 organisations 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 5-8 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 organisation 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 3-2: Small ditch blocked with peat dam.



Figure 3-3: Small ditch blocked with sandbags and soil



Figure 3-4: Successive ditch blocks made of wood and soil bags in a medium-width canal in Central Kalimantan.

The experience of Sime Darby Plantations in raising water levels in boundary canals to enhance forest regeneration is given in **Box 3**.

Box 3

Sime Darby partnership programme in conservation and rehabilitation of North Selangor peat swamp forest

North Selangor Peat Swamp Forest (NSPSF; 81,304 ha – slightly bigger than the size of Singapore Island) is the largest remaining PSF in the west coast of Peninsular Malaysia (see Figure 3-5). The PSF plays a critical role in the economy and ecology of the region – providing non-timber forest products (NTFP) and playing a key role in flood control and water supply to adjacent areas (e.g. Tanjung Karang Rice Schemes and towns such as Tanjung Karang, Sekinchan and Sabak Bernam), as well as playing a very significant role of global importance in storing huge amounts of carbon in the soil and acting as repositories for unique and important biodiversity.

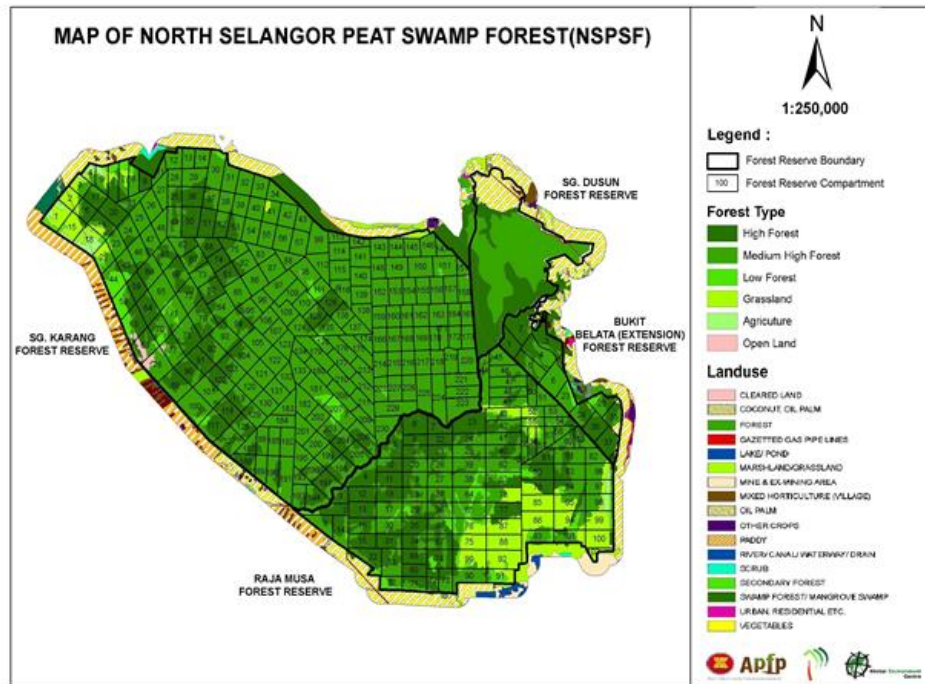


Figure 3-5: Map of NSPSF

Administratively, the NSPSF is further divided into Raja Musa FR (RMFR: 35,656 ha), Sg. Karang FR (SKFR: 37,417 ha), part of Bukit Belata (Extension) FR (3,140 ha) and Sungai Dusun Wildlife Reserve/FR (5,091 ha). RMFR is located immediately north and west of Sime Darby's Bukit Talang and Tennamaram Estates. Here the FR has been continuously impacted by forest fires caused by illegal encroachment for agriculture activities and past unsustainable forestry practices. Such activities have caused excessive drainage making the peat susceptible to peat fire outbreaks especially during the dry season. Almost every year since 1992, there have severe fires which generate serious smoke haze affecting adjacent areas as well as much of the Klang Valley. Therefore the prevention of peatland fires and haze, and reduction in GHG emissions from forest and peat degradation will be a very important issue here.

A project was initiated in 2015 by Sime Darby plantations and Global Environment Centre to prevent fires and enhance water management along the boundary between one of Sime Darby's plantations and the RMFR. The main activities undertaken between 2015-2019 include:

Objective 1: Project Site Demarcation and Assessment

- Survey and marking of boundaries of the rehabilitation site/ degraded forest area
- Placement of signboards highlighting Sime Darby's initiative
- Assessment and mapping of the existing vegetation, water levels and soil depths
- Assessment of adjacent lands developed by communities to assess drainage, peatland and plantation (agronomic) management and fire risks

Objective 2: Water Management and Fire Prevention through BMPs Application in the Buffer Areas

- a. Assessment of all drainage canals in the project site and install blocks to manage water levels to maintain optimal levels for PSF growth and prevent the area from drying up in the dry season and reduce fire risk and GHG emissions
- b. Support for good peatland management through sustainable livelihood development and/or BMPs for adjacent communities
- c. Strengthen capacity of State Forestry Department and local community and landowners to prevent peatland fires by promoting the fire danger and warning system and undertaking collaborative patrolling

Objective 3: Forest Rehabilitation

- a. Seedling cultivation in community nursery
- b. Land preparation, and planting of 20 ha with indigenous PSF pioneer species with the involvement of local communities, school children and plantation staff and workers
- c. Maintenance of the planted seedlings/trees (20 ha)
- d. Encouragement of natural regeneration of less degraded portions of the forest.

The project has been very successful in preventing fires and rehabilitating the degraded forest area. A key element has been the raising of water levels in the boundary canal of the plantation and blocking the smaller drains dug in the forest by local community. Almost 50 ha of degraded forest along the border have been rehabilitated through higher water tables and a further 20 ha of severely degraded forest has been replanted.

AVOIDING ELEVATED WATER LEVELS

Avoiding water levels which are too high are as important as avoiding water levels which are too low. The PSF 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 the PSF cannot survive in 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 PSFs 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 3-6: 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 3-7: Peat swamp forest killed by elevated water levels above the peat surface.

3.2 FIRE PREVENTION AND CONTROL

As mentioned previously, fire constitutes a major threat to the peatlands. This fact has triggered added scrutiny from governments in Indonesia and Malaysia (as examples) for any type of development in the peatland. This is especially true for plantation development, and the regulations surrounding fire prevention from the 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) and ASEAN Guidelines on Peatland Fire Management (2015), under the framework of ASEAN Agreement on Transboundary Haze Pollution (AATHP).



Figure 3-8: Burnt forest adjacent to land developed for oil palm plantations.



Figure 3-9: 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 PSF by ensuring the following recommendations are in place and implemented:

- Zero Burning methods for land clearing/replanting: Implementation of Zero Burning concept greatly reduces the risk of fires
- Maintaining high water levels in boundary canals or installation of sufficient buffer zones inside the plantation to prevent forest and peat to dry out
- Engaging surrounding communities in fire prevention programmes that enhances the awareness, capacity and means for fire-free peatland management
- Construction of fire watch-towers or use of drones for regular aerial surveillance
- Effective surveillance and monitoring: Maintenance of internal roads near fire prone areas – can ease patrolling and access of fire suppression equipment as needed. Care should be taken that such roads do not permit access or encroachment by external parties
- Formation of land and peat forest fire management units: It is important to develop an organisational structure to handle fire control in a plantation company. Overall leadership should be provided by the Head of the Fire Protection Division (or similar division/department) 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 risk
 - 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 estate or division): patrol units who have the task of surveillance over the whole block
 - Water management sections – to ensure high water tables are maintained especially in fire prone areas

Fires may often enter a peatland from areas outside (but adjacent to) plantations especially from areas with local communities or smallholders. Collaboration on landscape level is vital to avoid fires from starting and spreading.

In the case of PSF 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:

- For PSF a buffer zone within the plantation boundary without drainage infrastructure or high water tables maintained by bunds or high level canals;
- For other undrained areas, the 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 PSF, river buffers and adjacent peatland areas to check for land clearing, drainage or other activities that could lead to fires;
- Rapid response units for fire control within and adjacent to the plantation; and
- Dialogue and cooperation with neighbouring stakeholders including plantation companies, local communities and local authorities 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. But it should be noted that if peatlands are drained over 40 cm from the ground surface, the chance of fire is greatly increased. Hence it is extremely important to ensure water in the plantation and any adjacent forest areas is managed effectively. Maintaining a moist peat surface will help to minimize the risk of accidental peat fire. Water management plans should ensure that there is no drainage of any peatland conservation area within or adjacent to the plantation. The water management systems should ensure that water control structures are well maintained and monitored and measures taken to rapidly address any problems of lower water table in conservation areas. Care should be exercised to monitor and ensure water management activities within the plantation do not have adverse effects on adjacent peat swamp areas (Figure 3-10 and Figure 3-11).

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 is 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. Specific attention should be taken to monitor the water levels in and adjacent to conservation areas and take actions to increase water levels when low. Options to supplement water tables in conservation areas by pumping of surface or groundwater during dry periods may need to be considered.



Figure 3-10: Plantation perimeter drain maintained with low water level may lead to drainage of adjacent peat swamp forest thus increasing the risk of fire.



Figure 3-11: High water level in canal between the peat swamp forest and oil palm plantation prevents drainage of the forest edge and minimizes fire risk (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 that provides information about the possibility of fire break-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 behaviour.

One key fire information systems is the Fire Danger Rating System (FDRS) – which is 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 fire risk and supplies information that assists in fire management. The products of FDRS can be used to predict fire behaviour 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 codes and 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 undrained 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 fire risk

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 maintaining the FDRS for Southeast Asia on a daily basis since September 2003. The regional FDRS was adapted from the Canadian FDRS developed by the Canadian Forest Service. A more detailed FDRS for Malaysia is also prepared by MMD based on information

from more than 160 automatic weather stations. The Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and National Institute of Aeronautics and Space (LAPAN) of Indonesia also produce localised FDRS for the country. A pilot project on FDRS for Mekong was initiated by Thailand of which providing information to the Mekong countries.

Daily maps of the regional FDRS for Southeast Asia are available at: <http://www.met.gov.my/iklim/fdrs/afdrs>.

The FDRS maps are also available as an overlay to 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 of FDRS map is shown in Figure 3-12.

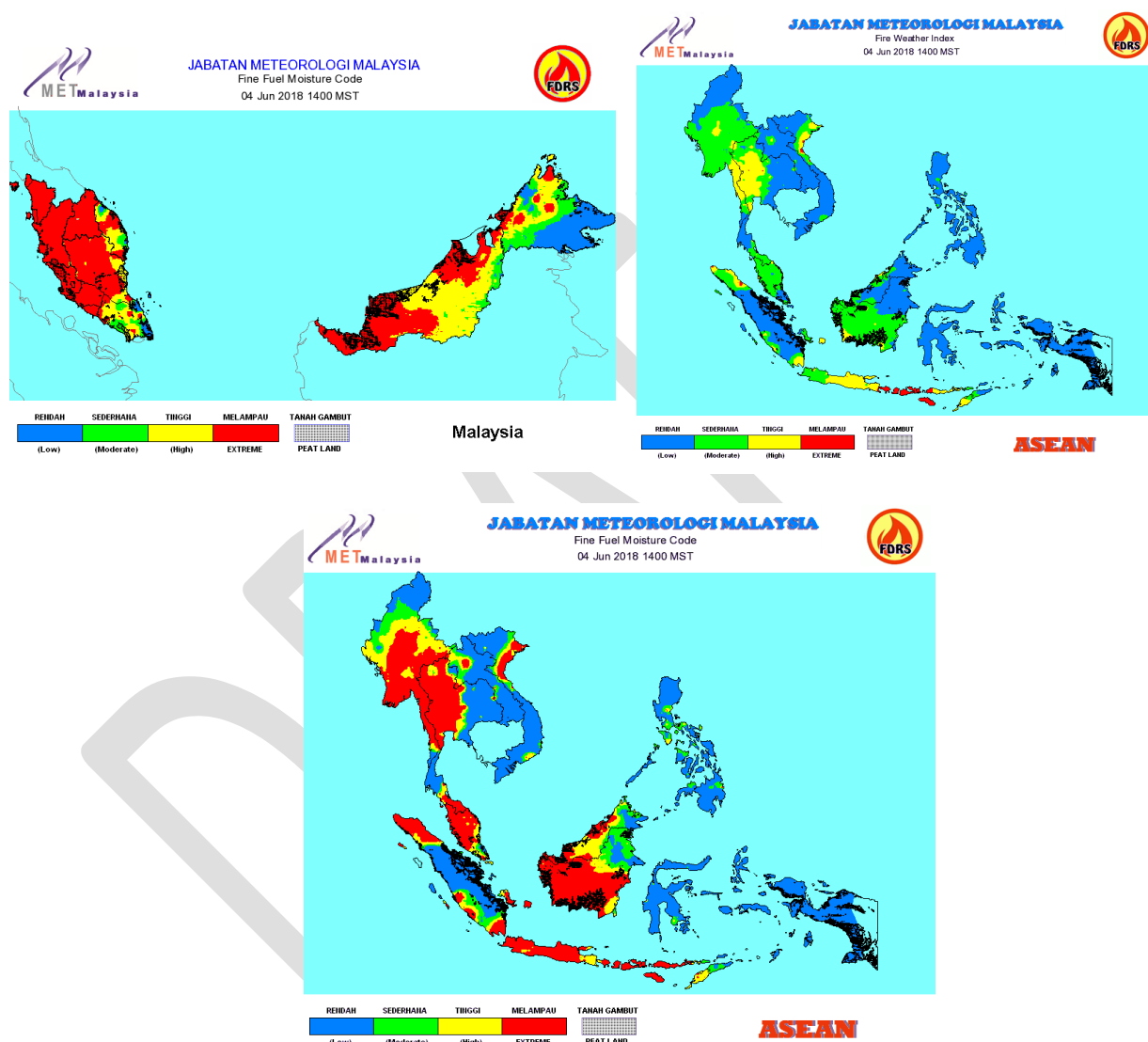


Figure 3-12: Series of images of FDRS Maps for Fine Fuel Moisture Code, Duff Moisture Code and Fire Weather Index for Malaysia and Southeast Asia

ASEAN FIRE ALERT TOOL

The ASEAN Fire Alert Tool is an application that was developed purposely to send notifications to alert the land managers when a hotspot occurs on their land and inform the land managers on fire risk level of the land. They are then able to verify ground conditions and take necessary action. The application allows users to determine their land boundaries and select Registration Points for monitoring changes of FDRS and Fire Weather Index (FWI). Features of this application can be seen in Figure 3-13. This tool is made possible with funding from USAID LEAF, data as provided by ASMC, MMD and LAPAN, and project designed by GEC and SIG. Enhancement of the tool was supported by the USAID-IFACS project and the LEDS AFOLU Working Group.

METHODS:

STEP 1: SIGN UP

Go to www.aseanfirealert.org and sign up. You will be given a Verification Code. Write this down as it will be use for your phone app later.



Scan and register

Plot your land parcels and nominate FWI points you wish to monitor.



STEP 2: INSTALL APP






STEP 3: VERIFY APP

Enter your verification code (given to you when you register at this website) into your phone.



STEP 4: ALERT MESSAGE

Once verified, you will be able to receive Push Notifications to your phone from this website. Each day, whenever there are hotspots within your defined land parcels / regions, or changes in FDRS / FWI on your registered monitoring points, you will receive a Push Notification (alert message) on your phone.

ASEAN Fire Alert Tool

01 Aug. 2016 03:05 PM

You have 3 regions with hotspots:

1. Riau (J)
2. Kalimantan (J)
3. Indonesia: Sumatra - South, Lampung (J)

Changes in Fire Weather Index (FWI)



01 Aug. 2016 03:05 PM

1. NSPSF
Moderate → Moderate
2. Harapan Jaya
Low → Moderate
3. Default (J)
Low → Moderate
4. Riau Kerumutan (J)
Low → Moderate
5. Sebangau National Park (J)
Moderate → Low

Your Regions

1. Riau (J) [Edit] [Remove]
2. Kalimantan (J) [Edit] [Remove]
3. Sarawak (J) [Edit] [Remove]
4. Perlis (J) [Edit] [Remove]
5. Philippines Agusan (J) [Edit] [Remove]
6. Philippines Leyte (J) [Edit] [Remove]
7. Indonesia: Sumatra-jambi (J) [Edit] [Remove]
8. Brunei (J) [Edit] [Remove]
9. Indonesia: Sumatra - South, Lampung (J) [Edit] [Remove]
10. Borneo Hill (J) [Edit] [Remove]
11. Sebangau National Park (J) [Edit] [Remove]
12. Bangkulu (J) [Edit] [Remove]
13. Borneo Hill (J) [Edit] [Remove]

(0/200 used) [Plot a new Region] [View all Regions with Hotspots]

Figure 3-11: The ASEAN Fire Alert Tool smartphone application

For other countries The fire danger rating can be calculated manually using meteorological data from the plantation or site concerned.

FIRE SUPPRESSION

Where fire breaks out in a plantation, adjacent or nearby PSF areas become extremely vulnerable due to the nature of the 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 peatland and forest fires in Kalimantan and Sumatra, Indonesia. The following are important elements quoted from the 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 the peat fires are difficulties in obtaining large quantities of water source 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 – plantation management together with various stakeholders including the community, NGOs, institutions and relevant agencies that 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 (fire-proof suits, boots, helmets, gloves, torches, machetes, etc.)
 - Emergency clinic, facilities for treating fire victims
- Organization of fire-fighting teams – 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

- a. Determine the direction in which the fire is spreading (this can be done by observation from a higher point or by climbing a tree);
- b. 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;
- c. 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;
- d. If there are no water sources in the area, boreholes must be sunk. If the water sources are far from the fire, water supply is obtained through a relay (using several water pumps);
- e. Fire-fighters must walk with great care in burnt peat areas, to reduce risk of them sinking into holes/burned area;
- f. Specialized equipment such as a peat spear, which is a 1-2 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 smouldering 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;

- g. 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; and
- h. The burned area 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 the areas within or adjacent to plantations. These areas may include PSFs and associated resources including NTFPs and fisheries. Management of access to the PSFs 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 PSF 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 the local communities and also with the involvement of relevant local government agencies. For PSF without a legal land title, it may be possible to have them zoned as Conservation Zones (e.g. Kawasan Ekosistem Essential (KEE) in Indonesia) or community forest under national regulation (e.g. Hutan Desa in Indonesia) which provides certain safeguards for the PSF to be managed well and for communities to feel responsible and held accountable.

Management of rehabilitated peatland or forested peat swamp needs to undergo Free, Prior and Informed Consent (FPIC) processes if there is a local community existing within and adjacent to the peatlands. If should these areas will be zoned as conservation areas, the management and monitoring plan needs to include engagement of the local stakeholders and communities as required by the international and national standards/schemes.

3.4 AVOIDING FRAGMENTATION

PSFs are perfect examples of the inter-connected nature of forest ecosystems. The inter-dependence of the entire ecosystem makes PSFs especially vulnerable to a collapse from fragmentation. Subdividing the PSF due to establishment of canals, weirs (water gates), bunds and access roads constructed by oil palm plantations, and making them in to smaller fragmented units makes the peat 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 PSF areas to be conserved/managed needs to take this factor into consideration. Areas that provide connectivity/ecological links between larger landscapes of PSFs should be prioritized. The size of the area should also be adequate to ensure the long-term ecological survival of the PSF. 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 space for undisturbed movement of wildlife.

4.0 REHABILITATION OF PEAT SWAMP FORESTS IN DEGRADED SITES

4.1 ADDRESSING THE ROOT CAUSES OF DEGRADATION

Understanding the root causes of degradation requires careful and honest assessment of the role of various stakeholders in the area that have an impact on the PSF. 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 local government, communities and other 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 grower 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 PSF 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 PSF in 2001. In 2004, the main cause of degradation was found to be the widespread illegal logging in the National Park (NP) both by a logging company with a concession adjacent to the NP 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 NP 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 4

Causes of Peat Swamp Forest Degradation on Berbak-Sembilang National Park, Indonesia

Berbak-Sembilang National Park

Berbak National Park (162,000 ha) was designated in 1992 as Indonesia's first Ramsar Site with a special emphasis on its representativeness for Southeast Asian PSF. In 2016, its management was merged with the adjacent Sembilang National Park (205,100 ha), also designated as a Ramsar Site, comprising one of the largest mangrove area (77,500 ha) of the Indo-Malayan region, the only one that still has an intact natural transition towards inland freshwater and PSF. The hydrological integrity of this transition is of crucial importance to the survival of the mangrove ecosystem and its biodiversity.

Both Ramsar sites are famous for their rich biodiversity, including many fish that are restricted or endemic to peat swamp black waters, as well as rare and endangered species, such as the Sumatran Tiger (*Panthera tigris sumatranus*), Malaysan Tapir (*Tapirus indicus*), Malaysian Sun Bear (*Helarctos malayanus*), Whitehanded Gibbon (*Hylobates lar*) and Siamang (*Symphalangus syndactylus*), False Gharial (*Tomistoma schlegelii*), Painted Terrapin (*Batagur borneoensis*), Storm's Stork (*Ciconia stormi*) and the White-winged Duck (*Cairina scutulata*). The Sembilang NP is one of the most important wintering sites for the Asian Dowitcher (*Limnodromus semipalmatus*) with a maximum count of 10,000 individuals at the Banyuasin Peninsula (Silvius et al. 2016, Giesen et al., 2016).

Land conversion and fires within the National Park

Encroachment in Berbak NP is regarded as the single greatest threat by the park authorities, as it directly leads to loss of forest (illegal logging), drainage and fires. Most encroachment has occurred to the north of the NP and from the villages along the coast. The level of encroachment has rapidly

increased over the past 5-10 years in tandem with the rapid expansion of oil palm in the province. To the north, villages have encroached into the NP by almost 4km and extending over roughly 670 ha, while along the east coast the encroachment has extended into the NP by about 2km, extending over 690 ha. General disturbance from illegal logging and clearing, followed by fires, has extended much further from the coast to the Simpang Melaka, a tributary of the Air Hitam Laut river, over a length of more than 10km. There is also illegal conversion ongoing to the northwest of Berbak NP in the Tahura, where about 1,250 ha has been converted by smallholders, and to the southwest of Berbak NP on the edge of (but within) the logging concessions where a further 1,530 ha has been converted to oil palm.

Logging and fires within the National Park and peatland protection forests

Illegal logging has been ongoing in Berbak NP for many decades and at least since the early 1980s. It occurs all around the NP, but the largest, most organized and widespread illegal logging appears to occur via the logging concessions to the southwest of Berbak NP and to a lesser extent through the Tahura in the west. This is especially via the forestry concession (HPH) located south-west of the NP, that has been operational since about 1979. Logging trails (and possibly canals) lead from their concession area to areas within the NP and the peatland protection forest (HLG). The large degraded area in the central part of Berbak NP along the Air Hitam Laut river started with illegal logging in the mid 1990s, and expanded rapidly with major fires over 17,000 ha in 1997 (Giesen 2004) and fires in all dry years since, especially in El Niño years. The HLG that lies to the south-west of Berbak NP and extends over 20,000 ha has been logged to about 40-50% over the past 10-15 years. Two logging companies south-west of Berbak NP have a combined licensed area (HPH) of about 58,000 ha, and this area has a legal status of limited production forest (HPT). The southern license has been suspended pending an investigative audit, as the company has planted pulp species such as jabon (*Neolamarckia cadamba*) and sengon (*Falcataria moluccana*) and converted part of the concession to oil palm, which is against regulations for HPT.

Further details can be found in the report on the 2017 Ramsar Advisory Mission to Berbak: https://www.ramsar.org/sites/default/files/documents/library/ram85e_berbak_indonesia.pdf

In Central Kalimantan – the degradation of the PSFs was driven by the development of a 1.5 million ha rice production scheme (so-called the Mega Rice Project) in 1996-97. This involved the construction of 4,600 km of so-called irrigation canals through the PSF with expectation that they would carry irrigation water into the forest area from rivers. Unfortunately the canals 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 PSF was 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 (CCFPI) project) to block the abandoned canals using local materials and community action. This 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 to other projects and now has been adopted by the Indonesian Government for rehabilitating the degraded peatlands.

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 PSFs in Central Kalimantan specifically for the ex-Mega Rice project area (Euroconsult MMD *et al.*, 2009) include:

A. SOCIO-ECONOMICS

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.

B. 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 discussion/consultation with the local communities; or
- are important as food species for key wildlife such as orang utan, gibbon and hornbills.

C. 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 the rehabilitation programmes, and the emphasis should be on hydrological restoration prior or at least in parallel to the replanting programmes.

D. BIODIVERSITY

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

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

E. EXOTIC TREE SPECIES

Only native species should be used in the rehabilitation programmes and the use of exotics should be prohibited.

Setting up any structures for rehabilitation should also utilize locally found 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 1kPa or 100 kg/m²) (Budiman and Wosten, 2009).

F. COSTS

The overall budget required for the rehabilitation is likely to be substantial. Hansson *et al* (2018)¹ estimated the costs to be around USD 2,300 per hectare in the context of the Indonesia government ambition to restore 2 million hectares. Therefore, the rehabilitation programmes must opt for most cost-effective solutions – the end result must of course be successful rehabilitation, as this should not be compromised.

G. 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-

¹ Hansson, Amanda and Dargusch, Paul. 2018. "An Estimate of the Financial Cost of Peatland Restoration in Indonesia." *Case Studies in the Environment*. University of California Press. January. <https://doi.org/10.1525/cse.2017.000695>.

related criteria, and it is much more important to assess success on the real impact (medium to long-term) of the rehabilitation. Implementers should therefore not only be held accountable for use of funds for planting trees and hectareage covered, but be responsible for survival of tracts of replanted PSFs. 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, from a management point of view, the following key principles for the PSF rehabilitation programmes are recommended (Euroconsult *et al.*, 2008b):

A. 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.

B. 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 harmonise these needs so as to reduce any conflicts and to maximize synergies.

C. 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 programme needs to take a resource-based approach to lowland management. In Indonesia – the importance of the landscape approach has been incorporated into the National Regulation for Protection and Management of Peatland Ecosystems (PP71/2014 amended to PP57/2016) which requires all peatlands to be managed as Peatland Hydrological Units (PHU) – which link together all peatlands in the same landscape.

D. 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 the local communities is essential to measure the effectiveness (or not) of the interventions and this will serve to constantly improve planning and future actions in conserving and protecting the PSFs.

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 Chapter 3.1), prevention of fires (see Chapter 3.2), or
- c. active rehabilitation (see Chapter 5)

MAPPING OF DEGRADED AREA

Mapping of the area needs to be in 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 4-1 and 4-2 for examples of the degradation and site condition mapping.

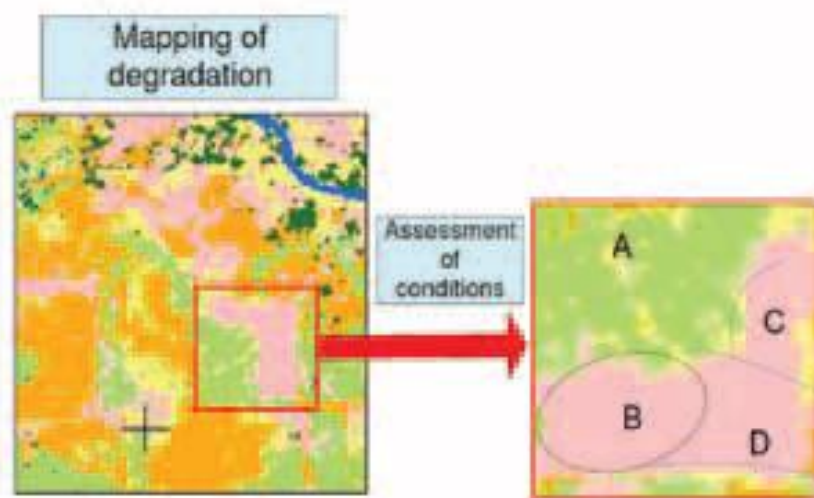


Figure 4-1: Example of mapping degradation and site conditions (Source: Euroconsult MMD *et al.*, 2009). Area marked “A” shows an area with deeply (1.5m) flooded peat (2x burnt, 1.5m of peat has disappeared); areas marked “B” shows an area with moderately deep flooding (1m), 1x burnt, 1m of peat has disappeared; area marked “C” shows an area that is shallowly flooded (0.5m), 1x burnt, 0.5m of peat has disappeared; area marked “D” is similar to “C” but with

riverine influence (nutrients, current and some erosion).



Figure 4-2: 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 FOR BLOCKING

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

RAPID SURVEY OF SITE CONDITIONS

Rapid surveys will be required in addition to the mapping, to assess site conditions, and determine the possible causes of the degradation (see Chapter 4.1). 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, and
- nutrient-availability and pH of each of the mapped units.

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

BOX 5

Example of Planning and Mapping for Peat Swamp Forest Rehabilitation Projects from the Ex-Mega Rice Project Area in Central Kalimantan

Figure 4-3 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 PSF rehabilitation project.

Earlier field surveys revealed that while areas with remaining PSF do not require replanting, vast areas of shrub land, burnt shrub land and sedge-grass-fern vegetation may require 100% replanting with suitable PSF tree species. This includes shrub land that already has some small trees although replanting these areas could include more mature trees if these can be shaded. Patches of severely degraded PSFs were estimated to require 30-50% replanting, while burnt PSFs required an average of 50% replanting as trees often remained in patches in the latter areas. The areas targeted for the replanting according to these planting regimes (0%, 30-50%, 50% and 100%) are indicated in Figure 4-3.

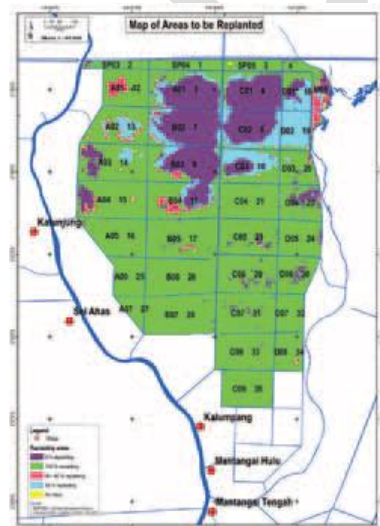


Figure 4-3: Sample map showing areas to be replanted as part of the peatland rehabilitation plan for one of the planting blocks within the Ex-Mega Rice Area in Central Kalimantan (Source: Euroconsult Mott MacDonald and Deltares, Delft Hydraulics, 2009).

4.4 ESTABLISHMENT OF AN APPROPRIATE HYDROLOGICAL REGIME

Restoring hydrological functioning should be the first consideration in the PSF rehabilitation. It is estimated that the hydrology is the most important environmental factor (50% relative importance) in controlling plant community structure (Graf, 2009). The hydrological regime is also the most important factor in establishment and maintenance of the PSF types and processes. The 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 the wetland hydrology. This simple step will retain surface water and elevate the ground water level (see Chapter 3.1). Blocking of canals with multiple dams can be considered successful if blocked canal sections also hold water during the dry season;
- Berms or bunds along the edges of PSF to isolate them from low water levels in adjacent lands – e.g. peatland areas which have subsided due to over drainage or hydrological site (however care should be taken not to increase the water level too high in the PSF);
- Ensuring adequate water flow from upslope in the peatland – for example by putting outlets or overflows in boundary canals of plantations which may be upslope of the targeted rehabilitation areas; and
- 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 the PSFs 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 the hydrological regimes should be restored to natural/original conditions prior to any disturbances (assessments can be done on healthy adjacent PSF 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 tree species for the PSF rehabilitation should in the first place guided by suitability of the species for the site conditions. Certain PSF 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 4-1).

Table 4-1: Main peatland tree species and ecological zoning (Principal tree species occurring in three PSF 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
<i>Palaquium ridleyi</i>	X		
<i>Calophyllum hoesi</i>	X		
<i>Mesua sp.</i>	X		
<i>Mezzettia parviflora</i>	X		X
<i>Combretocarpus rotundatus</i>	X	X	
<i>Syzygium sp.</i>		X	
<i>Tristaniopsis obovata</i>		X	
<i>Shorea teysmanniana</i>		X	X
<i>Palaquium leiocarpum</i>			X
<i>Stemonurus secundiflorus</i>			X
<i>Neoscortechinia kingii</i>	X		X
<i>Palaquium cochlearifolium</i>	X		X

Depending on the degree of degradation, conditions may differ considerably from the original PSF conditions, and this should be given due consideration. Former PSF areas that have been drained will be a lot drier than the original state, while areas that have been prone 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 PSF state. On the whole, species used for reforestation of the 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 PSFs will therefore not be suitable for the replanting of the 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 4-2).

Table 4-2: Pioneer/secondary PSF 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	<i>Camposperma coriaceum</i>	terentang
2	Anacardiaceae	<i>Camposperma macrophylla</i>	terentang
3	Anacardiaceae	<i>Gluta renghas</i>	rengas
4	Anacardiaceae	<i>Gluta wallichii</i>	rengas manuk
5	Anisophylleaceae	<i>Combretocarpus rotundatus</i>	tumih, parapat, tanah tanah
6	Apocynaceae	<i>Alstonia pneumatophora</i>	pulai
7	Apocynaceae	<i>Dyera polyphylla</i>	pantong, jelutung
8	Arecaceae	<i>Licuala paludosa</i>	
9	Arecaceae	<i>Nenga pumila</i>	
10	Arecaceae	<i>Pholidocarpus sumatranus</i>	
11	Caesalpiniaceae	<i>Koompassia malaccensis</i>	kempas merah
12	Dipterocarpaceae	<i>Shorea balangeran</i>	belangiran
13	Ebenaceae	<i>Diospyros siamang</i>	eang
14	Elaeocarpaceae	<i>Elaeocarpus petiolatus</i>	
15	Euphorbiaceae	<i>Austrobuxus nitidus</i>	
16	Euphorbiaceae	<i>Glochidion rubrum</i>	
17	Euphorbiaceae	<i>Macaranga amissa</i>	
18	Euphorbiaceae	<i>Macaranga pruinosa</i>	mahang
19	Euphorbiaceae	<i>Mallotus muticus</i>	perupuk
20	Euphorbiaceae	<i>Mallotus sumatranus</i>	
21	Euphorbiaceae	<i>Pimelodendron griffithianum</i>	
22	Hypericaceae	<i>Cratoxylum arborescens</i>	geronggang
23	Hypericaceae	<i>Cratoxylum formosum</i>	popakan
24	Hypericaceae	<i>Cratoxylum glaucum</i>	bentaleng
25	Icacinaceae	<i>Stemonurus scorpioides</i>	pasir pasir
26	Lauraceae	<i>Actinodaphne macrophylla</i>	
27	Lecythidaceae	<i>Barringtonia macrostachya</i>	
28	Lecythidaceae	<i>Barringtonia racemosa</i>	
29	Melastomataceae	<i>Melastoma malabathricum</i>	senduduk
30	Melastomataceae	<i>Pternandra galeata</i>	
31	Mimosaceae	<i>Archidendron clypearia</i>	
32	Moraceae	<i>Artocarpus gomeziana</i>	
33	Moraceae	<i>Ficus deltoidea</i>	ara
34	Moraceae	<i>Ficus virens</i>	
35	Myristicaceae	<i>Knema laytericia</i>	pirawas

36	Myrtaceae	<i>Eugenia spicata</i>	ubah, kayu lalas
37	Myrtaceae	<i>Melaleuca cajuputi</i>	gelam
38	Myrtaceae	<i>Syzygium cerina</i>	
39	Myrtaceae	<i>Syzygium zippeliana</i>	
40	Pandanaceae	<i>Pandanus helicopus</i>	rasau
41	Rubiaceae	<i>Neolamarckia cadamba</i>	bengkak
42	Rubiaceae	<i>Timonius salicifolius</i>	
43	Rutaceae	<i>Melicope accedens</i>	
44	Theaceae	<i>Ploiarium alternifolium</i>	asam-asam
45	Ulmaceae	<i>Trema cannabina</i>	
46	Ulmaceae	<i>Trema orientalis</i>	landuhung

Many of the trials and the PSF reforestation attempts to date have mainly failed because the species used were unsuitable for the conditions at the specific location. Table 4-3 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 4-3: Species used in restoration trials in Southeast Asia (adapted from Giesen, 2008).

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

28	Myrtaceae	<i>Syzygium oblatum</i> (syn. <i>Eugenia oblata</i>)	Thailand	•
29	Theaceae	<i>Tetramerista glabra</i>	Jambi	o

*Note: • = 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 the PSF restoration attempts, allocating these into four different flooding regimes:

- (I) Deepwater areas (deeply flooded for long periods),
- (II) Deeply flooded areas (frequently deeply flooded areas),
- (III) Moderately flooded areas (regularly, shallowly flooded areas), and
- (IV) Rarely flooded areas

For each of these flooding types, a suite of potentially suitable species is listed (Table 4-4). The same suite can also be used for channel blocking programmes, with type (I) being equivalent to deep-sided channels, type (II) partially in filled channels, type (III) largely in filled channels, and type (IV) completely in filled channels. Over time, these types will naturally evolve from one into another. Studies in the PSFs 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 PSF areas, a similar succession may be attempted. In type (IV), 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 4-4: PSF 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	TYPE (I): Deep water • <i>Hanguana malayana</i> • <i>Pandanus helicopus</i>	• <i>Hanguana malayana</i> • <i>Hypolytrum nemorum</i> • <i>Pandanus helicopus</i>	• Bakung • rasau
2	Sloping sides (eroded or back filled) of canals	Frequently, deeply flooded PSF areas	TYPE (II): Deeply flooded • <i>Combretocarpus rotundatus</i> • <i>Lepironia articulata</i>	• <i>Combretocarpus rotundatus</i> • <i>Lepironia articulata</i> • <i>Mallotus sumatranus</i> • <i>Morinda philippensis</i> • <i>Psychotria montensis</i> • <i>Stenochlaena palustris</i>	• tumih • purun • perupuk • kiapak
3	Largely in-filled canals, with shallow pools	Regularly (shallowly) flooded PSF areas	TYPE (III): Moderately flooded • <i>Cratoxylum glaucescens</i> • <i>Ploiarium alternifolium</i> • <i>Shorea balangeran</i>	• <i>Blechnum indicum</i> • <i>Cratoxylum glaucescens</i> • <i>Ploiarium alternifolium</i> • <i>Shorea balangeran</i> • <i>Stenochlaena palustris</i>	• gerongang • asam-asam • belangeran/ kahui • kiapak
4	Infilled canals	Flooding rare or absent in these PSF areas	TYPE (IV): Rarely flooded • <i>Alstonia spathulata</i> • <i>Dyera polyphylla</i>	• <i>Alstonia spathulata</i> • <i>Blechnum indicum</i> • <i>Dyera polyphylla</i> • <i>Macaranga sp.</i> • <i>Stenochlaena palustris</i>	• pulai • jelutung/ patung • mahang • kiapak
4b	As #4 above, with shade	As #4 above, with shade trees	TYPE (IV)B: Rarely flooded shade required	• <i>Alseodaphne coriacea</i> • <i>Baccaurea bracteata</i> • <i>Dialium patens</i>	• gemor • rambai

trees			<ul style="list-style-type: none"> • <i>Diospyros evena</i> • <i>Durio carinatus</i> • <i>Ganua motleyana</i> • <i>Gonystylus bancanus</i> • <i>Peronema canescens</i> • <i>Shorea pinanga</i> • <i>Syzygium spp.</i> • <i>Tetramerista glabra</i> 	<ul style="list-style-type: none"> • uring pake • durian hutan • ramin • punak
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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*. 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 NTFPs. A preliminary list of potentially beneficial species – both for timber and NTFPs is included in Table 4-5. It should be remembered that restoration of the peatland hydrology is one of the key guiding principles (see Chapter 4.4), and that exotic species that require drainage are incompatible with this principle in areas on margins of peat domes.

Table 4-5: Peat swamp forest species suitable for timber and NTFPs².

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

² See also Giesen et al. 2013 "Quick Assessment and Nationwide Screening (QANS) of Peat and Lowland Resources and Action Planning for then Implementation of a National Lowland Strategy. Paludiculture: sustainable alternatives on degraded peat land in Indonesia"

29	Thymelaceae	<i>Gonystylus bancanus</i>	ramin	++	
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Notes:

+ Good timber species

++ Excellent, valuable timber species

* Needs to be surveyed; *tengkawang* is produced and marketed in West Kalimantan, and specialists consider that PSF dipterocarp species probably also include a number of species producing illipe nuts/oil.

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



Figure 4-4: Jelutung seedlings at a nursery

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.

SUCCESSION-BASED APPROACH

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 PSFs species. The latter would be appropriate if, for example, the aim is to increase the density of certain beneficial species characteristic of mature PSFs, 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 PSF. 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 4-5.

As peat accumulates over time, a particular site may develop a mixed PSF. Although containing less biodiversity than lowland dipterocarp forests, mixed PSFs 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 the degraded conditions, light conditions will be harsh and shade requiring species more common in mature PSFs will not flourish. In pole forest, light penetration is greater than in mixed/mature PSFs, and once again light conditions may be more harsh and contribute to unfavorable conditions for certain species. Little is known about light requirements of the PSF tree species, but one may assume that pioneer species have a high tolerance, while species that occur only in mature-mixed PSFs 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. Plantation growers 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 Chapter 4.4). 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 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 Chapter 4.7) 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 4-5 and 4-6.

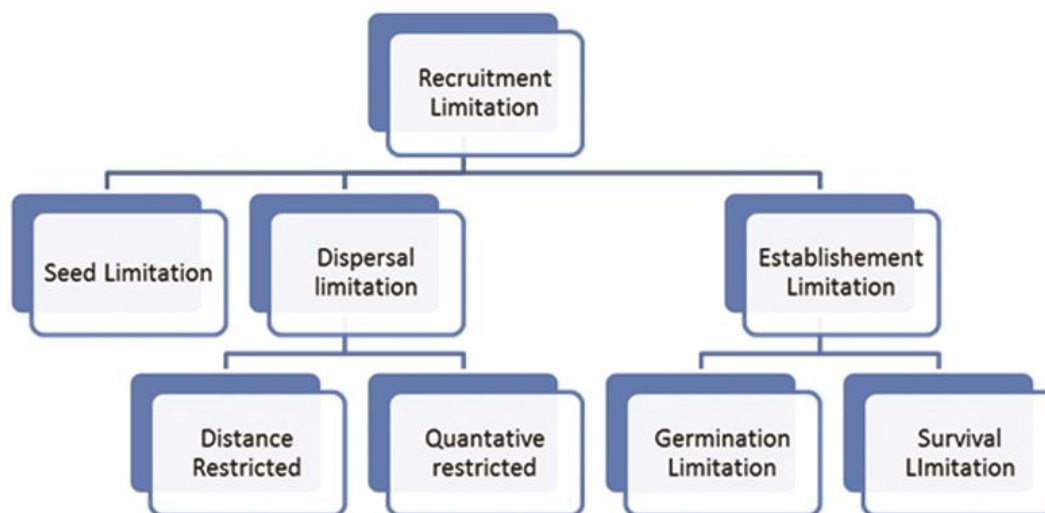


Figure 4-5: Factors that may limit regeneration of peat swamp forests.

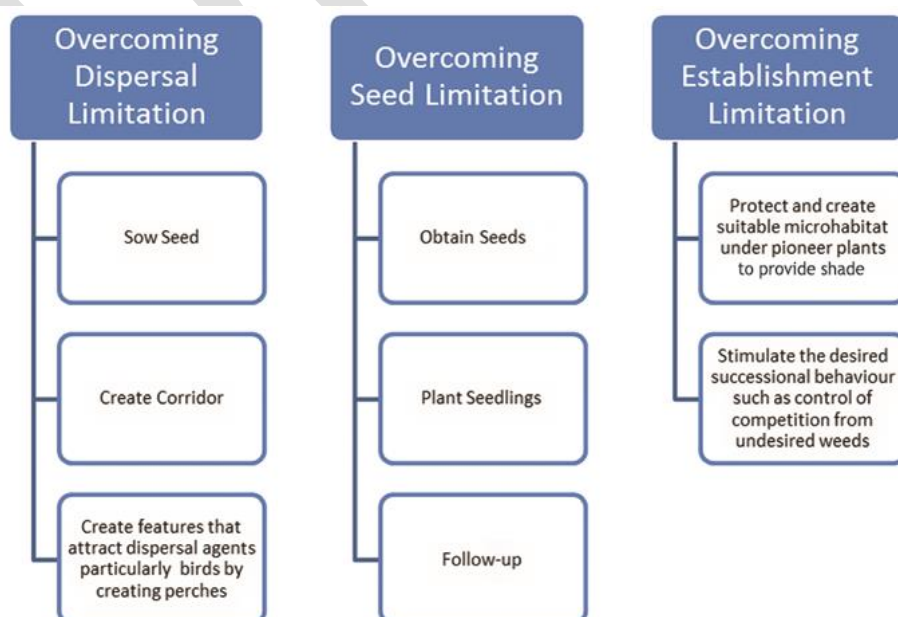


Figure 4-6: Approaches to overcome primary limitations.

4.7 ENRICHMENT PLANTING/REPLANTING

Enrichment planting or active replanting may be necessary depending on the degree of degradation of the PSF area. If the natural regeneration is not possible or insufficient, enrichment planting can be a useful intervention to assist the rehabilitation. Suitable species 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 PSF rehabilitation programme.

Detailed guidance on implementing such programme is provided in Chapter 5. It is useful to note that government research units are sometimes able to provide ready-to-plant material that is available in sufficient quantities at reasonable cost (see Box 5 for an example of an offer in Indonesia).

BOX 6

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 4-6: Available seedlings for PSF rehabilitation.

#	Type	Specifications	Stock	Price per seedling (IDR)
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:

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

More recent costings for seedlings are given in Hansson & Dargusch (2018)

4.8 PALUDICULTURE

Large-scale agriculture on tropical peatland is using species that require drainage (i.e. Acacia, oil palm). Although these species contributed significantly to the local and national economies, it also comes with high environmental cost – e.g. peat subsidence, fire and associated haze, GHG emission, etc. To prolong economic lifespan of cultivated peatlands, there is a need to replace existing drainage-based agriculture with a land-use that does not need drainage.

Productive land use on rewetted peatland with crops that are adapted to the high water levels in peatlands is called ‘paludiculture’. The PSF species are being used traditionally and there are over 400 species known which have productive use. For centuries, the local population have used paludiculture techniques to cultivate crops that are native to peatlands, such as sago (starch for noodles and cookies), rattan (for furniture), gelam (for pole-wood and medicinal oil), jelutong (for latex), tengkawang (illipe nut, for vegetable oil) and purun grass (for thatching and basketry). Their cultivation however, is little-known on large scale and requires extensive trialling and up-scaling for it to become a viable solution for sustainable development needs. This is, however, a necessary investment to sustain productivity on the peatlands.

Cooperation with communities and local governments is important to get acknowledgements for new forms of cultivation. Buffer zones could be prioritized for piloting the different paludiculture species, to study agronomic, economic and political feasibility of such new business model.

POTENTIAL PALUDICULTURE CROP SPECIES

Information on potential paludiculture crop species (mainly extracted from Giesen & Nurmala, 2018) is given below:

a. Swamp jelutung (*Dyera polyphylla*)

Swamp jelutung was cultivated near Sungai Aur village, Tanjung Jabung Timur district, in Jambi, by the company PT Dyera Hutan Lestari, from 1991-2004 and by 2004 a total of about 2,000 ha had been planted and latex tapping already occurring (Muuss 1996, Giesen 2004). However, as the hydrology had not been rehabilitated, the plantation was destroyed by fires in 1997 and again in 2004 and subsequently abandoned. The company did demonstrate, however, that cultivation of the species on a commercial industrial scale is indeed possible. Since then, ICRAF, FORDA and the local forestry department have continued trial plantings with swamp jelutung and the species can be regarded as being well on the way to domestication (Tata et al. 2016), although all hurdles have far from been cleared. Further information is also given in Perdana *et al* (2016)³

b. Alternative pulp species

The pulp and paper company Asia Pulp and Paper (APP, part of the Sinarmas group) has conducted trials, on alternative species for *Acacia crassiparpa* on rewetted peat. A 16 ha trial area was planted in 2016 with four species: terentang (*Campnosperma coriaceum*), geronggang (*Cratoxylum arborescens*), gelam (*Melaleuca cajuputi*) and belangeran (*Shorea balangeran*), of which gelam seems the most promising in terms of growth rate and pulping properties (APP, 2017). In addition to these four species APP aims to trial tumih/perapat (*Combretocarpus rotundatus*), sesendok (*Endospermum diadenum*), perupuk (*Lophopetalum multinervium*), bengkal (*Nauclea subdita*) and kess/bus putih (*Lophostemon* spp.). In addition, with assistance from UGM, they are sourcing a second gelam species from Kalimantan (*Melaleuca leucadendra*) and pine species (*Casuarina equisetifolia*) from Pulau Belitung (APP, 2017).

c. Tengkawang (*Shorea* spp.)

Tengkawang or illipe nut produces high value fats/butter that can be used as a cocoa substitute or in cosmetics. In 2017, the company PT Tolan Tiga Indonesia (PT TTI) established trials with tengkawang species on 10 ha of rewetted peatland at Sungai Barumon in Riau. In all, five *Shorea* species were trialled, namely *Shorea stenoptera*, *S. pinanga*, *S. seminis*, *S. leprosula* and *S. selanica*, of which the first three species produce tengkawang (illipe) nuts. These first trials faced lots of challenges, such as difficulties in sourcing propagation material, and their mortality rates were high (67% average). Nevertheless, PT TTI is optimistic that they can greatly improve plantings and can reach survival rates of 60% or more; they will continue their trials in the coming years (de Clermont-Tonnerre, 2017).

d. Sago

Sago (*Metroxylon* spp.) has been cultivated traditionally in parts of Sumatra for decades, if not hundreds of years, especially in Riau and Aceh, and in all extends over a total area of probably several tens of thousands of hectares. The starch is traded with Malaysia and Singapore, across the Malacca Strait. In Papua naturally-dense sago peatland forests exits providing the main staple food for local communities. In some parts of Sumatra it has disappeared, such as in Jambi where it also was common until several decades ago. In Riau, it is commonly grown in peatland on the islands of Bengkalis, Padang and Tebing Tinggi, where cultivation goes back more than 100 years. Sago cultivation on Pulau Padang was studied by Sonderegger and Lanting (2011). On this island it forms the main commodity grown, together with rubber, as both extend over about the same area. Sago is grown extensively with low investments, nevertheless generating revenue of IDR 4.5 million (US\$300) /ha/year. As mentioned in

³ Perdana A, Sofyuddin M, Harun M, Widayati A. 2016. *Understanding Jelutung (Dyera polyphylla) value chains for the promotion in peatland restoration and sustainable peatland management in Indonesia*. Brief no. 72. Bogor, Indonesia: World Agroforestry Centre (ICRAF), Southeast Asia Regional Program.

Giesen (2013), peatland is generally undrained, although small channels (*parit*) of 20-30 cm depth are excavated to allow easier access and extraction of the sago trunks.

On adjacent Pulau Tebing Tinggi, the main peatland commodity is also sago, which is grown as a cash crop and for subsistence by communities living in the area. The inauguration of the Peatland Restoration Agency (BRG) was held in Sungai Tohor (on the north-eastern side of the island), as this village has been depicted as an “International Peatland Laboratory” (Widaretna & Janssen 2017). Sago has been grown by the community of Sungai Tohor at least for decades; it has been their staple food since the 1970s and sago plays a central role in the community’s daily life. Processing of sago is conducted at home industry level, and delivers end user products such as sago starch, noodles, snack such as *sagu telur* and *sagu lemak*, while sago starch is commonly exported abroad. The community has had conflicts with external investors who would like to see sago replaced with oil palm or *Acacia*. The planting area of sago palms near Sungai Tohor is always wet peat, and although the community has constructed canals, this is for transportation purposes only and traditional canal blocks are made from wood to manage the water level (Widaretna & Janssen 2017). Due to the success of the sago planting in Sg Tohor, BRG had seen the potential for sago as the main species for restoration of degraded peatlands. The selection is in line with the President’s directive that restoring the degraded peatlands should bring economic value to the local community.

e. Rattan

Rattan (*Calamus rotang*) is a climbing palm, mostly living as a colony, which grows fast. It is easy to harvest, requiring simple tools, and is easy to transport. It is used for making furniture, baskets and souvenirs. Rattan requires trees to climb in and reach the canopy to catch the necessary sunlight. In Mendawai village, Katingan, Central Kalimantan, rattan has been cultivated since the 1970s. It is planted in pairs with Jelutung to have both swamp rubber and rattan harvests. This land-use system is applied in two-thirds of the village land covering almost 7,000 ha. The yield from rattan is the second largest source of income for the village. The rattan used to be exported to China but since the government of Indonesia has installed a export ban, only domestic trade is possible.

UPSCALING PALUDICULTURE

Currently multiple aspects have been identified that act as barriers to upscaling of paludiculture as a sustainable alternative of sustainable land-use including:

- Gaps in technical knowledge of paludiculture species. This includes information about seed sourcing and treatment, nutrient requirements, intercropping possibilities, harvesting methods and intensities, product processing and so on (Giesen & Nurmala, 2018).
- Lack of market incentives. Markets for paludiculture products are small, under developed or inaccessible. Expertise is needed to analyse market requirements for products ((uniformity in) quality and quantity) and gain access to these markets (logistics, standards required).

BOX 7

Paludiculture species and flood tolerance (from Giesen &Nurmala 2018: Tropical Peatland Restoration Report: The Indonesian Case)

Species	Rarely flooded peatland	Moderately flooded peatland	Frequently/deeply flooded peatland
<i>Actinoscirpus grossus</i>			
<i>Agathis borneensis</i>			
<i>Aleurites moluccana</i>			
<i>Anacolsa frutescens</i>			
<i>Apososa frutescens</i>			
<i>Aquilaria species</i>			
<i>Artocarpus elasticus</i>			
<i>Baccaurea species</i>			
<i>Canarium species</i>			
<i>Caryota mitis</i>			
<i>Caryota urens</i>			
<i>Calamus caesius</i>			
<i>Chloranthus erectus</i>			
<i>Cyperus rotundatus</i>			
<i>Cyrtosperma merkusii</i>			
<i>Dimocarpus longan</i>			
<i>Dipterocarpus gracilis</i>			
<i>Donax canniformis</i>			
<i>Dyera costulata</i>			
<i>Dyera polyphylla</i>			
<i>Elateriospermum tapos</i>			
<i>Eleocharis dulcis</i>			
<i>Fibraurea tinctoria</i>			
<i>Finschia chloroxantha</i>			
<i>Flacourtia rukam</i>			
<i>Gaultheria leucocarpa</i>			
<i>Garcinia mangostana</i>			
<i>Gonystylus bancanus</i>			
<i>Ipomoea aquatica</i>			
<i>Juncus effusus</i>			
<i>Korthalsia species</i>			
<i>Lepironia acutangula</i>			
<i>Macaranga tanarius</i>			
<i>Madhuca motleyana</i>			
<i>Mangifera species</i>			
<i>Melaleuca cajuputi</i>			
<i>Metroxylon sagu</i>			
<i>Momordica charantia</i>			
<i>Nepenthes species</i>			
<i>Nephelium species</i>			
<i>Nothaphoebe species</i>			
<i>Palaquium species</i>			

5.0 IMPLEMENTING PEAT SWAMP FOREST REHABILITATION

The following detailed guidance on replanting activities in PSFs is mainly adapted from the ‘Manual on Peat Swamp Forest Rehabilitation and Planning in Thailand’ (Nuyim, 2005), the “Guidelines for the Rehabilitation of Degraded Peat Swamp Forests in Central Kalimantan” (Giesen and van der Meer, 2009) and a guideline on revegetation for peatlands produced by the Indonesian Peatland Restoration Agency (BRG) in 2016.

In terms of rehabilitation strategy, it is important to determine the root causes of the degradation of the site and ensure that these root causes will be addressed as part of the rehabilitation programme. If the root cause is over-drainage – then drains should be blocked or water control structures constructed to restore natural hydrology; if the root cause is encroachment by local community – this needs to be addressed through enforcement or negotiation before rehabilitating the site.

In addition, it is necessary to decide whether the rehabilitation will be undertaken through assisted natural regeneration or replanting or a combination of the two. In general natural regeneration is preferable but may be slow (depending on site conditions) while replanting may generate faster initial results, but will be more expensive and in the long term may be less resilient.

5.1 SEED STOCK COLLECTION AND DEVELOPMENT OF NURSERIES

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 to 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 programme.

It is also critical to select appropriate species for the rehabilitation work. As mentioned in Chapter 4 there are a range of possible species that can be used for PSF rehabilitation. The selection should be linked to the level of site degradation and the ecology of the region. In degraded, open sites it is necessary to plant relatively fast growing species which are tolerant of open conditions. Species such as Mahang (*Macaranga pruinosa*), Gelam (*Melaleuca cajuputi*) and Tenggek Burung (*Euodia redleyi*) are fast growing pioneer species which can flower and fruit within two years enabling further natural regeneration. In sites where there are already pioneer species present the focus may be on bringing in a broader range of species suitable for the nature forest.

SEEDLING PREPARATION

Ensuring an adequate supply of quality seedlings requires planners to be well-informed of the types of seedlings to be used for the rehabilitation. Requirements include the planners’ prior knowledge about the quantity of seedlings required for the planting including estimated replacement planting, size and height of seedlings suitable for the planting, time for the planting, as well as planting patterns and conditions. In addition, good planning for quality seedlings requires the planners to make additional efforts for collecting wildings or seeds, determining seed sources and the collection season (Figure 5-1). Certain seeds have to be sought from distant areas if the seeds are not available on-site. 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 5-1: To supplement wild seed supplies, wild seedlings can be collected on-site or in adjacent areas.

SELECTING PLOTS FOR NURSERY

A critical criterion for selecting a suitable plot for seedling nursery is that the plot should be located on flat land outside the PSF, or the plot area must not be waterlogged. The plot should be convenient for undertaking nursery work with for example sandy loam soil. If necessary, sand can be put on top of the soil to prevent the nursery plot from being soggy. 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. More importantly, the plots should be accessible to vehicles all year round and preferably equipped with electricity. In addition, labour should be easily available in the area. A case study in Ketapang, West Kalimantan from PT SNA is included as in Box 8.

BOX 8

Case Study from PT. SNA Ketapang, West Kalimantan

A nursery with forest species for rehabilitation programme had been set up in the plantation concession of PT. BSS (one of the plantation companies of PT. SNA in Ketapang). The nursery raised approximately 15,000 seedlings of a variety of species from October 2016 – July 2017 see Figure 5-2.

Table 5-1: Seedlings raised in the forest nursery of PT. BSS from October 2016-July 2017

Species name	Local name	Number
<i>Combretocarpus rotundatus</i>	Perepat	4,570
<i>Alstonia spp.</i>	Pulai	2,550
<i>Melaleuca cajuputi</i>	Gelam	17
<i>Macaranga pruinosa</i>	Mahang	865
<i>Shorea belangiran</i>	Belangiran	6,892
<i>Ploiarium alternifolium</i>	Asam-asam	30
<i>Ficus spp.</i>	Ara	50
Total		14,974





Figure 5-2: Seedlings at nursery

CONSTRUCTION OF NURSERY HOUSE AND SEEDLING NURSERY

After selecting the site for the 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.

Initially, existing vegetation on the site should be cleared. Then, the area must be levelled and the nursery house 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 or metal wire. Depending on the colour 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 to form a structure that looks like an open box. The bed is filled with sandy loam or crushed coconut fibre. This is for sowing seeds.



Figure 5-3: Example of nursery set up for a peat rehabilitation project.

ESTABLISHMENT OF WATER PROVISION

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

SOWING SEEDS AND REPLANTING SEEDLINGS

Most seeds of plant species in the PSFs 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. The seeds should be distributed evenly in the pan and not too close to each other. Fine sand is topped on the seeds and watering is carried out in the mornings and afternoons, using a watering can with a fine rose. 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 potting soil. The 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, the seeds should be collected from good plant stocks and those from different stocks should be mixed when sowing to help lessen in-breeding 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). 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 5-4: 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 just with organic soil.

To prepare soil for seedlings 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

The 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 the 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 appropriate 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 away so that all seedlings are fully exposed to sunlight, thus promoting the hardening of the seedlings. If it is not possible to take away the shading panel, all seedling bags should be translocated to an open areas preferably close to a main road. This will help to harden the seedlings, accustom them to real planting conditions and also easier for transportation to planting plots later.

5.2 PREPARATION OF REHABILITATION PLOTS AND PLANTING OF SEEDLINGS

Procedures and practices in the preparation of rehabilitation 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 planting 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. Planning should be done for temporary walkway or ditch crossings, blocking any ditches or drains in the area, calculation of the number of seedlings required and other necessary preparations. Measurements should be taken such as boundary and boundary posts should be erected to prevent encroachment. The planting location should be marked on a map with a scale of 1:50,000. A more detailed map showing the planting plots should be drawn on a letter-size paper (A4) with an appropriate scale. The map should include details about permanent physical features of the landscape such as roads and canals as well as other details. A preliminary survey provides information on suitable plant species to be cultivated and the quantity required for the 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



Figure 5-5: Preparation of rehabilitation area

The bases of the seedlings must be buried when they are planted. 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 (1 m) tall – hence a need for land preparation. Cutting the weeds close to the ground requires a lot of labour 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 procedure makes the preparation cost for planting in the PSF 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 the newly planted seedlings. The seedlings exposed to more sunlight grow better. 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

The PSFs are waterlogged and peat soil is loose and very sodden, the movements of labourers, and transportation of tools or seedlings into the planting site is rather difficult. For a planting area of more than 8ha, 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 the PSFs; 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, *Comptosperma 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 cramp. Therefore, the planting space of each plant species differs. On average, the most appropriate number of seedlings to be planted in the PSFs is 600-1,250 seedlings per hectare. Planting of the seedlings can be in rows especially in open sites which will need high maintenance and rows will enable the easy location of the seedlings. In sites where there is already a presence of scattered trees, the placing can be more random and focused on gap filling.

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 on site (which can last for 6 months).



Figure 5-6: 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 (which are less water tolerant) 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 fruticosum*.

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.

The dry season is a good time for making mounds because the water level in the peat swamp is low. The forest manager often mobilizes the workforce to build mounds for the whole planting area during this season. The seedlings are planted early in the rainy season. 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 large 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 5-7). 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 PSFs grow slowly. Depending on the site conditions, fertilizer applications may be necessary. It has been suggested to use 100g of controlled release fertilizer (15% N: 15% P₂O₅: 15% K₂O) in each planting hole.



Figure 5-7: 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 them. Healthy seedlings may have dried or leaf abscission and broken roots. It should be noted that transporting the 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 the seedlings is time. The 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 the seedlings into large plastic bags with straps. It should be avoided at all times that roots are exposed to sunlight and wind as they will dry out and die off quickly then the seedling will have less chance of survival after planting. 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 5-8: Transportation of seedlings at the planting site.

5.3 MAINTENANCE

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 the seedlings not being able to survive after one month are: they are unhealthy; damaged by the planting procedure; not properly planted; or the soil is not suitable. The 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

The PSF 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 the PSFs. By taking the plant's growth rate and weeding cost into consideration, the weeding twice a month was the most optimum practice in planting programmes in Thailand (Nuyim, 1995).

Maintenance of areas 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

FIRE-PREVENTION AND CONTROL

Most PSFs are degraded and the major cause of degradation is wildfire. 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 PSFs. Fires also burn both above and below ground surface. The fire above the ground may be put out but the underground fire may still be burning or smoldering. When the fire spreads to a larger area and 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 PSFs is low. The only occasion where it is feasible to use water pumps is when there is a large reservoir next to the PSF. Ultimately, prevention is the best strategy to manage fires in the PSFs.

PEST AND DISEASE CONTROL

Problems of disease and insect infestation in peat swamp rehabilitation pilot projects in Southeast 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 the 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. 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 the PSF rehabilitation programme.



Figure 5-9: Tagging and monitoring of planted saplings.

A plot for studying the plant growth should be a permanent plot of at least 40 x 40 meters. Each rehabilitation area should have at least 4 study plots, sited at different locations in the 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 monthly water level.

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 earlier rehabilitation activities indicated that rehabilitation requires wider support, direct commitment from key players (i.e. local government, communities and the private sector).

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

- a. 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.).
- b. Providing management of the area and rehabilitation process (i.e. monitoring, water table management, other inputs, etc.).
- c. 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 factors like negative upstream activities, designation of conservation areas, law enforcement to protect rehabilitation zones etc. . 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 9** for a case study on the rehabilitation of Raja Musa Forest Reserve in Malaysia by the Selangor State Forestry Department and Global Environment Centre.

BOX 9

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



Figure 6-1: Tree planting for peat swamp forest rehabilitation at Raja Musa Forest Reserve, Selangor, Malaysia.

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 gazettment, 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*), *Kedondong* (*Santiria* spp.), *Kelat* (*Syzygium* spp.) (see Figure 6-2) and *Durian* (*Durio carinatus*) (see Figure 6-3) are the dominant tree species within the forest. *Ramin* (*Gonystylus bancanus*) (see Figure 6-4), 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 6-2: Two-year old Kelat Paya (*Syzygium cerinum*) seedlings in a nursery.



Figure 7-3: Durian (*Durio carinatus*)



Figure 7-4: 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

Past 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 yielded 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. Longer term support has been provided by HSBC Bank Malaysia Berhad and Sim Darby Foundation.

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. 1000ha). SFD faced difficulties in getting adequate supply to sustain the planting activities and so a local community nursery was established in partnership with the local community and a local school.

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*, *Camposperma coriaceum*, *Cratogeomys 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 sumatrensis*), *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, waterlogged areas 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 order:

- i. Open grassland → Shrubland → Secondary forest → Regenerating forest
- ii. 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 1: 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) HCV is a Forest Stewardship Council (FSC) forest management designation used to describe areas who meet criteria defined by the FSC Principles and Criteria of Forest Stewardship. Specifically, high conservation value are those that possess one or more of the following attributes:

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

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 paralleled 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., *Diospyros 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 grey zone formed by leaching, overlying a reddish-orange zone formed by the deposition of iron oxide, alumina, and organic matter.

DRAFT

ANNEX 2: SUMMARY TERMS OF REFERENCE FOR THE SECOND RSPO PEATLAND WORKING GROUP (PLWG-2)

Scope of Work

- Monitor trends in oil palm cultivation on peatlands
- Propose refinement related to peatlands in RSPO tools, standards and guidance (PalmGHG, GHG assessment procedure, P&C 2013, NPP, RSPO Next, auditing etc.)
- Review and analyse the experience in implementing RSPO BMPs on peatlands
- Review and update the guidance in the RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat
- Review and update the guidance in the RSPO Manual on Best Management Practices (BMPs) for Management and rehabilitation of Natural Vegetation
- Oversee development of Guidance on drainability assessments for peatlands
- Develop additional guidance and explore incentive options on rewetting and rehabilitation/conservation in peatlands
- Provide guidance for smallholder cultivation on peat.
- Guidance on regionally appropriate definition and practices
- Develop or guide appropriate outreach and capacity building programmes related to the BMP manuals.

Expected Outputs

- i. A review assessing trends in Oil palm cultivation on peat and use of BMPs.
- ii. Updated version of the RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat.
- iii. Updated version of the RSPO Manual on Best Management Practices (BMPs) for Management and rehabilitation of Natural Vegetation associated with Oil Palm Cultivation on Peat.
- iv. New guidance on drainability assessments for peatlands.
- v. New guidance for smallholder cultivation on peat.
- vi. Outreach and capacity development materials.
- vii. Inputs to other RSPO processes

PLWG MEMBERS

The following members of the PLWG2 participated in working group meetings and provided specific inputs or references to support the work of the group. Affiliations were correct at the time of involvement in preparation of manual.

Sector	Substantive members	Alternate members
Growers (Malaysia)	1. Jason Foong (KLK) 2. Raymond Alfred (IOI)	12. Sim Choon Cheak (AAR KLK)
Growers (Indonesia)	3. Joshua Matthews (Bumitama) 4. Gotz Martin (GAR)	12. Lim Sian Choo (Bumitama) 13. Richard Kan (GAR)
Grower (ROW)	5. Ian Orrel (NBPOL) 6. Shahrakbah (Sime Darby)	
Social NGO	7. Jason Hon (WWFM) 8. Riza Harijadudin (Sawit Watch)	14. Wida Nindita (Sawit Watch)
Environmental NGO	9. Faizal Parish (GEC) 10. Arina Schrier/ Kheizrul Abdullah (WI)	15. Julia Lo/Muhamad Faizuddin (GEC) 16. Almo Pradana (WRI)
Palm Oil Processor and Traders	11. Chin Kaixiang (Bunge Loders Croklaan)	17. Rianto Sitanggang (Bunge Loders Croklaan)