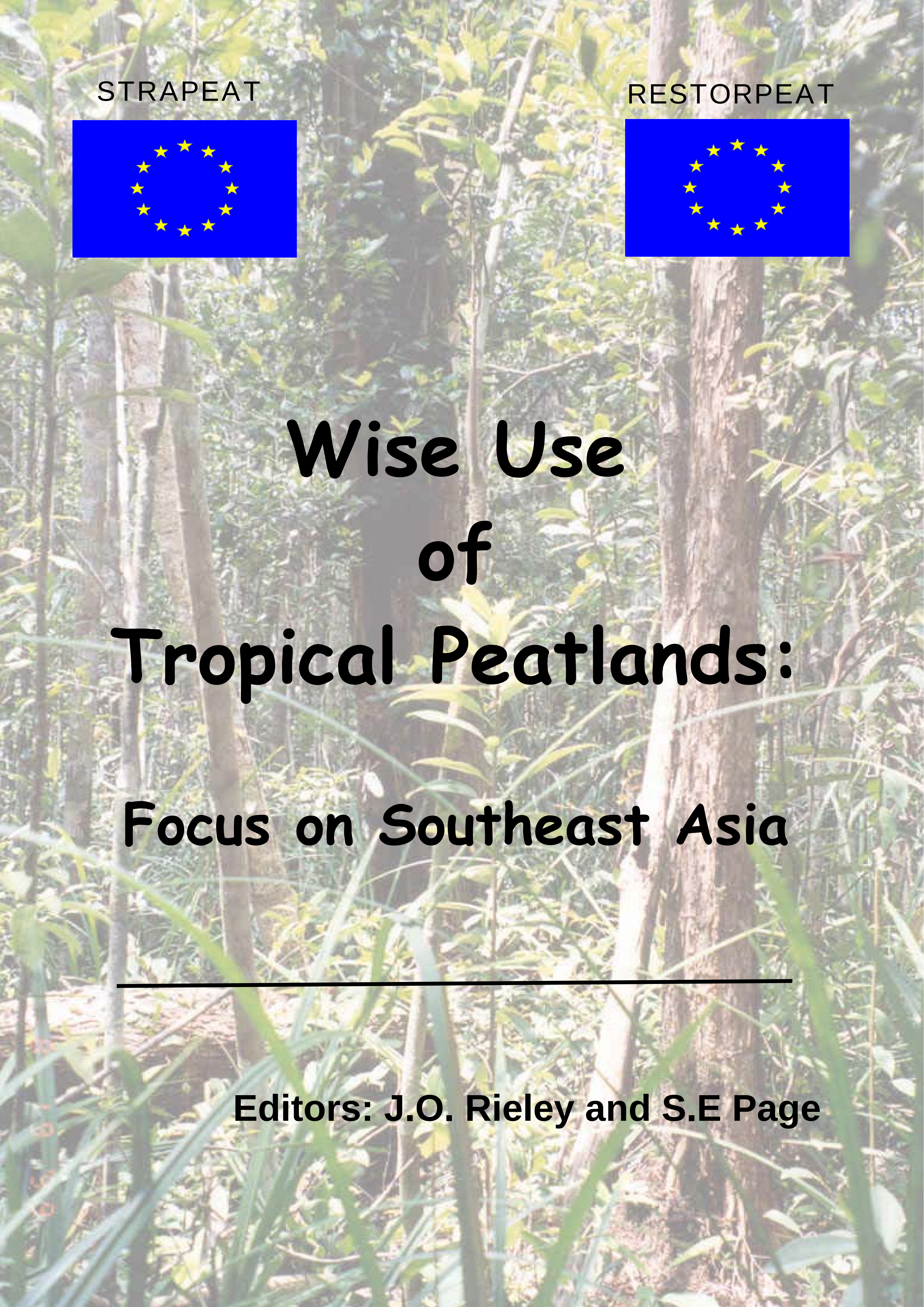

STRAPEAT

RESTORPEAT

Wise Use of Tropical Peatlands:

Focus on Southeast Asia

Editors: J.O. Rieley and S.E Page

Wise Use of Tropical Peatlands:
Focus on Southeast Asia

Synthesis of results and conclusions of the UK Darwin Initiative and the EU INCO EUTROP, STRAPEAT AND RESTORPEAT Partnerships together with proposals for implementing wise use of tropical peatlands

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FOREWORD

International recognition of the biological, environmental and economic importance of tropical peatland has been a slow process. The earliest interest was shown by British and Dutch foresters in the former British protectorates of several Malay States and Northern Borneo, and in the former "Nederlandsch Indië" that later became Indonesia. They focussed on the identification of tree species and assessed the potential of peat swamp forests for commercial forestry. Similarly, employees of the Malayan Department of Agriculture determined properties of peat soils and assessed their potential for crop cultivation. Most studies, however, were low-key and sector development orientated except for the work of J.A.R. Anderson who carried out detailed ecological and taxonomic investigations of the peat swamp forests of Sarawak and Brunei in the 1950s and 1960s. These classic studies, and the publications that ensued, have become benchmarks for subsequent investigations on all aspects of tropical peatland.

Following independence, there was a greater interest in the peatland resource of both Indonesia and Malaysia that led to an increase in the rate of its development. By the end of the 1980s extensive areas of peatland in Southeast Asia, especially in Indonesia, Malaysia and Thailand, had been drained and converted to agriculture. Unfortunately, many of these projects were unsuccessful and gave rise to major land degradation problems. Whilst this peatland development was proceeding, little was being done to document the natural biodiversity of this ecosystem or to determine its natural resource functions and values. Detailed studies began in earnest in 1992 when Jack Rieley, Susan Page, Gaston Sieffermann, Suwido Limin and Bambang Setiadi identified a study site in prime peat swamp forest in the upper catchment of Sungai Sebangau, Central Kalimantan within the logging concession of Pt. Setia Alam Jaya. This became a reference site for a large range of biological, ecological, forestry and microclimatic studies related to the natural resource functions of tropical peatland.

Fieldwork commenced in 1993 when Hidenori Takahashi of the University of Hokkaido, Japan joined this group and for the next five years a large range of studies and monitoring was carried out, on very low budgets, and assisted by a large number of volunteers. More than 100 people were involved, including over 30 international scientists from Indonesia, the United Kingdom, the Netherlands, Japan, Australia, Finland, Germany, Switzerland, Belgium, Malaysia, France and the United States. An extensive database of primary data and published information was accumulated. The research site was given official recognition in 1998 when the Indonesian Minister of Forestry, Nasution, handed over what was now known as the "Natural Laboratory for Sustainable Management of Tropical Peatland" (NAMTROP) to the Ministry of Research and Technology to be managed by the Natural Resources Division of BPPT, while day to day operation was placed in the hands of the Centre for International Cooperation in Management of Tropical Peatland (CIMTROP) under its director, Suwido Limin.

The research intensity increased greatly from 1998 onwards when several applications for funding were successful and the Indonesian partners based at the University of Palangka Raya were able to carry out studies throughout the year. These were as follows:

- 1998-2001: UK Darwin Initiative, partners Universities of Nottingham and Leicester, UK and Palangka Raya, Indonesia; "Impact of land use change and fire on biodiversity of peatland in Central Kalimantan, Indonesia".

- 1998-2002: EU EUTROP Project, partners Universities of Nottingham and Leicester, UK, Helsinki, Finland, Palangka Raya, Gadjah Mada and Sriwijaya, Indonesia, Kalteng Consultants, Germany and Universiti Sains Malaysia, Penang; "Natural resource functions, biodiversity and sustainable management of tropical peatland".
- 1997-2006: (Japanese) JSPS/LIPI Project: "Sustainable management of wetlands in SE Asia".
- 2001-2004: EU STRAPEAT Project, partners ALTERRA - Wageningen University and Research Centre, The Netherlands, Universities of Nottingham and Leicester, UK, Helsinki, Finland, Palangka Raya, Gadjah Mada and Sriwijaya, Indonesia, Universiti Sains and Universiti Malaysia Sarawak, Malaysia, Remote Sensing Solutions, Germany and the Indonesian Agency for Assessment and Implementation of Technology (BPPT); "Strategies for implementing sustainable management of tropical peatland in Borneo".
- 2004-2007: EU RESTORPEAT Project: partners – the same as in STRAPEAT but with the addition of Cantho University, Thailand and Vapo Oy, Finland: "Restoration of tropical peatland to provide sustainable livelihoods".

The range and amount of information collected has increased dramatically as a result of these funded projects and the emphasis has changed from biodiversity, biological and ecological studies to natural resource functions, impact assessment and sustainable management linked to peatland restoration and wise use. In the course of these programmes many developing country personnel have been trained by expatriate scientists and short courses but, more importantly, by masters and doctorate research programmes in the UK, Indonesia and Japan. There is now a highly trained human capacity resource in peatlands research in Indonesia and Malaysia.

The results of these research programmes have been presented at many international meetings and published in numerous scientific and popular journals and magazines. Notable amongst the former are:

- 1995: *International Symposium on Tropical Peatland – Biodiversity and Sustainable Management,* Palangka Raya, Central Kalimantan, September 1995 (Rieley & Page, 1997).

- 1999: *Indonesian National Symposium on Sustainable Management of Tropical Peatlands – Case Study of the Mega Rice Project.* BPPT, Jakarta, April 1999. (This evaluated the failure of the MRP and set out seven guiding principles to President Habibie to formally abandon it (Setiadi, 1999)).

- 1999: *International Symposium on Tropical Peat Swamps.* Penang, Malaysia, July 1999. (Mansor et al, 2004).

- 2001: *International Symposium on Tropical Peatlands – Peatlands for People: Natural Resource Functions and Sustainable Management,* Jakarta, Indonesia, August 2001 (Rieley *et al.,* 2002*)*.

- 2001: *International Symposium on Management of Wetlands – Asian Wetlands* 2001, Penang, Malaysia, August 2001 (Ali *et al.*, 2002).

- 2003: *International Symposium on Land management and Biodiversity in Southeast Asia,* Bali, Indonesia, 17-20 September 2002 (Osaki *et al.,* 2002.)

- 2004: *12. International Peat Congress "Wise Use of Peatlands"* in Tampere, Finland, 06.-11.06.2004 (Päivänen *et al*., 2004)

These meetings and the papers presented at them represent a massive amount of information on tropical peatlands that is now available to help formulate strategies for the implementation of sustainable management of tropical peatlands according to principles of wise use.

Several notable events since 1993 changed the course of scientific research, especially in Central Kalimantan, and increased the importance of the reference data collected there. These are:

- 1995: initiation of the Mega Rice Project to develop one million hectares of wetland, mostly forested peatland, for rice cultivation;
- 1997: the major El Niño event in which a dry season of 8 months duration led to the most damaging fire event in history on the peatland areas of Indonesia, especially Central Kalimantan.
- 1998: downfall of the Suharto regime of 30 years in Indonesia and the ensuing social and economic consequences. This coincided with a financial crisis throughout the whole of the Southeast Asian region.
- 1998 to present: upsurge in illegal logging throughout Indonesia's forests, but with major impact on peat swamp forest
- 1999: abandonment of the Mega Rice Project by President Habibie and its incorporation in the Central Kalimantan *Kapet das Kakab* to promote development of some 2.8 million hectares of peatland for applied economic use, mostly, oil palm, rice and rubber plantations. This scheme was put on ice by the then Minister of Regional Development, Erna Witoelar where it has been cooling ever since but this inappropriate scheme has never been rescinded.
- 2002: a minor El Niño event that led to further widespread fires on peatland areas in Indonesia.

Detailed studies carried out in Central Kalimantan, Indonesia since 1993 show that peat swamp forest has an abundance of fauna and flora and confirm the uniqueness of the ecosystem and its ecological attributes and values. The very special characteristics of tropical peat swamp arise because it is really two ecosystems that have evolved together and maintained each other for thousands of years – peatland and tropical rain forest. The problems that result from development of tropical peatland stem mainly from a lack of understanding of the complexities of this dual ecosystem and the fragility of the relationship between peat and forest. Under natural conditions, for example, waterlogging may occur to a depth of one metre above the surface in the rainy season but the water table may decrease to more than 1.5 metres below the surface in the dry season. This presents a major problem for all kinds of development of tropical peatland since drainage is necessary to prevent flooding during the rainy season whilst irrigation may also be required to overcome periods of water shortage. Once peat swamp forest has been removed and the peat drained, the exposed peat oxidises and loses carbon to the atmosphere, which results in progressive subsidence of the peat surface.

In lowland Southeast Asia most of the peatland is covered in forest and forms part of the mosaic of humid rain forest types that includes mangrove swamp, lowland dipterocarp forest, montane and cloud forest. Peat swamp forests are important for the maintenance of biodiversity but they are also vital for water storage and supply, coastal protection, erosion prevention, flood mitigation and climatic stability. Several of the trees found in tropical peat swamp forest are endemic to the ecosystem and, for some animals, it is their preferred habitat, often because it is the only relatively undisturbed lowland forest habitat remaining for their survival. The most notable example is the orang utan, which used to be common throughout lowland

Dipterocarp forest in the islands of Borneo and Sumatra, but which is now almost confined to peat swamp forest.

Much of the recent increased interest in peatlands globally has resulted from their importance as carbon sinks and stores and their role in carbon cycling between the earth's surface and the atmosphere. There is considerable debate about whether or not peatlands globally are net absorbers or emitters of carbon and under what conditions they may sequester or release this environmentally important element. Much detailed work has been carried out on carbon gas emissions from tropical peatland in Southeast Asia in recent years and is contributing to knowledge of this important topic.

Large areas of lowland tropical peatland in Southeast Asia have been converted to agriculture, following forest clearance and drainage. In Indonesia, for example, the tidal swamps on shallow peat have been cultivated successfully for many years using traditional techniques that utilise daily tidal movements to flush toxic organic substances out of the rice fields. Agricultural development of thicker tropical peats, beyond tidal influence has failed, largely because planners consider peatlands to be just another type of land and do not take into account the special physical and chemical properties of peat soils. This was the case with the Mega Rice Project in Central Kalimantan, which failed in the attempt to convert about one million hectares of wetland (mostly peatland) to rice fields. Similar problems with exploiting deep peat soils (i.e. those with peat exceeding 3 m) have been experienced elsewhere in the Southeast Asia region. Peatland drainage can have a serious impact on water quality. For example, the Mega Rice Project acidified the water in some of the channels making it unsuitable for either domestic or agricultural use. Ironically, one of the main reasons given for locating this project in a peatland area was that the water supply required for padi field irrigation was already in situ, thus reducing the costs of installing an irrigation infrastructure. There is now a vacuum after the failure of this project with uncertainty about how to proceed. Unfortunately, the forces of development and business still view the peatland areas of Central Kalimantan as major opportunities for making large profits at the expense of the environment and its resources.

In common with other forest types in Indonesia, peat swamp forests have been subjected to intensive illegal logging that threatens the integrity and long-term stability of the peat swamp forest ecosystem. Extraction of felled trunks is facilitated by narrow, shallow canals that are dug into the surface of the peat. The bark is usually stripped from the trees and preserving agents applied before they are moved to the rivers along larger canals, causing pollution and a hazard to human health. In the rivers they are tied into rafts and floated downstream to sawmills. The illegal logging in Kalimantan shows some signs of abating largely because the timber resource has almost disappeared. Law enforcement efforts are weak and sporadic at best and government policy is ineffective. Large areas of forest continue to be logged and damaged, however, reducing Indonesia's timber resource, threatening the survival of many species of plants and animals and depressing local economies. In the Sebangau catchment, the reduction in habitat area and quality has affected the orang-utan population, which is showing signs of stress. Illegal logging must be stopped and the canals filled in order to conserve the peat swamp forest and enable its hydrology to recover and its biodiversity to regenerate.

Tropical peat swamp forest resources and natural functions are also being damaged severely by fire and may be destroyed forever with potentially devastating consequences both regionally and globally. The failed Mega Rice Project in Central Kalimantan disrupted the peat swamp forest ecosystem over an area of at least one million hectares and it became fire prone. Eighty per cent of this landscape burned in 1997 releasing about 0.15 billion tonnes of carbon to the atmosphere while peatland fires throughout Indonesia as a whole liberated 1-2.5 billion tonnes of carbon equal to 15-40% of the annual global carbon emissions from the burning of fossil fuels. This was a disaster of catastrophic proportions that not only released vast amounts of carbon from the peat store to the atmosphere as carbon dioxide, methane and soot but also affected human health. In the aftermath of the fires the water absorption and retention properties of the peatland have been impaired. As a result, there has been increased flooding of these vast landscapes during the rainy season with impacts on downstream habitations. There are also increasing periods of protracted drought in the dry season because the drainage channels excavated for agriculture and human settlement as part of the MRP enable water to flow from the peatland quicker than in the previous natural state. Prolonged droughts and fires reoccurred in Kalimantan in 2002, 2003 and 2004, although with less severity than the fires of 1997. Never the less these fires resulted in a further loss to the atmosphere of carbon from the peat carbon store.

It is essential that future land use of tropical peatland takes fully into account the principles and practices of sustainable development and incorporates the 'wise use' approach. Unfortunately, Governments of developing countries in the tropics have priorities other than the maintenance of the natural resource functions of peatlands. The wise use of peatlands involves several elements, foremost amongst which is the identification of the benefits and values that these wetlands can provide and the adverse environmental and human consequences resulting from their disturbance. In this way, the role that tropical peatlands play in providing goods and services to society can be assessed properly and the scale and consequence of various impacts forecast. One of the biggest obstacles to the wise use of tropical peatlands is the division of responsibility for the resources within the peatland landscape to several separate agencies (e.g. agriculture, forestry, land use planning, settlement) that operate virtually independently. These groups often fail to recognise the consequences that their involvement has for others and their unisectoral approach to peatland resource management means that problems are not addressed in an integrated manner. Multiple resource use, involving stakeholders, is more likely to safeguard the range of functions, attributes and services that forested peatlands can provide to a wide range of users.

It is hoped that this book will provide sufficient information and insight on tropical peat and peatland to enable stakeholders to understand this ecosystem and its derivatives better and to anticipate problems before they arise and to put principles of wise use into effect. The various chapters contain data and information that have been obtained from the detailed research carried out in Southeast Asia for more than 10 years, combined with relevant information obtained from a detailed screening of the published literature.

Chapter 1, Introduction, begins with a historical review of tropical peatland in Southeast Asia and outlines the increasing interest in this resource, especially for development and the environment. There is reference to the traditional uses of this peatland by indigenous people and ways in which their livelihoods have been linked to maintaining the resource. There is also an assessment of the problems of deforestation and drainage of tropical peatlands; how these are related to a lack of understanding of the unique properties of tropical peat; and the regional and global role of tropical peatland in climate processes. The need for a wise use approach to the sustainable management of tropical peatland is outlined.

Chapter 2, Tropical Peatlands and Peat, presents information on the location and extent of tropical lowland peatlands in Southeast Asia, an appraisal of their origin and genesis and data on the physical and chemical properties of tropical peat soils. The problem of peat subsidence following land conversion to agriculture is also dealt with.

Chapter 3, Natural Resource Functions and Values of Tropical Peatlands, contains a review of ecological and landscape values, including biodiversity, biomass and nutrient cycling, hydrology, carbon storage, climate and socio-economic aspects.

Chapter 4, Importance of Lowland Tropical Peatlands of Southeast Asia in the Global Carbon Cycle and Climate Change Processes, details their role in carbon sequestration, storage and release from the Late Quaternary to the Present. Data are presented from peat cores obtained from the upper Sebangau catchment in Central Kalimantan, Indonesia. The impact of human disturbance on the carbon cycle of tropical peatlands is evaluated and discussed.

Chapter 5, Uses of and Impacts on Tropical Peatlands and Peat, gives an account of the various types of sector development that have been practiced on lowland tropical peatlands in Southeast Asia with an appraisal of their impacts on the peat swamp forest ecosystem and local, regional and global environments. Agriculture is the principal development land use but consideration is also given to forestry, transmigration (settlement), industrial uses including for energy, commercial and infrastructure provision and wildlife conservation. The over-riding problem of fire that endangers the natural peat swamp forest ecosystem and sector developments is also considered. Prospects for the future of tropical peatlands are discussed.

Chapter 6, Wise Use of Tropical Peatland, synthesises the information presented in the preceding five chapters and integrates this into an assessment of the wise use approach and its application to the sustainable management of lowland tropical peatland in Southeast Asia. It commences with the Ramsar definition of wise use and its key role in the Guidelines for Global Action on Peatlands (GGAP), combines this with concepts defined by Joosten and Clarke (2002) in their book "*Wise Use of Mires and Peatlands*" and applies the synthesis to tropical peatlands. Functions and values of lowland tropical peatlands are elucidated upon and conflicts and constraints identified. Strategies are proposed for the wise use of tropical peatlands that involve balancing requirements for their conservation and development; guidelines for strategic planning and management are provided and tools are suggested for implementation and monitoring.

Several annexes provide supplementary information on the location and extent of peatland in tropical countries (Annex 1), the 'Mega Rice Project' in Central Kalimantan (Annex 2), an alternative funding mechanism for maintaining the biodiversity of natural peat swamp forest and providing sustainable livelihoods for local people (Biorights, Annex 3), the 'Wise Use Statement on Tropical Peatland' (Annex 4) and the Ramsar 'Guidelines for Global Action on Peatlands' (Annex 5).

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CHAPTER 1: INTRODUCTION

Tropical Peatlands – a historical perspective

The oldest reference to peatland in Southeast Asia was by John Andersen (cited in Wichman, 1910) that referred to the presence of peat in Riau, Sumatra in 1794, more than 200 years ago. Peat in Sumatra, and its potential use, was referred to anecdotally by Bernelot Moens in 1863 (a & b), quoting an army captain Meyer who encountered “well combustible peat” near Siak Indrapura, Riau. Subsequently, between 1895 and 1915, large expanses of lowland peatland in Sumatra were described by Bylert, Koorders, Mohr, Potonïé and van Baren. Similar peat-covered landscapes were noted in Kalimantan (Schwaner – South and East Kalimantan; Molengraaff and Teysmann - Kapuas, West Kalimantan) and Sarawak (Hose and Halton) with a suggestion that the combined area of these might extend over more than a million hectares (see Soepraptohardjo & Driessen, 1976).

Figure 1-1: Sumatran peat swamp forest in the 1930s

These were mostly casual references made in the course of other activities, especially land exploration into the interiors of Sumatra and Borneo, without detailed scientific survey, although some descriptive work was carried out by Endert (1920) and van Bodegom (1922) in South Sumatra and Riau provinces (see Anderson, 1976). It was not until the 1930s that specific studies were made of these lowland tropical peatland ecosystems, initiated by Polak (1933, 1950). She investigated their genesis, botanical diversity and agricultural potential over a period of 20 years.

There seems to have been little interest in peatlands in Malaysia (Peninsular Malaya, Sabah and Sarawak) and Brunei for development until the 1950s and 1960s, when Fitch (1952) and Beveridge (1953) described peat soils between old raised beaches along the coasts of Pahang and Terengganu States. Around the same time, Coulter (1950, 1957), in a detailed survey of peatland in Peninsular Malaya, estimated that there were about 800,000 hectares (approximately 6 per cent of the total land area), mostly in poorly draining coastal areas in the centre and south of the country. He classified most of this peat as 'oligotrophic', which is low in mineral nutrients, especially calcium, and high in acidity. The vegetation of Malayan peat swamp forests was described in detail by Wyatt-Smith (1959).

This work was followed by studies carried out in Sarawak and Brunei, including the first ecological appraisal of this ecosystem by Anderson who carried out extensive field surveys of peat thickness, surface levels and tree species composition (Anderson, 1961, 1963, 1964). He described a catena of vegetation types on well-developed peat swamps that is related to ecological conditions and environmental factor differences (Anderson, 1983). After the establishment of Malaysia in 1963, attention was turned to the potential of peatland for agricultural development (Tay, 1969) and numerous assessments were carried out for growing a range of crops and their fertiliser requirements. Peat research stations were opened at Klang in Peninsular Malaysia, and at Stapok in Sarawak as a result of which the results of some 20 years of agronomic research have been made available to serve the region (Kanapathy & Keat, 1970; Kanapathy, 1976, 1978; Kueh, 1972; Tie & Kueh, 1979). This led to the initiation of several agricultural development projects on peatland areas, especially in Johore.

Little emphasis was placed upon the study of peatlands during the first quarter century of the Republic of Indonesia but, in the early 1970s, interest accelerated because the need to increase domestic food production was highlighted in a five year development plan (REPELITA) that promoted rice production in coastal areas. As a result, multidisciplinary studies of soils, ecology, agronomy, engineering and social economy were carried out in the coastal peat areas of Riau and Central and West Kalimantan, jointly by Dutch and Indonesian scientists, which identified the principal problems of reclamation of tropical peatlands (Soepraptohardjo & Driessen, 1976). Apart from the chemical impoverishment of the peat soil and its oligotrophic, acidic nature with extremely low ash content they also noted a range of physical problems of these peats and were firmly of the opinion that *"no other soil type combines so many unused possibilities with so many unsolved difficulties"* and that "*a multidisciplinary effort is needed to find ways to exploit the potentially suitable peat formations in a non-destructing way".* They concluded that the main problems encountered in attempts to develop Indonesian lowland peatlands for agriculture resulted from the lack of nutrients in the peat, poor physical properties and a lack of access to peatland areas that are characteristically remote from centres of population. The first two constraints mean that only a limited range of crops can grow successfully under these difficult conditions while the latter presents major problems for storage, transportation and marketing. Nevertheless, large areas of coastal peatland, especially within the influence of daily tidal movements, were developed for agriculture and human settlement over the ensuing 25 years, albeit with limited success.

Lack of access and limited use

Local people have always understood the adverse and dangerous nature of tropical peat swamps that were flooded for most of the year and which presented virtually impenetrable barriers to access and settlement. As a result, peat swamps were both feared and respected and these wilderness areas were often incorporated into traditional rituals and worship. Traditionally, peat swamps in Southeast Asia were not utilised intensively by indigenous people. Habitation was focused along the banks of major rivers that provided access into the interior where mineral soil and shallow peat soils were used for shifting cultivation. Limited resource exploitation of the forests took place (e.g. mining, latex, rattan, construction timber, food and medicines) to supplement local peoples' subsistence living and provide them with some cash income.

Traditional agriculture on tropical peatland

Traditionally, the indigenous Dayak people of Borneo used only organic soils or very shallow peat areas near to the banks of the rivers (petak luwau) for agriculture, especially for the cultivation of rice, vegetables and rattan. They acknowledged that peat more than 50 cm thick (located in both inland and coastal areas) was unsuitable for agriculture and this was confirmed by the distribution of their villages, which were located mostly in alluvial areas or on shallow peat. Generally, the peat they cultivated was only 20 – 50 cm thick with clay underneath and was water saturated. Rice productivity was low at 1.75 – 3.00 t ha^{-1} depending on the height and duration of flooding and also the incidence of plant disease. The ability of indigenous people to manage shallow peat soils in inland and coastal areas of Central Kalimantan has been destroyed by the construction of the extensive system of wide and deep channels by the Indonesian Government over the last 40 years. Since then rice yields have decreased as the swamp land has dried out (Limin, 1994).

Post-independence peatland development – the demand for land

The cumulative effect of urban migration in Malaysia during the last three to four decades has led to rapid expansion of cities and this has stretched their infrastructure. The ensuing real estate development, together with policy-driven industrial growth since the late 1960s, has caused rapid urban expansion onto agricultural land and peatland on the outskirts of cities. It is common to find plantation areas fringing cities being converted to real estate and other infrastructural development (see Chapter 5).

This large scale conversion of land out of plantation agriculture has resulted in the loss of some of the country's best land to other forms of land use. For example, the rapid industrial and urban development in the State of Johor, which has the best rainfall pattern for oil palm cultivation, has led to a decrease in the area available for this crop. The lack of land with mineral soils for new plantation development in Peninsular Malaysia has led to peat areas being cultivated with oil palm and, to a much lesser degree, with pineapples. In addition, owing to the very high price and demand for palm oil and the availability of vast tracts of low cost, idle land in the East Malaysian States of Sabah and Sarawak, there has been a "gold rush" by plantation companies since the late 1980s to establish plantations in these two states. Today, approximately one-third of the peatland areas in the coastal lowlands of Sarawak have been converted to agricultural land use.

In 1985, Indonesia produced 26.3 million tonnes of rice, more than the demand of 19.8 million tonnes (Kleden *et. al.,* 1999). As a result, President Suharto received an award from the FAO for successfully bringing Indonesia to self-sufficiency in rice production. The success story didn't remain long because Indonesian rice production dropped drastically in subsequent years as some of the best rice growing land in Java was converted progressively for industrial and urban development. In June 1995, President Suharto (Decree 82/1995) decided to open new rice production areas that supposedly would produce 5.1 million tonnes of rice per annum (Kleden *et al.* 1999; WALHI 1999). From this original plan only 1.7 million hectares was finally agreed and the Mega Rice Project in Central Kalimantan was born (see Annex 2).

Government (national and local) perceptions of tropical peatland

In the past, the Government of Indonesia (national and local) did not realise the magnitude of the problems of agriculture on peatland, although local Dayak communities have understood for hundreds of years and many Indonesian agronomists have been carrying out detailed studies of plant growth problems on peat soils for more than 30 years. Even now, sectoral interests make it difficult to manage Indonesia's peatlands and to plan restoration of degraded areas such as the former Mega Rice Project (MRP) (see Chapters 5 and 6, and Annex 2). The Government of Indonesia has conceded that the MRP failed because of inappropriate construction of drainage and irrigation channels but it does not understand how much the hydrology of the ecosystem has been changed as a result. Consequently, new land feasibility projections have been prepared for certain crops based upon obsolete information and outdated policies that justify further transmigration settlement of lowland peatland within the former MRP area. In other words, local knowledge approaches that are compatible with the existing ecosystem are being ignored. The problem for the Indonesian Government is that it is difficult for it to change its policy on projects because planning is made only for short time scales. Project establishment alone is the indicator of success and there are no elements of aftercare, monitoring or sustainability. Even when problems are known, projects are implemented without sufficient experience and only for a particular project in isolation from others. This approach leads to project failures with loss of much money and creation of new problems of poverty and racial tension that are even more difficult and expensive to solve.

Much of the peatland in Sarawak occurs in populated floodplain and coastal zones. In the interests of socio-economic growth, the Government of Sarawak has identified these for sustainable agricultural development as well as urban and commercial growth centres. An increasing area of peatlands in Sarawak is being converted to agriculture, urbanization and other land uses mainly because of the increasing shortage of good or suitable land for further development. Peat soils are generally recognized as problem soils with marginal agricultural capability (Tek *et al.,* 2001). The peat swamps in Sarawak are waterlogged for most of the year and drainage is needed to make them suitable for agriculture or other land uses (DID, 2001). However, drainage causes the peat surface to subside to a level that eventually approaches the river or sea levels. This situation renders further drainage by gravity difficult. The technological gap is the main constraint to peatland development in which current R & D activities are skewed toward agricultural development and only very marginal efforts have been directed to civil, mechanical, and hydrological engineering related R & D solutions.

Lack of understanding and knowledge of natural resource functions and of the regional and global importance of tropical peatlands

In their natural state, tropical peatlands (see Chapter 2) contribute to biodiversity and they perform important environmental and landscape functions (see Chapter 3). In the face of increased demands for development and human settlement, there is an urgent need to demonstrate the direct and indirect environmental and socio-economic importance and values of these ecosystems. Peat swamp forests are important water catchment and control systems (Boelter, 1964). They perform as aquifers by absorbing and storing rain and river flood water during wet periods and releasing water when rainfall is low. They can also provide water for irrigation (Page & Rieley, 1998) and store large amounts of carbon (see Chapter 4). Coastal peat swamps act as buffers between salt and freshwater hydrological systems.

Tropical peatlands are unique ecosystems with chemical, physical and biological attributes that distinguish them from all other terrestrial and wetland areas. Not only does their very existence depend upon precise environmental conditions but they also influence the environment itself. Any changes brought about to this intricate relationship downgrades the landscape functions of tropical peatlands and reduces their natural resource value to both the environment and human communities. Most of the problems result from a lack of understanding of the ecology and natural resource functions of peatland systems and the environmental consequences of draining and developing them (see Chapter 5). There is an urgent need for an holistic approach to gain a much better understanding, not only of their extent and depth, but also of the intricate relationships between the forest and peatland components. It is also important to understand the interrelationships between peat swamp forest trees and the environmental factors that led to the initiation of peat formation and its accumulation over thousands of years. In addition, the functional roles of tropical peatland and their impact upon local, regional and global climates, past, present and future (see Chapter 4), must be evaluated and their contribution to environmental sustainability determined (Rieley *et al.* 1996a).

The need for wise use of tropical peatlands

Wise use of tropical peatlands is essential to ensure that sufficient area of this resource remains to carry out vital natural resource functions while satisfying essential requirements of people now and in the future. It involves evaluation of their functions, uses, impacts, and constraints so that, by assessment and reasoning, it is possible to highlight priorities for their management and wise use, including mitigation of past and future damage. Wise use of tropical peatlands involves integrated planning and management of vast landscapes and the challenge is to develop mechanisms that can balance the conflicting demands on the tropical peatland heritage to ensure its continued survival to meet the future needs of humankind (see Chapter 6).

Peatland resources can provide long-term support to the economy of local communities and to the economic growth of developing tropical countries. The planning for wise use of tropical peatland, however, requires an understanding of the necessity for both development and conservation of tropical peatland, and the ability to choose management options to balance the two optimally. In developing countries in the tropics these two apparently opposing requirements have failed, largely because they have been directed from 'top down' and funded and propelled by outside agencies, governments and international NGOs. As a result, local people have become enmeshed in the 'poverty trap' and resort to over-exploitation of natural resources that places consequential stress upon environmental functions and processes and can lead to racial tension.

CHAPTER 2: TROPICAL PEATLANDS AND PEAT

Introduction

Many aspects of peatlands globally have been studied in detail, but there is still little concordance between the various estimates of the extent of the resource. This is a major problem in the tropics where the area occupied by peatlands has not been assessed accurately and data are being updated constantly (Immirzi & Maltby, 1992). The reasons for this are (a) lack of agreement on the definition of peatlands and their soils, (b) evaluation for single sector interests, which ignore peatlands suitable for other purposes, (c) different techniques used in surveying and mapping and (d) loss of natural peatlands to other land uses since surveys were carried out. The data for the area of peatland in Indonesia, for example, highlight these problems. Jansen *et al.* (1985) estimated that there were 16 million hectares with a peat thickness of at least 0.5 metres; in the same report, however, they referred to 27 million hectares of peat soils. Andriesse (1988), however, believed that the higher figure, which was based upon aerial photographs, was an over-estimate since much of the land interpreted as coastal peat swamp had been found to consist of mineral soils. The inventories for some tropical countries, e.g. Malaysia and Thailand, have become outdated and inaccurate owing to rapid decrease in the area of natural peatland following forest removal, drainage and utilisation for agriculture and settlement. In both of these countries most of the shallowest peats have already oxidised and disappeared following exploitation and fire.

The area covered by peatlands in the tropics is very large, therefore surveys have relied strongly on aerial photographs and, more recently, satellite remote sensing. With both of these methods, however, it is difficult to determine accurately the boundaries between mineral and peat soils since both support forest, often of similar structure. It is almost impossible to differentiate between sub-types of peat swamp forest or to estimate the thickness of the peat underneath using satellite imagery, including Radar. For example, some areas of tall forest (>40 m) in Central Kalimantan, now known to be on peat 8-13 metres thick, were believed formerly to be growing on podzolized mineral soil.

Major problems in classifying peat and understanding peat-forming processes in the tropics arise from the lack of detailed, standardized and precise site-based information across the equatorial zone. The theories concerning the origin of peat in the tropics and its genesis are based upon experience of temperate peatlands with the underling assumption that they are analogous systems, an approach that has clouded the evaluation of tropical peatlands. There are major differences between the genesis, evolution and present vegetation of the lowland acid peatlands of boreal/temperate and tropical zones. In the tropics, lowland peat-forming systems are almost exclusively sub-coastal in location and influenced by a climate that is hot and humid with little temperature variation either diurnally or seasonally. Initiation of tropical peat is unlikely to have conformed to the open water/fen model favoured for boreal/temperate peatlands and probably commenced in response to substrate waterlogging caused by extremely high rainfall and permanent flooding. It is also possible, however, that organic matter accumulation could have been promoted following prolonged periods of high rainfall, which caused soil leaching and acidification and a reduction in microbial activity (Sieffermann, 1988). In both temperate and tropical regions evolution of peatlands has taken place over thousands of years with the eventual formation of ombrotrophic peat bogs, although the initiating circumstances and environmental conditions were not the same and the vegetation which grew on them and formed the peat was very different, not only in species but also structure. This has resulted in the formation of peat of greatly divergent physical and chemical nature between these major climatic zones.

Figure 2-1: Aerial view of forest in the peat swamp area of Central Kalimantan

Figure 2-2: Dense forest vegetation on degraded peatland in Central Kalimantan

Whilst there are some publications on the structure and vegetation of peat swamp forests in Southeast Asia, the peat soils to which they give rise and their potential for various kinds of development, there is comparatively little information on the peatlands of other tropical regions. Many of the scientific articles which have been published in Malaysia, Indonesia and Thailand, however, are reviews of data provided by the same few primary sources. Even in these countries, the picture is far from complete and detailed information is still required on the true extent of the resource, the genesis and evolution of individual peatlands, the natural vegetation that they support and the environmental functions they perform. This chapter attempts to fill some of the gaps in knowledge.

Origin and genesis of tropical peatlands

Wetlands, in general, provide conditions conducive to the accumulation of organic deposits as a result of the reduced rate of decomposition of the many plants that grow in, on and around them. Decomposition under waterlogged conditions is facilitated largely by fungi, anaerobic bacteria, algae and certain types of microscopic aquatic animals (Brady, 1990). These break down some of the organic material liberating gases, for example hydrogen sulphide, methane and ammonia, and producing humus. Over time, this incomplete decomposition leads to progressive accumulation of organic material that is termed ‘peat’. There is some debate over the minimum thickness of peat (30 - 50 cm) and the amount of organic matter (>30 %) to define a peatland. Peat is formed in organic matter-accumulating ecosystems called mires (Joosten & Clarke, 2002); a peatland may or may not be accumulating peat; some peatlands are degrading and their surface peat is oxidising and liberating carbon dioxide to the atmosphere.

Figure 2-3: Flood zone along Sungai Sebangau, Central Kalimantan

The conditions necessary for organic matter accumulation and peat formation are topographical (flat, gently sloping, water impounded landscapes), climatic (high rainfall and humidity), hydrological (waterlogging and water stagnation), chemical (high acidity, low nutrient status and oxygen deficiency), biological (reduced activity of decomposers) and temporal (up to many thousands of years). These conditions prevail in the per humid tropics wherever the amount of rainfall exceeds the rate at which surface water can evaporate or drain off the landscape and they have led to peat formation across vast areas at low altitudes between rivers in coastal and sub-coastal locations. The South East Asian peatlands are included within the area with an annual water deficit of less than 100 mm. Resistance to the outflow and subsurface drainage of water is increased by low gradients and land surface changes (e.g. sea level increase and/or land surface decline) and soil podzolization. The last of these has led to formation of sub-surface iron pans that prevent vertical drainage (Sieffermann, 1988). In Southeast Asia, waterlogged conditions prevail in the coastal lowlands of Kalimantan, Sumatra and West Papua in Indonesia, Peninsular Malaysia, Sarawak and Sabah in Malaysia and in the provinces of Narathiwat, Nakornsrithamrat, Chumporn and Trad of Southeast Thailand. There is a small area of shallow peat in the Mekong Delta of Vietnam and some in the southern islands of the Philippines.

The waterlogged conditions that developed in these extensive lowlands favoured establishment of mangrove, freshwater swamp and peat swamp forests and resulted in the accumulation of peat up to 17 m thick (Polak, 1950). Peat that forms under the influence of fluctuating levels of river flood water is referred to as *topogenous* whilst that subjected to rainfall only is *ombrogenous*. The former can be found along the banks and flood zones of rivers but the latter makes up most of the tropical peatland resource in the lowlands of Southeast Asia where it extends over catchments and watersheds. Ombrogenous peats have a characteristically domed surface that is reminiscent of the raised bogs of temperate and boreal zones (see Box 2.1). They have been studied intensively in Sarawak (Anderson, 1961), Sumatra (Diemont and Supardi, 1987; Brady, 1997, Neuzil, 1997) and Central Kalimantan (Page *et al.,* 1999; Sieffermann, 1988).

Table 2.1: Changes in peat thickness, peat surface elevation and peat surface gradient along a 24.5 km transect from Sungai Sebangau to the watershed with Sungai Bulan in Central Kalimantan. (from Page *et al.,* 1999)

Distance from Sg. Sebangau (km)	Mean peat thickness (m)	Cumulative change in surface elevation from Sg. Sebangau (m)	Gradient	Main forest types
0-1.5	1.2	+1.7	1:882	Riverine
1.6-5.5	3.7	+7.6	1:678	Mixed swamp
5.6-12.5	8.4	+11.9	1:1628	Low pole
12.6-16.0	8.3	+17.5	1:625	Tall interior
16.1-20.0	10.5	+20.2	1:1482	Tall interior
20.1-24.5	9.5	+19.1	1:4091	Tall interior/very low pole
overall	7.8	+20.2	1:990	Peat swamp forest

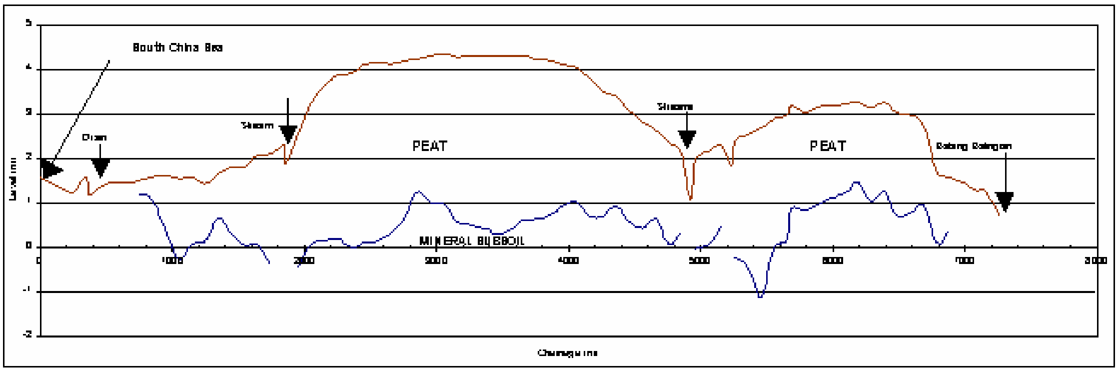


Figure 2.1: Cross-section through a peat dome in Sarawak (PS Konsultant 1998)

Age of lowland peat swamps of Southeast Asia

Palaeoenvironmental studies of the coastal peat deposits have demonstrated that these are the youngest peatlands in the region. Peat accumulation in most of these deposits commenced around 3500-5500 14C yrs BP, following stabilisation of rising sea levels (e.g. Anderson & Muller, 1975). In comparison, investigations of sub-coastal and inland peatlands, particularly in Borneo, have revealed much earlier dates for the initiation of peat formation, ranging from Late Pleistocene (~40,000 14C yrs BP) for the peatlands of the Danau Sentarum basin in West Kalimantan (Anshari *et al.*, 2001, 2004) to ~22,000 14C yrs BP for high peat in the Sebangau catchment, Central Kalimantan (Page *et al.*, 2004) through to the early Holocene (10,000-7000 14C yrs BP) for other high and basin/valley deposits within Borneo (Neuzil, 1997; Sieffermann *et al.,* 1988; Staub & Esterle, 1994). Clearly some tropical peatlands were involved in the global carbon cycle prior to the commencement of the latest main phase of peat formation in the boreal and temperate zones, where extensive peat growth did not begin until around 7,000 to 8,000 14C yrs BP (Maltby & Proctor, 1996). Several studies of tropical peatlands have, however, emphasised that the formation of contemporary deposits has been a dynamic process and that periods of alternating accumulation (during which they act as carbon sinks) and degradation (when they are carbon sources) have probably occurred in most deposits throughout their history (e.g. Anshari *et al.*, 2001).

At the present time, and in the absence of human intervention, many tropical deposits are actively accumulating peat or are in a steady state (Brady, 2002), although climatic and land use conditions are no longer conducive to continued accumulation at all sites (Page *et al.*, 1999; Sieffermann *et al.*, 1988). The current average peat accumulation rate for Indonesian peatlands has been estimated to be between 1 and 2 mm yr^{-1} (Sorensen, 1993), which is substantially higher than the rates of 0.2 to 0.8 mm yr^{-1} obtained for boreal and subarctic peatlands (Gorham, 1991) and of 0.2 to 1 mm yr^{-1} for temperate peatlands (Aaby & Tauber, 1975). Estimates of carbon accumulation rates in tropical peatlands range from 0.59 – 1.18 t ha^{-1} yr^{-1} (Sorensen, 1993) to 0.61 – 1.45 t ha^{-1} yr^{-1}. These values greatly exceed the average carbon accumulation rate for boreal and subarctic peatlands of 0.21 t ha^{-1} yr^{-1} (Clymo *et al.*, 1998).

Box 2.1: Ombrogenous lowland peat swamps of Southeast Asia

Many ombrogenous tropical peat swamps are bordered by the sea and by rivers, and have a dome-shaped surface (Fig. 2.1). On the seaward side, the borders consist of mudflats or sandy beach deposits. On the landward side, along the banks of major rivers, levees of mineral soils form the boundaries. Levees are prone to flooding; sometimes they are very narrow or non existent. Most lowland tropical peatlands are located in areas under tidal influence. Tidal ranges along the Borneo coast may vary from about 2 m to almost 6 m. The influence of the tide is not restricted to the immediate coastal area but it can extend up rivers, reaching as far as 100 km inland. The youngest peat swamps are found closest to the coast with their highest point only 3–4 m above mean sea level.

The gradient of the marginal zone of the peat domes of coastal peat swamps is relatively steep (e.g. 6.85 m in 604 m in Sarawak equal to 1 in 88) and is analogous to the rand of temperate and boreal bogs (Anderson, 1983). The centre of these bogs is almost flat with a rise of only about 1 metre per kilometre. This steep marginal zone is not evident on the inland peat swamps of Central Kalimantan where the gradients are much less (e.g. 7.6 m in 5,500 m, equivalent to 1 in 724) and the landscape appears virtually flat. In addition, the gradient on the surface of these bogs changes across the watershed and is least in the centre (Table 2.1) (Page *et al.* 1999). In basin tropical peatlands (q.v), the subsoil beneath the peat is mainly below normal river level but only rarely below sea level. The topography of the subsoil usually drops gently from riverbanks or the coast to the centre of the swamps and gives the peat deposits their characteristic biconvex cross-section. Where old riverbeds or levees are buried under the peat, there are small rises and falls in the mineral substratum (Anderson, 1961), which is often sulphidic. When this is the case, the peat layer acts as a protective sponge that keeps the underlying mineral subsoil in a wet, anaerobic condition. Once the peat has disappeared, however, the mineral subsoil surfaces, available pyrite oxidises, and acid sulphate soils form with consequently very low pH values.

In coastal parts of Borneo, and also probably in Sumatra, the subsoil is composed largely of clay, sand and silt that was deposited originally in bays, deltas and estuaries of the main rivers, where these were colonized initially by mangrove vegetation. In Peninsular Malaysia, particularly on the east coast, the initial development of peat may have occurred in isolated lagoons formed by sand bars and spits over subsoil composed of coarser material. In the interior of Central Kalimantan, the peat was initiated more than 20,000 years BP on top of the upper coarse sand layer of the Giant Podzol formation that extends across the middle of this province where it was formed more than 50,000 years ago as a result of intense leaching of the soil when the sea level was much lower than at present (Sieffermann, 1988). The creation of an impervious 'hard pan' up to two metres thick at a depth of several metres below the surface gradually impeded vertical drainage and led to the waterlogging that was a prerequisite for peat initiation and accumulation.

Peatland formation in the coastal lowlands of Southeast Asia has been influenced by sea level changes and tectonic land surface movements over many millennia. In general, the coastlines of northern Borneo and eastern Sumatra are rising and new land is constantly being added that presents continuing opportunities for increasing the area of peat swamps. In Sarawak, for example, the coastline at the mouth of the Sungai Baram has been advancing at an average rate of 9 - 10 m per year (Anderson, 1964). On the southern side of Borneo and on the west of Sumatra the coastlines are in decline causing water to back up the major rivers, leading to flooding throughout much of the year and promoting further peat accumulation

Location and extent of tropical peatlands

Tropical peatlands occur in mainland East Asia, Southeast Asia, the Caribbean and Central America, South America and southern Africa (Annex 1). The current estimate of the total area of undeveloped tropical peatland is in the range 30-45 million hectares, which is approximately 10-12% of the global peatland resource (Immirzi & Maltby, 1992). Since most of this is situated at low altitude in coastal and sub-coastal locations it is likely to be developed at a faster rate than the peatlands that remain in temperate and boreal zones

Table 2-2: Summary Statistics for Tropical Peatlands (based on Immirzi & Maltby, 1992; Rieley *et al.*, 1996)

REGION	Area (1000 ha)	
	Mean	Range
Central America	2,437	2,276 - 2,599
South America	4,037	4,037
Africa	2,995	2,995
Asia (mainland)	2,351	1,351-3,351
Asia (southeast)	26,435	19,932 - 32,938
The Pacific	40	36 - 45
TOTAL	38,295	30,627 - 45,965

Location and extent of peatlands in Southeast Asia

These occupy mostly low altitude coastal and sub-coastal situations and extend inland for distances of more than 100 km along river valleys and across watersheds. They cover more than 26 million hectares (69% of all tropical peatlands) at altitudes from sea level to about 50 m amsl. They are most fully developed on the coasts of East Sumatra, Kalimantan (Central, East, South and West Kalimantan provinces), West Papua, Papua New Guinea, Brunei, Peninsular Malaya, Sabah, Sarawak, Southeast Thailand and the Philippines (Figure 2.2; Table 2.3).

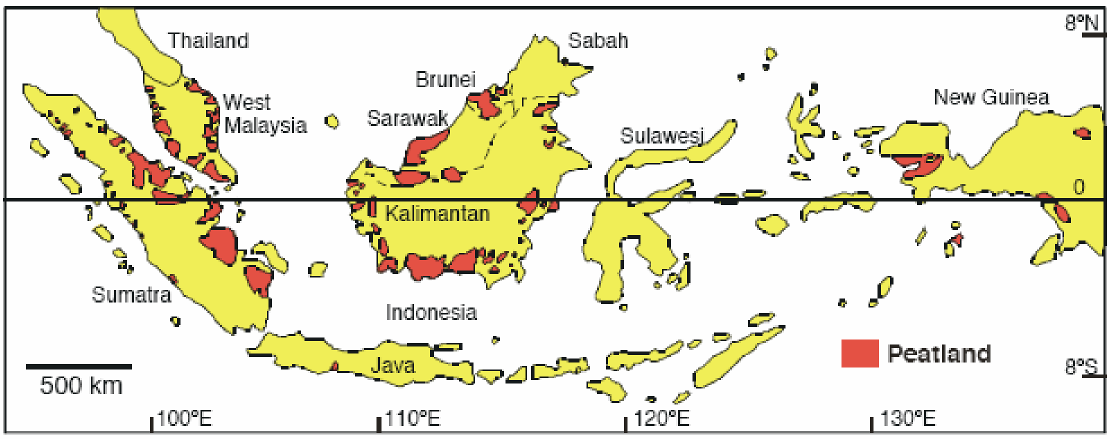


Figure 2.2: Geographical distribution of peatland in Malaysia and Indonesia

Table 2-3: Summary statistics for tropical peatlands of Southeast Asia (based on Immirzi & Maltby, 1992; Rieley *et al.,* 1996)

Region	Area (1,000 ha)	
	Mean	Range
Indonesia	18,963	17,853 - 20,073[1]
Malaysia	2,730	2,730[2]
Papua New Guinea	1,695	500 - 2,890[3]
Thailand	64	64[4]
Brunei	110	110[5]
Vietnam	24	24[6]
Philippines	10	10[4]
Total	23,596	21,291-25,901

[1]The figures for Indonesia show the greatest variation in estimates for the tropical region as a whole. The range is based on information in RePPProT (1988-1990). [2]Data are derived from several sources, e.g. Mutalib *et al.,* 1992. [3]Shier (1985) and FAO (1974) provide the lower estimate, Wayi & Freyne (1992) who included upland peat are responsible for the higher. [4]Lappalainen (1996). [5] Hunting Technical Services Ltd (1969); Anderson & Marsden, 1988. [6]Institute of Soil and Agriculture, Ministry of Agriculture and Rural Development. Inventory data are for wetlands and it is difficult to determine the area of peatland, much of which has been drained and converted to agriculture and aquaculture (Oravainen *et al.,* 1992)

Brunei Darussalam

Large areas of swamp forests still exist in Brunei, of which the most widespread type is peat swamp forest. The greater proportion of Brunei's peatlands occurs at low altitude, near to the coast, from sea level to about 50 m amsl. Small areas of peatland are found also in highland areas, where they are associated with Kerangas or heathland. The estimated extent and distribution of peat soil types (Histosols) in Brunei is summarised in Table 2.4**.**

Table 2-4: The extent and types of organic soil in Brunei (Source: Hunting Technical Services Ltd (1969); Anderson & Marsden, 1988)

	Area (ha)	% of Land
Deep Peat Soils	98,884	17.4
Shallow Peat	10,616	1.9
Total	109,500	19.3

Based on their topography, three categories of peatlands are described from Brunei:

1. *Coastal Peat* is located in sub-coastal and deltaic areas and is the most extensive type. The largest single area is in the lower Belait Plain, which is part of the great Baram-Belait peat swamp, covering about 101,500 ha. Peat thickness is frequently in the range 10 - 15 metres (James, 1984).
2. *Basin or River Valley Peat* occurs inland along river valleys at levels slightly higher than coastal peat, usually 5 - 15 metres above mean sea level, forming a transition between the basin swamps and the uplands in the interior. The main areas are along the middle and lower reaches of the Sungai Tutung and Sungai Belait.
3. *Highland Peat* develops in elevated sites on wet mountains and plateaux or along low altitude river terraces or raised beaches in the Tutung, Belait and Temburong Highlands.

Indonesia

Although Indonesia possesses the largest area of peat in the tropics there are several estimates of the resource arising from differences in the definition of peat and peat soils and the survey techniques employed. The highest estimate of 27 million hectares (Radjagukguk, 1992) places Indonesia fourth in the world league table of peatland resource by area, behind the former USSR, Canada and the USA. Sukardi & Hidayat (1988) provided a lower estimate of 18.5 million hectares for the total peatland area, of which 50.4% occurs in Kalimantan, 24.9% in West Papua and 24.3% in Sumatra. In addition, there are small amounts in West Java, Central Sulawesi, South Sulawesi and Moluccas.

Table 2.6: Peatland use in Indonesia

	Land use	**Area (ha) RePPProt (1990)**	**Area (ha) RePPProt (1988)**
Sumatra	UNC	2,800,000	3,637,150
	UPC	2,640,625	2,950,125
	PCF	715,625	822,450
	NCF	436,250	477,225
	LPF	192,500	199,250
	PF	156,250	166,250
	Total	6,941,250	8,252,450
Kalimantan	UNC	1,800,050	3,722,600
	UPC	2,057,350	312,250
	PCF	1,826,250	1,994,050
	NCF	216,875	246,875
	LPF	384,375	411,350
	PF	97,500	100,425
	Total	6,378,800	6,787,550
Irian Jaya	UNC	500,000	314,550
	UPC	1,606,875	1,892,675
	PCF	977,500	998,250
	NCF	596,375	646,275
	LPF	430,625	530,750
	PF	146,875	241,650
	Total	4,231,250	4,624,150
Sulawesi	UNC	NA	NA
	UPC	76,000	61,125
	PCF	84,400	82,450
	NCF	NA	NA
	LPF	10,900	77,800
	PF	32,200	90,075
	Total	203,500	311,450
Halmahera & Seram	UNC	NA	NA
	UPC	14,170	12,060
	PCF	49,640	47,050
	NCF	4,425	4,890
	LPF	21,150	24,150
	PF	8,740	9,075
	Total	98,125	97,225
Indonesia Total		17,883,525	20,072,825

UNC = unclassified, UPF = unlimited production forest, PCF = production & conservation forest, NCF = natural conservation forest, LPF = limited production forest, PF = protection forest

Almost all of the peat in Indonesia is of the ombrogenous type with topogenous peat occurring only in a few locations; there are at least 4.46 million hectares of lowland ombrogenous peat with a thickness greater than 2 m (Euroconsult, 1983). Two recent estimates of the area and geographical distribution of Indonesian peatlands are provided by RePPProT (1988, 1990) (Table 2.5), and a breakdown of the principal land use is provided in Table 2.6

By 1990, about 531,000 ha of peatlands in Indonesia had been used for agriculture-based transmigration settlement and by local inhabitants. These lands will eventually come under private ownership. The rest of Indonesia's peatlands are under the stewardship (legally) of the Ministry of Forestry (Radjagukguk, 1990). An increasing area of peatland in Indonesia is being used for the cultivation of perennial estate crops such as coconut and oil palm but this is dwarfed by the infamous 'Mega Rice Project' that operated between 1996 and 1999 with the objective of converting around one million hectares of wetland in Central Kalimantan (mostly peatland) to rice cultivation to support nearly a quarter of a million families (see Annex 2). No definitive figure is available for the overall extent of peatland development in Indonesia

Malaysia

The total peatland area in Malaysia has been estimated to be 2,730,500 hectares (Mohd Ali, 1989). The geographical distribution and land use of Malaysian peatlands are shown in Table 2.7.

Table 2.7: Geographical distribution and area of Malaysian peatlands

Region	Peatland area (1000 ha)	% of total	Agriculture (1000 ha)	Forest (1000 ha)
Peninsular Malaysia[1]	984.5	36.0	313.6	670.9
Sarawak[2]	1,660	60.8	260	1,400
Sabah[3]	86	3.2	-	86
Total	2,730.5	100	573.6	2,156.9

[1] Coulter, 1957, [2] Tie & Kue, 1979, [3] Scott, 1989

Peat swamp forests occur chiefly in the southern third of **Peninsular Malaysia** where they extend inland, especially in Pahang; they are of scattered occurrence elsewhere along both the east and west coasts. On the west coast the underlying soil may be clay, but in the east it is usually sand (Stone, 1971). Pristine peat swamps used to occupy an area of almost one million hectares (Coulter, 1957) but this has been reduced by almost 50% as a result of forest clearance and drainage for agriculture and other uses, and there are only three major areas of peat swamp forest remaining (Anon, 1987): (a) the North Selangor Peat Swamp which has been gazetted as permanent forest reserve; (b) the South Selangor Peat Swamp (also known as Kuala Langat South Forest Reserve); and (c) a continuous block of peat swamp forest which extends from Kuantan to Endau along the east coast. Most of the peat swamp forests in permanent forest reserves on the east coast are unlogged, whereas on the west coast most, including permanent forest reserves, have been extensively logged.

The peat swamp forests of **Sarawak** and **Sabah** are located behind the coastline extending from the mangrove swamps inland along the lower reaches of the main rivers.

Sarawak: There are about 1.66 million hectares (Tie & Kueh, 1979) of peatlands in Sarawak, which accounts for about 13% of the State's total land area. They are concentrated near the towns of Miri, Sibu and Sri Aman. In 1990 large tracts of peatland, particularly in Sarawak, were still forested and under the stewardship and management of the Forestry Department. In recent years, there has been increasing pressure to develop peatlands for plantation agriculture since, apart from their extensive occurrence, they are easily accessible and close to highly populated areas (Hashim, 1984). The areas which have been converted to agriculture are under private ownership by smallholders and large firms.

***Sabah**:* The conservation of peat swamp forests in Sabah is a cause for great concern since their extent has always been relatively small. Peat swamp forests once covered an estimated area of 100,000 ha state-wide, less than 2% of Sabah's land surface. In the 1980s, their extent was estimated to be 86,000 ha (Scott, 1989) but by 1998 this had fallen to only 40,000 ha. There is floristic variation between the peat swamp forests of the east and west coasts of Sabah, the underlying causes of which are poorly understood (Ong *et al.* 1998). The Klias Peninsula formerly supported the largest area of PSF in Sabah of some 60,000 ha in total. Virtually all the remaining mixed PSFs are found within the Binsuluk and Klias Forest Reserves, while some occurs within the IPPA (Identification of Potential Protected Areas component of the Sabah Biodiversity Conservation Project area). Unfortunately, fires during the El Niño-associated drought of 1997/8 destroyed more than half of the Binsuluk Forest Reserve. As a result, it is estimated that not more than 10,000 ha of the Klias PSF remains intact (Ong *et al.* 1998).

Papua New Guinea

The land area of Papua New Guinea is 46.5 million hectares of which approximately 2.89 million hectares consists of peat soils or histosols. These include high altitude peats (>3,400 m) and those of the highlands (c. 1,600 m amsl) and lowlands (<600 m amsl); the latter jointly total 2.19 million hectares. The exact area of lowland coastal peat has not been documented separately (Wayi & Freyne, 1992). Peat can be up to 10 m thick, consisting of layers in various stages of decomposition, the deepest being generally the most decomposed. In areas of volcanic activity the peat may contain zones of deposited mineral material of varying thickness. According to Richards (1952) there are vast areas of swamp vegetation in the lowlands of New Guinea, including forests of sago palm (*Metroxylon spp*.), which provide food for local inhabitants.

Philippines

The literature refers to the presence of only a small amount of peatland, mostly in the southern island of Mindanao, primarily in Agusan and Liguasan marshes. The information, however, is not precise on location and area (Lappalainen, 1996). A feasibility study carried out in the late 1980s estimated that marshy and swampy areas in the Philippines occupied between 103,500 and 240,000 ha of which only around 10,700 ha was peatland (Oravainen *et al.,* 1992). Much of this peatland is shallow, compacted, and has been converted to agriculture.

Thailand

The peat swamps of Thailand, which constitute only 0.1% of the land area (Dent, 1986), occur mainly in coastal areas of the east and southeast of the peninsula around the Gulf of Thailand in the provinces of Narathiwat, Pattani, Noi Phattalung, Chumporn and Trad. Most of the remaining peat swamp forest, however, is situated in Narathiwat Province, which contains 45,336 hectares of the 64,000 hectares (Urapeepatanapong & Pitayakajornwute, 1992) (Table 2.8). Prior to 1975, most of the peat swamps of Narathiwat Province were undeveloped owing to permanent waterlogging, dense vegetation and inaccessibility. Prompted by national requirements for increased agricultural production about 16,000 hectares of peat swamp forest were drained for land development. Lack of understanding of the characteristics of peat swamp land created major problems in its conversion and much of this drained land has not yet been utilised successfully. In pristine peat swamps the thickness of peat is up to 3 m whilst, in drained areas, it is less than 1.5 m. The latter are subject to subsidence (often hastened by fire) and some have disappeared, exposing acid sulphate soils.

Province	Peatland area (ha)	% of total
Narathiwat	45,336	71.1
Nakornsri-thamarat	12,330	19.3
Chunporn	2,704	4.2
Trad	1,917	3.0
Songkhla	887	1.4
Pattelung	446	0.7
Pattani	180	0.3
Total	**63,770**	**100**

Table 2.8: Geographical distribution and extent of peatland in Thailand (Urapeepatanapong & Pitayakajornwute, 1992)

The nature of tropical peat soils

Classification of tropical peat soils

The classification of tropical peat soils has long been a controversial and confusing topic (Mutalib *et al.,* 1992). Different approaches have led to poor correlation of information between countries and sometimes even within a single country. In Indonesia, swamps are differentiated into three broad zones, namely, brackish tidal land, freshwater tidal land and non-tidal land. Peat soils in Malaysia were classified originally according to their inherent fertility status as eutrophic, oligotrophic or mesotrophic (Coulter, 1950). Soils in the first of these categories have a high nutrient content and are neutral or alkaline in reaction; the second have a low mineral content and are acid in reaction; the last is intermediate between the first two types with a pH around 5.0. Early, semi-detailed soil surveys utilised other criteria, including, (1) loss on ignition, (2) peat thickness and (3) fibre content (Farnham & Finney, 1965; Law & Selvaduri, 1968).

Based on loss on ignition, tropical peat soils were classified as organic clay (20-35%), muck (35-65%) and peat (>65%). Loss on ignition provides information on organic matter content only and does not define the nature of the organic materials.

The thickness categories used to classify tropical peat have also varied. Three thickness intervals are usually provided. The early reconnaissance surveys in Peninsular Malaysia used (1) <0.6 m (2 feet), (2) 0.6-1.5 m (2-5 feet) and (3) >1.5 m (5 feet) (Coulter *et al.*, 1956). In subsequent, semi-detailed soil surveys these were revised to (1) shallow peat (<150 cm), (2) moderately deep peat (150-300 cm) and (3) deep peat (>300 cm). In order to stress that the minimum thickness of the organic layer should be 50 cm to qualify for classification as peat, the categories were changed to reflect this important condition to (1) shallow peat (50-100 cm), (2) moderately deep peat (100-300 cm) and (3) deep peat (>300 cm) (Lim, 1989). In Sarawak, in contrast, only two major peat depth classes are differentiated, namely, shallow (50-150 cm) and deep (>150 cm) but, in addition, three depth phases are identified for deep organic soils: 150-200 cm, 200-250 cm and >250 cm. There is similar confusion in Indonesia where the Centre for Soil and Agroclimate Research has classified lowland tropical peatlands into four depth classes: (1) shallow (50-100 cm); (2) moderate (100-200 cm), (3) deep (200-300 cm) and (4) very deep (>300 cm); the Land Resources Project has used three categories, <50, 50-200 and >200 cm; while in the RePPRot Report <50, 50-300 and >300 cm were used (Widjaja-Adhi, 1997).

The system of field description used to assess the fibre content of tropical peat is an adaptation of the three basic terms that are thought to reflect decreasing particle size and increasing decomposition in temperate peats (Farnham & Finney, 1965; Esterle *et al.,* 1992). As a result, tropical peat can be classified as fibric, hemic or sapric if the fibre content is >66%, 33-66% or <33%, respectively (see table 2.9). The presence of fibric peat denotes good organic matter preservation while sapric peat is the most decomposed.

The United States Department of Agriculture (USDA) Soil Taxonomy Classification (USDA Soil Survey Division Staff, 1990) has been adopted for the classification of peat soils in Sarawak and Indonesia while Sabah has used the FAO/UNESCO Legend (1974) system. According to both systems of classification, peat soils are classified as Histosols when the organic matter is >30% occurring in a 40 cm layer within the upper 80 cm of the soil profile. In Sarawak, the USDA System has been modified to suit local conditions by adopting 50 cm as the minimum thickness of the upper organic horizon before recognizing the soil as 'peat'. Some attempts have been made to harmonise these various systems. Histosols may be divided into suborders, primarily on the basis of their degree of decomposition. The majority of Indonesian peat soils are in the order Histosol (78.8%) while the remainder come within Histic subgroups of mineral soils. Peat soils (Histosols) consist of the subgroups Typic Tropohemists (25.2%), Typic Sulfihemists (13.3%), Terric Troposaprists (11.9%), Typic Tropofibrists (9.4%), Terric Tropohemists (8.8%), Typic Sulfohemists (8.2%), Halic Sulfihemists (0.5%), Fluventic Tropohemists (0.4%) and Terric Tropofibrists (0.3%), whereas those belonging to the Histic subgroups consist of Hystic Hydraquents (39.9%), Thapto Histic Fluvaquents (26.9%), Histic Tropaquents (23.0%), Histic Sulfaquents (8.6%) and Histic Tropaquents (1.5%).

Physical properties of peat soils

Peat humification

Once peat swamp forest is drained the peat starts to humify. In this process the original raw peat, with its many coarse root and tree remnants, decomposes slowly into humified peat, which has many small, uniform pores. The humification process has a strong influence on the hydraulic conductivity and moisture retention characteristics of the peat. The degree of peat humification can be expressed using the von Post Scale which ranges from H1 (least humified) to H10 (most humified). For simplification purposes the 10 von Post classes are condensed, based on their fibre content, into 3 main peat types using the US Department of Agriculture terminology (USDA Soil Survey Division Staff 1993) (Table 2.9).

Table 2.9: Simplified classification of peat based on humification

Fibre content	USDA classification	Corresponding Von Post class
> 66 %	Fibric	H1 to H3
33 – 66 %	Hemic	H4 to H6
< 33 %	Sapric	H7 to H10

Bulk density, particle density and total porosity

Histosols are light in weight when dry and the bulk density of surface peat is only 0.15-0.30 g cm^{-3} compared to 1.25-1.45 g cm^{-3} for mineral soils (Brady, 1990). Bulk density values of peat soils in Kalimantan vary between 0.15 and 0.25 g cm^{-3} under natural conditions (Lambert & Staelens, 1993; Kurnain *et al.*, 2001; Sajarwan *et al.*, 2002). In Kalampangan, Central Kalimantan, the bulk density values of the upper 30 cm layer vary between 0.12 and 0.17 g cm^{-3} under pristine peat swamp forest while, in cultivated and fire damaged peatlands, they vary between 0.17 and 0.31 g cm^{-3} (Kurnain *et al.*, 2001). After land reclamation peat substrates start to decompose and become compacted, leading to an increase in bulk density.

Particle density values of peat soils in Kalimantan vary between 1.23 and 1.76 g cm^{-3} (Lambert & Staelens, 1993; Sajarwan *et al.*, 2002). For agricultural purposes, a single value of particle density is almost meaningless but, together with the bulk density, it reflects the total porosity and density of peat soil. The total porosity of peat soils in Kalimantan, in general, varies between 80% and 90%. There is a lack of information, however, regarding the effect of peat drainage and reclamation on the total porosity, which tends to decrease with agricultural practices owing to peat compaction.

Swelling, shrinking and irreversible drying

Most peat soils shrink when dried but swell when re-wetted, unless water content falls below a threshold value beyond which irreversible drying occurs (Andriesse, 1988). Over drainage can cause irreversible drying and shrinkage. Irreversible drying of the peat soil from Kereng Bangkirai, Sebangau, Central Kalimantan occurred at mean critical water contents ranging from 27.9 to 17.9%, 34.7 to 22.0%, and 5.5 to 3.5% for fibric, hemic and sapric peats, respectively (Haris *et al.*, 1998). Shrinkage values can be expressed as specific volumes of peat soil (McLay *et al.*, 1992). Specific volumes of peat soil from Kalampangan ranged between 2.7 and 6.5 cm^{3} g^{-1} and these decreased significantly with cultivation and fire damage, especially in the top 0-30 cm layer (Kurnain *et al.*, 2001). Using the 1:1 saturation line introduced by McLay *et al.* (1992), dewatering appears to cause subsidence of peat surfaces, which is evident from the positive linear relationship between specific volume of peat soil and its moisture content (Figure 2.2).

Hydraulic conductivity

Hydraulic conductivity in peat soils is controlled by several factors, including, total porosity, bulk density, and degree of decomposition. Very few determinations of hydraulic conductivity have been carried out on tropical peat soils but those that are available range greatly from 0.2 to 52 cm h^{-1} (Sajarwan *et al.*, 2002). Evidently, hydraulic conductivity varies owing to the differences in methods of determination employed and the difficulties in sampling peat soil without disturbing its field structure. Hydraulic conductivity of waterlogged peat 1-2 m below the surface of peat swamp forest in Central Kalimantan varied between 0.001 and 0.0001 cm sec^{-1} whereas, at the surface, it was so rapid, it was impossible to measure (Takahashi & Yonetani, 1997).

Moisture relationships

Information on the moisture relationships of peat soils is extremely important in reclamation, particularly for the design of efficient drainage layouts. There are various methods of determining the moisture content of peat soils, each of which gives variable results in different kinds of relationships. The moisture relationships are often expressed as maximum moisture content (water holding capacity), moisture retention, and available water. Similarly, moisture relationships are important in peatland restoration since different rehabilitation land uses require different hydrological regimes.

Maximum moisture content. A recent study of pristine peat swamp forest in the eastern part of the upper Sungai Sebangau catchment, Central Kalimantan shows that maximum moisture contents of peat soils of the upper 15 cm peat layer vary between 700% and 1,080% on a weight basis (Kurnain, 2001). In contrast, in drained areas at Kalampangan, Central Kalimantan they range from 430% to 630%. When expressed on a volume basis the values are similar, ranging from 120 to 160%, because decrease in the maximum moisture contents after reclamation is followed by an increase in the bulk density. Lower values of maximum moisture contents ranging from 430% to 600% were obtained under natural forest in the upper Sungai Sebangau catchment (Sajarwan *et al.,* 2002). The differences between these two measurements are related to the nature of the peat samples used. The former were derived from fresh peat while the latter used air dried peat.

Moisture retention. Knowledge of moisture retention values is particularly important in the management of peat soils. They depend on the degree of peat decomposition (Andriesse, 1988). Peat soils with fibric materials apparently lose much of their retained water at low suctions. Water appears to be increasingly held as the degree of decomposition increases. There is a lack of data on moisture retention of tropical peat soils although a recent study carried out at Kalampangan, Central Kalimantan provides moisture retention values of peat soil (Kurnain *et al*., 2001) (Table 2.10). These are comparable with the observations of Driessen & Rochimah (1976) on coastal lowland peat from Kalimantan of 79-91% by volume at a suction of 0.01 bar (pF 1), 75-89% by volume at 0.1 bar (pF 2), and 71-85% by volume at 0.33 bar (pF 2.54).

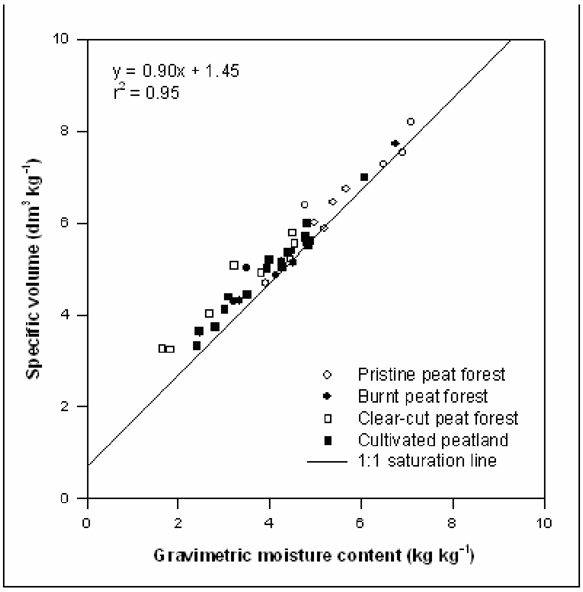


Figure 2.2: Shrinkage curve as a function of field water content of the peat soil under different land use systems. - The 1:1 saturation line indicates the theoretical shrinkage curve to be expected if the soil were saturated and shrinkage resulted from dewatering only, as explained by equation: $V = \theta w Vw + Vs$ (McLay *et al*., 1992). θw is gravimetric water content (kg kg^{-1}), *Vw* is specific volume of water, assumed to be 1.0 dm^3 kg^{-1}, and *Vs* is volume of solids, assumed to be 1/1.4 or 0.71 dm^3 kg^{-1} (Driessen & Rochimah, 1976; Sajarwan *et al*., 2002).

Table 2.10: Moisture retention values (%, v/v) in various ranges of pF for the upper 15 cm layer of peat soils under different land use systems at Kalampangan, Central Kalimantan, Indonesia

Land use system	pF 0	pF 1	pF 1.3	pF 1.7	pF 2	pF 2.5	pF 3
Pristine peat swamp forest	88.5	74.4	64.9	50.3	42.9	40.6	38.2
Burnt peat forest	84.7	76.5	71.1	56.4	51.4	45.7	40.6
Clear-cut peat forest	80.7	77.6	74.9	58.4	51.2	38.7	28.6
Maize-cultivated peatland	88.8	77.3	66.2	56.4	48.7	40.5	31.8
Pineapple-cultivated peatland	82.0	79.0	76.4	58.4	52.2	40.6	33.8
Rubber-cultivated peatland	86.1	77.3	74.3	57.5	51.3	46.1	37.1

Table 2.11: Gravity water, easily available water and water buffer capacity of the upper 15 cm layer of peat soils under different land use systems at Kalampangan, Central Kalimantan

Land use system	Gravity water (%,v/v)	Easily available water (%,v/v)	Water buffer capacity (%,v/v)
Pristine peat swamp forest	25.4	23.0	5.8
Burnt peat forest	18.3	22.2	3.7
Clear-cut peat forest	21.7	27.0	5.9
Maize-cultivated peatland	20.1	17.0	6.0
Pineapple-cultivated peatland	27.6	19.6	4.5
Rubber-cultivated peatland	30.2	16.5	4.7

The values are calculated by the formulation compiled from Lambert (1995) and Uomori & Yamaguchi (1997): Gravity water = water retention at pF 0 - that at pF 1; easily available water = water retention at pF 1 - that at pF 2; Water buffer capacity = water retention at pF 2 - that at pF 2.54.

For agricultural management purposes the differences between the quantity of water retained at field capacity and the water retained at the permanent wilting point are defined as the amount of water available for uptake by plants. Both values are measured quantitatively by pF analysis; the field capacity being the amount of water held at pF 2.54 and the wilting point at pF 4.2 (Andriesse, 1988). In practice, under field conditions, the quantity of water in peat soils available to the plant appears to be much less than the quantity of water between the two pF values. The actual amount of water available in peat soils is worth checking under tropical conditions where drought can be severe. The quantity of gravity water and available water, and water buffer capacity using the formulation compiled from Lambert (1995) and Uomori & Yamaguchi (1997) are presented in Table 2.11.

Chemical properties

Ash content

The ash content of peat and peat soils varies considerably from less than 5% to more than 65% (Rieley *et al.,* 1996). Higher values are attributed to increased mineral contents. Ash contents of ombrotrophic peats are very low and do not change much with depth except at the surface and towards the base of the peat deposit. Under natural conditions ash contents of peat soils in Kalimantan vary between 0.2% and 2% (Lambert & Staelens, 1993; Kurnain *et al.*, 2001; Sajarwan *et al.*, 2002). When drained they ranged from 0.6-3% in Central Kalimantan, especially in the upper 0-30 cm layer (Kurnain *et al.*, 2001), and 1-9% in West Kalimantan (Lambert & Staelens 1993). Ash contents of the peat soils of Kalimantan are similar throughout the profile under natural conditions, but they decrease with depth in drained areas. Substantial changes in ash contents in the top layer, as a result of agricultural management, signify that these practices have affected the top layer of peat soil intensively.

Soil pH and electrical conductivity

Under natural conditions the pH (H_2O suspension) of peat soils in Central Kalimantan ranges from 3.0 to 4.0. In general, the pH of peat soils in Kalimantan tends to decrease with increasing depth of peat. In secondary peat forests of South Kalimantan pH is between 3.2 and 3.8 (Hadi *et al.*, 2000). When drained, pH ranges greatly from 3.2 to 7.8, depending on peat soil utilization and management. Suryanto (1994) reported that cultivation of various crops subsequently increased the pH of peat soil in the Sungai Slamet area, West Kalimantan up to 7.8, depending on the ash and fertilizer materials applied, the kind of crops cultivated, and time of reclamation. At Kalampangan, where local inhabitants have utilised peatland for cultivation, the pH of the peat soil varies between 3.5 and 4.0 and is similar to that of adjacent pristine peat swamp forest (Kurnain *et al.*, 2001; Sajarwan *et al.*, 2002). In South Kalimantan, however, the pH of cultivated peat soils ranges from 4.1 to 4.7 (Hadi *et al.*, 2000).

Determination of electrical conductivity (EC) of peat soils is a very important requirement for agriculture as it provides an indirect estimate of the solubility of ions required in plant nutrition. The EC of peat soils is usually much lower than that of mineral soils. At Kalampangan the ECs of peat soils range from 40-100 $\mu S\ cm^{-1}$ (Kurnain *et al*. 2001), reflecting the very low nutrient status in this area. In contrast, in the Sungai Slamet area of West Kalimantan EC values of cultivated peat soils ranged from 140 to 320 $\mu S\ cm^{-1}$ (Suryanto 1994), which is about three times higher than in Central Kalimantan.

Organic C, total N and C/N ratio

In contrast to mineral soils, the determination of a single value of organic C in peat soils is almost meaningless, particularly for agricultural development purposes, and it should be combined with total nitrogen contents in order to calculate the C/N ratio. Organic C contents, total N contents, and C/N ratios of peat soils in the upper 100 cm profile at Kalampangan range from 49% to 57%, 1.0% to 2.2%, and 29 to 52, respectively (Kurnain *et al.*, 2001). In the top 0-15 cm peat layer, organic C contents and total N contents tend to decrease with agricultural practices, whilst C/N ratios increase substantially (Figure 2.3). Similar values of total N content of peat soils were obtained in the upper Sungai Sebangau catchment (Sajarwan *et al.*, 2002).

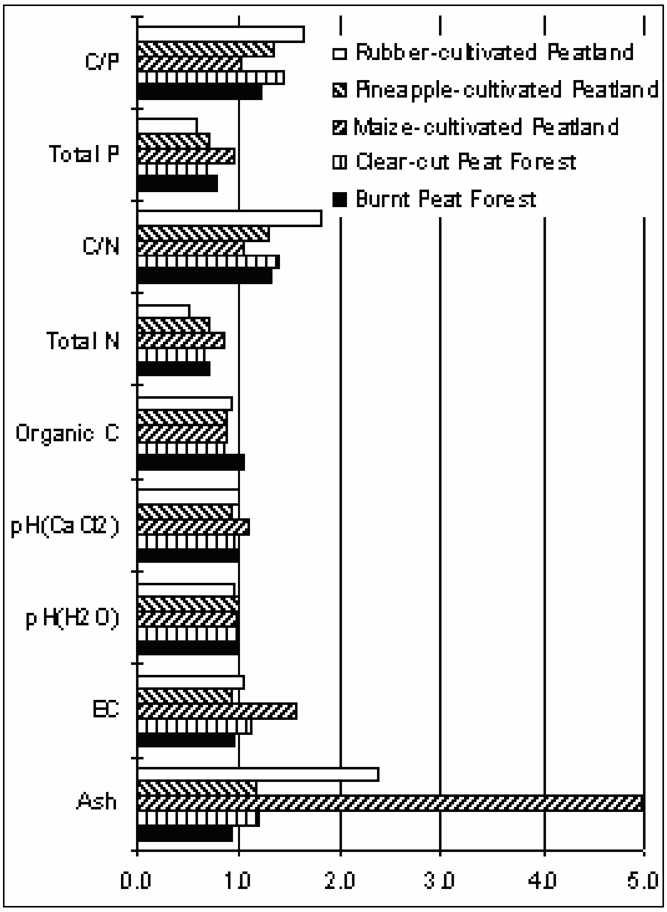


Figure 2.3: Chemical properties of peat soils in the top 0-15 cm layer of cultivated and fire damaged sites at Kalampangan, Central Kalimantan relative to the adjacent pristine peat swamp forest.

Total phosphorus (P) and C/P ratios

Total P contents and C/P ratios of peat soils in the upper 100 cm profile at Kalampangan range from 0.4 to 0.7 g kg^{-1} and 760 to 1,330, respectively (Kurnain *et al.*, 2001). In contrast, in the upper Sungai Sebangau catchment, total P contents range from 0.3 to 0.9 g kg^{-1} (Sajarwan *et al.*, 2002). In the top 0-15 cm peat layer, total P contents decrease with agricultural practices, whilst C/P ratios increase substantially. As peat substrates are more decomposed under cultivation than in their natural state, mineralization of organic material releases N and P to the inorganic fraction of the soil and these are leached down to a lower layer. Total P and N contents in the lower layer of cultivated peat soils are higher than in the top layer.

Cation exchange capacity (CEC) and base saturation

The sum total of the exchangeable cations that a peat soil can adsorb (CEC), as commonly measured in peat soils at pH 7.0, is very high, usually more than 50 cmol(+) kg^{-1}, but is considerably less when it is determined at field soil pH because almost all of the surface charges are pH dependent (Lambert &Staelens, 1993). Lambert (1995) reported that ion adsorption and exchange in peat soils are associated with hydrophilic colloids derived from humic substances, which have COOH and phenolic OH groups as complexing agents. The CEC of peat soils from South Kalimantan ranges from 70.6 to 132.8 cmol(+) kg^{-1} (Hadi *et al.* 2000).

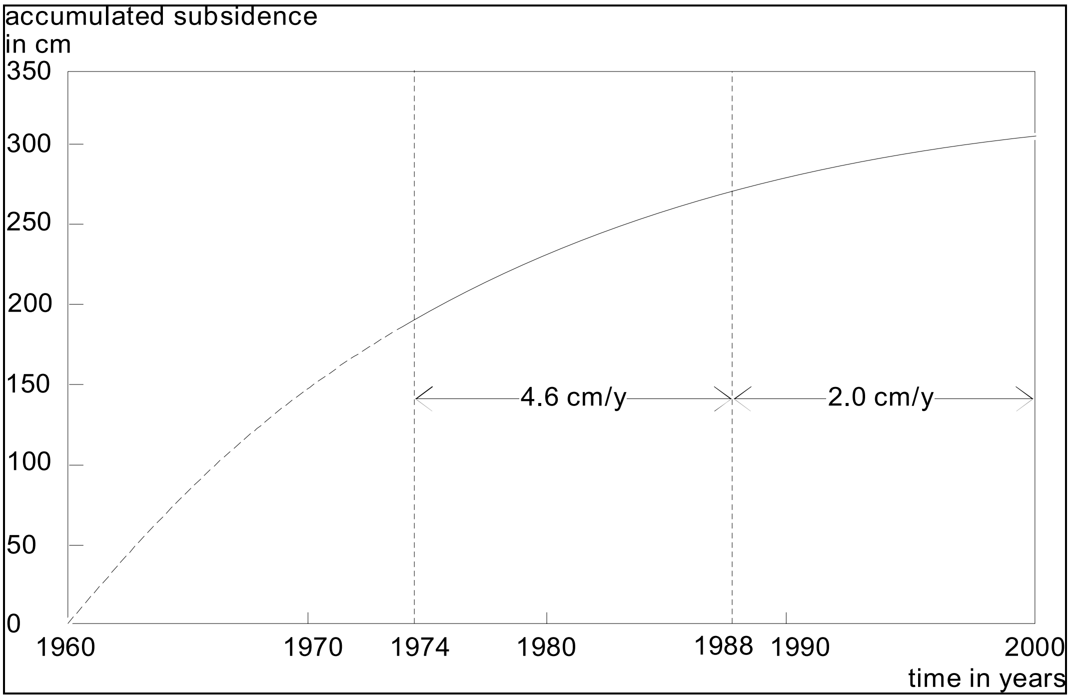


Figure 2.4: Average subsidence versus time relationship for Western Johore (DID, 2001).

Peat subsidence

Subsidence is defined as the continuous lowering of the level of the soil surface. Peat soils show characteristically different subsidence behaviour from mineral soils such as clays and sands. Over time, subsidence of mineral soils stops, first with sands and then with clays. Subsidence of peat soils, however, continues over time, albeit at decreasing rates. To understand the complex relationship between total subsidence and drainage, it is useful to divide peat subsidence into three phases, namely consolidation, oxidation, and shrinkage. Each of these three phases represents a characteristic behaviour of peat and has different practical consequences for its agricultural use and the environmental issue of CO_2 emission. The initial rapid subsidence occurs because of consolidation. It results in compression of permanently saturated peat layers without a permanent loss of peat. The subsidence rate slows down after the first two years of rapid subsidence (see Figure 2.4). In Western Johore, the first subsidence recordings started in 1974, so no measured data are available on the initial, rapid subsidence (dotted line). In the very beginning, when subsidence is mainly from consolidation, it can be as high as 20 – 50 cm yr^{-1}. After these initial high values, the rates for Western Johore decreased from 4.6 to 2 cm yr^{-1}.

Peat subsidence and groundwater level

The relationship between subsidence and the groundwater level is an important tool for converting optimal groundwater levels, as dictated by different land use options, into subsidence rates. This combination makes it possible to evaluate the sustainability of various cultivation practices on peat soils. For example, the rate of subsidence of peat under sago cultivation with an optimal water table depth of 25 cm is only half the rate of subsidence of peat under oil palm cultivation with an optimal water table depth of 50 cm (Table 2.12).

The relationship between subsidence and groundwater level follows the equation:

Peat subsidence rate *(cm yr^{-1})* ***=***
0.x * depth of the water table *(cm).*

The actual co-efficient value (0.x in the general form) depends on the peat characteristics, and it has been found to vary between 0.1 − 0.04 in Sarawak and Western Johore (Wösten *et al.*, 1997). The equation can be used as a tool for converting the optimal groundwater levels, as dictated by the different land-use options, into subsidence rates. With the equation it is possible to combine subsidence rates with the thickness of peat layers to assess the time it will take for all of the peat to disappear and the mineral subsoil to surface.

Table 2.12: Time span in years that will elapse until the peat has disappeared and the mineral subsoil has surfaced under two different types of cultivation.

Peat depth (cm)	**Elapsed time span (years) for peat disappearance *)**	
	Oil palm	**Sago**
Shallow peat (< 150)	< 10	< 20
Anderson 1 (150 – 200)	10 – 20	20 – 40
Anderson 2 (200 – 250)	20 – 30	40 – 60
Anderson 3 (>250):		
250 – 500	30 – 80	60 – 160
500 – 1000	80 – 180	160 – 360
1000 – 1500	180 – 280	360 – 560
1500 – 2000	280 – 380	560 – 760
>2000	> 380	> 760

***)** In the example it is assumed that there is an initial rapid subsidence owing to consolidation of 1 m in two years and then a subsequent subsidence, according to the subsidence – groundwater level relationship. We also assume that the optimal water table depth is 50 cm for oil palm cultivation and 25 cm for sago cultivation.

CHAPTER 3: NATURAL RESOURCE FUNCTIONS AND VALUES OF TROPICAL PEATLANDS

Ecological and landscape values of tropical peatlands

Natural tropical peatlands can be valued according to their functions, which can be either, direct or indirect, products or attributes (Dugan, 1990; Maltby, 1997; Sugandhy, 1997) (figure 3.1). Direct functions include water flow regulation, protection from natural forces, recreation and education, and production of food and other resources for local communities. Indirect or ecological functions of peatlands include sediment retention, nutrient detention, and micro-climate stabilization. Peatland products include provision of: water supply to other ecosystems and human communities; forest resources ranging from fuel wood, timber and bark to resins and medicines; wildlife resources; agricultural and horticultural resources; and energy resources. Attributes of peatlands are values, other than products that can be derived directly from the ecosystem or functions that are related closely to the maintenance of environmental quality. These attributes include biological diversity since tropical peatlands are important genetic reservoirs of certain animals and plants, unique locations for culture and heritage and habitats for the life cycles of flora and fauna.

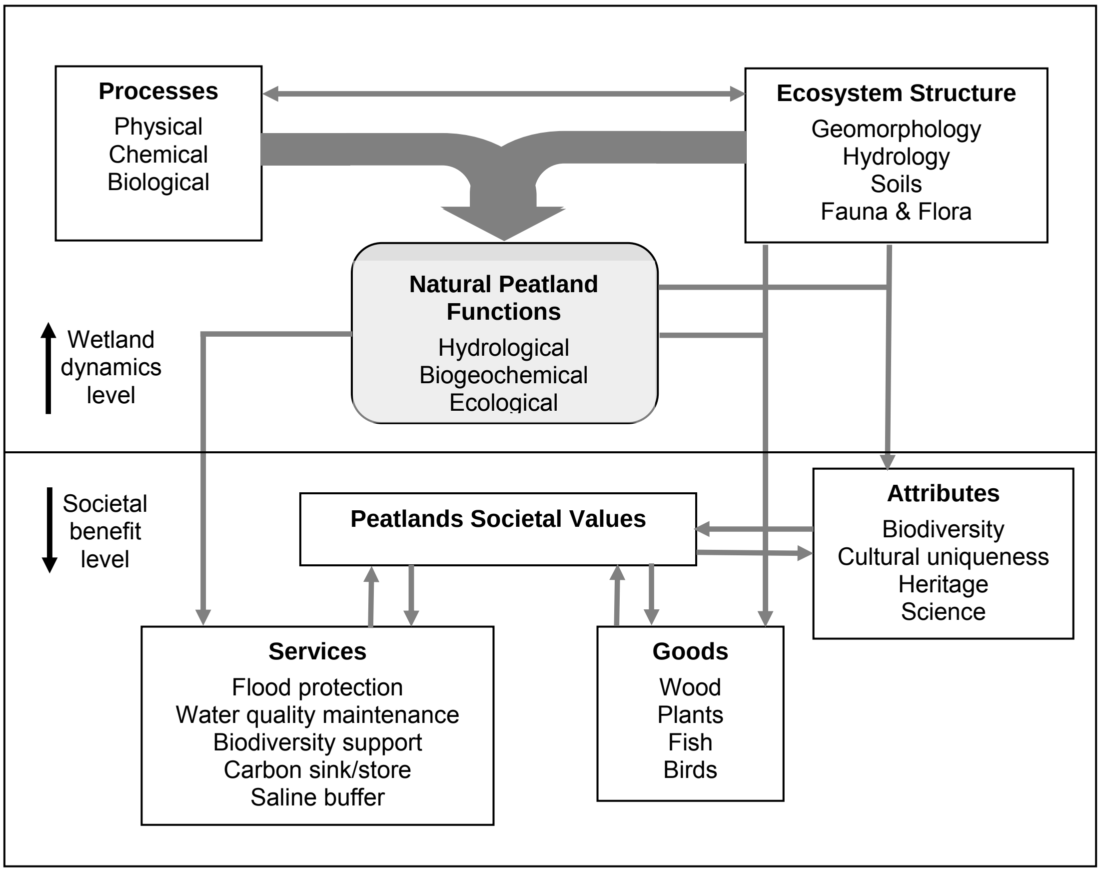


Figure 3.1: Tropical peatland resource values (adapted from Maltby *et al.,* 1994)

Tropical peatlands have long provided goods and services for local communities to fulfil their daily, basic requirements, for example, hunting grounds and fishing areas, food and medicines and construction materials. In the marginal areas surrounding tropical peatlands subsistence dry land agriculture has been practised by indigenous people for generations. More recently, timber extraction has been carried out, particularly in the peat swamp forests of Kalimantan, Sumatra and West Papua, providing employment, local income, new jobs and business opportunities, and contributing to national exchequers, but at the expense of the ecosystem and the environment.

Tropical peatlands play important roles regionally and locally in the water cycle and landscape stabilisation (Page & Rieley, 1998). Tropical peatlands mitigate against landscape erosion and downstream flooding by reducing river flood water peaks and duration and providing water during dry periods (Andriesse, 1988).

Biodiversity

Biodiversity is the range of different living organisms and the habitats in which they occur. This includes diversity within species, between species and of ecosystems; many of the former have yet to be discovered. The rapid loss of biological diversity that is occurring as a result of species loss owing to habitat destruction and fragmentation is considered one of the world's most pressing environmental problems.

Whilst the diversity associated with ombrotrophic lowland tropical peatlands is usually lower than adjacent terrestrial rain forest ecosystems, many peatland species are specialists, which are not found in other habitats. The inaccessibility of peatlands has also drawn in species that, although not confined to this habitat, are dependent upon the shelter and food that peat swamp forests provide, compared to the intensively logged forests on mineral soils. As more information on the biodiversity of tropical peat swamp forests accumulate it is clear that this ecosystem has been undervalued as a habitat for rare and threatened species (Laumonier, 1997).

In overall terms, tall peat swamp forest sub-types, which have the greatest tree species diversity and canopy stratification, support the greatest faunal diversity (Page *et al.*, 1997). Lower canopy sub-types are less species diverse. The latter coincide with zones of extreme hydrological and nutrient stress (as a result of waterlogging and oligotrophy) and most closely resemble the depauperate plant and animal communities described in earlier accounts of this ecosystem (Merton, 1962; Janzen, 1974). These forests are not without interest, however, and several noteworthy species of mammals and birds have been recorded in low pole forest (Page *et al.*, 1997), whilst the many water-filled hollows on the forest floor support unusual species of blackwater fish (Ng *et al.*, 1994).

Flora

The vegetation of the peat swamp forests of Southeast Asia has been investigated in more detail than the associated animal communities (Anderson, 1964, 1976; Rieley & Ahmad-Shah, 1996; Rieley *et al.*, 1998; Silvius *et al.*, 1984; Whitmore, 1984). The tree species diversity of these forests is lower than in most other types of lowland rain forest in the region, but some are restricted to this ecosystem and make an important contribution to regional biodiversity (Shepherd *et al.*, 1997). The species composition and vegetation types of peat swamp forest are not uniform across Southeast Asia and there is significant local and regional variation, although there is presently insufficient information available to establish definite phytogeographical trends (Rieley & Ahmad-Shah, 1996).

Within one lowland tropical peatland catchment, there may be a catena of between two and six different forest types, reflecting differences in peat thickness, hydrology and nutrient availability. These range from a mixed swamp community with up to 240 tree species per hectare on shallow peat around the margins of the peat dome to a less diverse, low canopy, small pole forest, usually associated with the wettest, deepest peat, in which tree species number declines to 30–55 species per hectare. Local differences in peatland hydrology and nutrient availability probably exert strong influences on forest composition and structure (Anderson, 1964, 1976; Brady, 1997; Shepherd *et al.*, 1997; Stoneman, 1997; Rieley *et al.*, 1998; Page *et al.*, 1999; Wyatt-Smith, 1959). Six phasic communities have been described for the peatlands of Sarawak (Anderson, 1963, 1964) while, in the peat swamps of Central Kalimantan, five have been identified (Page *et al.*, 1999). In contrast, the peatlands of the Malay Peninsula and Sumatra support only two main forest types (Anderson, 1976; Morley, 1981; Morley, 2000). Pollen analyses from peat cores in Sarawak have shown that the zonation of forest types may represent succession over time (Anderson, 1964; Muller, 1970).

The peat swamp vegetation is dominated by trees, many of which have buttress or stilt roots that provide improved stability in the waterlogged peat soils; many also have breathing roots (pneumatophores) that protrude above the peat surface, enabling respiratory gas exchange to occur under anaerobic conditions. Most of the tree families of lowland dipterocarp forests in Southeast Asia are found in peat swamp forests (Polak, 1975; Whitmore, 1984) with members of the *Anacardiaceae*, *Annonaceae*, *Burseraceae*, *Clusiaceae*, *Dipterocarpaceae*, *Euphorbiaceae*, *Lauraceae*, *Leguminosae*, *Myristicaceae*, *Myrtaceae* and *Rubiaceae* being well-represented (Bruenig, 1990; Flenley, 1998; Flenley, 1985; Morley & Flenley, 1987; Morley, 1981; Ibrahim & Hall, 1992; Shepherd *et al.*, 1997; Waldes pers. comm.; Wyatt-Smith, 1959). Characteristic and widespread tree species include *Baccaurea bracteata*, *Campnosperma coriaceum*, *Ilex cymosa*, *Madhuca motleyana* and *Stemonorus secundiflorus*; commercially important timber species include *Dactylocladus stenostachys*, *Cratoxylum arborescens*, *Gonystylus bancanus*, *Koompassia malaccensis* and *Shorea spp*. A few species have a distribution confined exclusively, or almost so, to peat swamp forest, for example, *D. stenostachys*, *G. bancanus*, *Horsfieldia crassifolia*, *Shorea balangeran* and *S. teysmanniana*, of which *G. bancanus*, *H. crassifolia* and *S. balangeran* are endangered and protected by law (CITES Appendix III). Members of the *Pandanaceae*, which often form a dense ground cover, ferns and insectivorous pitcher plants (*Nepenthaceae*) also occur. Bryophytes are abundant on the tops of hummocks and on tree bases, but Sphagnum spp. are present in marginal drainage areas only and are not associated with peat formation as they are in temperate and boreal regions (Flenley, 1979; Gates, 1915; Rubeli, 1986).

The forest floor exhibits a well-marked microtopography, with small hummocks, up to 0.5 m in height, interspersed with shallow hollows of similar depth. The hummocks are usually formed around tree bases and comprise of a large proportion of both living and dead tree roots. Hummock surfaces have an open vegetation cover, largely of small tree seedlings while hollows have little or no vegetation but are characterized by an abundance of pneumatophores and surface-growing fine roots. The hollows form an interconnected network that carries water from the interior of the peatland dome to its periphery. The inherent heterogeneity of peat swamp forest vegetation across the Southeast Asian region is recognised as a key conservation issue, with important implications for the maintenance of biological diversity (Prentice & Parish, 1992; Silvius & Giesen, 1996).

Fauna

The base-line information on animal diversity in lowland tropical peat swamps is very limited and has not been related to the different vegetation types. A few studies have highlighted the role that peat swamp forests play in providing habitats for a number of endangered and rare species, especially birds, fish, mammals and reptiles (Silvius *et al.*, 1984; Prentice & Parish, 1992).

Mammals

Several recent studies have highlighted the role that tropical peat swamp forests play in providing habitats for many species of mammals (Bennett & Gombek, 1992; Doody *et al.*, 1997; Page *et al.*, 1997; Prentice & Parish, 1992). Of particular conservation importance is the relatively large population of orang utan (*Pongo pygmaeus pygmaeus*) associated with peat swamp forest in Borneo (Bennett & Gombek, 1991; Meijaard, 1997; Page *et al.*, 1997; Husson *et al.* 2002: Morrogh-Bernard *et al.* 2003), which provide one of the most important remaining habitats for this endangered primate. A study carried out in the upper Sungai Sebangau catchment from 1993-1995 (Page *et al.*, 1997) revealed 35 species of mammal, the majority of which are arboreal. Twenty nine species were observed in the field whilst six were captured in traps as part of small mammal surveys. Observations at sunrise and sunset ensured that some nocturnal animals (e.g. civets) were recorded; other nocturnal groups, however, notably lorises and bats, were under-represented. The largest number of animals was identified in the mixed swamp forest (26), nearest to the river, followed by tall interior forest on the watershed (20). Only 8 species were encountered in low pole forest from which most arboreal species were absent. Several species of mammal were encountered, which are regarded as endangered, threatened or vulnerable by the Convention on Trade in Endangered Species (CITES) and the World Conservation Union (IUCN) (Table 3.1).

Common name	Scientific name	Status	Habitat		
			MSF	LPF	TIF
Agile gibbon	*Hylobates agilis*	Endangered	*		*
Orang utan	*Pongo pygmaeus pygmaeus*	Endangered	*	*	*
Pig-tailed macaque	*Macaca nemestrina*	Endangered	*	*	*
Red leaf monkey	*Presbytis rubicunda*	Endemic to Borneo	*		*
Sun bear	*Helarctos malayanus*	Endangered	*	*	*
Clouded leopard	*Neofelis nebulosa*	Threatened	*		
Leopard cat	*Felis bengalensis*	Threatened	*		
Marbled cat	*Felis marmorata*	Threatened	*		*
Flat-headed cat	*Felis planiceps*	Rare	*		
Binturong (bear cat)	*Arctitis binturong*	Vulnerable			
Small-toothed palm civet	*Arctogalidia trivirgata*	Status indeterminate	*		*
Plain pygmy squirrel	*Exilisciurus exilis*	Endemic to Borneo	*		*
Painted tree shrew	*Tupaia picta*	Endemic to Borneo	*		*

Table 3.1: Checklist of rare, endangered and vulnerable mammal species recorded in peat swamp forest in the upper Sungai Sebangau catchment (status according to CITES & IUCN) (MSF: mixed swamp forest, 1-5 km from river; LPF: low pole forest, 5-12 km from river; TIF: tall interior forest, 12-25 km from river)

Orang utan

Natural orang-utan densities in the Sungai Sebangau peat swamp forest were found to vary from 0.8 individuals per 100 hectares in low pole forest to over 2 individuals in tall interior forest. This is comparable to densities found in other habitat types in Borneo and indicates that peat swamp forest is an important habitat for this endangered primate. Mixed swamp forest and tall interior forest are the preferred habitat sub-types although low pole forest is utilised during certain seasons, as a corridor between preferred habitat sub-types and as a refuge from logging. Illegal logging caused widespread shifts in distribution between 1999 and 2001, resulting in overcrowding in certain areas which has led to deaths of individuals. Fire and illegal logging have led to a decline in population size of 36% since 1996.

Figure 3.2. Orang utan mother and infant

Orang-utans are distributed continuously throughout the Sebangau catchment and surrounding peat swamp forest areas, with the probable exception of the extremely wet low interior forest. The highest density areas of those surveyed appear to be in the tall interior forest and around the upper reaches of Sungai Sebangau, Bulan, Paduran and Rasau, although preservation of the entire catchment is required to maintain a viable population. The latest estimate of the population size of the catchment between Sungai Sebangau and Sungai Katingan, stretching northwards to the Palangka Raya-Kasongan road, is 3767 – 4709 individuals (Morrough-Bernard *et al.,* 2003). This remains one of the biggest populations of orang-utans in Borneo.

Fire, encroachment by transmigration settlements, illegal logging and hunting remain major problems that need to be tackled to ensure survival of the orang utan. Illegal logging extraction canals are causing extreme drainage of the peat dome during the dry season. A dense network of canals has been constructed and their combined draining effect lowers the water table well below normal levels in the dry season. This promotes peat degradation and the risk of fire. The canals need to be dammed as the highest priority in actively managing the catchment for conservation of orang utan and their peat swamp forest habitat.

Birds

The avian species diversity of peat swamp forest is considerable and the importance of this habitat as a refuge for a number of rare and threatened species has been demonstrated (Page *et al.*, 1997). Studies over several years in peat swamp forest in the upper catchment of Sungai Sebangau in Central Kalimantan revealed 150 bird species. These were dominated by insectivores, the main guild being foliage gleaning species. The largest number was recorded in mixed swamp forest (106) followed by tall interior forest (77), although this lower figure may reflect both less intensive recording effort and the difficulty of bird observation in tall, closed canopy rain forest. In contrast, the smallest number of species was recorded in low pole forest (27). In addition 32 species were observed in deforested, riverine sedge swamp. Six of the bird species recorded are Red Data Book species (Groombridge, 1993) constituting 50% (six out of 13) of the listed bird species for the island of Borneo. (Table 3.3). Several bird species within the Southeast Asian region are considered to be peat swamp specialists, i.e. they are not associated with any other wetland or forest habitat. This group includes white-winged duck (*Cairina scutulata*), Storm's stork (*Ciconia stormi*), hook-billed bulbul (*Setornis criniger*) and grey-breasted babbler (*Malacopteran albogulare*) (Sheldon, 1987).

It is now evident that peat swamp forest is important for many bird species and some have specific preferences for this habitat, which acts as one of their last refuges. Preliminary observations suggest that the majority of bird species (80%) can survive in selectively logged forest. Whilst a number of birds may utilise regenerating peat swamp forest for feeding, this habitat may be unsuitable at other stages of the avian life cycle. Loss of nesting sites and nesting materials, for example, may reduce breeding potential of some species (Lambert, 1992) and alterations in the forest microclimate may also exclude species (Johns, 1986). Further quantitative studies of bird species distributions and abundances are required to determine the long-term effects of logging operations on the peat swamp forest avifauna.

Figure 3.3: Helmeted hornbill

Common name	Scientific name	Status	Habitat			
			RSS	MSF	LPF	TIF
Storm's stork	*Ciconia stormi*	Red Data Book Peat swamp forest specialist		*		
Lesser adjutant stork	*Leptopilus javanicus*	Red Data Book	*			
Wrinkled hornbill	*Aceros corrugatos*	Red Data Book		*		*
Helmeted hornbill	*Buceros vigil*	Red Data Book				*
Short-toed coucal	*Centropus rectunguis*	Red Data Book		*		*
Wallace's hawk eagle	*Spizaetus nanus*	Red Data Book		*	*	*
Grey-breasted babbler	*Malacopteran albogulare*	Uncommon species of wetlands & swamp forests				*
Hook-billed bulbul	*Setornis criniger*	- as above -		*		*
Great-billed heron	*Ardea sumatrana*	- as above -	*			
Black bittern	*Dupetor flavicollis*	- as above -	*			
Cinnamon-headed green pigeon	*Treron fulvicollis*	- as above -		*		
Striped wren babbler	*Kenopia striata*	- as above -		*		*
Malaysian blue flycatcher	*Cyornis turcosus*	- as above -				*
Crestless fireback pheasant	*Lophura erythrophthalma*	Uncommon species of lowland forests				*
Greater coucal	*Centropus sinensis*	- as above -		*		
Brown wood owl	*Strix leptogrammica*	- as above -				*
Red-naped trogon	*Harpactes kasumba*	- as above -		*		*
Rufous-backed kingfisher	*Ceyx rufidorsa*	- as above -		*		*
Rufous-collared kingfisher	*Actenoides concretus*	- as above -		*		
Asian black hornbill	*Anthracoceros malayanus*	- as above -		*		*
White-bellied woodpecker	*Dryocopus javensis*	- as above -		*		
Lesser cuckoo-shrike	*Coracina fimbriata*	- as above -	*	*		
Grey-bellied bulbul	*Pycnonotus cyaniventris*	- as above -				*
Rufous-tailed shama	*Trichixos pyrropygus*	- as above -		*		*

Table 3.2: Checklist of notable bird species recorded in peat swamp forest, upper Sungai Sebangau catchment (records from 1993, 1994 and 1995)

Fish

The rivers of the Southeast Asian peat swamp forests have long been considered to have low fish biomass, productivity and species diversity owing to low pH, low oxygen concentrations, toxicity from plant-derived chemicals, lack of transparency and hence primary productivity, and depauperate invertebrate communities owing to the lack of minerals such as calcium (Janzen, 1974). In the last decade, some efforts have been made to reassess the fish communities of these habitats. For example, several new species have been found associated with peat swamp habitat in North Selangor, Malaysia (Ng *et al.,* 1994). In addition, 44 species from 17 families, including 10 new species or subspecies, have been identified from blackwater rivers and pools in the upper Sungai Sebangau catchment, Central Kalimantan (Page *et al.,* 1997). These studies are beginning to demonstrate that the blackwater rivers of Southeast Asia have a higher degree of localised endemism of fish species than alluvial rivers in the region. There is, however, an urgent requirement for studies to be carried out on a more systematic and widespread basis to confirm their conservation status.

Invertebrates

There has been little systematic collection of or research on the invertebrates of peat swamp forest. In the Sebangau catchment in Central Kalimantan, preliminary investigations of several invertebrate groups have highlighted the presence of many noteworthy species.

Biomass and nutrient cycling

Peat swamps of Southeast Asia are ombrotrophic wetlands in which the principal input of water and nutrients is from atmospheric deposition and precipitation while outputs are by mass flow of surface drainage water. Internal nutrient transfers are related to maintenance of forest biomass through nutrient uptake and recycling, and storage in or release from the surface peat (accumulation or degradation). A detailed study of the nutrient dynamics of peat swamp forest (Sulistiyanto, 2004) indicates that chemical elements are being taken up and retained by swamp forest trees that achieve a biomass equilibrium regulated by overall nutrient availability within the ecosystem. It is likely that some of the nutrients falling in rainfall are being stored in currently accumulating peat (see Box 3.1). Based on the results of this study (nutrient input, transfer, output and storage), it is concluded that nutrient concentrations in peat soils are low and the substrates are acidic and are likely to be strongly limiting to agricultural development, including plantations of estate crops and trees. Consequently, management and conservation of peat swamp forest in its natural condition is the best land use choice from a long-term perspective, especially for optimisation of ecosystem services (e.g. carbon storage, watershed, biodiversity maintenance, timber production).

Box 3.1: Peat swamp forest biomass and nutrient dynamics of two sub-types of peat swamp forest, mixed swamp forest and low pole forest, in the upper catchment of Sungai Sebangau in Central Kalimantan, Indonesia

Biomass and nutrient content

The total above ground biomass in mixed swamp forest (MSF) was 313,899 kg ha^{-1} comprising 312,000 kg ha^{-1} (99.4%) from trees of dbh ≥5 cm, 1,501 kg ha^{-1} (0.5%) from trees of dbh <5 cm, and 398 kg ha^{-1} (0.1%) from *Pandanus* spp. The total nutrient element content in above ground biomass decreased in the order: Ca>N>K>Mg>Na>P>Fe>Mn. Calcium amounted to 4576.9 kg ha^{-1} while manganese was only 4.73 kg ha^{-1}. Total nutrient content was greatest in trees of dbh ≥5 cm (99.1%) followed by trees of dbh ≤5 cm (0.5%) and *Pandanus* spp. (0.4%). In low pole forest (LPF) the total above ground biomass was 252,547.6 kg ha^{-1} comprising 249,000 kg ha^{-1} (98.6%) from trees of dbh ≥5 cm, 2389.2 kg ha^{-1} (1.0%) from trees of dbh <5 cm, and 1158.4 kg ha^{-1} (0.4%) from *Pandanus* spp. The total element content in above ground biomass decreased in the order: Ca>N>K>Mg>Na>Fe>P>Mn. Calcium contributed 3730.5 kg ha^{-1} while manganese comprised of only 1.94 kg ha^{-1}. Total nutrient content was greatest in trees of diameter ≥5 cm (97.5%) followed by *Pandanus* spp. (1.6%) and trees of diameter <5 cm (0.9%).

Rainfall and throughfall

Rainfall was slightly acid (pH between 5.02 and 6.92 with an average of 5.92) with a predominance of Ca and K. Throughfall was enriched in most elements compared to rainfall and its pH was lower. Throughfall pH ranged from 3.25 to 6.13 (average 4.76) in mixed swamp forest and from 2.90 to 6.12 (average 4.37) in low pole forest.

Nutrient input in rainwater (rainfall) and canopy leachate (throughfall) showed temporal variation. The amount of throughfall decreased with decreasing rainfall and in mixed swamp forest was 1969 mm (70.1 %) of the total precipitation whereas in low pole forest it was 2136 mm (76.0 %). The order of magnitude of cations reaching the forest floor in throughfall was in the order Ca>K>Mg>Na in low pole forest, and K>Ca>Mg>Na in mixed swamp forest.

Litter

There was greater litter production in mixed swamp forest (8411 kg ha^{-1} yr^{-1}) compared to low pole forest (6534 kg ha^{-1} yr^{-1}). Dry weight of the different fractions (leaves, branches, reproductive parts and other debris) for MSF and LPF were 6216, 1246, 459 and 489 kg ha^{-1} and 4864, 1251, 169 and 251 kg ha^{-1}, respectively.

The proportions of each litter component were: (1) mixed swamp forest - leaf litter 74%, branches 15%, reproductive parts 5% and other debris 6%; (2) low pole forest - leaf litter 74%, branches 19%, reproductive parts 3% and other debris 4%. There were differences in nutrient concentration between these components. Leaves had a high content of Ca, Mg, Na, Fe and Mn while reproductive parts were high in N, P, and K. Mixed swamp forest and low pole forest exhibited similar bimodal peaks of leaf fall at the end of the wet season (Feb-March) and the end of the dry season (August-September).

Hydrological functions

Peatlands, with their high water-holding capacity, perform a major function in regulating water in tropical lowlands. They serve as reservoirs of fresh water, stabilise water levels, reduce storm-flow and maintain low-flow to buffer against saltwater intrusion (Safford & Maltby, 1998).

The dome-shaped surface of most peat swamps causes rainwater to drain off to the sides. This phenomenon divides a peat swamp into several catchments. Compared to upland catchments, peat swamps have minimal topographic gradients, which make it difficult to determine the catchment boundaries. The groundwater table in a drained area influences the water table in adjacent non-drained areas in a zone several kilometres wide. Just as drained areas affect water tables in contiguous non-drained areas so do catchments influence each other. Activities or projects that take place in one catchment can influence activities in another and lead to conflicts of interest. It is easy to imagine the conflicts that would occur if, for instance, an agricultural project were adjacent to a water-supply area. Drainage in the agricultural project would lower the water table in the water-supply area, reducing the volume of water available for domestic and industrial use (SWRC 1997; DID 2001).

The majority of lowland peat swamps of Borneo are completely rain-fed. Water flow from upland areas does not enter these swamps. The rainfall either evaporates or is transported from the swamps as near surface run-off, inter-flow, or groundwater flow. The general water balance of a peat swamp can be written as follows:

$$P = E + Q + \Delta S$$

Where:

P	total rainfall (m)
E	total evapotranspiration (m)
Q	total discharge (m)
ΔS	change in storage (m)

Under natural conditions, the water table will rise with rainfall and fall as a result of evapotranspiration and the outflow of excess water. The resulting change in storage can be considerable over short periods (i.e. days or weeks). Over years, however, this change in storage will be negligible compared to the total in- and outflow (figure 3.4).

Fluctuation of water tables in a peat swamp depends mainly on rainfall because evaporation and (groundwater) outflow are fairly constant. During the wet season, rainfall always exceeds the combination of evaporation and groundwater run-off. Thus, in this period, the water table rises and may come above the peat surface. These wet conditions are favourable for peat accumulation. During the drier months of the year, when rain-free periods may last for weeks, the water level in peat swamps can drop below the soil surface often to a metre or more. Furthermore, fluctuations vary within the peat dome itself (Box 3.2).

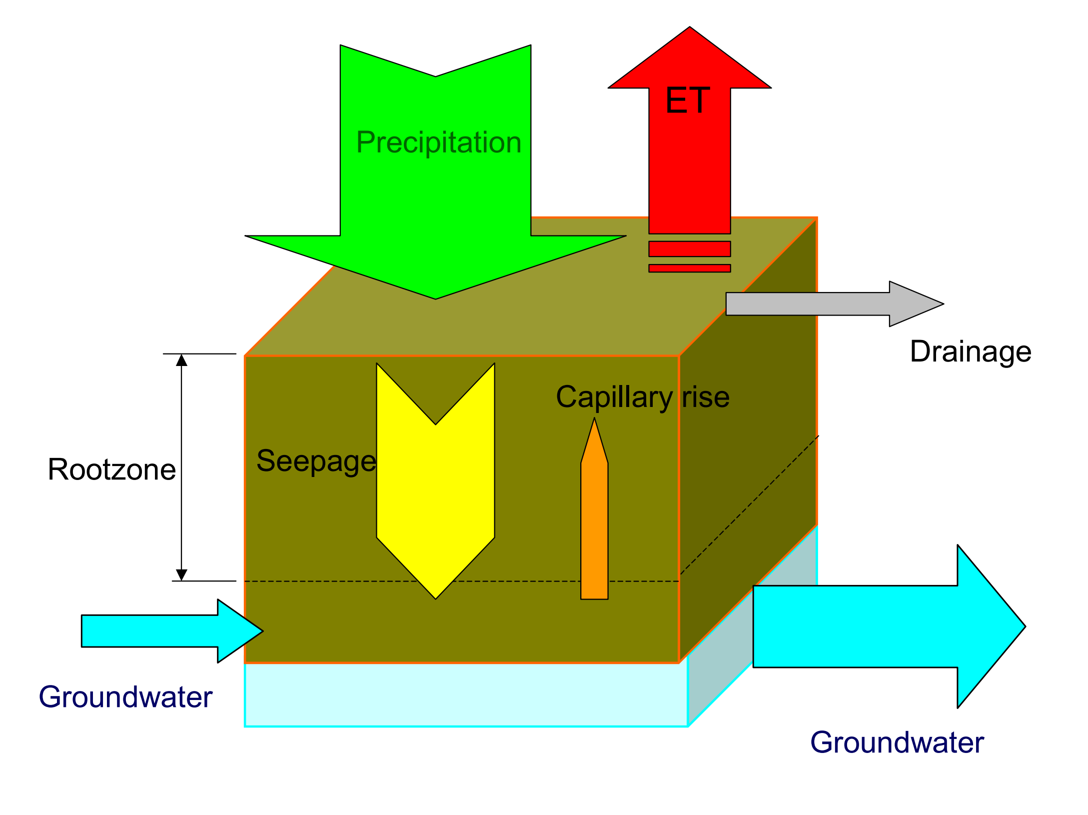


Figure 3.4 Schematic water balance of a unit area of tropical peatland.

Box 3.2: Fluctuation of the water table in a tropical peat swamp

Between dry and wet seasons, the water table in a peat swamp can fluctuate up to 0.60 m near the edge of a peat dome. In the centre, the seasonal fluctuation is slightly smaller (0.45 m). The relatively steep periphery has a deeper water table than the flat centre. Under natural conditions, fluctuation of the water table will be as follows (Ong & Yogeswaran, 1991; Takahashi *et al*. 2002):

- On hot and non-rainy days, surface water may drop 10–15 mm daily.
- When initial water levels are below the surface, the drop is 5–10 mm daily.
- Water levels drop fastest during the day when transpiration is greatest.
- The maximum drop of the water table depends on the length of the dry spell.
- The maximum depth of the water table varies for different peat swamps from 0.3 to 1.0 m below the soil surface.

Peat swamps influence the hydrology of entire catchments. Drainage ultimately destroys the sponge effect of peat swamps and their reservoir function is eventually lost (Andriesse, 1988). Exploitation of the overlying forest resource reduces the ability of the ecosystem to hold rainfall (Rieley & Page, 1997) and water is flushed more quickly into the rivers (Box 3.3). Under natural, undrained conditions, there are three types of outflow from the peat body of a swamp:

- Surface run-off or depression flow;
- Sub-surface flow or interflow, and;
- Deep groundwater flow.

Owing to the predominantly high water levels in a peat swamp, surface flow accounts for most of the natural outflow. Groundwater flow forms only a small component of the water balance and sub-surface flow. The latter is defined as the flow that takes place through an upper soil layer of higher permeability, and is of intermediate importance.

Box 3.3: Impacts of land use change on the hydrology of peat swamp forest in Central Kalimantan

In natural peat swamp forest the surface layer of peat, in which the water table fluctuates over time (acrotelm), may be flooded for at least nine months of the year. The peat dome acts as a water reservoir, intercepting and storing water, and releasing it slowly into adjacent rivers. During the dry season the acrotelm drains slowly, although pools of water may be present in surface depressions throughout.

Land use change, to agriculture and illegal logging, has serious impacts upon the hydrology of lowland tropical peatlands. Both activities involve the excavation of channels into the surface of the peat. In the former this is part of water management to maintain appropriate levels for crop production while, in the latter, canals are constructed along which to remove illegally cut timber. The construction of drainage, irrigation and extraction channels has severe consequences for peatland hydrology

At the onset of the dry season water floods out of the acrotelm along the channels and surface pools dry out rapidly. The acrotelm may remain dry, and penetrate to much deeper levels, for up to three months each year (longer during El Niño years), increasing the risk of fire significantly. The fires of 1997, which were promoted by deforestation during implementation of the Mega Rice Project (see Annex 2), were an ecological disaster on a grand scale, in which more than 20% of the peat swamp forest of Central Kalimantan was destroyed (Page *et al.,* 2002). The newly established channel network aggravated the situation.

In the short term, decrease in the water table allows more air to enter the acrotelm thus increasing the aerobic decomposition of organic matter and promoting nutrient release (Brady, 1997). Drier conditions, however, lead to cessation of peat accumulation and peat degradation (Page *et al*., 1997), which will have consequences for both the type and density of vegetation that the ecosystem can support in the future. Prentice & Parish (1992) believe that even a slight drop in the water table affects the regeneration capacity of peat swamp trees leading to changes in the species composition of the forest. Severe drainage leads ultimately to collapse of the peat structure, increasing tree-fall and eventually complete loss of forest cover.

Rainfall can infiltrate easily into a peat soil. The storage capacity of peat works as a buffer during times of heavy rainfall: the deeper the water table, the larger the storage capacity. Although tropical peat has a high drainage pore space varying between 0.3 and 0.85, water storage capacity in peats is relatively small, because under natural, undrained, conditions, water tables fluctuate around soil surfaces. Even in dry periods, when water tables can drop to 0.6 m below soil surface, storage capacities in the soil will only be in the same order of magnitude as rainstorms with a 1-year return period.

Water losses

Many workers have reported that runoff is the major route of water loss from ecosystems (Crisp, 1966; Likens & Bormann, 1999) and this is particularly so for tropical peatlands. The other major output of water is evapotranspiration from the peat surface and the forest canopy (Takahashi *et al.*, 2002; Sulistiyanto 2004), which is estimated to be between 3 and 4 mm d^{-1} in the upper catchment of Sungai Sebangau, Central Kalimantan (Takahashi & Yonetani, 1997). From the data available for this peat covered catchment it is possible to calculate that:

runoff = rainfall - evapotranspiration.

The amount of run off in Sungai Sebangau = 2809.38 mm - 366 X 3.5 mm
= 2809.38 - 1281
= 1528.38 mm or 15.28×10^6 l ha^{-1} yr^{-1}

Carbon storage function

Peat soils globally, store about 20% of all terrestrial organic soil carbon, totalling 1,220 Gt (Immirzi & Maltby, 1992). Diemont *et al*. (1997) estimated that peatlands contain up to 5000 t^{-1} ha^{-1} of carbon with a total amount of at least 20 Gt while Page *et al.,* (2004) suggest it could be as much as 70 Gt.

Carbon dioxide is fixed from the atmosphere in the photosynthesis of green plants, and is released back to the atmosphere in plant and animal respiration, and by micro-organisms in aerobic decomposition of organic matter (Fig. 3.5). Anaerobic decomposition takes place in waterlogged peat under the influence of a consortium of micro-organisms that break down plant polymers into substrates for methanogenic bacteria (CH_4 production). Part of the CH_4 produced usually escapes to the atmosphere but some may be converted, by methanotrophic bacteria that consume CH_4 as an energy source, to CO_2 that is released to the atmosphere. Factors controlling CO_2 and CH_4 production in peat include water table depth, temperature, pH, substrate availability and degradability, competitive electron acceptors and methanogenic bacteria populations (Valentine *et al*., 1994; Lovley *et al*., 1996; Miyajima *et al*., 1997). Substrate quality and peat hydrology have the greatest influence on carbon gas formation in tropical peatlands.

Deposition of fresh organic matter to the forest floor may be assumed to be constant in terms of both quality and supply rate but net ecosystem C storage is reduced by removal of above ground biomass. Even in selectively logged forests, harvesting leads to a decline in organic matter incorporation into soil (Brady, 1997). Under agricultural cropping the C cycle is even more rapid. Owing to the diminishing input of easily degradable organic matter in managed areas decomposition rates in peat can also be expected to slow down but they continue because of oxidation of exposed peat. The drainage of lowland tropical peatland and consequent oxidation of peat releases carbon dioxide to the atmosphere, further contributing to the greenhouse effect and the potential for climate and sea-level change (see Chapter 4).

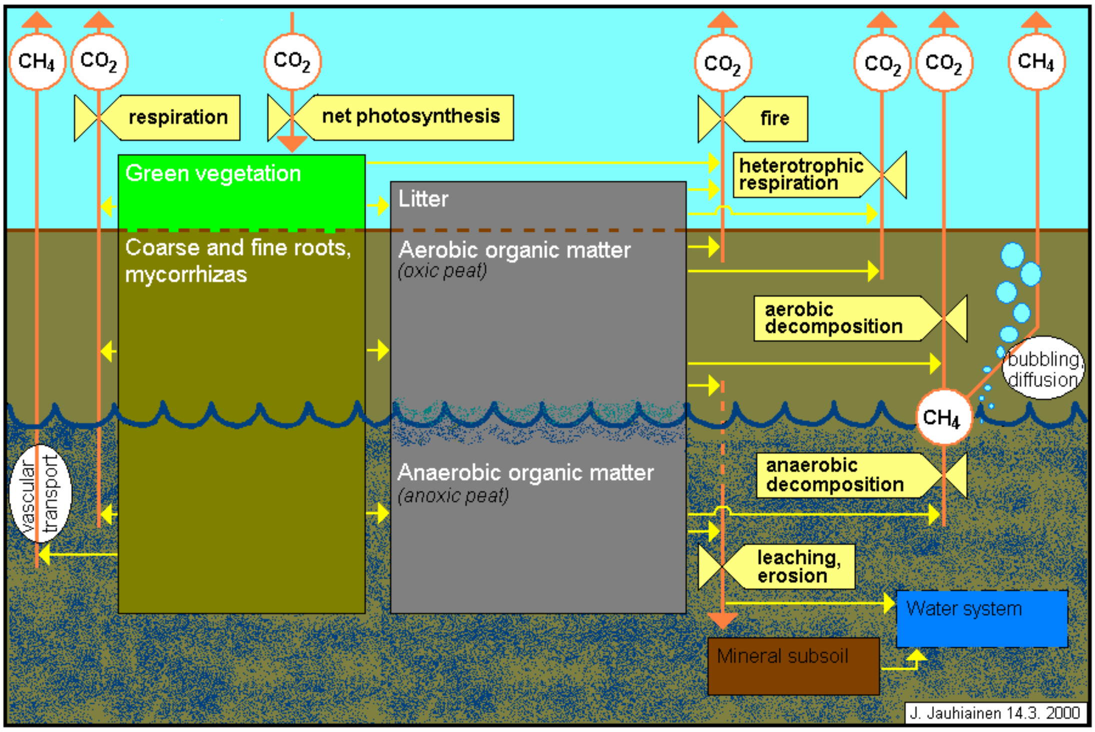


Figure 3.5. Potential carbon cycling pathways in tropical peat.

Climatic functions

Peat has different characteristics compared to mineral soils, especially surface albedo, thermal conductivity and heat capacity, which change with water content. Heat balance of peatland changes with ground water level and water content of the subsurface layer. Peat is usually formed, and accumulates, under waterlogged conditions and a large part of the solar energy that insolates and is absorbed by peat surfaces is used for evaporation from the ground surface. If the ground surface is dry, however, the solar energy absorbed is converted to heat. The low thermal conductivity of dry peat prevents heat from the ground surface penetrating into deeper layers. The low heat capacity of dry peat raises the temperature of the peat surface and the air layer above the ground. Low evaporation rate and high air temperature near to the ground make the humidity of air near to the ground very dry. This mechanism of heat balance on drained peatland leads to very dry regional and local climates and increases the risk of peat and forest fires to very high levels. Air temperature inside peat swamp forest is lower than on opened peatland in daytime because, in the former, less than 10% of solar radiation penetrates to the forest floor. In addition, most of the solar energy is converted into latent heat and sensible heat in the top layer of the forest canopy. The resulting mild climatic conditions inside water-logged forest reduce greatly the rate of decomposition of organic matter and increase the accumulation rate of peat.

Under tropical climatic conditions daily and annual variation in the amount of rainfall can be considerable (Takahashi & Yonetani, 1997), and long periods of extremely low precipitation can lead to temporary drought. For the peat swamps, rainfall, in particular that in excess of evaporation, is the most important hydrological parameter. The annual rainfall is much higher than the annual evaporation. Rainfall distribution, however, is much more irregular both in time and space than evaporation. The diurnal solar radiation on the forest floor is reduced to 3.7% of that in open area in average ranging from 2.5% to 6.8% in the tropical peat swamp forest

(Figure 3.6). This small amount of solar radiation, which penetrates to the forest floor, suppresses the air temperature near the forest floor during daytime. On the other hand, the dense canopy reduces the radiative cooling of air near the forest floor during the night. So the diurnal fluctuation of air temperature inside the forest is usually smaller than that in open and drained areas (Figure 3.7)

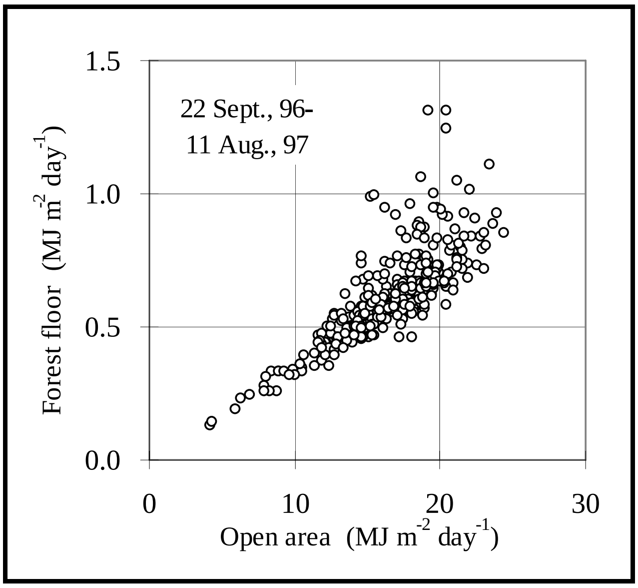


Figure 3.6: Relationship between the daily total solar radiation in the forest floor of tropical peat swamp forest in Central Kalimantan, Indonesia and that in an open area near to the forest.

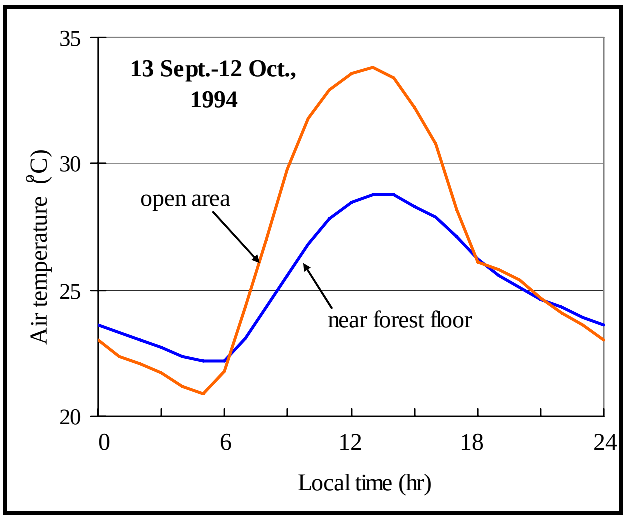


Figure 3.7: Diurnal changes of air temperature in tropical peat swamp forest and an open drained area nearby in Central Kalimantan during the end of the dry season. (The air temperatures at both sites were obtained from the average of 30 days from 13 September to 12 October 1994.)

The climate of Borneo, for example, is characterised by its uniform temperature, high humidity, and high rainfall intensity. The mean monthly temperature is stable and varies between 24°C and 27°C. According to the Köppen classification system, which is based on precipitation and temperature, the climate is a tropical rain climate without a dry season and a long-term mean precipitation in the driest month higher than 60 mm (Class Af). The climate is influenced by two monsoon winds, namely the Northeast Monsoon from November to February and the Southwest Monsoon from April to September. The average evaporation is fairly constant, varying between 3.5 mm d^{-1} and 4.8 mm d^{-1} with a total of around 1500 mm per year (Fig. 3.8).

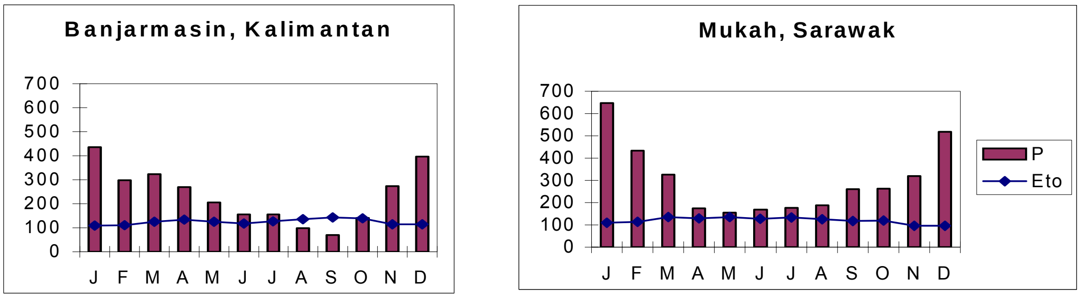


Figure 3.8: Mean monthly rainfall and evaporation (mm) in a) Mukah, Central Sarawak and, b) Banjarmasin, South Kalimantan

Along the coast of Sarawak, the annual rainfall varies from 2800 mm to 4700 mm with an overall average of around 3600 mm. In South Kalimantan, rainfall is significantly lower, varying between 1900 and 3000 mm per year with an overall average of around 2800 mm. Differences in space are linked closely to the average rainfall intensity and not so much to the number of days of rainfall. Rainfall is also not distributed evenly over the year. In the coastal region of Sarawak, during the Northeast Monsoon, when rainfall may exceed 600 mm per month, the wettest months are December–February. During the dry season (March–November) the monthly average rainfall is about 200–300 mm, which still exceeds the rate of evaporation. This is not the case in South Kalimantan, where during the driest months (August and September) evaporation exceeds rainfall.

Despite the tropical rain climate, peat swamps suffer from water shortage during the dry period. In Sarawak, periods with negligible rainfall (<5 mm/week) and a duration of about two weeks occur at least once or twice every year. The average four-week minimum rainfall varies from 50 to 100 mm. This amount is often less than the evapotranspiration, which is around 3 mm d^{-1} (or 84 mm every four weeks). In South Kalimantan, the average dry season (weekly rainfall < 25 mm) can last for 3 to 4 months. During this period the rainfall deficit is around 100 mm. In extreme dry years (probability of exceedance 10%) this period can be extended to seven months. Without water conservation, evaporation can lead to slight but persistent moisture deficits and so to increased oxidation. In very dry years, the water table can fall 1 m below the peat surface.

Socio-economic and cultural functions

Tropical peat swamp forests have been used by people living in the vicinity for millennia for a large variety of life support products and services. Departments of Forestry do not usually regard these non-timber forest resources as anything of value to be conserved and managed in a sustainable way. They do, however, form an important component of livelihood subsistence and also cash income for local and indigenous people who live near and around peatland areas. These important services and values should be incorporated into any wise use strategy for the sustainable management of this ecosystem since they come in many different forms and provide a range of benefits.

Peat swamp forest in Central Kalimantan (Indonesian Borneo) has been used by indigenous peoples for generations for satisfying some of their subsistence requirements. These activities include gathering, hunting, fishing, shifting agriculture and timber extraction. In recent times some of these have become important as major sources of cash income to satisfy the market economy requirements of both indigenous and migrant communities. This increased and continuous utilisation is threatening the very existence of the natural resources and the peat swamp forests; it is also causing racial disharmony. Field research shows that local people in Central Kalimantan, for example, are very dependent on bio-natural resources for both subsistence and cash incomes (Nasir, 2001). In 2002 they obtained 38% of their subsistence and 41% of their cash income requirements from non-timber forest products. In addition they generated about 23% of their cash income from timber extraction (logging) showing that a total of 64% of their income comes from bio-natural resources.

Change in land use of tropical peatland from peat swamp forest to agriculture, and the loss of bio-natural resource commodities, has led to significant changes in the contribution of non-timber and timber products for both subsistence and cash incomes. People who live on the banks of Sungai Sebangau generate more of their subsistence and cash from bio-natural resources compared to the people who live along Sungai Kahayan, which has been impacted greatly by the failed Mega Rice Project (q.v.). The former can obtain about 12% more for subsistence and 18% more for cash income compared to the people of Sungai Kahayan. It is reasonable to conclude: (1) if the natural resources are diminished or lost, pressure on the remaining nearest resources will increase; (2) if timber can make a substantial contribution to their income, people will become involved in activities related to illegal logging.

Direct use values in support of peoples' basic needs

Various tradeable goods are harvested by people from peatland ecosystems in Kalimantan. This has amounted to around US$ 1.5 billion annually during the last 15 years mostly from logs and processed timber. Other peat swamp forest products, including rattan, jelutung latex, gemur bark, medicinal plants, charcoal and fire-wood, honey, various inland water fish, frogs and crabs (not to mention some wild species of endangered animals), are being traded by local people after being harvested from peatland ecosystems.

In order to appreciate the importance of peatland forest resources to existing communities, in Central Kalimantan, it is essential to understand the traditional means of livelihood of local inhabitants.

1. **Extractive:** this is typified by tapping non-renewable resources, for example, gold mining from a river bed, clay-brick making and stone breaking by using the heat generated by wood fires. These activities are usually complemented by exploiting trees from nearby forest to be used as a source of firewood energy, and therefore doubling the environmental impact of this particular business effort. The work is conducted mostly by transmigrant labourers (Javanese) in conjunction with Dayak or Buginese owners.

2. **Exploitative:** this type of business activity depends on the ability to exploit the abundant, but somewhat fixed availability, of the natural resources within the peatland ecosystem. Tree cutting and jelutung latex-tapping and gemur bark stripping are examples and, of course, forest logging is obviously the most popular. The masterminds of this earning activity are Banjarese people in cooperation with some Dayaks, whilst transmigrants act as labourers.

3. **Explorative:** this effort is about harvesting fish or prawns, medicinal herbs or roots, rattan and swamp turtle, which are available in abundance in remote parts of the peat swamp forest ecosystem. These activities impose minor

negative impacts on the ecosystem and have good economic prospects given the fact that modern society has been attracted back to nature for its pharmaceutical and luxury needs. Many potential resources are still unknown within the peat swamp forest and there is therefore a potential for future development. Indigenous local people together with educated Dayaks are certainly very talented in undertaking this kind of business.

4. **Conservative:** this is typified by win-win efforts by local people in utilizing the peat swamp forest in environmentally friendly ways. Examples include bee-keeping within a forest site and Toman (*Ophiocephalus micropeltes*) fish fattening. The latter is conducted by families taking advantage of kitchen (organic) solid wastes to feed small wild fish that are caught easily in square nets placed underneath their houses and, in which they are fattened for 10 months until they are large enough to sell.

5. **Intensive:** this is a sedentary and more technologically oriented earning effort that is practiced mostly by well-settled transmigrant farmers, although some Dayaks and Banjarese families are also involved. It focuses on intensive fishpond management and associated business. The actual performance is unfortunately impaired by pests and diseases because appropriate technology for peatland agriculture (including aquaculture and animal husbandry) has not been developed so far by local communities. This is the challenge to be answered by scientists that really care about the optimal and wise utilization of the tropical peat swamp forest ecosystem.

Indirect use (societal) values in support of peoples' quality of life

Traditional wisdom among indigenous people of Borneo clearly recognizes peatland forests as natural stores for various daily living needs. There are seven common major characteristics of Dayak civilization: (1) long house, (2) mandau and sampit hunting and defence instruments; (3) plaiting and weaving with rattan and tree bark materials; (4) pottery utensils; (5) swidden agriculture; (6) paternal (both patrilineal and matrilineal) hood; and (7) ritual traditional dances. Characteristically (1) and (4) require landscape sites with a mineral soil base, while the rest (1, 2, 3 and 5) may be supported by peatland forests. Therefore pristine peatland ecosystems are not only indirectly valuable in terms of their (bio-geophysical) ecological functions that support socio-ecological harmony but they also imbue socio-economic and socio-cultural strength to the native people.

Failure to direct environmentally sound and sustainable development could clearly bring the region to ecological and social disaster. Considering that natural (peatland ecosystem) and socio-anthropological entities have been in dynamic evolution for thousand of years, it becomes predictable and calculable how much of the indirect value would be lost and consequently wasted if peatland forest degradation should become out of control.

Option values that support peoples' desire to improve their future economic welfare

The peatland ecosystem has the potential to be developed economically for ecotourism, carbon trading, as the home of important medicinal plants and animals, and as a future source of renewable energy for the benefit of the economy of Kalimantan (Indonesian Borneo) and its inhabitants. A better understanding of the social behaviour of the native and migrant peoples is needed urgently in order to guide various interests of communities and local, provincial and central governments to harvest particular peatland forest resources. It is important that these option values are not wasted before a sustainable model for best practice and wise use of forest resources is formulated.

Bequest values in support of peoples' faith and cultural traditions

Social attitudes and local traditions surrounding a peatland ecosystem are believed to have long been influenced and structured by the bounty of peatland bio-geophysical resources. A pristine tropical peatland ecosystem is rich in biodiversity. Various tree species suitable for building traditional houses and equipment can easily be harvested in a sustainable manner from the forest by the native people. The peatland ecosystem and the 'adat' values and traditional leadership are necessarily composed of some important values and sustainable norms for peatland forest development. Traditional rules should neither be dismissed nor undervalued, and could become the key whenever a social change needs to be introduced in the course of a sustainable management program.

Existence values that support peoples' right to secure the welfare of future generations

Wherever a primary peatland ecosystem still exists nowadays, it is very likely to be because of the thickness of the peat deposit, which makes it unsuitable for agricultural use. It is understood that peat thickness varies throughout a peatland landscape and that areas of shallow peat support an associated fauna and flora that is different, in terms of species composition, population density and size, from areas of thick peat. In the eyes of the native tribes, who hold animistic beliefs, such locations and associated ecological phenomena would have been recognized as holy spots to be respected and revered. Anthropologically speaking a peatland ecosystem to some extent has been influenced by socio-ecological values, socio-economic attitudes, and the socio-cultural behaviour of the surrounding tribes and people. Socio-economically speaking, however, those sacred spots and sites will necessarily determine the 'existing values' of a peatland ecosystem. They present a bargaining position that may only be exchanged by the native people for an extremely high monetary value.

CHAPTER 4: IMPORTANCE OF LOWLAND TROPICAL PEATLANDS OF SOUTHEAST ASIA IN GLOBAL CARBON CYCLE AND CLIMATE CHANGE PROCESSES

Introduction

Peatlands worldwide are now recognized to play a vital role in biosphere biogeochemical processes (Immirzi *et al.*, 1992). The special characteristic of lowland tropical peatland is peat swamp forest (part of the rainforest formation) growing on top of and contributing to the accumulation of a thick surficial layer of peat. The forest is the carbon allocating machinery that forms a biomass carbon store comparable to that of other rainforest types, whilst the waterlogged, acidic and nutrient deficient substrate, on which it grows, creates conditions under which the rate of biomass decomposition is reduced greatly and peat accumulates. Together, the vegetation and underlying peat constitute a large and highly concentrated carbon store (Sorensen, 1993). There is a growing body of information concerning, and international interest in, the importance of tropical peat carbon stores and their role in environmental change processes. Unfortunately, they have also become a focus for large-scale land development projects that cause the natural resource functions of this important ecosystem to fail, changing it from a carbon sink to a carbon source. It is important to determine the role that tropical peatlands have played and continue to play in global environmental processes, especially those implicated in climate change through the ecosystem carbon cycle connected functions (see also Chapter 3).

Peat formation and accumulation rates

Several factors influence peat formation and preservation, including a positive climatic moisture balance (precipitation minus evaporation), high relative humidity, topographic and geological conditions that favour water retention, and low substrate pH and nutrient availability. The majority of the world's peatlands occur in boreal and temperate zones where they have formed under high precipitation-low temperature climatic regimes. In the humid tropics, however, regional environmental and topographic conditions have enabled peat to form under high precipitation-high temperature conditions (Andriesse, 1988). Most tropical peatlands are located at low altitudes where the peat swamp forest grows on a thick mass of organic matter accumulated over thousands or tens of thousands of years, to form deposits up to 20 m thick (Anderson, 1983) (see Chapter 2).

Peat accumulation in the perhumid lowlands of Southeast Asia in the Late Pleistocene and Early Holocene

Palaeoenvironmental studies of coastal peat deposits in Southeast Asia have demonstrated that these are the youngest peatlands in the region with peat accumulation commencing around 3,500-5,500 ^{14}C yrs BP, following stabilization of rising sea levels (e.g. Anderson & Muller, 1975). In comparison, more recent investigations of sub-coastal and inland peatlands, particularly in Borneo, have revealed much earlier dates for the initiation of peat formation, ranging from Late Pleistocene (~40,000 ^{14}C yrs BP) for the peatlands of the Danau Sentarum basin in West Kalimantan (Anshari *et al*., 2001, 2004) to ~22,600 ^{14}C yrs BP for high peat in the Sebangau catchment, Central Kalimantan (Page *et al.*, 2004) through to the early Holocene (10,000-7,000 ^{14}C yrs BP) for other high and basin/valley deposits within Borneo (Sieffermann *et al*., 1988; Staub & Esterle, 1994; Neuzil, 1997). The study by Page *et al*. (2004) has provided one of the oldest reported dates for the initiation of a massive peat deposit in lowland Southeast Asia, with accumulation taking place during both the Late Pleistocene and the Holocene (Figure 4.1; Box 4.1). Evidence from several other locations also confirms that peat formation commenced in this region before the Last Glacial Maximum (LGM, approx. 21,000 cal yrs BP or 18,000 ^{14}C yrs BP) (e.g. Anshari *et al*., 2001; Taylor *et al*., 2001; Anshari *et al*., 2004), but the peat at these sites is commonly very shallow (less than 150 cm thick) in contrast to the extensive, thick, ombrotrophic peat that characterizes the core from Central Kalimantan. The largest part of the global peatland carbon pool is contained within postglacial boreal and temperate peatlands (Gorham, 1991), most of which commenced formation during the Holocene. The discovery of a much longer palaeorecord in some tropical peat deposits makes an important contribution to knowledge of the longer-term behaviour of the peatland carbon reservoir (Large *et al.*, 2004) and, in particular, where carbon was stored during glacial periods of low atmospheric carbon dioxide levels (Anshari *et al.*, 2004).

Contemporary peat accumulation in Southeast Asia

Published estimates of present global carbon sequestration by peatlands vary between 0.06 and 0.30 Gt yr^{-1} (Buringh, 1984; Armentano & Menges, 1986; Armentano & Verhoeven, 1988), while the share of tropical peat is reputed to be about 0.06–0.093 Gt yr^{-1} (Immirzi *et al*., 1992; Franzen, 1994). These large ranges of values are mostly the result of differences in estimates of the total area of peatlands globally (120–450 Mha), and tropical peatlands in particular (30.6 – 46.0 Mha), employed by various authors. They are accentuated by different values used for accumulation rates of peat and its bulk density and carbon content in different parts of the world.

The current average accumulation rate for Indonesian peatlands has been estimated to be between 1 and 2 mm yr^{-1} (Sorensen, 1993), which is substantially higher than the rates of 0.2 to 0.8 mm yr^{-1} obtained for boreal and subarctic peatlands (Gorham, 1991) and of 0.2 to 1 mm yr^{-1} for temperate peatlands (Aaby & Tauber, 1975). Estimates of carbon accumulation rates in tropical peatlands range from 59-118 g m^{-2} yr^{-1} (Sorensen, 1993) to 61-145 g m^{-2} yr^{-1} (Neuzil, 1997), values that exceed greatly the average carbon accumulation rate for boreal and subarctic peatlands of 21 g m^{-2} yr^{-1} (Clymo *et al*., 1998). Field research studies indicate that peat accumulation in the Sebangau peatland of Central Kalimantan, Indonesia is taking place currently at a rapid rate, with implications for contemporary carbon storage within tropical peatlands and for carbon cycling globally (Page *et al.,* 2004) (Box 4.2).

The amount of carbon sequestered by peat swamp forest vegetation and allocated partly to accumulating peat is assumed to be high in climax vegetation (Brady, 1997). Suzuki *et al*. (1999) estimated primary tropical peat swamp forest annual net carbon absorption to be 532 g C m^{-2} yr^{-1} (To-Daeng, Thailand). This rate is similar to other tropical rainforest types resulting in estimates of net ecosystem carbon uptake of 516 g C m^{-2} yr^{-1} (Williams *et al*., 2001) and 415–1,448 g C m^{-2} yr^{-1} (Whittaker & Likens, 1975). Tropical forests and, in particular, tropical peat swamp forests are sensitive, however, to temperature and precipitation changes, and evidence shows that long periods of drought can change peat swamp forest annual net carbon balance from positive to negative (Suzuki *et al*., 1999).

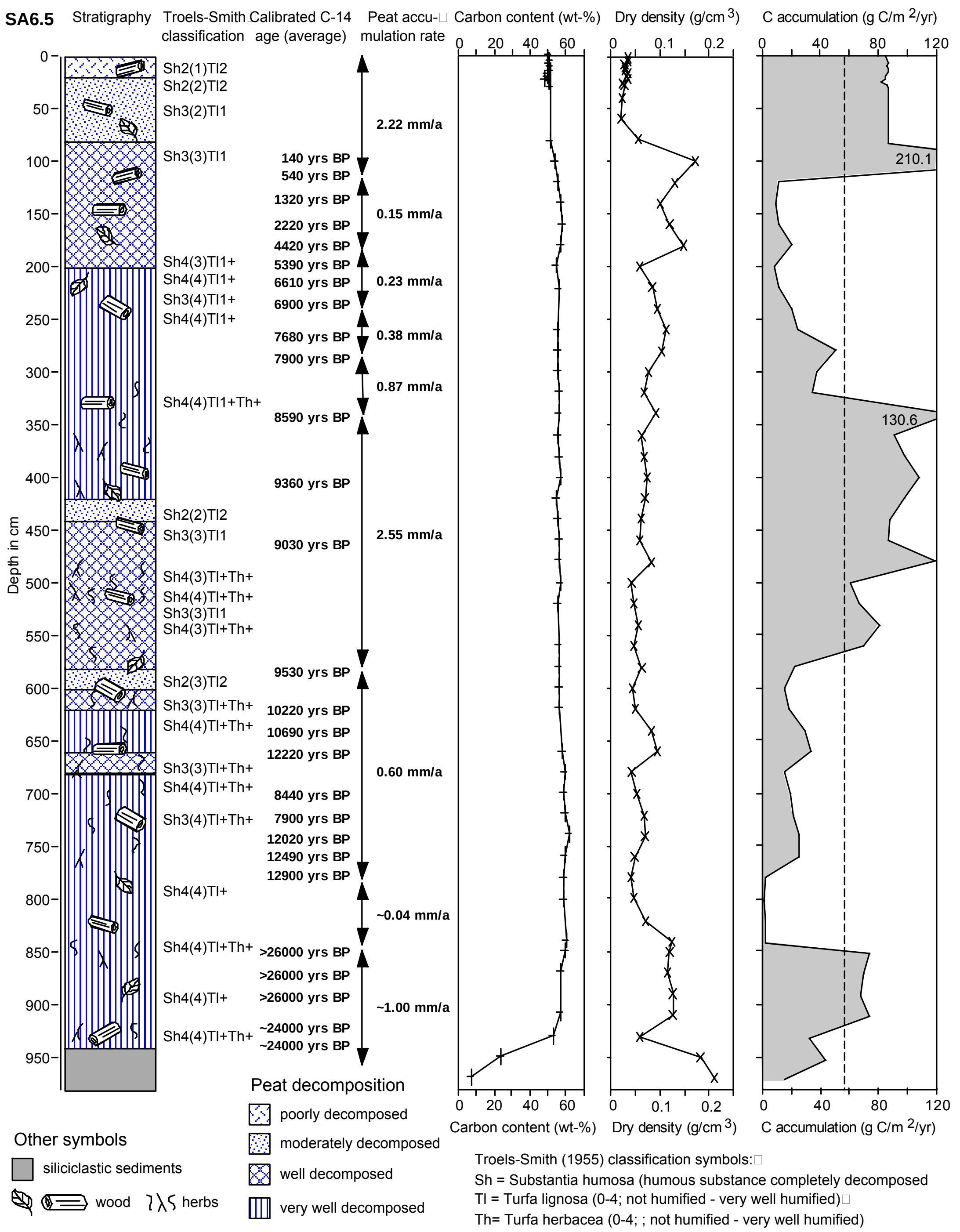


Figure 4.1: Stratigraphic description of peat core from the upper Sungai Sebangau catchment, Central Kalimantan, Indonesia illustrating stage of peat humification after Troels-Smith (1955), calibrated ^{14}C ages, peat accumulation rates, carbon content, dry density, and carbon accumulation rates during the Late Pleistocene and Holocene (from Page *et al.,* 2004). The lowermost age dates are approximately 26,000-27,000 cal yrs BP (22,000-23,000 ^{14}C yrs BP).

Box 4.1: Peat and carbon accumulation in Central Kalimantan and the South China Sea area during the Late Pleistocene and Holocene (Page *et al.,* 2004)

The record of peat and carbon accumulation from the upper catchment of Sungai Sebangau reveals a relatively rapid initial rate of peat accumulation of 1.0 mm yr^{-1} between 23,000-22,000 ^{14}C yrs BP. This is equivalent to a carbon burial rate of about 54 g C m^{-2} yr^{-1} but it was short-lived, falling to an average of only 0.04 mm yr^{-1} during and after the LGM. By 10,830 ^{14}C yrs BP average carbon accumulation rate was only 1.3 g C m^{-2} yr^{-1}.

The beginning of the Holocene coincided with increased rates of both peat and carbon accumulation. Between 8,540 and 7,820 cal yrs BP the average peat accumulation rate increased from 0.60 to 2.55 mm yr^{-1}; over a 2,180 year period (9,060-6,880 cal yrs BP) more than 3.5 m of peat accrued. These values are similar to those reported by Sieffermann *et al*. (1988) (2.4 mm yr^{-1}), but are higher than Neuzil's (1997) (0.3-1.7 mm yr^{-1}). The average rate of carbon accumulation during the early Holocene was 92 g C m^{-2} yr^{-1}, with a maximum of 131 g C m^{-2} yr^{-1}. These values exceed early Holocene rates reported by Neuzil (1997) (47-75 g C m^{-2} yr^{-1}), and are three to four times higher than C accumulation rates reported for this same period in temperate and boreal bogs (20-25 g C m^{-2} yr^{-1}) (Turunen & Turunen, 2003).

Around 6,000 years BP rising sea levels stabilised and dropped slightly, resulting in exposure of large, relatively flat areas of marine sediments (Tjia, 1975; Geyh *et al*., 1979; Tjia *et al*., 1984; Hu *et al*., 2003). The combination of favourable topographic and wet, humid, climatic conditions led to rapid peat accumulation in coastal and sub-coastal areas throughout the region (Wilford, 1959; Staub & Esterle, 1994; Hesp *et al.*, 1998). In the Rajang delta of Sarawak, 4.45 m of peat accumulated between 5,610 to 2,070 ^{14}C yr BP (Staub & Esterle, 1994), equivalent to an average peat accumulation rate of 1.26 mm yr^{-1} whilst, on the east coast of Sumatra, the peatlands of Riau province also underwent very rapid accumulation with initial rates as high as 6-13 mm yr^{-1} between 4,700 and 3,900 yrs BP, subsequently reducing to 0.6-2.7 mm yr^{-1} (Neuzil, 1997). These rates are significantly higher than the rates for mid- to late Holocene peat accumulation in the Sebangau peatland at this time of only 0.15-0.23 mm yr^{-1}.

The Sebangau peat core is important because: (1) it confirms that peat accumulation in the lowlands of the tropics occurred before the LGM; (2) the comprehensive ^{14}C record demonstrates that tropical peatlands are complex systems that develop stepwise rather than continuously and have acted naturally as both carbon sinks and carbon sources; (3) there was a major period of peat accumulation during the Late Pleistocene, culminating in a phase of very rapid peat formation and high rates of carbon accumulation during the early Holocene (Figure 4.1); (4) the peatlands of Southeast Asia played a significant role in the global carbon cycle by acting as a carbon sink from the end of the late Pleistocene until about 7,000 yrs BP; (4) it raises the question of how much carbon was stored from the early to mid-Holocene in the peatlands of Kalimantan and in tropical peatlands in general.

A continuous Holocene CO_2 record from Taylor Dome, Antarctica shows that CO_2 concentrations decreased from 268 ppmv at 9,500 yr BP to 260 ppmv at 8,500 ^{14}C yrs BP (Indermühle *et al*., 1999). Based on the data of Bard *et al*. (1996), it has been assumed that a sea level rise over the same time period of ~26 m, as a result of melt water input, could have accounted for a decrease in the atmospheric CO_2 concentration of 2.8 ppmv. The rapid expansion of peatlands in the tropics and northern hemisphere at the same time could also have contributed to the early Holocene decrease in atmospheric CO_2. On the basis that a reduction in atmospheric CO_2 of 0.47 ppmv requires the removal of 1 Pg of carbon (Sundquist, 1985), the area of tropical peatland required to sequester and store the unaccounted 5.2 ppmv (11 Pg carbon) would have to be at least 5,200,000 ha (at an average carbon accumulation rate of 92 g C m^{-2} yr^{-1}, based on the early Holocene carbon accumulation rate from this study, and over a time period of 2,300 years). This is equivalent to only 26% of the current area of peatland in Indonesia (Table 4.1) and therefore the role of tropical peat in reducing atmospheric CO_2 levels in the early Holocene is feasible although an accurate estimate of their true area is not available.

Additional problems are encountered when calculating the carbon pool (store) in tropical peatlands, either nationally (e.g. Indonesia), regionally (e.g. Southeast Asia) or globally. National peatland inventories are inaccurate, especially in tropical countries, owing to a lack of resources for survey (remote sensing and aerial photographs), difficulty of separating forested peatland from other forest types (e.g. peat swamp forest from other rain forest types), developed peatland from non-peatland, and inadequate ground truthing. In addition, areas of tropical peatland cleared of their forest cover and then drained and cultivated are usually no longer regarded officially as peatland and are excluded from inventories, although they may continue to have a considerable thickness of peat and a substantial carbon store for a long time after removal of their vegetation. Information on peat thickness in all tropical countries is very inadequate making it virtually impossible to calculate accurate estimates of peat volume and therefore carbon pools. Despite these difficulties, it is possible to provide reasonably accurate values for the total carbon store within the peatlands of Kalimantan from which to derive approximations for the whole of Indonesia and tropical peatlands globally using information derived from remote sensed and field checked data for the first (Page *et al.*, 2002), official statistics for the second (RePPProT, 1990) and published information for the last (Immirzi & Maltby, 1992). These areas, when combined with values for peat thickness, bulk density and carbon content, provide estimates of the different carbon pools (Table 4.1). The peatlands of Kalimantan represent a carbon store of 13 Pg, those of Indonesia contain 35 Pg and the global total for tropical peatlands is estimated to be 54 Pg. The value for the Indonesian peatland carbon pool is higher than previously published values in the range 16-19 Pg (Sorensen, 1993), but the value for all tropical peatlands is at the lower end of the range of 53-70 Pg estimated by Immirzi and Maltby (1992), who used higher values of dry bulk density and carbon content than in more recent studies (Page *et al.,* 2004).

Peat Volume and Carbon Storage in Central Kalimantan

The combined evaluation of peat depth field measurements, maps of peat soils and data from Landsat and SRTM DEM satellite data show that about 4.9 Pg carbon are stored within the former Mega Rice Project area and the Greater Sebangau water catchment (Figure 4.2; Bechteler, 2005). These results are of a similar order of magnitude to those in the “Map of Peatland Distribution and Carbon content” which estimates the carbon store in Central Kalimantan to be 6.3 Pg (Wahyunto *et al.,* 2004). However, the present analysis is more detailed and accurate, especially for Block B and C, as extensive field data and peat depth measurements were collected from which to model peat domes and volumes.

The analysis of more than one hundred peat drillings collected in Block B and C clearly show the dome shape of the peat layer (Figure 4.3) providing average peat thickness of 513 cm for block B and 410 cm for Block C. This equates to mean volumes of peat of 8.254 and 15.891 $\times 10^9$ m^3, respectively. The peat volume can be estimated more accurately, however, using 3D modelling and including locations where the peat is shallow or non-existent such as close to rivers. This method results in a lower estimate for average peat thickness of 296 cm for Block B and 189 cm for Block C. The peat volume shown in Table 4.2 was calculated using this model. The peat dome of the Greater Sebangau water catchment area, representing the largest area of peatland in Central Kalimantan, covers 0.794 Mha. Its peat volume is estimated to be about 67.998 $\times 10^9$ m^3, containing 3.8 Pg carbon. This estimate was based on a newly established method using the SRTM DEM data. To analyse the accuracy of this method it was applied to Block B and this shows good agreement with the result based on IDW model. Comparison of the 3D model with the SRTM DEM data indicates a remarkable subsidence of peat in some areas of Block B

(Figure 4.3). Satellite data show that recurrent fire events have occurred in this area during the past 10 years suggesting that these have burned away 1-3 metres of peat.

Table 4.1: Potential carbon pools and sinks in both Indonesian and all tropical peatlands (based on Page *et al.,* 2004).

Location	Area (km^2) (a)	Dry bulk density (g cm^{-3})	C content (dry wt)	Average peat thickness (cm)	Current C accumulation rate (g C m^{-2} yr^{-1})	Total C pool* (Pg)	Current C sink** (Tg C yr^{-1})
Kalimantan	6,787,600	0.076 (b)	0.56 (b)	440 (e)	85 (b)	12.71	5.77
Sumatra	8,252,500	0.076 (c)	0.58 (d)	440 (f)	85 (c)	16.01	7.01
West Papua	4,624,200	0.076 (c)	0.56 (c)	300 (c)	85 (c)	5.90	3.93
Rest of Indonesia	408,800	0.076 (c)	0.56 (c)	300 (c)	85 (c)	0.52	0.35
Total for Indonesia	20,072,800	0.076 (c)	0.56 (c)	405 (c)	85 (c)	35.14	17.06
Total tropical peatland	42,000,000	0.076 (c)	0.56 (c)	300 (c)	85 (c)	53.63	35.7

(a) Rieley *et al*. (1996), (b) Value based on this study, (c) Estimated average, (d) Based on Neuzil (1997), (e) Page *et al*. (2002) (*n* = 126), (f) Average value (based on: Cameron *et al*., 1989; Esterle, 1990; Esterle & Ferm, 1994; Silvius *et al*., 1984; Diemont & Supardi, 1987; Neuzil, 1997) (*n* = 17). * Total carbon pool = peatland area x peat dry bulk density x peat carbon content x average peat thickness, ** Current carbon sink = peatland area x current carbon accumulation rate

Box 4.2: Contemporary carbon accumulation by peatland in Central Kalimantan

By applying the surface peat carbon accumulation rate of 85 g C m^{-2} yr^{-1} to the entire peatland area of Kalimantan (6,787,600 km^2) (Rieley *et al*., 1996), the potential (pre-disturbance) carbon sink is estimated to be 5.77 Tg yr^{-1} (Table 4.1). Extending this to the area covered by all of Indonesia's peatlands (20,072,800 ha) (Rieley *et al*., 1996), produces an estimate of a potential peatland carbon sink of 17.06 Tg yr^{-1}. If this is extrapolated to the global area of tropical peatland (42,000,000 ha) their carbon sink potential is 35.7 Tg yr^{-1}, which is equivalent to about 54% of that for all temperate, boreal and subarctic peatlands (66.2 Tg yr^{-1}) (Turunen *et al.,* 2002). The value for carbon storage in all tropical peatlands is below the range of 41.5–93.4 Tg yr^{-1} estimated by Maltby and Immirzi (1993) but is close to the value of 34 Tg yr^{-1} calculated by Armentano & Verhoeven (1988). It should be noted, however, that these values refer to potential rather than actual carbon storage; the carbon sequestration function of large areas of tropical peatland has been reduced by deforestation, drainage, agricultural conversion and fire, all of which enhance carbon losses to the atmosphere.

Table 4.2: Peat volume and carbon storage within the MRP and the Greater Sebangau Water Catchment Area, Central Kalimantan.

		MRP				Greater Sebangau water catchment area
		Block A	Block B	Block C	Block D	
Area (Mha)		0.135	0.161	0.388	0.138	0.79
Peat drillings	Volume (10^9 m³)	4.5	8.2	15.9	0.791	67.9
	Average depth (cm) from peat depth measurements		513	410		
3D Modelling	Average depth (cm) from IDW interpolation	333	296	189	57	856
Carbon Storage (Pg) based on 3D model		0.257	0.272	0.419	0.045	3.79

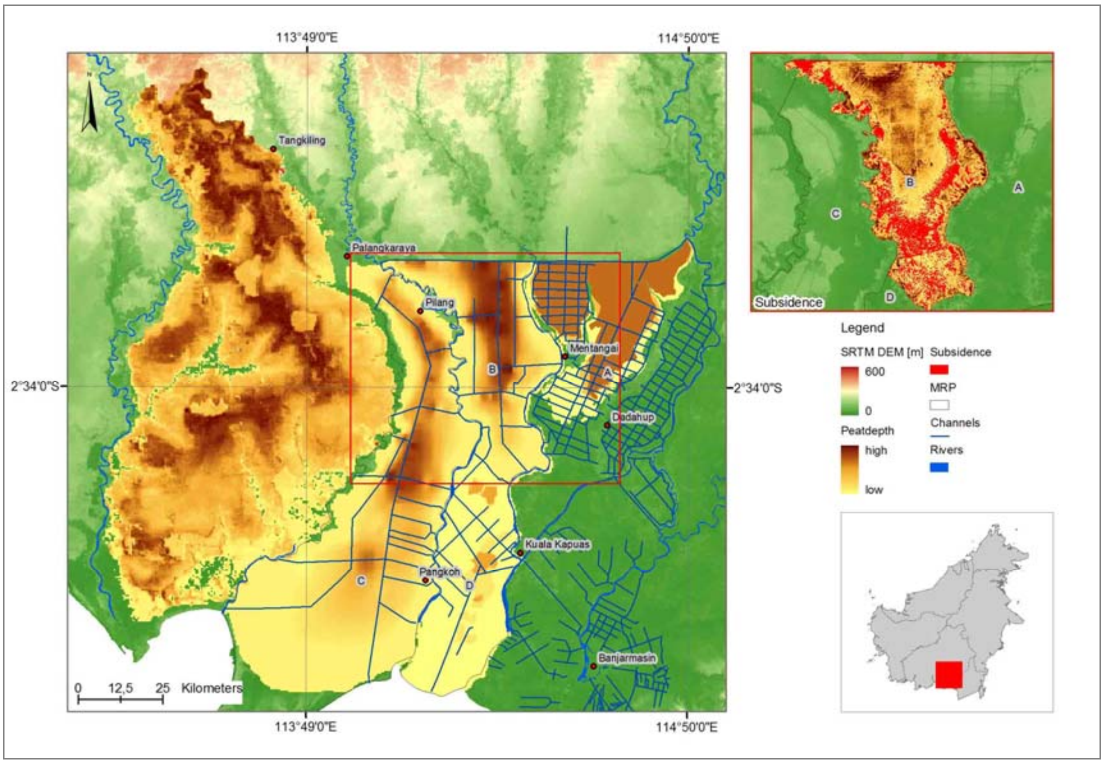
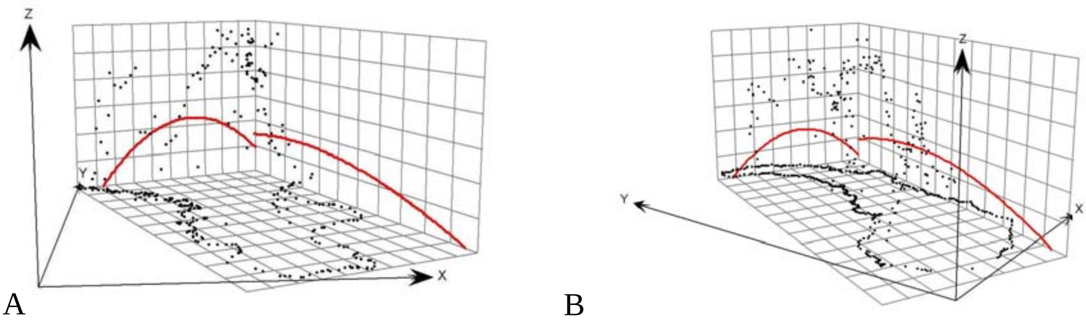


Figure 4.2: Peat deposits within the MRP and the Greater Sebangau water catchment area, Central Kalimantan. Different outward forms depend on different methods used for creating the surface models.



A B

Figure 4.3: Trend analysis of peat depth measurement of bock B and C. The best arithmetic chart sets the orientation of the plots. A. Block B of the MRP. B. Block C of the MRP; both show a clear dome shape and a decrease in thickness close to the edges/rivers and to the south in the direction of the sea (towards the front).

Impact of human disturbance on tropical peatland sink and store capacities

In their natural condition most tropical peat swamp forests function as carbon sinks and stores, but forest clearance and drainage can convert them rapidly to carbon sources. This happens because destruction of the forest cover leads to a decrease in the amount of carbon allocated into the ecosystem and agricultural practices require low water tables within the peat which increase further surface peat oxidation leading to peat subsidence and loss of stored carbon (see Chapter 2). One example of the carbon allocation reducing effect is from the late 1980s when 3.7 million hectares of Indonesian peat swamp forest were developed (Silvius *et al*., 1987). This led to an 18% decrease in natural peatland area with an estimated consequent reduction in the carbon fixation potential of 0.005 – 0.009 Pg yr^{-1} (Sorensen, 1993).

Carbon gas fluxes to and from tropical peatland

Carbon dioxide is fixed in the process of photosynthesis. Some of the fixed carbon is released back to the atmosphere in the parallel process of respiration but the surplus is stored in plant biomass. This is the basis of carbon sequestration by peat swamp forest trees and incorporation of some of this biomass and the carbon it contains as peat. This peat carbon store is labile i.e. it may be stored for thousands of years but it can be released back to the atmosphere, as CO_2 or CH_4, as a result of aerobic and anaerobic decomposition. The balance between the ecosystem carbon uptake and continuous losses to the atmosphere may change as a result of natural climate change or human activities (development), leading to lower carbon allocation rates or increased carbon losses.

The most important carbon containing gases emitted from peatlands are carbon dioxide (CO_2) and methane (CH_4) with the former far exceeding the latter in both amount and effect. CO_2 emissions from peat swamp forest range from 139–620 mg m^{-2} h^{-1} (Table 4.2). In contrast, *Sphagnum*-dominated ombrotrophic sites in the Boreal Region release, on average, 314 – 320 mg m^{-2} h^{-1} (Martikainen *et al.,* 1995; Nykänen *et al.,* 1998). The highest CO_2 emission rates are found on hummocks (formed mostly from aggregations of fine tree roots); emission rates are much less in hollows (depressions between hummocks), especially when the peat is water-saturated (Jauhiainen *et al.,* 2005). Higher CO_2 emissions occur in peat swamp forest in the dry compared to the wet season when the peat in both hummocks and hollows is dry for long periods. Cumulative peat swamp forest CO_2-C emissions, including losses from peat decomposition, autotrophic respiration of vegetation and heterotrophic respiration of soil animals, vary from 880 g m^{-2} yr^{-1} (Ishida *et al.*, 2001), 950 g m^{-2} yr^{-1} (Jauhiainen *et al.*, 2005), up to 2,100 g m^{-2} yr^{-1} (Melling *et al.*, 2005), compared to only 270 g m^{-2} yr^{-1} (Alm *et al.,* 1998) and 320 g m^{-2} yr^{-1} (Alm *et al.,* 1999) from boreal peatlands. As a consequence of selective logging and artificial drainage, peat oxidation, after the initial very high loss rates during development, is estimated to result in further losses of about 2,000-2,700 g m^{-2} yr^{-1} CO_2 (i.e. 550-740 g m^{-2} yr^{-1} CO_2-C) annually (Wösten *et al.,* 1997; Jauhiainen *et al.,* 2004). Carbon losses immediately after drainage, however, are much higher, and the loss rate depends largely on the water table depth within the peat (see Table 2.9).

The basic relationship between peat subsidence and CO_2 emission is that every centimetre of peat subsidence results in a CO_2 emission of approximately 1,300 g m^{-2} yr^{-1} (360 g m^{-2} yr^{-1} CO_2-C) (see Chapter 2). This value can be combined with information on long-term average relationships between peat subsidence and water table depths for different regions of the world in order to obtain estimates of CO_2 emissions under different environmental conditions. Figure 4.2 shows the result of this combination for Malaysia, Florida (USA), Indiana (USA) and the Netherlands. An increase in soil temperature and the absence of winter-summer periodicity explain the increase in subsidence rates at all groundwater levels from temperate through to tropical areas in the world. At the same time the figure shows that lowering the water table depth causes a dramatic increase in the release of CO_2 for all peatland locations.

Methane is produced as a by-product of microbial decomposition of organic matter under anaerobic conditions (see Chapter 3). Methane emissions from tropical peatlands are low and during dry conditions peat can form a weak methane sink (Table 4.2). The average methane emissions range in forest sites from 0.000303-3.04 mg CH_4 m^{-2} h^{-1} (0.00023–2.28 mg CH_4-C m^{-2} h^{-1}) (Table 4.2). These values are low compared to other wetland ecosystems. For example, alluvial Amazonian flooded forests and their adjacent floodplains release 8.0±1.1 and 9.6±3.0 mg CH_4 m^{-2} h^{-1}, respectively (Bartlett *et al.,* 1988), while boreal *Sphagnum*-dominated ombrotrophic mire release 2.05-2.5 mg CH_4 m^{-2} h^{-1} (Martikainen *et al., 1995;* Nykänen *et al.,* 1998). The low methane flux rates in peat swamp forests are reflected in the annual cumulative methane fluxes which range from 0.018-1.02 g CH_4-C m^{-2} yr^{-1} (Jauhiainen *et al.,* 2002; Melling *et al*., 2005b). Drained, unused tropical peatland is more or less inactive in terms of CH_4 production, which may be largely a consequence of modest inputs of debris and peat dryness (Jauhiainen *et al.,* 2003, 2004). The annual estimates of cumulative CH_4 fluxes have been -0.015 g CH_4-C m^{-2} yr^{-1} on oil palm plantation peat (Melling *et al*., 2005b), +0.09 g CH_4-C m^{-2} yr^{-1} on fallow peat (Jauhiainen *et al*., 2004), and up to +0.18 g CH_4-C m^{-2} yr^{-1} on Sago plantation peat (Melling *et al*., 2005). It should be remembered that low CH_4 fluxes or even small gas uptake on developed peat takes place as an exchange for increase in the CO_2 emissions and increased risk of carbon losses by fire. Inubushi *et al.,* (1998) estimated CH_4 emissions from tropical peat soils to be 2.43 Tg yr^{-1}, thus contributing only 2.1% of methane emissions from global natural wetlands and 0.45% of global methane emissions.

Table 4.2: Atmospheric flux rates of CO_2 and CH_4 from tropical peat swamps. Presented results are based on *in situ* measurements in various locations and are not directly comparable because the environmental conditions, such as, peat water table depth may have differed greatly.

Site	CO_2 flux ($mg\ m^{-2}\ h^{-1}$)	CH_4 flux ($mg\ m^{-2}\ h^{-1}$)	Site type description	Ref.
Western Johor, Malaysia	444		Forest	a)
Sarawak, Malaysia	915		Forest	b)
Central Kalimantan, Indonesia	484 ± 21 – 610 ± 17 (*		Forest hummocks	c)
Central Kalimantan, Indonesia	139 ± 46 – 689 ± 62 (*	~-0.1 – 0.35	Forest depressions	c)
To Daeng swamp, Thailand	620 ± 616	2.09 ± 0.64 (**	Forest	d)
To Daeng Swamp, Thailand		1.07 ± 2.71	Forest	e)
Sarawak, Malaysia		1.10 ± 0.61	Forest	f)
Sarawak, Malaysia		0.00303 ± 0.00183 (*	Forest	g)
Bacho swamp, Thailand	488 ± 528	3.04 ± 1.28 (**	Drained, secondary forest	d)
Central Kalimantan, Indonesia	220 – 430	-0.11 – 0.06	Fallow peat	h)
Central Kalimantan, Indonesia	49 – 52	6.10 – 10.77	Paddy rice field	i)
Sarawak, Malaysia	504		Sago palm plantation	b)
Sarawak, Malaysia		1.39 ± 0.82	Sago palm plantation	f)
Sarawak, Malaysia		0.0294 ± 0.00757 (*	Sago palm plantation	g)
Sarawak, Malaysia		-0.0048 ± 0.0030 (*	Oil palm plantation	g)
Western Johor, Malaysia	620		Oil palm plantation	a)
Sarawak, Malaysia	693		Oil palm plantation	b)
Western Johor, Malaysia	345		Pineapple field	a)
Central Selangor, Malaysia	327		Maize field	a)
Central Selangor, Malaysia	256		Fallow peat	a)

Note: *) Average ± SE presented, **) Average ± SD presented. References: a) Murayama & Bakar, (1996); b) Melling *et al*., (2005); c) Jauhiainen *et al*., (2005); d) Vijarnsorn *et al*., (1995); e) Ueda *et al*., (2000); f) Inubushi *et al*., (1998); g) Melling *et al*., (2005); h) Jauhiainen *et al*., (2002a); i) Barchia & Sabiham, (2002).

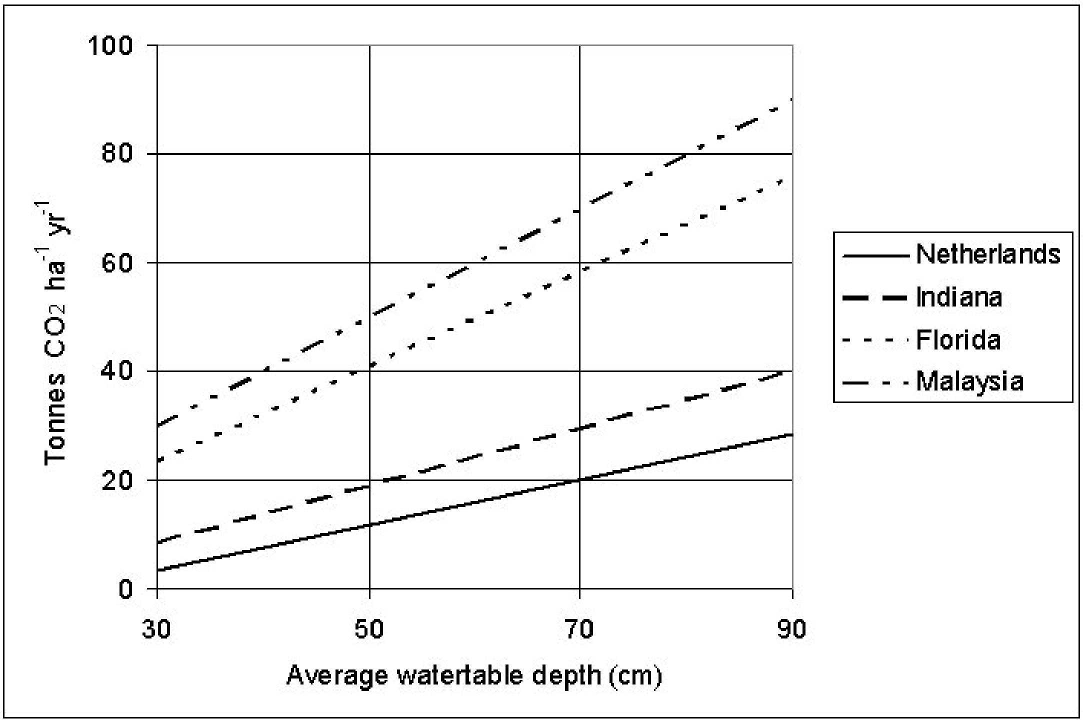


Figure 4.2: CO_2 emission rates as a function of water table depths in peat soils at different locations.

Role of fire in losses of carbon from tropical peatland

Owing to poor management, fires ignited on peatland used for land clearance can spread to logged forests, destroying the vegetation (Uhl & Kauffman 1990; Verissimo *et al.,* 1995) and increasing the vulnerability of the landscape to subsequent fires (Nepstad *et al.,* 1995; Page *et al.,* 2002). Emissions from peat fires can release 5,000–10,000 g C m^{-2} (Page *et al.,* 2000; Siegert *et al.,* 2001) but may be as much as 30,000 g C m^{-2} (Page *et al.,* 2002). Based on estimates of the total area of fire-affected peatlands, it was concluded that the fires of 1997/98 released between 0.8 and 3.7 Pg C to the atmosphere as a result of burning peat and vegetation in Indonesia (Page *et al.,* 2002; Langenfelds *et al.,* 2002) (Box 4.3). An estimate of the amount of carbon released in the 1994/95 ENSO fires was 0.6–3.5 Pg C (Langenfelds *et al.,* 2002) while a further 0.25–0.5 Pg could have been released in subsequent fires in 2002. This magnitude of carbon bursts to the atmosphere is comparable to nearly half of the current global 6.4 Pg yr^{-1} (IPCC, 2001) carbon emission from the burning of fossil fuels (see also Box 4.3).

Box 4.3: Impact of fire on carbon release from peatland in Indonesia

Tropical peat swamp forest resources and natural functions are being damaged severely by fire and may be destroyed forever with potentially devastating consequences regionally and globally. The combination of an extremely long El Niño of 8 months in 1997, linked with land clearance for the ill-fated, one million hectare Mega Rice Project in Central Kalimantan, Indonesia disrupted the peat swamp forest ecosystem and made it extremely prone to fire. An area of around 55% of this landscape burned in 1997 releasing about 0.15 Pg carbon to the atmosphere while peatland fires throughout Indonesia as a whole affected an area of more than 1.5 million hectares of peatland and liberated 0.8-2.7 Pg carbon equal to 15-40% of the annual global carbon emissions from the burning of fossil fuels (Table 4.3) (Page *et al.,* 2002). This was a disaster of catastrophic proportions that not only released vast amounts of carbon from the tropical peat store to the atmosphere as carbon dioxide, methane and soot but it also affected human health. In addition, it has led to increased flooding of these vast landscapes and downstream habitations in the rainy season, because the peatland has lost much of its water absorption and retention properties.

There are now increasing periods of protracted drought in the dry season because the drainage channels excavated for agriculture and human settlement enable water to flow from the peatland quicker than in their natural state. Fires reoccurred in Kalimantan in both 2002 and 2003, although with less severity than in 1997 but, never the less, these resulted in a further loss to the atmosphere of large amounts of carbon (Limin *et al*., 2004). A study based on the quantitative evaluation of satellite imagery showed that peat drainage, logging and previous fire damage are the major factors that make peat swamp forests susceptible to fire. Forests, which had been burnt once, are more likely to burn again, leading to a progressive degradation of the forest vegetation into fire prone bush land that is even more susceptible to fire (Bechteler & Siegert, 2004). Other peatland development areas in Kalimantan, Sumatra and West Papua were similarly affected.

Forest and peat fires have important impacts within the peatland area affected, on surrounding landscapes and the global environment. Forest fire in peatland areas results in the loss of vegetation and the surface peat layer, creation of smoke (haze), and changes in the peat characteristics. Based on a field survey reported by Page *et al.* (2002), the thickness of peat lost through combustion during the 1997 fire averaged 0.40 m over the peatland areas of Central Kalimantan.

The post-fire condition of the peatlands is such that they are open and exposed to the climatic elements and, therefore, they become much more susceptible to erosion and are at greater risk of future fires. The peat also becomes much more compact and decomposed. Compaction and enhanced decomposition of the peat, as well as the loss of peat in combustion, result in a more rapid subsidence (see Chapter 2). In relation to the enhanced peat decomposition, a recent study of the peatlands of Central Kalimantan (Kurnain *et al.,* 2001) showed that the 1997 fires affected certain important physical and chemical properties of the peat, and the changes observed were closely related to the progress of peat decomposition.

Table 4.3: Peat areas, volumes, carbon stores and carbon transferred to the atmosphere in the 1997 fires (from Page *et al.,* 2002)

	Block C of MRP (383,800 ha)	Entire MRP (988,568 ha)	Study Area (2,491,619 ha)	Extrapolated values for whole of Indonesia (190,400,000 ha)		
				Lower estimate	Inter-mediate estimate	Upper estimate
Peatland Area	337,632	854,809	2,153,304		20,072,825[4]	
Peat volume*	7.8-14.9	19.7-37.6	49.5-94.7		461.7-883.2	
Carbon store*,†	0.44-0.85	1.12-2.14	2.82-5.4		26.32-50.34	
Area of fire damaged peatland	184,564 (48.1%)	474,009 (48.0%)	729,500 (29.3%)	1,450,000 ✎	2,441,000‖	6,804,688 §
% of peatland area damaged	54.7%	55.5%	33.9%	7.2%	12.1%	33.9%§
Peat volume loss‡	0.85-1.03	2.18-2.66	3.36-4.09	6.67-8.12	11.23-13.67	31.30-38.30
Peat Carbon loss to atmosphere‡	0.05-0.06	0.12-0.15	0.19-0.23	0.38-0.46	0.64-0.78	1.78-2.17
% Peat Carbon loss from store‡	5.9-13.6%	5.6-13.4%	3.5-8.2%	0.8-1.8%	1.3-3.0%	3.5-8.2%
Biomass carbon loss∞	0.01	0.03	0.05	0.10	0.17	0.40
Total carbon loss	0.07-0.07	0.14-0.17	0.24-0.28	0.48-0.56	0.81-0.95	2.18-2.57

Peatland area in hectares; peat volume in $m^3 \times 10^9$; carbon store and loss in Gt = Pg = $g \times 10^{15}$; *range derived from the IDW interpolation model average peat thickness of 2.3 m and 4.4 m from 126 field drillings; †based on a peat bulk density of 0.1 g cm^{-3} and peat carbon content of 57% (0.57)[18]; ‡using 0.5 m for the estimated average depth by which peat burned down in the 1997 fires; ✎this value is obtained from the ADB/BAPPENAS Report (1998)[9]

Tropical peatlands and global climate change

During the past 100 years, the mean global temperature of the earth's surface is estimated to have increased by 0.3–0.6°C (IPCC, 2001). It is generally accepted that this change is primarily the result of rising atmospheric concentrations of greenhouse gases, especially carbon dioxide, methane and nitrous oxide. Combustion of fossil-fuels and deforestation have increased the concentration of atmospheric carbon dioxide by 30%, and more than doubled the atmospheric methane concentration from pre-industrial levels. One of the consequences of a climate warming of 3–4°C could be elimination of 85% of all existing wetlands (WCMC, 2003).

Severe and long-lasting regional smoke-haze and fire episodes during extreme droughts associated with ENSO events have occurred repeatedly in Southeast Asia over the last two decades (Maltby, 1986; Page *et al*., 2000). The danger of an increased frequency of major fires in years with prolonged dry seasons, and future climate scenarios, suggest there will be an increase in the number of days with high risk of fire in tropical areas (Goldammer & Price, 1998; Stocks *et al*., 1998). Some studies suggest an increase in ENSO related tropical storm intensities with CO_2-induced warming in the Asia Pacific region in the future (Henderson-Sellers *et al.*, 1998; Royer *et al*., 1998). This is likely to increase the abundance and size of gaps in fragmented forest canopies and areas with long, convoluted boundaries or degraded forest structure resulting from previous fires and logging activities. Storm damage and logging both reduce leaf canopy coverage, thus allowing sunlight to dry out the organic debris on the ground, leading to increased amounts of flammable undergrowth and frequency and intensity of fires with consequent release of large amounts of stored carbon from biomass and peat (Verissimo *et al*., 1995; Holdsworth & Uhl, 1997; Siegert *et al*., 2001). The forest and peatland fires that affected large areas of Southeast Asia during 1997 - 1998 are believed to have been a major contributor to the sharp increase in atmospheric CO_2 concentration detected in 1998, from the 1990-1999 average of 3.2 ± 0.1-6.0 Gt C yr^{-1}, the highest value recorded since direct measurements began in 1957 (IPCC, 2001).

Contribution of peatlands to climate change

The contribution of peatlands to climate change comes about as a result of emissions of the greenhouse gases carbon dioxide, methane and nitrous oxide, but mostly the first two. In this respect, the main source of carbon dioxide to the atmosphere is from peatlands that are degrading naturally or have been damaged by human interference (see Chapter 2). The former may occur when a peatland has reached a stage at which it is no longer acting as a carbon sink and may become subjected to periods when the hydrological conditions are no longer conducive to accumulation of peat. If the surface dries out for part or all of the year the peatland is likely to experience aerobic oxidation coupled with an increased release of carbon dioxide as a result of decomposition. The same conditions can prevail, but more severely, as a result of anthropogenic activities that involve drainage and/or damage to the surface of the peatland (Table 4.4). These practices include conversion of peatland to agriculture or forestry, although the latter may off-set CO_2 losses for a time as a result of carbon incorporation into the biomass of growing young trees, and the utilisation of peat for industrial and horticultural purposes, including energy.

The cumulative increase of carbon from changes in land use up to 1980 may have diverted 6.6-8.1 Tg of carbon from the peatland store equivalent to 0.18-0.27 Tg of carbon a year. This implies that in the 21 years since 1980 4-6 Tg carbon may have been released, equal to one year's release attributed to fossil fuels.

The significance of methane as a greenhouse gas, even though it has a relatively low atmospheric concentration, results from its high radiative absorption potential (about 30 times that of carbon dioxide). In natural mires (actively accumulating peatlands), it is unlikely that emissions of methane have contributed to the observed increases in atmospheric methane in recent decades since these are probably negated by the sink role of peatlands as a result of anthropogenic disturbance (van Breeman & Feijtel, 1990).

Table 4.4: Net Changes in Carbon Relations Attributable to Development of Peatland Resources (from Immirzi & Maltby, compiled from Armentano & Menges, (1986), Armentano & Verhoeven (1988))

<table>
<tr><th>Impact</th><th>Annual shift (tg)</th><th>Aggregate shift to 1980 (tg)</th><th>Former area (tg)</th><th>Total area lost (million hectares)</th></tr>
<tr><td>Temperate agriculture/ forestry [1]</td><td>63 - 85</td><td>4,140 - 5,600</td><td>349</td><td>20-23,9</td></tr>
<tr><td>Tropical agriculture/ forestry [2], [3]</td><td>53 - 114</td><td>746</td><td>44</td><td>1.76 - 4.49</td></tr>
<tr><td>Subtotal agriculture/ forestry</td><td>116 - 119</td><td>4,886 - 6,346</td><td>393</td><td>21.76 - 28.39</td></tr>
<tr><td>Fuel</td><td>32 - 39</td><td>690 - 800</td><td></td><td rowspan="2">5</td></tr>
<tr><td>Horticulture</td><td>34</td><td>> 1000</td><td></td></tr>
<tr><td>Total [1]</td><td>182 - 272</td><td>6,576 - 8,146</td><td>393</td><td>26.76 - 33.39</td></tr>
</table>

Notes: [1]. The higher area estimates might include substantial areas previously cut for fuel or horticulture and then converted to agricultural or forestry use; [2]. This includes drainage and deforestation of peatswamp; [3]. While we have established that a larger area has been altered, we do not know the time scale and therefore cannot offer a higher figure for aggregate shift, although it may be at last 50 per cent higher

Impact of climate change upon peatlands

The main impacts of climate change on tropical peatlands are likely to be through changes in temperature and water resources (see Chapter 3) that may bring about replacement of the original species by others (i.e. influencing successional change patterns and sequences) that may also change the biodiversity of these ecosystems (see Box 4.4). The natural temporal and spatial variability of peatlands that are consequences of water supply and storage characteristics make it difficult to predict impacts of climate change. Sea level rise may affect a range of freshwater wetlands, including peatlands, in low altitude situations by, for example, displacing coastal freshwater habitats by saline or brackish ones or causing enhanced flooding further inland that may lead to the extension of swamp and peatland.

Climate change may also affect the peatland carbon sink, although the direction of this change is uncertain owing to various climate related contributory factors, human interference and the number of possible responses.

Lowland tropical peatlands and climate change adaptation

Tropical peatlands play at least two critical but contrasting roles in adaptation to the effects of climate change:

1. Management of greenhouse gases (especially carbon dioxide).
2. Physically buffering climate change impacts.

Peatlands will play a further role as the frontline defenders of coastal and inland areas as countries deal with the full effects of climate change including, increasing frequency of storms, changing rainfall patterns, rising sea levels and sea surface temperatures. A major component of adaptation that needs further attention is assessment of the vulnerability and response of peatlands to climate change and sea level rise and identification of specific options. Various methods have been identified for vulnerability assessment although, at present, there is no agreement on a single approach to this problem.

Implications of carbon flux for wise use of peatlands

Carbon releases from peatlands are likely to remain less than those from fossil fuel sources. At a national level inputs from various peat utilization sectors to the global carbon balance may appear trivial, but cumulatively the amount is important. If global measures are required to diminish carbon dioxide releases from natural sources, one goal should be the maintenance of the peatland store. This can only be achieved by ensuring that peatlands remain hydrologically intact and their peat-forming vegetation is maintained, so that their carbon sequestering capacity, however small, is preserved and the carbon store is not released.

Box 4.4: Climate change prediction for peatlands of Borneo (IPCC, 2001)

Borneo is one of the largest islands (53,946,000 ha) in the Malaysia-Indonesian archipelago. The region has a humid tropical climate, with high temperature and precipitation. The peatlands of Borneo may play a major role in determining regional climate at the present time, although there is no substantial evidence to confirm this. The peatlands of Borneo are deteriorating currently through the loss of natural ecosystems, including primary forest cover. Deforestation, drainage and agriculture all limit the buffering capacity of developed peatlands, causing changes that are long-term and irreversible. Because much of the human settlement at the present time is located in the coastal zone, peat swamp forest on the thicker interior peats has not been subject to large-scale peat extraction. Until recently, these areas have been used mainly for timber extraction rather than agriculture and their vegetation cover had remained relatively unmodified. This is now changing as a result of Government pressure to obtain new areas of land for human settlement and plantation agriculture.

Temperature change

The projected climate change for the Borneo region involves an increase in annual surface temperature of 1.05 °C by 2020, and 3.3 °C by 2080. The effects of higher temperature and longer dry periods will be to produce longer periods when evapotranspiration will exceed rainfall and effective rainfall will be reduced greatly. This, linked with increased human activity on tropical peatlands, could have serious consequences. Much of the Bornean lowlands experience a distinct dry season during which water levels drop and peat oxidation occurs with a loss of some carbon to the atmosphere. This situation also increases the risk of fire that is a major threat to the integrity of these tropical wetlands by causing damage to their vegetation and underlying peat. The risk of fire spreading to natural peat swamp forest from developed areas increases during the dry season and would be even greater if the dry season is extended.

Precipitation change

Estimates of precipitation changes for this region range from 2.4% increase in precipitation by 2020 to a total of 8.5% increase by 2080. Temporal distribution of precipitation over the year is expected to remain relatively small, although the share of dry season precipitation is expected to decrease in the longer term estimate.

Possible impacts

Increased temperatures are likely to result in longer periods of drought because evaporation will be increased and may overcome the effect of increased precipitation on peat water table. It is likely that vegetation net carbon uptake will not increase as a result of increased temperatures, because of a likely net decrease in photosynthesis. Therefore the overall impact from the expected changes in the climate on the hydrology and vegetation of peatlands is likely to be negative during the next few decades.

Remediation actions

The principal way to maintain the integrity and sustainability of Borneo’s peatlands is by maintaining hydrological and ecological intactness of these ecosystems and especially the high water table and forest cover. It is best not to remove the forest and attempt drainage and land conversion since rehabilitation of degraded wetlands and peatlands is very difficult (if not impossible) and extremely costly.

CHAPTER 5: USES OF AND IMPACTS ON TROPICAL PEATLANDS AND PEAT

Introduction

Uses of tropical peatland can take the form of various types of sector development, for example agriculture, forestry, mining and urban, or they may involve retention of the natural peat swamp forest ecosystem for community resource provision or wildlife conservation. Sector utilization for socio-economic purposes is part of the planned development of a country and is governed by various legal instruments and actions. The objectives may be to increase the overall GDP, increase food supply or disperse dense populations to less populated areas. Different sectors do not communicate well with each other and often compete for the same landscapes and sources of funding. Sector development planning decisions may be taken quickly in order to alleviate some short-term problem and, inevitably, environmental consequences may be ignored.

Unplanned events, including unauthorized (illegal) activities and natural disasters, affect both pristine and sector developed tropical peatlands, often seriously. The former may be illegal logging that threatens the future of forests and forestry in many developing countries, including those with tropical peatland, but it also includes resource utilization of natural forest products and services that have been put under pressure as a result of poverty, immigration and settlement. Illegal activities could be stopped if the three evils of collusion, corruption and nepotism would be dealt with through law enforcement with adequate resources. The solution to poverty is more problematic and requires government, even international, action, to address the core issue of how to provide sustainable livelihoods for an increasing population without overloading the carrying capacity of local natural resources.

Unexpected natural events of major impact include drought and flood in dry and wet seasons, respectively. As a consequence of climate change it appears that extremes of both are occurring with increasing frequency in the Southeast Asia region. The impacts of these have been increased, however, as a result of inappropriate sector development activities, for example the ill-fated Mega Rice Project in Central Kalimantan, Indonesia (Annex 2) and illegal logging. Lightning strikes are frequent and may cause localized fires in peat swamp forest (Anderson, 1964)

There are several options for sector development or ‘use’ of tropical peatlands. The dominant one at present is agriculture which forms the core of most planned developments (Andriesse 1988). Peatland conversion for this purpose has been taking place in Sarawak for at least 50 years, initially to provide land for poor, landless immigrants, especially Chinese. Peatland development in Indonesia has been a more recent process, initially to allocate land for subsistence farming by transmigrants but, more recently, for plantation crops. It should be noted, however, that indigenous people have never lived permanently in tropical peat swamps or cultivated peat soils regularly. There have been few instances of successful agriculture on tropical peat, although uncritical transfer of experience from one area to another has led to over-optimistic expectations. Forestry has been a major sector in peat swamp forest only since the 1970s when it commenced in response to the decrease in available dry land forest. Peat swamps support several species of native trees that are of commercial value, for example, ramin (*Gonystylus bancanus*) and meranti (*Shorea spp*.) (see chapter 3, biodiversity). Unfortunately, sustainable forestry seems to have been abandoned as a long-term prospect for tropical peat swamp forests partly because the land is viewed as more valuable if it is used for agriculture or urban development and partly because unauthorized activities (e.g. illegal logging) appear to be impossible to control or eradicate. A new approach is required if forests and forestry on tropical peatland are to have a future.

Two other lesser known and practiced sector activities on tropical peatland are peat mining and wildlife conservation (Andriesse 1992). The former involves the excavation of peat to be used as fuel (domestic and energy generation), as a soil ameliorant (soil improver in agriculture and horticulture), in pottery making and for a variety of industrial uses. At present, the large scale use of peat for energy and horticulture in the tropics has little economic prospect. Removal of lowland tropical peat creates major environmental and socio-economic problems including lowered land surfaces that are prone to flooding and exposure of underlying pyrite or quartz sand that have the potential to make resultant soils more acidic and nutrient deficient than the peat itself. The conservation of tropical peatland is severely under-served probably because this land is viewed by governments as a potential for future development that would contribute to the income earning capacity of a local area or country. This low priority is reflected in the small area of tropical peatland protected in National Parks and Nature Reserves throughout Southeast Asia.

There are a few protected areas in Indonesia (a small part of Tanjung Puting National Park in Central Kalimantan and the Berbak NP in Sumatra), Sarawak (Maludam NP and proposed Bruit NP) and Thailand (Narathiwat Province). A major step forward, however, occurred in November 2004 when the Government of Indonesia proposed to gazette some 580,000 hectares of peat swamp forest in the Sungai Sebangau catchment of Central Kalimantan as a National Park.

The Ramsar Convention has recently adopted a policy to increase the number and area of peatland sites in its inventory of ‘Wetlands of International Importance’ and recommends that many more should be designated. There are opportunities to combine conservation of tropical peat swamp forests with sustainable forestry since this could be the best way to ensure the survival of this important ecosystem while contributing to socio-economic improvement.

Every sector use of tropical peat swamps has an impact upon the ecosystem, its fauna and flora and the human communities that live in the surrounding area. There is a range of management options that are identified by policy makers and planners from which choices are made mostly by administrators and decision takers. The environment and local people have little say in the matter although the latter may be beneficiaries. Sector interests follow well defined procedures and their consequences can be predicted fairly accurately, whether in terms of crop and timber yields, socio-economic benefits or environmental impacts. It is for society to decide the priorities.

Agriculture

Tropical peats are problem soils, which are classified not only as marginal or unsuitable for crop cultivation (see Chapter 2). Apart from nutrient deficiencies, the development of tropical peatlands for agriculture faces many other constraints associated with their inherent properties and behaviour, lack of understanding of which has often led to excessive subsidence and rapid exhaustion of the natural fertility of the peat (Widjaja-Adhi 1997). The fragility of tropical peatland ecosystems necessitates the preparation of well planned resource management strategies to implement sustainable non-damaging development, equitable resource allocation, and conservation of peat resources.

Development of peatlands for agriculture faces many constraints. In addition to soil and chemical problems, there are also the following (Soepraptohardjo & Driessen, 1976):

- High rate of subsidence following removal of the original vegetation and drainage
- Extremely rapid horizontal hydraulic conductivity and slow vertical conductivity
- High heat capacity and low thermal conductivity
- Reduced rate of decomposition and a high percentage of wood
- Low weight bearing capacity
- Rapid oxidation and subsequent decomposition of organic matter after drainage; and
- Irreversible shrinkage which causes adverse water retention characteristics and increased susceptibility to erosion.

The reclamation, or conversion, of tropical peatland for agriculture involves drainage and land clearing, which, apart from causing loss of biodiversity, inevitably produce changes in the physical, chemical, and biological properties of the peat soil, introducing constraints for cropping (see Chapter 2). In addition, subsequent cultivation practices will also have an influence on these properties.

In terms of physical properties, drainage results in rapid peat subsidence within the first 4-10 years, followed by a slowing down to a somewhat constant rate thereafter (see Chapter 2). With subsidence and compaction, various changes occur to soil physical properties, including increased bulk density, and decreased total porosity, oxygen diffusion, air capacity, available water volume and water infiltration rate. Other problems associated with subsidence are a compacted land surface and the exposure of buried tree trunks, which pose tillage problems. After drainage and cultivation, peat decomposition continues, contributing further to increase in bulk density. Excessive drying of the peat soil results in hydrophobicity which renders it much more susceptible to surface waterlogging and erosion (Radjagukguk, 2000). The effects of peatland reclamation on the physical properties of the peat soil are summarized in Table 5.1.

With regards to chemical properties, drainage and tillage increase CO_2 release owing to increased peat decomposition which, in turn, results in higher acidification. This is offset, however, by the effect of drainage in expelling toxic and non toxic organic substances. If the peat layer is underlain by pyritic (FeS_2) material, which may be exposed or brought to the surface by canal construction, tillage or "surjan" construction, the resulting pyrite oxidation will cause extreme lowering of the soil pH (to pH 2.0 or less) and acid pollution in waterways. On the other hand, if the underlying material is quartz sand, a complete loss of the peat layer through oxidation and combustion will render the land unusable because of the almost complete lack of plant nutrient elements, including micronutrients (Radjagukguk, 2000). Cultivation practices, in particular excessive use of lime and ash, result in an excessively high pH, which depresses micronutrient availability. Liming and ash application also increase microbial activity which, in turn, further increases the peat decomposition rate. The growth and yield of crops are determined by whichever plant nutrient is the most severely deficient. The effects of peatland reclamation on the chemical properties of the peat soil and their implications are summarized in Table 5.2.

Table 5.1: The effects of land reclamation and cultivation practices on physical properties of peat soil and its implications (From Radjagukguk (2000)

Inherent property of natural peatland	Effects of reclamation and cultivation practices	Implication
Raised soil surface	Lowering of soil surface(*subsidence*), more pronounced with burning	reduced peat thickness, exposure of buried tree trunks
Low bulk density	Increased bulk density	Increased surface contact between plant roots and peat matrix
Low bearing capacity	Increased bearing capacity	Better plant anchorage
High total porosity	Decreased total porosity	Decreased aeration and moisture infiltration rate
High available water content at field capacity	Field capacity available water content decreased	Less water available to plants
Vertical moisture conductivity relatively high	Vertical moisture conductivity decreased	Increased susceptibility to surface erosion
High moisture content in natural state	Drying of the upper soil layer and risk of hydrophobicity	Impeded rewetting and increased susceptibility to erosion, combustion and decomposition
Relatively low soil temperature	Drastic increase in upper soil temperature, and greater temperature fluctuation	Impeded root development
High groundwater table	Lowered groundwater table	Risk of saline water intrusion and surface crusting

There is a direct relationship between depth of the water table and rate of subsidence and thus the sustainability of the peat. A deep-rooting crop requires a lower water table than a shallow-rooting crop and, consequently, its cultivation will lead to a higher rate of subsidence and decomposition. Thus, in a given area, the choice of a specific land-use option determines the time it will take before either the peat disappears exposing the mineral subsoil, or the drainage base approaches the river level and further drainage by gravity becomes impossible.

Table 5.2: The effects of land reclamation and cultivation practices on chemical properties of tropical peat soil and its implications. From Radjagukguk (2000).

Inherent property of natural peatland	Effects of reclamation and cultivation practices	Implication
Low pH	Slight pH decrease. Exposure of FeS_2 will drastically decrease soil pH. Lime or ash application increase soil pH	Decreased soil pH hampers root growth. Increased soil pH decreases micronutrient availability and increases peat decomposition
Low exchangeable Al and Al saturation	Decreased exchangeable Al and Al saturation owing to leaching	Probably insignificant
Low availability of N, P, K, Ca, Zn, Cu	Increased availability, enhanced by lime and ash application, except for the micronutrients	Increased nutrient supply, except micronutrients
High C/N ratio	Decreased C/N ratio	Probably insignificant
High CEC based on dry weight	Slight increase in CEC due to decomposition	Probably insignificant
High contents of organic acids	Decreased contents of organic acids owing to leaching	Decreased toxicity
Low ash content	Increased ash content owing to decomposition and ash application	Increased peat ripeness*
Low redox potential	Increased redox potential	Increased formation of NO_3^- and its leaching, oxidation of Fe^{2+} and Mn^{2+}

*suitability for agriculture

Indonesia

In Indonesia, approximately 1 million ha (about 5% of total) of lowland peatlands have been developed for agriculture (Radjagukguk, 2001). Produce commonly cultivated includes horticultural crops (vegetables, fruits, spices, medicinal and ornamental plants), cash crops (soybean, corn, cassava, peanuts and sweet potato), and estate crops (oil palm and coconut) (Radjagukguk, 1992).

In Sumatra, shallow peats are generally fertile and suitable for agriculture, and part of the tidal swamp ecosystem has been exploited by local farmers for many years. The deep peats, which are located further away from the coast or river banks, are infertile (Hardjowigeno & Abdullah 1987), support cultivation of perennial crops rather than annual crops. Rambutan, for example, grows successfully; coconuts also grow well but require good drainage and often produce only a few nuts; coffee yields between 300 and 350 kg ha^{-1} yr^{-1} of dried beans (Rumawas 1986), which can be doubled by applying fertilizer; oil palms appear healthy and bear medium-sized bunches of fruits. The situation for annual crops, however, is not so good. Rice fails to grow on peat more than 1 m thick although some farmers have apparently improved yields by raking mineral spoil excavated from canals during construction into the peat (Sutandi 1987). Some upland food crops such as maize, soybean, groundnut and cassava are able to grow on peat between 1-1.5 m while on peat more than 1.5 m thick only some perennial crops such as coconut and pineapple succeed. Some exceptions do occur, for example, at Lunang, West Sumatra, where the peat is more than 2 m thick, rice and upland food crops grew quite well. In this area, however, the peat quality has been enriched by mineral inputs from volcanic activity providing a favourable pH (5.5) and enrichment with plant nutrients. The least favourable peats for agriculture are those overlying quartz sand on which both rice and upland crops fail to grow (Hardjowigeno 1997), even when the thickness of peat is less than 1 m. In Sumatra, this kind of peat is found in only a few locations while, it is widespread in Central Kalimantan.

Spatial planning of peatland reclamation areas

General policies on peatland reclamation for agriculture in Indonesia should be in line with the general objectives of resource development and management, outlined in GBHN (Garis-garis Besar Haluan Negara, Guidelines for State Policy (Widjaja-Adhi 1997)), which state that:

> *"The management of natural resources and the living environment is directed toward the utmost benefit for the welfare of people by maintaining their balance and preservation, thus continuing to be useful for future generations…."*

In other words, GBHN requests and dictates the need for ***wise land use*** and ***sustainable development*** (see Chapter 6). Spatial planning for land reclamation is an essential second phase in land development, especially of peatland, for agriculture. An ecosystem approach needs to be used in planning the land utilization categories within the proposed reclamation area so that wise land use can be accomplished as dictated by GBHN. The typology of the land is the physical component of the ecosystem and must be taken into account in the planning and management of peatlands. Areas for reclamation should be delineated firstly on a map. Based on the soil types, physical data and other information, detailed land typologies and flooding regimes for the area can be derived from which land utilization types are determined, plans for each stage of the land development prepared and appropriate soil and water management systems identified. Peatland utilization types for different thickness classes, based on substrate, are presented in Table 5.3.

Table 5.3: Land utilization types of peaty soils according to their depth class and substratum type (from Widjaja-Adhi 1997)

Land typology	**Depth classes (m)**	**Substratum type**	
		Marine clay	Quartz sand
G0, peaty soils	<0.5	Lowland rice	Housing
G1, shallow peats	0.5-1.0	Lowland/upland rice	Housing/upland crops
G2, Moderately deep peats	1.0-2.0	Housing/upland crops, horticulture	Upland crops/horticulture
G3, deep peats	>2.0 "dome"	Tree crop estates, Rain catchment	Tree crop estates, Rain catchment

Land typologies can be used as a guide to the utilization, reclamation and management of swamp lands for crop production. Constraints that may operate during land reclamation or land management can be assessed if the land typology is known. Measures to prevent or mitigate the constraints must be instituted from the beginning of the land reclamation and procedures to overcome problems should be established before they occur. The type and intensity of constraints that may occur should also be considered when proposing a land utilization type for a land typology.

In addition to effective planning for land use management and utilization of swamps, swamp development requires the application of appropriate technologies and correct water and soil management of swamps, as both land and water resources. Wise use, an equitable development and a management sympathetic to the characteristics and behaviour of peatlands, can maintain their functions and values to support environmentally compatible development for sustainable agriculture. Peatland development should include activities for management and reclamation. The reclamation activities commence with planning and include canal excavation, land clearance, farm road construction and land preparation for crop planting. Management includes water, soil, crop and environmental management.

Malaysia

Sarawak

Peatland is extensive in the coastal lowlands of Sarawak, covering approximately 1.6 million ha or 13% of the total land area. These coastal peatlands were identified in the Sarawak Agriculture Perspective Plan Study 1992 (see Table 2.4) as an important resource for agriculture and other land uses in the State. Realising the enormous potential of the coastal land and looking at peatland as the “most strategic alternative fast track resource (gold mine)” the State Government approach is to open up the coastal lowland areas for plantation development. The State Government targets to complete a new coastal highway by the end of 2005 in order to facilitate access into this area (Abdullah, 1999). This strategy is expected to trigger faster growth of existing urban centres as well as creating new ones.

Although some peat soil areas have been converted and used for housing/township development (particularly in and around Kuching and Sibu), such utilisation is quite insignificant compared to other uses of lowland tropical peatland. Apart from leaving the peat swamps under forests, the single largest usage of peatland is for agriculture development.

Crops that are considered for cultivation on the peat soils of Sarawak, their water management requirements and the main constraints to their yields, are given in Table 5.4. According to Melling (1999), 467,097 ha of peatland are being utilized for large-scale agricultural development in Sarawak (306,042 ha for oil palm; 111,615 ha for forest plantation; 40,568 ha for sago; and the rest for rubber, rice, pineapple, tapioca, etc.). In addition, 67,588 ha are being used by smallholders for the cultivation of oil palm, sago and rubber. Thus, some 534,685 ha or about 32% of the total peatland has been converted to agricultural land.

In Sarawak, peatland use has been initiated only during the last 10-15 years but it has spread very fast, and large areas have been converted and used, especially for oil palm cultivation. As shown by the land-use statistics quoted above, oil palm is the main crop on reclaimed peatland today.

Drahman (1999) reported that Sarawak’s target for agricultural plantation development (mainly oil palm) in terms of actual planted area by the Year 2020 is one million hectares on State land and Native Customary Rights (NCR) land. This implies that a significant amount of peat swamps will be converted.

Figure 5-1: Oil palm on peat in Sarawak

Sago is a crop that has been grown very successfully on organic soils by smallholder farmers in Sarawak. Tie (1990) reported that out of a total sago area of 19,720 ha, 12,240 ha (or 62%) were found on organic soils

During the rubber boom years in the early 20th Century, some 16,440 ha of peatland around Sibu were drained and planted with rubber trees (Tie 1988). Most of these rubber gardens have been abandoned, although some farmers who remained have diversified into pepper, vegetables, poultry and pig farming.

Small areas of "Sarawak" and "Mauritius" pineapples are grown on organic soils for the local fresh fruit market. These pineapple gardens are small and scattered. Some of the more important areas include Kota Samarahan and Kabong-Nyabor (Sri Aman Division). The exact area is not known

The farmers around Sibu grow a large variety of leaf and fruit vegetables quite successfully on drained organic soils in a unique fallow-cropping system with the use of organic and chemical fertilizers. The practice of burning the cleared vegetation on the plot plays an important role in deacidification, supply of nutrients and partial sterilization of the soil. The practice should not be encouraged, however, as it is a potential fire hazard and, even if well controlled, it increases the rate of peat subsidence. The extent of this land use is also not documented, but it is probably less than 200 ha (Tie 1988).

Table 5.4: Crops that are considered for cultivation on peat soils in Sarawak, their water management requirements and the main constraints to their yields

Crop	*Water Management Requirements*			**Main constraints to yields or productivity**[a]
	Optimum range of the water table (m)		Maximum period of flooding (days)	
	Min.	Max.		
Oil palm	0.6	0.75	3	Low fertility susceptible to termites poor anchorage drought stress
Cassava/Tapioca	0.3	0.6	nil[b]	mechanization
Sago	0.2	0.4		
Horticultural crops	0.3	0.6	nil	mechanization
Aquaculture				water quality construction of ponds water control in ponds
Paddy	-0.1	0.0		water control in individual plots plant nutritional problems mechanisation
Pineapple	0.75	0.9	1	mechanization
Rubber	0.75	1.0		poor anchorage
Acacia crassicarpa	0.70	0.8		poor anchorage

[a] *Constraints of transportation (e.g. good access) that apply for all crops are not mentioned in this list.* [b] *Very low tolerance, not to be planted in flood-prone areas*

Since it is a wetland crop, rice paddy may appear to be promising for cultivation on undrained organic soils but, in Sarawak, it is usually restricted to shallow peat at the fringes of peat swamps. Where paddy has been grown successfully on deep peats, there is usually a high mineral or ash content in the top 50 cm, either in the form of discrete clay lenses or well-mixed mineral amendments. In the majority of cases involving deep peats with low mineral content, the paddy may appear to grow well vegetatively but it does not produce grain. As a result, wet paddy is not recommended for deep peats with low ash content.

Extensive areas of organic soils are found in many of the drainage and/or irrigation schemes implemented by the Sarawak Government. In the Lebaan-Bawang Assan Scheme (Sibu), for example, nearly 78% of the area consists of organic soils (Tie 1988). Problems of water retention and lower yields are usually encountered in areas with organic soils. It is suspected that a fairly large proportion of the shallow peats of Sarawak have been used for wet paddy cultivation, but the exact area is not known.

Peninsular Malaysia

About 6.33 million hectares, or 48% of Peninsular Malaysia's total land area, are suitable for agriculture, of which about 984,500 ha are comprised of peat and organic soils (Abdul Jamil *et al.,* 1989). Approximately 313,600 ha of peat soils are under cultivation, representing 32% of the total peat area.

Currently, oil palm is the most important crop being grown on peatland in Peninsular Malaysia and is the principle crop used for plantation establishment (Ambak & Melling, 2000). Oil palm has been grown successfully on deep peats and, in some areas, plantings are in their third cycle.

Unlike oil palm, rubber does not perform well on peat and gives low yields. There are also problems of poor tree stability owing to the lack of support on the peat substrate, low latex quality resulting from the high water table and nutrient deficiencies, and fewer tapping days because of high rainfall.

Rice padi is unsuitable for growing on peat in Peninsular Malaysia owing to adverse soil physical and chemical characteristics and its cultivation is restricted mostly to former freshwater swamps and very shallow peat (organic soils) (see Chapter 2).

Sustainable agriculture

Sustainable agriculture should be viewed as a component of sustainable development in the wider sense (Mohamed & Ping 2004; Radjagukguk 2004). Sustainable development has been defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). Sustainable agriculture can be defined as the use of farming practices and systems that maintain or enhance (1) the economic viability of agricultural production, (2) the natural resource base and (3) other ecosystems that are influenced by the agricultural activities (SCA 1991). With respect to the management of tropical peatland for agriculture, there is an urgent requirement to develop management strategies and cultivation technologies that ensure sustainability, taking into account the characteristics of this unique natural resource.

Challenges and prospects of sustainable agriculture on tropical peatland

Management strategies should emphasize the maintenance or enhancement of the economic viability of the production system, the conservation of the peat soil as the substrate for plant growth, and minimizing the negative impacts of their utilization on the environment. In addition, they should propose cultivation technologies appropriate to the socio-economic condition of the average peatland farmer and, as far as possible, produce a long-term beneficial effect.

In the management of tropical peatlands, conflicts will always exist between the need for natural resource preservation and the need for sectoral development, particularly agriculture. Since their utilization for agriculture arises out of necessity rather than choice, it is essential to reconcile the two opposing objectives by wise allocation of this unique natural resource. Nonetheless, taking into account the large extent of the tropical peatland area, particularly in Indonesia and Malaysia, and the implications of its large scale development for sectoral uses such as agriculture, its utilization requires careful planning and implementation of the wise use approach. In order to ensure its sustainable use for agriculture, there is a need to have a good inventory of the resource and characteristics, a good policy for resource allocation, and a vigorous development of appropriate systems and technologies for crop production. The sustainability of each system should also be assessed carefully using biophysical indicators such as productivity, stability, resiliency and adaptability.

Environmental impacts

Given the large scale of peatland deforestation and the inherent denaturation of peat soils upon drainage and agronomic treatments, the question of sustainability of agricultural land use becomes relevant. Major issues identified for small scale farming practices include abandonment of land after a single cycle of cropping owing to the difficulties faced in managing the water table and sustaining soil fertility. As for large scale plantations, major issues include high capital and maintenance costs, social problems such as land disputes, alteration of water supply catchment area, difficulty associated with the disposal of cleared biomass, non-compliance with respect to buffer zone requirements for conservation, riparian and common boundaries, the complexity of drainage management, poor bearing capacity for mechanized farming and root anchorage, and rapid leaching of agrochemicals.

The canal systems used in peatland development are effective for drainage but not for irrigation. These are so efficient that drought can be a major problem in many areas; tidal water cannot reach the fields and rainwater cannot submerge the land, so that many rice fields dry out even during the wet season. This is because peat swamps are regarded only as land resources. The effectiveness of any irrigation system depends upon the availability and source of water. In swampy regions there is a need to allocate areas to function as rainwater catchments, which must be located in the upper reaches of swamp rivers (Widjaja-Adhi 1992). These may coincide with the central parts of peat domes. Rainwater catchments serve as 'lakes' for the surrounding cultivated land and, together with retarder areas and interception canals, should be incorporated into reclamation schemes. Peat swamps should not only be regarded as land resources but also water resources that require integrated, well planned development and management within entire catchments or river basins.

As the history of large-scale plantation development on tropical peatlands is very recent, the management knowledge of peatlands is limited. Activities are largely based on 'trial and error'. Major knowledge gaps include poor information on the physical and chemical variability of peat soil, peat hydrology, water management and subsidence, long-term reclamation and drainage impacts, optimal land clearing techniques, and cumulative impacts on the adjoining environment. Thus, 'sustainability' with respect to agricultural development on peatlands may be most relevant in the context of their socio-economic viability and significance, but questionable in terms of ecological integrity given the expected eventual irreversible net carbon loss and disappearance of the original habitat from the ecosystem once it is converted to agriculture land use. In so far as large scale agricultural development on tropical peatland is concerned, there are obvious needs for clear guidelines and intensification of R & D initiatives (Murtedza 2004).

The major environmental issues of intensive agricultural development on peat soils include the following:

- Potential long-term water pollution caused by fertilizers and other agrochemicals;
- Short-term air pollution caused by open burning of the felled vegetation in a peat area, resulting in impacts that may be difficult to control and which spread easily to adjacent areas; and
- Drainage of peat soils sets in motion the process of subsidence of the ground surface and causes hydrological changes that may eventually lead to the loss of the peat swamp environment along with its ecological functions, especially biodiversity, water storage and hydrological regulation, and carbon reservoir.

Some of these potentially adverse impacts can be avoided or reduced to acceptable levels through proper implementation of appropriate mitigation and abatement measures. Others cannot be avoided and will therefore have to be considered as trade-offs between environmental costs and economic benefits. It is much better if major land development schemes for agriculture on tropical peatland are subject to detailed and proper planning proposals within an integrated landscape management strategies and preceded by comprehensive, transparent Environmental Impact Assessment (Murtedza, 2004) (see Annex 2 for information on the failed Mega Rice Project in Indonesia).

Environmental Impact Assessment (EIA) is a mandatory requirement for proposed development projects categorized as 'prescribed activities' under the Sarawak Natural Resources and Environment (Prescribed Activities) Order, 1994. Agricultural, infrastructure, industrial, commercial and housing estates developments involve modifications, sometimes adverse, to the natural, physical and biological environment. In this context, the role of the EIA process is to identify other available options with respect to the location and type of development, examine the existing environment and the potential significant adverse impacts of the proposed development project, recommend appropriate measures to mitigate these impacts and formulate an environmental monitoring plan when deemed necessary, especially during the development and operational phases of the project. This information, recommendations and findings are documented in an EIA report that must be submitted to the Natural Resources and Environment Board (NREB) Sarawak for evaluation in the decision making process.

Forestry

Peat swamp forests with their valuable trees have been subjected to timber and non-timber exploitation. As species regeneration in peat swamp forest is slower than in other forest types, both legal (controlled) and illegal (uncontrolled) logging practices have had considerable impacts on both peatland forests and the environment. The extent of the impacts differs according to the method and intensity of exploitation.

Indonesia

History of forestry on Indonesian peatlands

Systematic survey and inventory of peat swamp forest was carried out from 1933 to 1936, in Panglong, East Sumatra, Indonesia for the purpose of forest management and, around 1934, a survey was undertaken of peat swamp forests in Riau and Bengkalis in Sumatra to obtain data on the prospects for forest exploitation over the ensuing 10 years (Department of Forestry, 1986). Furthermore, in 1941, a plan was prepared for the extraction of *Agathis borneensis* at onder afdeling near Sampit in Central Kalimantan, but this was not implemented.

Intensive forestry on tropical peat swamp forest in Indonesia started around the same time as in other forest ecosystems as a consequence of Decree Number 1/1967 on Foreign Investment (PMA) and Legislation, and 6/1968 on Domestic Investment (PMDN). Most of the logging activities in peat swamp forest, especially before the1990's, involved the selective felling of commercial trees for both domestic use and for export. The most important timber species exploited in peat swamps were *Gonystylus bancanus, Shorea teysmanniana, S. platycarpa, S. uliginosa, and Tetramerista glabra*.

Peat swamp forest timber extraction increased significantly after the Three Ministers Decree (Surat Keputusan Bersama Tiga Menteri, SKBTM) in 1980 that led to expansion of the forest products manufacturing industry in Indonesia. This policy also caused environmental impacts since it led to overproduction and over cutting of species (Department of Forestry, 1986). Industrial capacity was much greater than could be satisfied by the logging companies and a major consequence was increase in the supply of illegal timber in order to satisfy this need. Recently, owing to over exploitation, very few logging companies operate in peat swamp forests. In 2002, the Department of Forestry placed a moratorium on the felling of *Gonystylus bancanus* and in 2004 it was declared a protected species under the CITES Convention in order to prevent it from becoming extinct.

Economics of forestry on peat swamps

According to the Regional Planning Agency of Central Kalimantan (BAPPEDA 1993/1994) about 40 logging concessions operated at that time in peat swamp forest in that province. There is no accurate information, however, on how much the contribution was, or still is, to the local economy from peat swamp forest timber extraction. Because of the system used, only the contribution from the forestry sector from specific types of forest is available. The only information that provides an insight into the importance of this ecosystem in the past is that it contributed almost 10% of Indonesia's export of forest products (Laurent, 1986).

Logging practice

Owing to the physical characteristic constraints of peat, such as low load bearing capacity, high water table and waterlogged condition, it is impossible to apply the logging practices employed in dry land forest ecosystems that depend mostly on road transportation. In peat swamp forest, the system for transporting logs from the felling site to the main extraction system (light railway) involves log skids ("kuda-kuda") and intensive manual labour (Figure 5.1). Logs are loaded onto small wooden sledges and dragged along the skid tracks to the loading ramp. The skid track consists of wooden stringers (15-30 cm in diameter), spaced 1.8 m apart and overlain by wooden cross-pieces (8-16 cm in diameter) placed 0.5 m apart. The wooden sledges vary in size but typically measure 3 m in length by 1 m wide. A team of 8-14 people carries out this traditional method. Logs are transported to the river bank by rail then either tied into rafts or placed on barges and towed down river by tugboat to the Java Sea where they are loaded on to freighters for conveyance to factories in Java or exported to various countries.

Figure 5.1: Logging operation in Sarawak

Silvicultural systems

The main silvicultural system applied to peat swamp forest in Central Kalimantan until recently was Selective Cutting with Enrichment Planting (Sistem Silvikultur Tebang

Pilih Tanam Indonesia, TPTI) that was established through Directorate General of Forest Exploitation Decree Number 151/KPTS/IV-BPHH/1993 as an improvement of the previous Decree Number 564/KPTS/IV-BPHH/1989. This regulates the exploitation methods on peat swamp forest as follows:

1. In peat swamp forest, containing special commercial species such as ramin (*Gonystylus bancanus)*, perupuk (*Ilex* cymosa) and other species, if a logging company had problems to implement enrichment planting, they were allowed to cut only 2/3 of the maximum number of trees specified in their concession agreement.
2. The number of trees permitted to be felled within peat swamp forest is based on a minimum diameter limit of 50 cm on condition there is a minimum of 25 trees per hectare of the main commercial species with diameters of 2-49 cm. For *Gonystylus bancanus*, however, the diameter limit could be reduced to 35 cm if there are no trees with diameter of >50 cm and there were the requisite number of main trees of diameter 15-34 cm.

Furthermore, based on Minister of Forestry Decree No. 8171/Kpts-II/2002, criteria were introduced to enforce a basic requirement of natural forest production upon concessions, as a condition for extending the life of the concession or the period of time it could operate as an active logging company (Table 5.5). Categorization of minimum forest potency in natural peat swamp forest is based on the Ministry of Forestry Decree No. 88/Kpts-II/2003 (Table 5.6)

Table 5.5: Forest Potency based on class diameter and condition of forest soil

No.	Region	Average number of trees per hectare		
		Diam. of 10-19 cm	Diam. of 20-49 cm	Diam. of >50 cm
1.	Sumatra	108	39	21
2.	Kalimantan	108	39	16
3.	Papua	109	39	18

Table 5.6: Minimum forest potency in natural peat swamp forest

No.	Class Diameter (cm)	Sumatra	Kalimantan	Papua
1.	10-19	75	75	75
2.	20-49	25	25	25
3.	≥ 50	8	5	7

Forest regeneration

The number of species in peat swamp forest at Kandan (near Sampit), Central Kalimantan, Indonesia based on Istomo (1995), was 23 at seedling stage, 30 at sapling stage, 29 at pole stage and 40 at tree stage. The tree stage contained the highest number of species. Furthermore, the density per hectare was 11,375 seedlings, 1,810 saplings, 300 poles and 290 trees. Table 5.7 shows the dominant species at several stages of growth development in peat swamp forest at Tangkiling, near Palangka Raya and Sampit, Central Kalimantan, Indonesia (Sutisna *et al.,* 1988).

Table 5.7: Dominant species at several stages of tree development in peat swamp forest

Stage	Tangkiling		Sampit	
	Virgin forest	Logged Over	Virgin forest	Logged Over
Seedling	*Palaquium leiocarpum* *Calophyllum teysmannii* *Gonystylus bancanus*	*Calophyllum sp.* *Shorea teysmanniana*	*Gonystylus bancanus*	*Memecylon sp.* *Ternstroemia elongata* *Gonystylus bancanus*
Sapling	*Palaquium leiocarpum* *Calophyllum sp* *Aromadendron nutans* *Blumeodendron tokbrai* *Eugenia sp.* *Urandra secundiflora*	*Palaquium leiocarpum* *Urandra secundiflora* *Calophyllum sp.*	*Eugenia sp.* *Diospyros bantamensis* *Memecylon sp.* *Magnolia sp.*	*Eugenia sp.* *Shorea teysmanniana* *Memecylon sp.* *Shorea uliginosa* *Diospyros bantamensis* *Magnolia sp.* *Tristaniopsis witheana* *Garcinia celebica* *Urandra secundiflora* *Gardenia sp.* *Platea sp.* *Xanthophyllum sp.* *Litsea resinosa* *Mangifera altissima*
Pole	*Palaquium leiocarpum* *Neonauclea moluccana* *Aromadendron nutans* *Calophyllum teysmannii*	*Palaquium leiocarpum* *Calophyllum sp.* *Palaquium rostratum* *Chaetocarpus castanocarpus*	*Diospyros bantamensis*	*Diospyros maingayi* *Xylopia caudata* *Garcinia sp.* *Garcinia celebica* *Mangifera altissima* *Eugenia sp.* *Magnolia sp.* *Shorea teysmanniana*
Tree	*Gonystylus bancanus* *Shorea parvifolia*	*Shorea teysmanniana* *Shorea parvifolia* *Mezzettia parviflora* *Dyera lowii* *Tetramerista glabra* *Palaquium rostratum*	*Gonystylus bancanus* *Diospyros bantamensis*	*Mangifera altissima* *Xylopia caudate* *Memecylon sp.* *Shorea uliginosa* *Aglaia rubiginosa* *Diospyros bantamensis* *Tetramerista glabra*

Impact of forest exploitation

Forest exploitation within peat swamp forest, requires an opened area of about 6 metres wide in which to establish the railway, while “kuda-kuda” skids need a width of 4 metres. The railway is established in the middle of a felling block of 100 hectares. Each of these blocks is divided into sub-areas of 200 m x 500 m (10 ha) that are located alongside of the railways. Therefore, within each felling block an area of about 6 m x 1 km (0.6 ha) or 0.6% is open (Istomo, 1995). The area opened as a result of forest clearing for the extraction railway to the river, “kuda-kuda” and the cutting of *Gonystylus bancanus* trees within an area of *Gonystylus bancanus* exploitation (case of PT INHUTANI III Sampit, Indonesia), is presented in Table 5.8.

Table 5.8: Open area required for the exploitation of Ramin (1 ha i.e 10,000 m^2)

No.	Activities	Open area (m^2)	Percentage (%)
1.	“Kuda-kuda”	1,200	12.00
2.	Port	625	6.25
3.	Cutting of Ramin	875	8.75
	Total	2,700	27.00

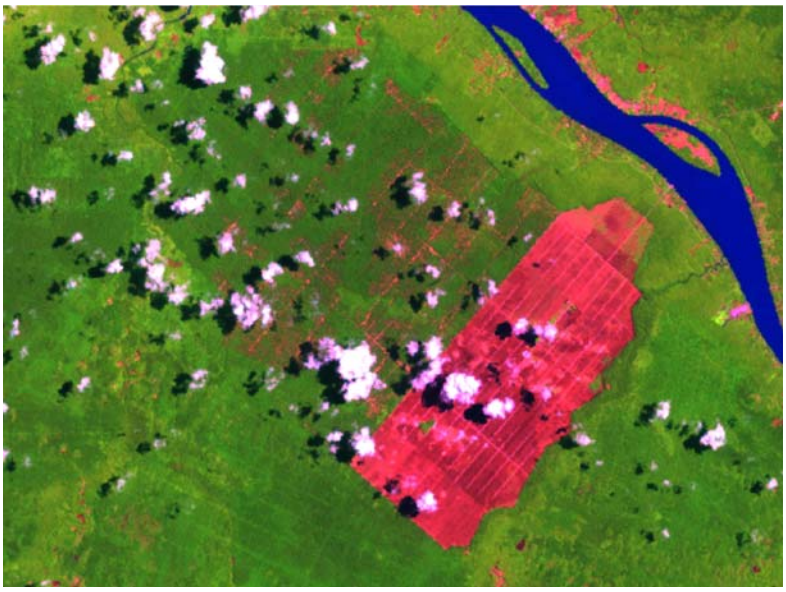


Figure 5.2: Landsat ETM+ image of logged over forest near Sibu, Sarawak, taken 18.06.2000

Plantation forestry

In Indonesia, plantations on peatlands commenced in Sumatra using fast-growing species such as *Acacia mangium,* but without success. Some attempts are being made to establish plantations of *Gonystylus bancanus* (BPS, 1997) but no information is available on either their location or success.

Sarawak

Forestry has traditionally been the backbone of Sarawak’s economy. It is the second biggest earner after oil and natural gas, being responsible for about one-third of the State’s total export earnings. In Sarawak, most of the peat swamp forest is gazetted as ‘permanent’ (managed to maintain forest cover for multiple purposes including commercial timber production), but not ‘totally protected’ forest (managed to preserve biodiversity and natural ecosystems *in situ* with no commercial activity allowed other than ecotourism). In fact, since the early 1960s, much of the peat swamp forest area has been harvested for commercial timber such as ramin (*Gonystylus bancanus*), alan (*Shorea albida*), meranti buaya (*Shorea uliginosa*), jongkong (*Dactylocladus stenostachys*), nyatoh (*Palaquium* spp), kapur (*Dryobalanops rappa*), sepetir (*Copaifera palustris*), jelutong (*Dyera lowii*) and geronggang padang (*Cratoxylon glaucum*) (FAO, 1974; Lee, 1992, Lee & Chai, 1996). During the 1950s, the timber industry was operating in at least 95% of the peat swamp forests (PSF). Production from the swamp forests has declined steadily during the past 20 years and is currently less than 20% of the total timber harvest which is of the order of 15 million cubic metres per year (Forest Department's Annual Reports). The peat swamp forests of the Samarahan, Sri Aman, Sarikei and Sibu Administrative Divisions, which represent roughly two-thirds of the total peat swamp forest area in Sarawak, have been heavily exploited. All are licensed for timber extraction and most have already been selectively logged for the first time (Bennett & Gombek, 1992). Old-growth peat swamp forest is worked on an empirical harvesting cycle of 45 years. The minimum girth limits may vary slightly between concessions but generally are 106 cm over bark for *Gonystylus bancanus*, 140 cm over bark for *Dryobalanops rappa, Dactylocladus stenostachys* and *Copaifera palustris* and 148 cm over bark for all others species (Lee, 1992).

The forest areas in Sarawak are managed under the following categories:

- Totally Protected Area (TPA)
- Permanent Forest Estate (PFE)
- State Forest

The Wildlife Protection Ordinance, 1990 and the National Parks and Nature Reserves (Amendment) Ordinance, 1990 govern the constitution and the management of the TPAs. There is no provision in the Ordinance for a TPA to be de-gazetted. (See this chapter: Wildlife Conservation)

The PFE is made up of three main categories of Reserved Land, namely Forest Reserve (FR), Protected Forest (PF) and Communal Forest (CF). These are gazetted and managed under the Forests Ordinance 1954 and its numerous subsequent amendments. Although the PFE is designated to remain under forest in perpetuity and is managed for the purpose of sustainable timber production, any part of a FR or PF can be de-gazetted. To do so, the Minister of Planning and Resource Management has to (amongst others) publish a notification in the Government Gazette (see section on State Land Application for plantation development). As of 1999, there are about 612,400 ha of peat swamp forests that are under PFE (Chai, 1999).

It is also noteworthy that the Forests Ordinance was amended at the end of 1996 to include planted forests established on State Land as well as alienated land as part of the PFE. Hence, it is likely that the peatlands which had been approved for the establishment of planted forests under Licenses for Planted Forest were not included in the statistics given by Chai (1999). State Forest is not designated to remain under forest in perpetuity. Though such areas may be protected as TPA or PFE, the likelihood of converting them to other forms of land use such as agriculture is probably higher. The area of peatland under State Forest is not known.

Tree plantation development on peat soils

From the studies on natural regeneration and experimental planting of *Shorea albida* on peatland in Sarawak, it is evident that there is a potential to establish forest plantations with indigenous swamp species in peat areas. Under plantation conditions, light, moisture and nutrient requirements can be controlled and optimized and, if well-managed, a much better survival rate and higher performance can be expected. Selection of high quality planting stock or clones will also ensure a more uniform performance.

One advantage of plantation over natural forest is the choice of fast-growing and high-value species to achieve maximum productivity. While fast growth rate and high productivity are important, the choice of species should also take into consideration their suitability for introduction as a plantation crop. In this regard, peat swamp forest offers the following choices:

- A number of fast-growing species regenerate successfully in logged-over forest.
- At least one medium-growth species, namely *alan (Shorea albida)* occurs naturally on peat forming pure stands in the emergent canopy in some instances.

The inclusion of both indigenous and exotic species with fast and medium growth rates will satisfy the future demand for hard wood chips, sawn timber, veneers, medium-density board and oriented-strand boards. The exotic and indigenous species are not and should not be viewed as competitors but rather as part of the diverse choice available to ensure that the supply of forest produce, functions and services are maximized. A diversity of species planted should provide a degree of flexibility in end-uses that may change in the future.

One constraint in plantation development on peat is the lack of basic information on performance, nutrient and silvicultural requirements of target trees, and their susceptibility to pests and diseases under planted conditions. *Acacia* spp. are popular because of their very fast growth rate, good stem form, nitrogen-fixing property and ability to grow even on degraded soils. Their performance on peat is known, however, only from one or two areas in Indonesia and Thailand.

Environmental impacts

Controlled exploitation of timber from peat swamp forest in West Kalimantan showed that seedlings and saplings of commercial timber species (*Gonystylus, Shorea* and *Palaquium* spp.) were damaged by tree felling. Uncontrolled and excessive removal of timber alters the forest canopy structure by creating large gaps, which promote rapid colonization of species intolerant of low light conditions. As such, the composition of vegetation in logged peat swamp forest changes drastically and rapidly, and the opened up areas become dominated by shrubs with a dense ground cover of grasses, ferns and sedges. Other impacts of logging practices include: (1) loss of biodiversity, (2) loss of habitat for wildlife, (3) disturbance of the hydrological cycle and reduction in water supply, (4) altered evapotranspiration and increased rates of oxidation and compaction of the peat, (5) modification of microclimate in the logged-over peatland forest, (6) increased run-off and erosion and (7) reduction in climate stabilization function (Phillips, 1997) (see Chapters 3 and 4).

There is virtually only remnant, scattered virgin peat swamp forest left in Borneo. Because documentation of the flora and fauna of the tropical lowland peat swamp forest ecosystem remains limited (Browne, 1955; Anderson, 1972), it is an urgent necessity to undertake additional, comprehensive biological surveys as soon as possible while pristine peat swamp forest parcels still persist.

Transmigration

Indonesia

Transmigration is an Indonesian Government programme to improve the lives of poor and landless people and to develop Indonesia's many under-populated islands by offering land and jobs to the settlers. Originated under Dutch colonial rule at the beginning of the 20th century, it was embraced by the Indonesian Government following independence in 1947. Between 1903 and 1990 more than 3.6 million people were resettled at Government expense but this has now reached 6.2 million.

Sumatra was the first island targeted to receive transmigrants but, since then, the programme has been extended to include Kalimantan, Sulawesi, Maluku and Papua (Irian Jaya) with major financial support from the World Bank, ADB and bilateral donors, especially since the 1980s. Many transmigration projects failed to meet their objectives and there have been allegations of corruption and infringement of human rights. Many of these projects failed to alleviate poverty, and only redistributed it, causing inter-racial conflict while pressure has been placed on natural forests, indigenous people and the environment. A recent study of five transmigration projects by the World Bank[1] revealed that farming in the settlements did not develop as planned and cropping intensities and yields of annual crops were much lower than expected. The reasons were many and included shortage of labour and mechanization, lack of experience by settlers, inefficiency of support services, soil degradation and erosion, difficulties of marketing crops and a preference for off-farm employment. Because settlers were unable to obtain all of their livelihood requirements from farming they turned to other activities such as latex and bark collecting and illegal logging in order to supplement their cash income. Since indigenous people were already involved in these non-farming activities tension developed between local people and settlers.

It is only within the last 20 years or so that transmigration has focused on lowland peatlands, especially in Kalimantan and Sumatra, because other categories of land were no longer available. In Central Kalimantan, as elsewhere, problems arose between settlers and indigenous people as a result of cultural differences and resource pressures. In addition, the environment suffered. Much of the land provided for transmigrants became unproductive ("lahan tidur").

At one transmigration village on thick peat, Bereng Bengkel, near to Palangka Raya, the provincial capital of Central Kalimantan, about 80% of the land ("lahan usaha") remains unproductive after 20 years of settlement (Limin *et al.* 2000), At another transmigration village, Tumbang Tahai, on shallow peat underlain by quartz sand, almost 100% of the transmigrants have abandoned the area while in the adjacent Sei Gohong village (on quartz sand but without peat) the planned commercial activity of rearing beef cattle was a failure. Similar problems are encountered in almost every transmigration site in coastal and upstream areas of Central Kalimantan. The main reasons for this failure are (1) inappropriate background of the transmigrants (not 100% farmers), (2) settlement sites are located in remote areas, (3) carrying capacity of the land is too low to provide crop yields large enough and of satisfactory quality to generate sufficient income and (4) lack of markets for produce. In addition, the Indonesian Government has not provided adequate support advice, materials and services or marketing infrastructure. Even where the cultivation of crops is possible the markets do not exist so the venture becomes unprofitable and, as a result, many of the transmigrants are forced to move to other jobs outside of their farm areas to become urban labourers, illegal loggers or illegal

[1] http://wbln0018.worldbank.org/oed/oeddoclib.nsf

miners (Limin *et al.,* 2003). Until these problems are resolved it would be unwise to continue to establish transmigration projects on peatland areas in Indonesia (Limin, 2002) (Figures 5.3, 5-4).

Figure 5.3 : Abandoned transmigrant house in Pangkoh, Central Kalimantan

Figure 5.4 Transmigrant settlement near Dadahup, Central Kalimantan

Aquaculture

<u>*Suitability of peat soils for aquaculture*</u>
Deep peat soils are not recommended for commercial aquaculture in any form. The waters emanating from peat swamps are highly acidic, have low dissolved oxygen, and are relatively high in tannins and organic acids. Moreover, the characteristics of peat soils make it very difficult to construct aquaculture ponds. The peat materials are too porous to retain water, they are unstable, and any embankments constructed around them collapse easily.

Industrial uses of tropical peat

In general, tropical peat can be used for a number of commercial purposes including horticulture and silviculture, raw materials for industry and energy generation (Andriesse, 1992). There has been little activity in these areas for several reasons.

Raw material for horticulture and industry
There is little use of tropical peat for these purposes, partly because there is not the same demand as that established in developed countries (i.e. it is a luxury market) and the physical and chemical characteristics of tropical peat make it less suitable than boreal and temperate peat. Since most of the markets for peat for these uses are in developed countries in Europe, East Asia and North America the cost of transportation would take away any price advantage over local peat supplies. Some tropical peat is used locally as a growing medium but this material is usually obtained locally and processed directly by users so there is little in the way of a commercial market.

Energy
Electricity generation is one of the more obvious and promising commercial uses of tropical peat and towards this end a feasibility study was carried out in Central Kalimantan from 1984-1989 financed by the Government of Finland. This assessed the suitability of peat milling and sod cutting technology used in northern Europe to excavate and process tropical peat. Following this pilot study it was decided not to proceed to the operational phase owing to a number of serious problems, namely, the heterogeneity of tropical peat, which contains much woody material, compared to boreal/temperate peat, the low demand for energy in the locality compared to the generating capacity, and environmental concerns about the release of carbon from the peatland store. The proximity of lowland tropical peatland to sea level also brought into question the ability to excavate to lower levels because of the risk of flooding. There is one small peat fired power station operating in South Sumatra.

Soil conditioner
This is not an established practice in SE Asia for the use of peat.

Industrial, Commercial, Housing Estate and Infrastructure Development

Apart from commercial agriculture, peatlands in Sarawak have been subjected to other development activities such as infrastructure, real estate and public utilities developments (Mamit & Sawal, 2003). The urban areas in Sarawak, particularly in the Kuching and Sibu Divisions, are developing rapidly, owing to rural/urban migration and intensive business development (Phillips, 1997). Some of the ongoing developments of residential, business and shopping centres and industrial estates are established on reclaimed peatlands. It is sometimes possible to avoid using peatlands by changing the location of the construction. However, in growth centres and fast developing areas, this approach works for some of the time but, ultimately, the pressure for land causes less desirable peatland to be developed too (Jarrett, 1997). The Batu Kawa New Township in Kuching, for example, occupies some 214 hectares of peatland.

Kuching is located on relatively flat terrain along the surrounding rivers and streams, large parts of which are founded on unstable ground (peat swamp or soft clay); most of the residential areas are within the catchments to Sungai Sarawak upstream of the barrage (Lynghus & Larsen 2004). The housing estates in some of the western parts of Kuching, along the Matang Road, have been constructed on about 1,800 - 2,000 ha of peatland of varying depth..

The Government is constructing a second trunk road in Sarawak to provide better linkage to settlements and towns scattered along the coast. The objective of this coastal road is to promote socio-economic growth and improve the standards of living of the riverine communities, in line with the vision to make Sarawak a developed state by 2020 in tandem with the other States in Malaysia. This 1,167-kilometre long Sarawak Coastal Road Network is to start from Sematan in Lundu and ends at Bakam in Miri, crossing many coastal peat swamps especially in Kuching, Samarahan, Sri Aman, Betong, Sarikei, Sibu, Mukah and Miri Divisions. In addition, about 30% of the new access road to the proposed Federal Administrative Centre in Matang cuts through peat overlying soft clay.

The current road construction method on deep peat is to firstly, construct drains alongside the route of the proposed road during the dry season and then grade the road over 2-3 years by regular topping with sandy fill. Geotextile is commonly used to permit faster road construction and reduce embankment settlement and deformation (Sime Darby Services, 1998).

Wildlife Conservation

Peat swamp forests are important ecosystems both for timber and non-timber products. They play an important role in the hydrological cycle and provide the natural habitat for rare and endangered species of fauna and flora. The demand for land, however, has increased the rate of conversion of peat swamp areas and is having detrimental effects upon the environment locally, regionally and globally (Rieley *et al.,* 1996). The sustainability of peat swamp forest is uncertain, especially if the silviculture techniques employed in their exploitation become more mechanised or if their conversion to agriculture continues. Consequently, it is increasingly important that large areas of peat swamp forest are left in their natural condition and conserved , so that their biodiversity, carbon and water can be protected and their benefits and natural resource functions made available to future generations .

In Indonesia about 2.5 million hectares of peat swamp forest have been gazetted as conservation areas in National Parks, Game Resource Areas and Nature Reserves (Dwiyono & Rachman, 1992). These include Berbak National Park in Sumatra, Danau Sentarum wildlife reserve in West Kalimantan, Lorentz National Park in West Papua, part of the Leuser National Park in Sumatra, part of Tanjung Puting National Park in Central Kalimantan and the proposed Sebangau National Park in Central Kalimantan. Berbak National Park was one of Indonesia's first Ramsar sites (1991). Much larger protected areas are required, however, in order to maintain a viable peat swamp forest resource, since much of the best, undisturbed peat swamp forest is still located outside of these reserves.

In Thailand, the whole of the remaining peat swamp forest area in Narathiwat Province has been divided into three management units namely, development, conservation and preservation zones (Vijarnson, 1992). The preservation zone covers an area of about 9,000 ha and has been declared a wildlife sanctuary by the Royal Forest Department. In the conservation zone of about 17,000 ha emphasis is placed on rehabilitation. Other activities, such as conversion for agriculture and settlement, are confined to the development zone, which has an area of about 15,000 hectares. This situation is unsatisfactory since not only has a major proportion of the peat swamp forest in this part of Thailand been damaged irreparably in the past but a significant part of what remains may still be lost to development. This casts serious doubts upon the sustainability of the small preservation zone.

In Peninsular Malaysia, 75,000 ha of peat swamp forest in Northern and Southern Selangor have been gazetted as forest reserves (Chan, 1989). Most of this area, however, has already been logged and a large part of the remainder is under threat from tin mining and urban development. The Kuala Langat forest reserve been impacted severely by construction of the new Kuala Lumpur International Airport, the runway of which cuts across part of the peat swamp forest. This same reserve is being destroyed slowly as a result of peripheral drainage by unlicensed farmers, illegal logging and fire.

Peat swamp forest conservation areas in Sarawak come within the official designation of Totally Protected Areas (TPA) that comprise wildlife sanctuaries, national parks and nature reserves and about 1.0 million hectares of forested land have been earmarked for these purposes. About 43,150 ha of peat swamp forest at Maludam has been fully constituted as a TPA in the form of Maludam National Park while the proposed Bruit National Park will cover approximately another 1,930 ha of mainly peat swamp forest at the northern tip of Pulau Bruit. Some strategies have been designed to address the conservation of peat swamp forest as follows:

- increase the reserve areas and improve coverage of ecosystem types and biogeographical zones;
- develop a multi-faceted approach to protect the natural forest;
- adopt improved management reserves to maximize potential and contribute to the national economy;
- improve the perception and understanding of conservation issues by people;
- implement regulations to support sustainable development of natural forest resources.

Non-sector impacts

In addition to ‘planned’ sector impacts upon natural tropical peatlands there are also unplanned and unauthorized impacts that are not desirable from most points of view. These may appear to arise independently of land use planning and management but they are consequences of the failure of these activities to fulfil their aims to improve the quality of life and livelihoods of local inhabitants by reducing poverty.

Most important in this category are fire and illegal logging. The former is a by-product of rapid, poorly planned land development, usually for some form of agriculture linked to human settlement. Since peat swamp forest clearance, prior to drainage, and cultivation, requires the removal of all of the trees and woody debris, the cheapest and quickest means is to use fire. In the humid tropics this can be applied only in the dry season that normally does not exceed three months in duration but, in El Niño years, it may extend up to 8 months. Fire can easily get out of control with devastating results that become even worse when it becomes embedded in the underlying peat.

Illegal logging, on the other hand, is unauthorized and uncontrolled tree removal by various vested interests, local, national and international that results in the destruction of the forest resource for future generations. It also causes severe damage to the peatland landscape because of the extensive networks of small canals excavated in order to extract the cut timber. These canals reduce the water retention capacity of the peatland landscapes and speed up runoff so that they dry out quicker following rain and suffer drought conditions in the dry season. This also makes them more susceptible to fire.

Fire

Forest and peatland fires have been a recurring problem, especially in Indonesia since the early 1980s when conversion of peat swamp forest to agriculture use began on a large scale, promoted by the Indonesian Government's transmigration programme (see this chapter: Transmigration). Fire is the principal tool of deforestation and is used to dispose of unwanted tree biomass every year during the dry season by both small farmers and large plantation owners alike (Figure 5.5).

The occurrence of extended periods without rain in El Niño years, however, provides drier conditions for longer periods when burning can be achieved for several months at a time. These fires are not only linked to the occurrence of periodic drought, but also land clearing for agriculture and plantation forest, and to drainage activities ((Bechteler & Siegert, 2004; Siegert *et al.*, 2004).This intensified use of fire gives rise to poor environmental conditions, especially 'haze' (smoke combined with fine particles of soot) that affects not only people locally but extends over distances of several thousands of kilometres across the Southeast Asian region (Figure 5.6).

Figure 5.5: Burning peat swamp forest

Since much of the forest area being cleared is located on peat, both surface and ground (peat) combustion occurs, resulting in the transfer of large amounts of carbon and other chemical compounds to the atmosphere (Page *et al.,* 2002) (see Box 5.1).

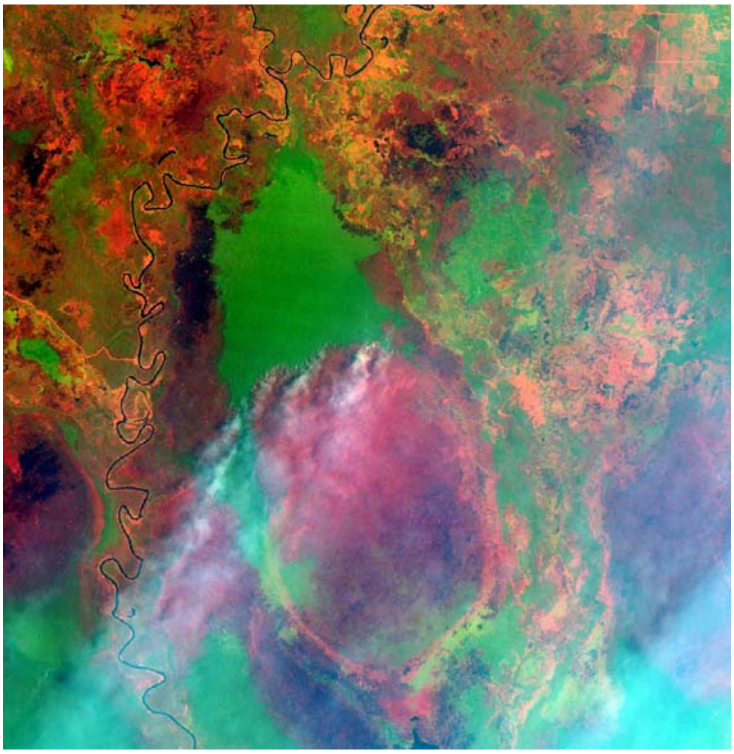


Figure 5.6: 50 x 50 km section of a Landsat ETM+ satellite image taken 22.03.1998, showing burning peat swamp forest

Smoke from the 1997/1998 peat fires in Indonesia was a major contributor to the cloud of haze which enveloped the Southeast Asian region for several months and affected visibility and air quality as far afield as Singapore, Peninsular Malaysia and southern Thailand. Several cities in Kalimantan and Sumatra had less than 100 m visibility during months of dense haze, which led to temporary airport, school and office closures. The haze produced by peatland fires had serious impacts on human, animal and plant health, as well on the regional economy (Schweithelm 1999).

Assessment of the fire problem

It is quite clear that there are several aspects to the spread of fires on tropical peatland. They take hold in and advance very quickly through the dried out surface vegetation, which has died as the water table lowered during the dry season. 'Flash fires' take firm hold in this material in the wake of previous fires. As a result the fires become much more substantial, cover very large areas, and reach very high temperatures, causing the surface peat to ignite.

Once the fires penetrate the peat the problems are elevated to a new and more dangerous level. The pattern of fire establishment and spread in the peat was observed to focus mainly on the woody remains of trees and branches embedded in the peat matrix. These tree remains are very old and under de-watered conditions are extremely fire-prone, probably enhanced by the resins and other chemicals they contain. They ignite easily and then burn quickly if on the surface, or smoulder if they are underneath. Most of these tree remains are partly buried so fire gets transferred below the surface where it can persist for days or even weeks, igniting new surface fires, especially when it is windy.

Box 5.1: Impact of fire on carbon release from peatland in Indonesia

Tropical peat swamp forest resources and natural functions are being damaged severely by fire and may be destroyed forever with potentially devastating consequences regionally and globally. The combination of an extremely long El Ni✱o of 8 months in 1997, linked with land clearance for the ill-fated, one million hectare Mega Rice Project in Indonesia, disrupted the peat swamp forest ecosystem and it became fire prone. An area of around 55% per cent of this landscape burned in 1997 releasing about 0.15 Gt carbon to the atmosphere while peatland fires throughout Indonesia as a whole affected more than 1.5 million hectares of peatland and liberated 0.8-2.7 Gt carbon equal to 15-40% of the annual global carbon emissions from the burning of fossil fuels (Table 5.9) (Page *et al.,* 2000, 2002). This was a disaster of catastrophic proportions that not only released vast amounts of carbon from the tropical peat store to the atmosphere as carbon dioxide, methane and soot but also affected human health. In addition, the fires have led to increased flooding of these vast landscapes and downstream habitations in the rainy season, because the peatland has lost much of its water absorption and retention properties.

There are increasing periods of protracted drought in the dry season because the drainage channels excavated for agriculture and human settlement enable water to flow off of the peatland quicker than in their natural state. Fires re-occurred in Kalimantan in both 2002 and 2003, although with less severity than in 1997 but, never the less, these resulted in a further loss to the atmosphere of large amounts of carbon (Limin *et al*., 2004). A study based on the quantitative evaluation of satellite imagery showed that peat drainage, logging and previous fire damage are the major factors that make peat swamp forests susceptible to fire. Forests that have been burnt once, are more likely to burn again, leading to a progressive degradation of the forest vegetation into fire prone bushland that is even more susceptible to fire (Bechteler & Siegert, 2004). Other peatland areas in Kalimantan, Sumatra and West Papua were affected similarly.

Forest and peat fires have important impacts not only within the peatland area affected but also on the surrounding landscapes and the global environment. Forest fire on peatland results in the loss of vegetation and the surface peat layer (subsidence), increased compaction and decomposition, changes to the peat chemical and physical characteristics (Kurnain *et al.,* 2001) (see Chapter 2) and creation of smoke (haze). Based on a field survey reported by Page *et al.* (2002), the thickness of peat lost through combustion during the 1997 fires averaged 0.40 m over the peatland areas of Central Kalimantan.

The Southeast Asian ‘haze’

The peat fires are the source of the ‘haze’, which is an aerial suspension of very fine particles (PM10s), especially ash, charcoal and soot that are so small that they do not settle out of the air. Owing to the small size of these particles face masks are ineffective and they reach the lungs regardless. In addition, peat fires produce a cocktail of other chemical pollutants that probably have worse, but little known, effects on human health. The ‘haze’ has become an emotive topic in SE Asia because it is a very visible form of atmospheric pollution that spreads northwards to affect neighbouring Malaysia, Singapore and Thailand.

What is the cause of the fires and what should be done to prevent them?
The use of fire is the time-honoured method of clearing land from forest and keeping it free of secondary re-growth. It has been practiced for centuries as part of swidden agriculture (slash and burn) under which it was small scale, low intensity and community controlled. With increased human settlement in remote places in order to disperse populations from high to low density areas and also to increase food production, the rate of forest clearance and land development has increased, especially in Indonesia, with a focus on Kalimantan, Sumatra and West Papua (Irian Jaya). This has led to an increase in the use of fire over larger and larger areas, and for longer periods of time, to satisfy the land requirements of settlers and also plantation owners. The latter see economic opportunities provided by a readily available cheap labour force. The result is environmental overload and nature's life support systems start to break down.

The solution is complex and the methods unknown, because there has never been a fire problem on peatland on this scale before. It necessitates an integrated multidisciplinary, multilateral approach combining scientists, technologists and engineers with policy makers, decision takers, stakeholders and funding organizations. There is already sufficient scientific information on natural peat swamp ecosystems and the impact of land use change and fire upon them to assist in formulating the decisions that need to be made. The principal way forward is to prevent fires from starting in the first place but this requires both public awareness and understanding, and official enforcement of laws and regulations. Government agencies, such as Departments of Forestry and local authorities, quite rightly focus on preserving infrastructure, for example, roads and bridges in peatland areas, that are being undermined by fire entering either the peat below or wooden supports on which they are constructed. Unfortunately, this does not get to the heart of the problem. Since the authorities have their fire-fighting equipment loaded onto the backs of trucks, they can only reach those areas that are served by roads and cannot even attempt to reach the vast wilderness beyond where most of the serious fires are located. In addition, the lack of available water is another serious limitation to the ability to control the fires because in these extreme dry periods the drainage ditches dry out and the water table sinks to several metres below the surface. Water has to be brought in which severely limits the effectiveness of fire fighting operations. The impact of these activities on suppressing fires is almost zero.

Present and future consequences
Peatland resources and natural functions are being damaged severely and may be destroyed forever with potentially devastating consequences. The failed Mega Rice Project in Central Kalimantan disrupted the peat swamp forest ecosystem over an area of more than one million hectares and it became fire prone (see Annex 2). This disaster not only released vast amounts of carbon from the peat store to the atmosphere but has also increased flooding in the rainy season, and drought in the dry season.

Natural peatland detains rainwater that eventually finds it way into the underground aquifer that supplies local communities with potable water. Lowland tropical peatland is the spawning ground for a large number of fish species that inhabit the adjacent rivers and coastal areas; the peatland maintains the water quality for these to survive and provides the water, through evaporation and cloud formation for rainfall elsewhere, especially inland on non-peat areas. If the peatland disappears or its vital functions are impaired, towns and villages could lose their water supply and some of the surrounding areas could become desert because much of the peat is underlain by sand.

Illegal logging

Illegal logging became part of normal life in Indonesia for more than 40 years because it was practiced by 'legal' logging companies as part of their concession extraction activities through a system of bribery, corruption and double accounting. More trees were removed by concessionaires than was officially specified in their extraction licenses and therefore these actions were illegal.

Since the demise of the Suharto regime in 1998 and the collapse of the Indonesian economy, illegal logging has taken on a new mantle that is practiced by local communities and imported labour and embraced by legally established logging companies and timber processing industries. Large amounts of illegal timber are absorbed into normal timber transport procedures and processes prior to being processed into timber products and exported worldwide. Illegal logging is very difficult to stop owing to the influence and power of the vested interests involved. The result, however, will be the end of commercial forestry and the downstream forest industries in Indonesia within relatively few years.

Illegal logging is widespread throughout all types of forest in Indonesia but it has become a major problem in peat swamp forest owing to the excavation of timber extraction canals that increase the rate of water runoff and lead to drying out of the surface peat, especially in the dry season, making it susceptible to fire (box 5.2).

Figure 5.7 a, b: Illegal logging camp, Sebangau catchment, Central Kalimantan.

Box 5.2: Impact of illegal logging in the upper catchment of Sungai Sebangau, Central Kalimantan

The peat swamp forests of the Sungai Sebangau catchment, Central Kalimantan, Indonesia, have been subject to intensive illegal logging for more nearly 10 years. This activity threatens the integrity and long-term stability of the peatland ecosystem, particularly as a result of the extraction methods used. These involve transferring felled trunks to staging areas using logging rails or 'skids', from where they are floated to the nearest river along narrow canals which have been dug into the peat. The bark is usually stripped from the trees and preserving agents applied before the timber is moved to the river, causing pollution that is a hazard to human health and animals of the forest. At the river bank, logs are tied into rafts and floated downstream to sawmills and wood processing factories (e.g. for paper and plywood manufacture). Illegal logging in Central Kalimantan shows some signs of abating largely because the resource is becoming depleted. Law enforcement efforts are weak, sporadic at best, and government policy is ineffective.

In the short-term, skids appear to be considerably more damaging to forest structure than canals. However the construction of the latter promotes drainage and peat desiccation, which will result in major long-term changes to the peatland ecosystem through peat decomposition and subsidence (see Chapter 2). A study carried out in the former Mega Rice project area shows that the maximum water table drawdown is much greater now than was recorded before illegal logging started. In September 2002 (the theoretical end of the dry season) a mean drawdown of 77 cm below the peat surface was observed, compared to 39 cm recorded in the same area in September 1993 (Page *et al*, 1999). An even larger drawdown was observed within 50 m of the major canals. Even in mid-July, two weeks into the dry season, the average mean drawdown was 47 cm below the peat surface. Very high water flow-rates through the canals appear to be the principal cause of this drainage. Flow-rates through the canals were found to be 100 – 3000 times faster than the natural flow-rate through the peat acrotelm, recorded before the construction of canals (Takahashi & Yonetani, 1997).

In the Sebangau catchment, the reduction in habitat area and quality has affected the size of the orang-utan population that is showing signs of stress (Morrogh-Bernard *et al.* (2003). It is clear that efforts must be made to stop illegal logging, but in the face of the huge obstacles to be overcome it is unlikely that this will be achieved within the next 2-3 years. This is the time-span that illegal loggers in the Sebangau catchment believe is left before all commercially valuable trees are removed from the area. Following this, sustainable peat swamp forest must be reinstated and allowed to regenerate to preserve the ecosystem's massive conservation value. This can only be achieved by maintaining peatland hydrology. As severe as the damage to forest structure may be, drainage caused by illegal logging extraction canals is the major threat to the future integrity of this ecosystem.

The adverse correlation with fire.

A detailed study carried out in Central Kalimantan, Indonesia (Böhm & Siegert, 2002) showed that the rate of reduction of the forest area between 1991 and 1997 was approximately 2.0% yr^{-1} as a result mainly of concession logging, and land clearing for small scale farming and plantations. Between 1997 and 2000, however, after the logging concessions licences had expired, the rate of deforestation increased to about 6.5% yr^{-1}, as a result of illegal logging, land clearance associated with the Mega Rice Project and the peatland fires that occurred in 1997. The average rate of forest disappearance between 1991 and 2000 was about 3.2% yr^{-1} in the 6 locations studied. The length of logging roads increased between 1991 and 1997 from 4419 km to 6621 km (34% increase), the length of logging railways and extraction tracks increased from 7136 km to 9406 km (25% increase). By the year 2000 the length of the logging railways and extraction tracks increased by another 1920 km making a total of more than 11,000 km within a study area of 2.5 million hectares. This investigation also showed that the logged over area increased by 44% between 1998 and 2000 mostly because of illegal operations (Böhm & Siegert, 2001). This over-exploitation made the forests more susceptible to fire and considerable damage occurred once more during the extended drought of 2002. It was demonstrated that besides peat drainage, forest disturbance by logging is the major catalyst for fire. A spatio-temporal analysis showed that fire hazard increased significantly in the vicinity of previous logging operations, recently logged forests were much more vulnerable to fire than forests which had been logged five or more years previously and intensively logged forest suffered more from fire damage than less intensively logged areas (Bechteler, 2005).

Is there a solution?

The solution is obvious. Illegal logging must be stopped and the canals must be filled in, in order to conserve the peat swamp forest, to enable its hydrology to recover and its biodiversity to regenerate.

Minor canals are beginning to silt up naturally, but flow-rates in the larger ones are too big to allow this, indeed they are likely to be eroding the peat further. Tree-falls produce natural dams, but many of the canals are being used and maintained by local people who collect jelutung (latex), gemur (bark used in the manufacture mosquito coils) and animals (e.g. birds, fruit bats, pigs and deer) using boats to access the forest and remove the products (Figure 5.4). Therefore artificial dams or water flow retarders need to be constructed as a first prerequisite to restoration of natural functions. This requires funding and Government support in the first instance, and must take into account the socio-economics of the area, particularly of those people making a living collecting forest products and who may find themselves excluded as a result. It should also be noted that many of the people using the canals pay a ‘toll’ to illegal entrepreneurs who financed the construction of the canals and therefore have a vested interest in their retention. These people are usually able to exert influence on local government decisions and law enforcement agencies.

Suitable methods need to be identified, including the material required, to construct the dams and retarders and to determine their most effective locations. The latter requires good mapping of the canal network and the surface topography. Whilst the materials used may be inexpensive, (e.g. Page & Rieley (1984) suggested the use of impermeable PVC sheets to control water drainage in Chartley Moss National Nature Reserve, Staffordshire, UK), aerial mapping, manpower and follow-up checking and maintenance will prove expensive.

CHAPTER 6: WISE USE OF TROPICAL PEATLAND

Introduction

Peatlands cover around 3% of the world's land surface and 10-12% of this resource is in the humid tropics covering between 30 and 45 million hectares and accounting for more than 15% of this planet's mass of organic carbon. Three quarters of the world's tropical peatland is located in Southeast Asia, principally Indonesia, but with considerable deposits in Malaysia. The remainder of tropical peatland occurs in the Caribbean, Central and South America and Southern Africa (Immirzi & Maltby, 1992; Page *et al.,* 1999). Most tropical peatland is found at low altitude at or near to sea level while a small amount occurs in upland areas.

Wise use of tropical peatlands is essential to ensure that sufficient area of this resource remains to carry out vital natural resource functions while satisfying essential requirements of people now and in the future. This involves evaluation of their functions and uses, impacts caused by, and constraints to development, so that, by assessment and reasoning, it will be possible to highlight priorities for their management and wise use, including mitigation of past and future damage.

Wise use of tropical peatlands necessitates integrated planning and management and the challenge is to develop mechanisms that can balance the conflicting demands on the tropical peatland heritage to ensure its continued survival to meet the future needs of humankind.

What is 'wise use'?

The concept of wise use, although it has been used for quite a long time, is hardly explained in detail in an understandable and useable form. Most sources concentrate on how wise use should be implemented without clarifying what it is or why it may be preferable to other approaches. 'Wise use' and 'sustainable use' are often regarded as synonymous, although their precise meanings indicate they are somewhat different. According to an English dictionary (Schwarz, 1993), 'use' is 'the act of, or state or fact of, being put to some purpose that is advantageous'. 'Wise' means 'having knowledge that is applied to good purpose' and implies the making of judgments in a prudent, sensible and skilful manner. In contrast, 'sustainable' means having the ability to maintain or keep going. These terms are often applied to planet earth, its ecosystems, habitats and natural resources and, when combined, are powerful statements that imply human responsibility for natural resource functions and biodiversity in the long term.

Wise use, therefore, involves the acquisition and application of knowledge to some beneficial purpose through a process of evaluation and decision making that will achieve the widest possible acceptance amongst 'stakeholders'. When linked to 'sustainable', 'wise use' adopts the mantle of continuity and permanence.

It is very easy to highjack key words and phrases, especially when they become important in economic and political terms, and to lose sight of their original meanings and intentions. An example of this is 'sustainable development', a most important concept that came to the fore in the Brundlandt Report (World Commission on Environment and Development, 1987). A key aspect of this report was the linkage of environment and development whereby the latter should not be promoted at the expense of the former to the disadvantage of future generations. Subsequently, the phrase has become polarized into the two extremes of 'environmentally sustainable development' and 'sustained economic growth' with little common ground between them; environmentalists and many scientists promote the former interpretation one vigorously while developers and many politicians and government officials take the side of the latter definition. The result has been relatively little progress in spite of the exciting statements agreed to in the 'Declaration on Environment and Biodiversity' issued at the end of the 'Earth Summit' held in Rio de Janeiro in 1992 (CBD, 1992). This reconfirmed the previous declaration issued at the United Nations Conference on the Human Environment held in Stockholm in 1972, which stressed that '..the natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of **present and future generations**, through careful planning or management...'. In addition, it was stated that 'the non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by **all mankind.** The Rio Convention defined 'sustainable use' as the 'use of biological diversity in a way and at a rate that does not lead to the long term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of **present and future generations**'. The themes of satisfying present and future requirements of everyone on this planet were taken further in the Rio Declaration, which states that 'the right to development must be fulfilled so as to equitably meet development and environmental needs of **present and future generations**' and to realise these by providing 'a higher quality of life **for all people'**. Similar statements have been issued by other international conventions and meetings, for example, the UN Framework Convention on Climate Change (New York 1992) urged its Contracting Parties to 'protect the climate system for the benefit of **present and future generations of humankind**' whilst affirming that this should be 'coordinated with social and economic developments (not environmental protection!) in an integrated manner….for the achievement of sustained economic growth and the eradication of poverty…'.

The inclusion of contradictory objectives and procedures within these statements has made them difficult to explain and apply, especially at the operational level. What seems clear, however, is that in order to ensure the survival of this planet and its population of humans, steps need to be taken to protect the earth's remaining natural resources and the global environment. This should be done in such a way that future generations will have available to them an adequate supply of natural resources and a healthy environment to live in so they will not have cause to blame the current generation for deterioration of both. This is a tall order, fraught with many problems not the least of which is the presumption that the present generation knows what the aspirations and needs of future generations might be! The only guide available is what current generations believe and practice, but there is no guarantee that this will not change over time, especially in response to future reduction in natural resources and environmental quality. Ethical and moral obligations are being placed upon humans at the present time and in the future; the test will be whether or not they are capable of meeting the challenge.

Wise use of peatlands

Joosten & Clarke (2002) provide a succinct definition of 'wise use of peatlands' as 'the uses of peatlands for which reasonable people now and in the future will not attribute blame' and a context for, and parameters within which, wise use decisions can be taken in relation to peatlands. They provide a framework, based upon values of peatlands, and including a decision tree, through which wise use of peatlands should be achieved assuming that conflicts arising could be resolved.

Functions and values of peatlands
Following the *preference approach* (Joosten & Clarke, 2002, page 45) values are generally divided into two categories:

1. *instrumental values* (= functions) are the beneficial effects of one entity upon another entity and these can be studied scientifically;
2. *intrinsic moral values* are independent entities in their own right.

Instrumental values can be sub-divided into *material* and *non-material life support functions.* The former contribute to the maintenance of physical health and consist of *production, carrier* and *regulation* functions that relate to the provision of resources, space and maintenance of ecological processes and global life support systems, respectively. The latter provides a wide and varied range of benefits related to either human behaviour and senses that provide pleasure and relaxation (*proxy functions*) or consciousness and identity (*identity functions*). Instrumental values identified by Joosten & Clarke (2002) are summarised in Table 6.1 with an overview of the most important functions of peatlands for humans in Table 6.2.

Wise use of peatlands and the Ramsar Convention on Wetlands
The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Article 3.1 of the Ramsar convention states that the Contracting parties *"shall formulate and implement their planning so as to promote the conservation of the wetlands included in the (Ramsar) List, and as far as possible the wise use of wetlands in their territory"*. The third meeting of the Conference of the Contracting parties in 1987 adopted the following definition: *"The wise use of wetlands is their* ***sustainable utilization*** *for the benefit of humankind in a way compatible with the* ***maintenance of the natural properties of the ecosystem***"[2].The Ramsar Convention Strategic Plan (1997-2002) Recommendation 6.1 called on Ramsar Contracting Parties to give priority to a range of actions to facilitate the conservation and wise use of peatlands at the national and regional levels. These actions include the formulation of regionally based peatland management guidelines.

The Ramsar Convention Strategic Plan 2003-2008 identifies the challenges for future wetland conservation and wise use, especially with respect to the global hydrological cycle, supply of water for the survival of biological diversity, human consumption, agricultural production and recreation, supply of food (e.g. fish and rice and other natural products) and fibre (e.g. wood, peat and reeds).

Major global issues influencing the conservation and wise use of wetlands, including peatlands are:

- increasing demands for water for agriculture, industry and human consumption and the need for water allocation and management to maintain ecological functions;
- climate change and its predicted impacts;
- increasing globalization of economic development, affecting agriculture, fisheries and other natural resources products;

[2] Sustainable utilization is defined as *"human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations"*. Natural properties of the ecosystem are defined as *"those physical, biological or chemical components, such as soil, water, plants, animals and nutrients, and the interactions between them"*.

- changing role of national governments through increasing privatization of services, devolution of decision-making responsibilities, and greater empowerment of local communities;
- increasing land-use pressures leading to continuing loss and damage to the ecological character of wetlands and their values and functions;
- increasing population pressure and economic challenges placing some local communities in the developing world on the edge of survival;
- increasing influence in the developing world of development banks and international development agencies and the need to ensure that such agencies are fully engaged in the major issues affecting wetlands; and
- need to ensure continuing political support and public interest in biodiversity issues and sustainable development.

To respond to this challenge, Contracting Parties to the Ramsar Convention seek to deliver their commitments to wetlands conservation and wise use by:

- working towards the wise use of wetlands through a wide range of actions and processes contributing to human well-being;
- devoting particular attention to the further identification, designation and management of a coherent and comprehensive suite of sites to complete the List of Wetlands of International Importance (the Ramsar List); and
- co-operating internationally in their delivery of wetland conservation and wise use, through the management of transboundary water resources and wetlands, and shared wetland species.

Most of these wetlands issues and processes are relevant to peatlands that make up 50% of all wetlands globally and are under-represented in the Ramsar List.

Guidelines for Global Action on Peatlands

The Ramsar Convention at its Eighth Meeting of the Contracting Parties in November 2002 adopted the *Guidelines for Global Action on Peatlands (GGAP)* that focus on encouraging partnerships and action at the national level by Contracting Parties. The *Guidelines* have several focal areas: (1) knowledge of global resources; (2) education and public awareness of peatlands; (3) policy and legislative instruments; (4) wise use of peatlands; (5) research networks, regional centres of expertise, and institutional capacity; (6) international cooperation; and (7) implementation and support (see Annex 5).

The *Guidelines* provide a framework for national, regional and international initiatives to promote the development of strategies for peatland wise use, conservation, and management; guidance on mechanisms to foster national, regional and international partnerships of government, the private sector, and non-government agencies to fund and implement actions in support of such strategies; and approaches to facilitate adoption and support for implementation of global action on peatlands through the Ramsar Convention, the Convention on Biological Diversity, the Framework Convention on Climate Change, and other appropriate national, regional or international instruments.

The development of the *Guidelines for Global Action on Peatlands* is particularly important to developing tropical countries with peatland because they are in urgent need of information, advice and management guidelines for this vulnerable resource. There is a pressing requirement for close cooperation between government agencies involved in planning and regulation, resource users, researchers and environmental conservation groups in order to achieve peatland sustainability through the application of wise use principles. Developed nations with peat and peatland expertise must share this with developing tropical countries. Since 1993 international efforts have focused on research and capacity building for local communities in the importance and use of tropical peatlands for their ecological and natural resource functions and the consequences of inappropriate development and disasters, especially fire.

Of particular interest are projects in Central Kalimantan, Indonesia led through international consortia of scientists from the United Kingdom, Indonesia, Malaysia, Finland, Germany, Japan and Canada that collaborate with other research institutions developing core science and analysis of management needs for the tropical peatland ecosystem and its sector development. Examples of these research and capacity development programmes are the UK Darwin Initiative on the biodiversity of tropical peatlands, EU INCO projects on natural resource functions of tropical peatland and formulation of strategies for implementing their sustainable management. A further EU funded project commenced in Southeast Asia and Europe in 2004 focusing on restoration of tropical peatland.

Wise use of tropical peatlands

Peatland utilization in the tropical zone commenced only in the early part of the 20th Century on a very small scale but speeded up after the Second World War. In Malaysia, some peatland was converted to agricultural use in the late 1950s and 1960s following assessment of its potential for growing a range of crops (Tay, 1969). In Indonesia, peatland development started in the 1970s because of the need to increase domestic food production to feed a rising population. This followed detailed multidisciplinary studies of soils, ecology, agronomy, engineering and socio-economics by Indonesian and Dutch scientists (e.g. Soepraptohardjo & Driessen, 1976) as a result of which many problems were identified, including:

- slow rate of natural decomposition of organic matter linked to the high wood content of the peat;
- rapid oxidation and decomposition of organic material after vegetation removal and drainage leading to a high rate of subsidence and subsequent increase in flooding;
- irreversible shrinkage causing adverse water retention and increased erosion;
- extremely rapid horizontal hydraulic conductivity and extremely slow vertical conductivity;
- high heat capacity and low thermal conductivity causing major temperature variations at the peat surface;
- low load-bearing capacity causing top-heavy tree crops to topple over and making it almost impossible to use farm machinery or to construct reliable roads and other infrastructure.

It was concluded that *"no other soil type combines so many unused possibilities with so many unsolved difficulties"* and that *"a multidisciplinary effort is needed to find ways to exploit the potentially suitable peat formations* ***in a non-destructing way****".* In spite of this warning, large areas of coastal peatland in Indonesia, especially within the influence of daily tidal movements, were developed for agriculture and human settlement over the ensuing 20 years with only limited success.

In the 1990s, most of the remaining natural peatlands in Southeast Asia, especially in Indonesia and Malaysia, were targeted for development. In the former country, this was a response partly to the rapidly declining economy that was being influenced by global financial and trading events and partly as a result of an increasing population and the loss of self sufficiency in rice production. The solution to these problems in Indonesia was to undertake large land development projects that, on peatland, involved aquaculture, agriculture and plantation crops. These were also linked to human resettlement through the government promoted transmigration programme. In Malaysia, especially Sarawak, lowland peatlands were viewed as potential areas on which to extend production of plantation crops, especially oil palm and sago. In both countries, these projects were initiated without, firstly, carrying out research on tropical peatlands, especially its very specific physical, chemical and biological attributes and properties, and the role that this ecosystem plays in landscape and environmental resources and control systems.

It is evident that traditional approaches to development when applied to tropical peatlands, are inappropriate and that many projects have failed to achieve their objectives of increasing food supply and alleviating poverty. Much money has been wasted and large areas of peatland (and its forest cover and natural resources) have been destroyed. The main reasons for the lack of success have been inadequate knowledge of the tropical peatland ecosystem, especially the nature and properties of peat soils, lack of post-development monitoring, and project mismanagement. As a consequence, in Indonesia, poverty continues to increase, investment remains low and racial tension intensifies while the peatland landscapes have been degraded and an increased risk of peatland fire brings additional problems to human health and the global environment.

Peatlands in Southeast Asia have been affected adversely by development policies that have relied strongly on single sector interests and lack of integration and an almost complete disregard of environmental consequences. Strategic planning has not been based upon sound knowledge of the peatland landscapes or the properties of peat and most developments have commenced without independent, reliable environmental impact assessments. There have been initial windfall benefits for a few from tree felling and timber removal, and infrastructure construction operations, while problems have been created long into the future for local populations and governments without the finance to provide mitigation or rehabilitation.

Forest and peatland fires have been increasing in frequency, duration and severity in Southeast Asia since the early 1980s. They are related to land clearance activities using fire that is difficult to control and, in the protracted dry seasons of El Niño years, spreads to adjacent areas of degraded and natural peat swamp. It is now known that most of the gases and particulates released come from the burning of peat (Page *et al.* 2002) and these not only enhance the greenhouse effect but, during recent forest and peatland fires, produce a dense cloud (haze) that blankets the region and affects neighbouring countries. Indonesia is the main culprit in starting the fires, although Malaysia is also a contributor, but the haze also affects Singapore and Thailand whilst the greenhouse gases (CO, CO_2, CH_4 and N_2O) enter the upper atmosphere and become a global problem. Concerted and coordinated action to stop or minimise this loss and degradation of tropical peatlands through inappropriate and non-sustainable land conversion is now a major priority whilst there is an urgent need to restore peatland landscapes that are already damaged and non-functional. This can be achieved only through planned programmes of peatland restoration based upon scientific and technical knowledge obtained through field experimentation and observation. The complete involvement of all stakeholders, including local communities, is essential in order to prevent further fires that will render any attempts at tropical peatland rehabilitation futile.

Functions of tropical peatlands for humans

Production functions

These are extractive uses of peat that have been beneficial to human beings throughout history and include those used in the vicinity of the peatland by local communities (fuel, bedding, water) and others that have been required and utilised some distance from the source of peat and became objects of commerce (energy generation, raw materials, food, bedding, soil improvers).

Peat extraction:

This is a relatively minor activity in Southeast Asia where there is little requirement for domestic heating fuel and no tradition of using peat and peat-based products in agriculture and horticulture (Prasodjo & Mukarwoto, 1997). A pilot study for a peat fuelled power station, carried out in Central Kalimantan in the 1980s, revealed that there would be little demand for the electricity it would produce while it would not be economic to transmit it elsewhere owing to the remote location of the peatland. Additional problems were related to the nature of tropical peat (high wood content) and problems of excavating and milling it in a humid tropical environment with a wet season of up to 10 months a year.

Some tropical peat is used as a growth medium, especially for nursery cultivation of trees from seed or cuttings and also for flower and ornamental plant culture. Sometimes soil improvers such as lime and fertilizers are added but the business is not on the large commercial scale that operates in Europe, North America and Japan.

Tropical peat is not used locally as a soil improver to increase water holding capacity and provide trace elements. It is possible that, in the future, tropical peat could be used effectively in the remediation of degraded soils and as topsoil replacement in the restoration of mining areas (copper, tin and gold). There have been proposals to export peat from Indonesia to the Middle East for soil improvement in the construction of golf courses but, at the current time, this is not feasible economically.

Drinking water:

The provision of drinking water from peatlands is very important in some tropical coastal lowlands where they act as vast catchments of rainfall that is released slowly into adjacent rivers from which it is abstracted for human use. In Sarawak, some domestic and urban water supplies are obtained or supplemented by water abstracted from tropical peatland. Some 45 water supply catchments with 70-100% of the water coming from peat swamp forests are being utilised as sources of water for over 140,000 people in coastal areas of Sarawak. In Central Kalimantan, Indonesia much of the peatland area is underlain by Giant Podzol quartz sand that is a vast reservoir of potable water. It is probable that much of this water is derived from the surface peatland and is likely to be available only as long as the peat is present. In remote peatland areas, local communities frequently use peatland 'blackwater' from drainage channels and pools in spite of its deep brown colour that results from the high content of humic acids.

Grazing of domestic animals and provision of fodder

It is likely that indigenous people in the tropics have always used some marginal peatland areas (shallow peat) for the grazing of livestock. Local people today collect grass (alan alan) from deforested, degraded peatland to feed to cattle and goats on their homesteads. Since there is no equivalent to fen dominated by grasses and sedges in the lowland tropics (all natural peatlands are dominated by trees) there has not been the intensive utilisation for fodder and grazing that prevailed over large areas of peatland in the boreal and temperate zones. There have been some pilot projects to assess the suitability of tropical peatland for the grazing of livestock (especially cattle and goats) but it is not known how successful these have been (Aden, 2000). In south-western Thailand, a 'King's' project was established to convert peat swamp forest to grazing pasture for intensive cattle rearing. After a short time the vegetation became dominated by members of the Cyperaceae (especially Cyperus spp.) that are largely unpalatable and wear down the teeth of ruminants.

Wild plants growing on peatlands for food, raw materials and medicine:
Utilization of tropical peatland plants for food and medicine has taken place on a small scale and selective basis. Indigenous people use rattan, not only for lashings, furniture, baskets and mats but they eat young shoots and pith. Other sources of food are obtained from ferns, fungi and various parts of other plants, including their fruits and seeds. Some plants are believed to have medicinal properties against malaria and other diseases and induce relief from pain, especially in childbirth. More intensive and coordinated utilization of peat swamp forest non-timber products has focused on collection of jelutung (latex of *Dyera* spp.) and gemur (bark of *Alsiodaphne coriacea*). The former is used to manufacture high quality rubber products and can be obtained in a sustainable manner that does not kill the trees. The latter is used in the manufacture of mosquito coils and surfactants for the recycling of used oil, but the trees are killed in the harvesting process. An important use of peat swamp forest resources, however, was large timber for house and boat construction and small wood for implement handles, fencing and scaffolding.

Wild animals for food, fur, medicine and trade:
In the tropics, hunting animals for food, fur and medicine has long been an essential part of the life of indigenous people and this would have been so in tropical peatland with its dense forest and large animal diversity. The large range of animals would have played an important role in providing food in the past, especially deer, pig, monkeys, orang utan and fruit bats.

The same is also true of capturing animals for trade. This is mostly illegal and completely undesirable. Unfortunately, in the absence of adequate law enforcement this practice still continues since it brings high rewards to those involved but also stiff penalties if prosecuted.

Agriculture:
Indigenous people in the lowland tropics of Southeast Asia probably never cultivated peatlands for food crops since their livelihood was based on 'shifting agriculture' in dryland forest near to major rivers that were used for fishing, communication and transportation. They practised a semi-nomadic life style that only recently has become more focused in one location. Indigenous people were familiar with and respected the peat swamps that formed part of their landscape and knew that they were unsuitable for permanent agriculture owing to their poor soils and high water levels over most of the year. On shallow peat and in coastal areas semi-cultivation of palms, especially sago, is commonplace.

Sago palms grow naturally on shallow peat and need little maintenance. Sarawak is the world's largest exporter of sago (largely cultivated on mineral soils) most of which goes to Japan, Taiwan and Singapore. Oil palm can also be cultivated although its root system is shallow and it is therefore prone to instability; it also requires a higher nutrient level than sago. Other plant species cultivated on tropical peat include fruit trees, pineapple (one of the most successful crops), coconut, coffee and spices.

In Indonesia, some local people, for example Banjarese, developed a proficiency in rice cultivation on shallow peat in coastal areas where they make use of daily tidal movements to flush out the acidic peat water from their padi. Gradually, they extended this technique up major rivers as far as tidal influence permitted and managed to produce reasonably high yields. As a result, some lowland peat soils can be productive not only for wetland rice but also for a wide range of annual crops, although these require intensive management through acidity control and fertilizer addition. Under these regimes the peat slowly oxidises and eventually disappears leading to future problems of soil sterility and toxicity. (see Chapter 2) Integrated systems of agriculture employing animal husbandry (cattle, goats, poultry), annual crops (soya beans, vegetables) and fish ponds (carp, tilapia) can provide a good subsistence living and cash income for some local communities (Fachrurrozie, 2002).

Forestry:
The natural climax vegetation of lowland tropical peatland is forest although human intervention (logging, burning) has led to sub-climax variants (grass/sedge and pandan). In Southeast Asia peat swamp forest covers vast areas of landscape between major rivers and bounded by coastal mangroves and interior Dipterocarp forest (Rieley *et al.,* 1996; Page *et al.,* 1999). While there was still a large area of terrestrial forest remaining in Indonesia and Malaysia the peat swamp forests were largely ignored but, since the 1970s, as a result of increasing demand for and scarcity of timber, attention has increasingly been directed at peatlands. On state forestry land tree removal followed legally prescribed actions to enable regrowth after a period of years (35-50) and usually involved a degree of replanting. In Malaysia this was usually facilitated by the construction of wide and deep channels along which to float out the felled timber, usually as large rafts. In Indonesia, the procedure involved mainly a primitive technology of light railways and manual labour. In peatland areas designated for conversion to agriculture the forestry practised was clear felling of all commercial species followed by burning of the residue prior to land clearance and crop establishment. Commercial forestry and land clearance were mostly not subjected to environmental impact assessments before they were carried out, even if the law provided for these.

Carrier functions

These functions provide space and substrate for a range of facilities and utilities beneficial to human populations including conservation, cultivation, energy generation, habitation and recreation.

Water reservoirs for irrigation:
Water reservoirs for drinking water, hydro-electricity and recreation are not normally a function of tropical peatlands but the Mega Rice Project (Annex 2) in Central Kalimantan, Indonesia was dependent upon water storage for the irrigation of the proposed rice fields. This was to be achieved through an extensive system of channels constructed throughout the peatland area that were supposed to have the dual functions of drainage and irrigation. The former function would operate in the rainy season to remove excess water from the area and make rice cultivation possible whereas, in the dry season, water stored in the channels would be used to irrigate the rice fields and flush out toxic and acidic compounds. These objectives were never realised because the construction engineers did not realise that the vast peatland landscape was dome-shaped and therefore water would move down slope and could not be stored.

Urban, industrial and infrastructural development:
Since land is at a premium even in developing countries lowland tropical peatland is being used increasingly for urban, industrial and infrastructural development purposes. The expansion of towns and villages in peatland areas takes place inevitably at the expense of peatland, both natural and that used for agriculture. The planned expansions of Palangka Raya in Central Kalimantan and Kuching in Sarawak are to take place on large areas of peatland, but not exclusively so. Most of these new urban areas are to house workers who will not be involved in farming but engaged in a variety of urban-based manufacturing and service jobs. New industrial estates are appearing around Kuching, some of which are on former peatland. Roads and canals are also being constructed across peatland landscapes with serious implications for their hydrology and ecological functions. In the establishment of the Mega Rice Project in Central Kalimantan (Annex 2) more than 4,500 km of drainage and irrigation channels were excavated across vast peatland landscapes and new settlements were constructed on peat.

Transport:
Rivers and canals are used for transportation of people and goods in and around tropical peatland areas. In Central Kalimantan some canals were excavated across shallow peatland during Dutch colonial times to link adjacent rivers to facilitate transportation of raw materials for export and reduce travelling times. Some blackwater (peatland) rivers, for example, Sungai Sebangau and Sungai Megatip in Central Kalimantan, are navigable throughout the year and the former has a very deep channel which enables quite large 'bugis' boats from Jakarta to sail 150 km upriver to the small port of Kereng Bengkirai near to Palangka Raya. Unfortunately, the construction of channels inside tropical peatland provides entrance routes for people who exploit the forest, especially, its timber resource that can be floated out into adjacent rivers.

Regulation functions

These are functions that contribute to the maintenance of environmental quality through provision of clean air, soil and water.

Regulation of global climate
Peatlands play a major role in the global carbon cycle and have done so for many millions of years. During some time periods peatlands have operated as carbon sinks while at others they have been carbon sources (see Chapter 4), depending upon the prevailing climate and hydrological conditions (Page *et al.,* 2004). Peatlands globally are major sinks of atmospheric carbon (CO_2) and significant stores of carbon and nitrogen. Pristine peatlands (mires) and re-wetted peatlands emit methane and nitrous oxide while drained peatlands emit carbon dioxide. The carbon in peat can be stored for many millennia while peat that has been converted to coal has kept its 'fossil' carbon for millions of years.

Around 50% of all soil carbon is in peat and therefore the maintenance and status of the world's peatlands is a matter of grave concern since their degradation leads to release of some of this stored carbon. This is recognised by Governments in most developed countries and the utilisation of peat and peatlands is subject to rigorous control through landscape planning procedures and regulations. Domestic and industrial uses of peat are minimised wherever possible.

In the developing countries of the tropics, however, this control and regulation is lacking and major developments on peatland have and still are taking place without adequate assessment of the importance of the peatlands as carbon stores or the consequences of converting them to some other purpose. Inevitably, every type of interventive development on peatland leads to destruction and loss of natural resource functions (ecology, hydrology, biodiversity) while drainage and lowering of the water table causes oxidation of the surface peat and emission of carbon dioxide to the atmosphere that enhances the greenhouse effect and contributes to climate change (see Chapter 4). In Indonesia and Malaysia, large-scale conversion of lowland tropical peatland to agriculture has led to the loss of large amounts of carbon that has been stored for millennia while, in the process, the drier peatland landscapes have become fire-prone, especially in El Niño years when peatland and its vegetation have burned, releasing enormous quantities of carbon (Page *et al.,* 2002). The climate regulating function of tropical peatlands is being destroyed with serious implications for the future of this planet.

Studies of the global carbon cycle emphasise that the interactions between the atmosphere, oceans and terrestrial ecosystems are complex and dynamic with many interconnections and feedback mechanisms. They contribute to the controversy and uncertainty surrounding climate change and the role of so-called greenhouse gases. It is widely held that small changes in the inputs to this dynamic system will produce correspondingly small impacts upon climate change, which will take place slowly. It is likely, however, that major inputs over short time periods (for example, biomass burning and peatland fires) will produce greater effects on climate change and more dramatic consequences.

It has recently become clear also in the tropics that there has long been interaction between the oceans' coral reefs and the peatlands on adjacent land masses. The common link is carbon that in coral is stored as carbonate while in peat it is locked up in the partially decomposed organic matter of the plants that formed it (carbohydrates, cellulose, lignin, etc). It is now believed that a feedback mechanism existed between coral and tropical peat such that when one (e.g. coral) was emitting some of its stored carbon, this was absorbed by actively forming peatlands (mires) and vice versa (Vecsei, 2004). The situation, is complex, however, since it was influenced not only by past climate change but also sea level oscillations, related to thawing and freezing of polar ice caps that led to the appearance and disappearance of vast areas of land.

Regulation of regional and local climates:
Peatlands have a specific microclimate that differs from their surroundings. Whereas the microclimate of boreal and temperate peatlands is characterized by a greater variation in temperature, higher air humidity, greater fog frequency and greater risk of night frosts compared to mineral soils, in the lowland tropics, where peatlands are covered in rain forest trees, the situation is different with higher minimum but lower mean and maximum temperatures compared to mineral, deforested soils, and a constantly high relative humidity. The tree canopy acts as a buffer against high atmospheric temperatures during the day and much lower temperatures at night so that diurnal variation is reduced (Takahashi & Yonetani, 1997).

The overall local and regional climatic result of a vast forested, peatland landscape that is holding a large amount of water is to reduce the ambient atmospheric temperature through evapotranspiration. In addition, tropical peatland operates as a large sponge, soaking up the rainfall that falls upon it and releasing much of this water slowly back to the atmosphere, enabling clouds to form at some distance away to become the rainfall for other landscapes. The destruction of peatland could lead to water shortages and drought conditions elsewhere in the region and loss of productive landscape. Loss of peatland in Central Kalimantan could lead in the future to desertification as the underlying podzol becomes exposed progressively and water levels within it fall.

Peatlands are also affected by the prevailing climate of their landscapes and surroundings, especially rainfall, humidity and temperature. Tropical peatlands are very susceptible to climatic change and are maintained by an exceptionally high rainfall that leads to high water tables and surface flooding for most of the year. Increased seasonality in the form of extended dry periods affects adversely the ability of tropical peatlands to maintain hydrological integrity and sequester carbon causing them to emit carbon dioxide during times of water stress. In extreme circumstances some tropical peatlands will cease to store carbon and become carbon sources until their peat disappears completely.

Regulation of catchment hydrology:
Peatlands owe their existence and maintenance to water surpluses without which they slowly disappear. Tropical peatlands are important water catchments, reservoirs and suppliers (Chapter 3). Natural peatland catchment hydrology is controlled by the amount of rainfall and speed of runoff; the difference remains in storage within the peatland. In natural tropical peat swamp forest, the water table is high or above the surface throughout the year and most of the water is stored in the catotelm within which it hardly moves. The ‘mobile’ water is in the very shallow acrotelm (20-50 cm) and in the flood water above the peat surface. The ‘head’ of this mobile water varies considerably throughout the year in response to rainfall and runoff; it is high in the middle of the rainy season when rainfall exceeds runoff but, in the dry season, it may disappear completely and the water table may drop to the surface of the catotelm. Under lowered water conditions the surface peat will start to oxidise and release carbon. Over many years, however, under natural conditions there is usually a greater amount of carbon sequestered (i.e. peat accumulated) in the wet season than is released (oxidized) in the dry season. El Niño years are a special case, however, in which there can be a net loss of carbon.

Drainage and development of tropical peatland for every purpose leads to severe hydrological changes and loss of carbon. Removal of the forest takes away the biomass that is the sole contributor to peat accumulation whilst impairing the water holding capacity of the peatland. Subsequent sector use requires critical hydrological management to ensure that water is maintained at levels most appropriate to the success of the new activity and to minimise the rate of consequent peat oxidation and subsidence. This latter process cannot, however, be reversed or stopped so it is only a matter of time before the peatland surface drops to levels that become prone to flooding. Eventually, the peat will disappear, exposing underlying mineral substrates that will not hold water and are liable to be nutrient deficient and/or toxic, leading to new, more difficult problems for land managers. The over-riding requirement of all forms of tropical peatland development is to remove surface water quickly and prevent flooding. As a result, the ‘mobile’ water’ in and above the surface of a natural peat swamp forest is removed from the surface of a developed peatland as quickly and effectively as possible through the network of drainage channels excavated for that purpose. These can be so effective that rain falling in wet seasons is induced to run off immediately, leading to high water levels in the adjacent rivers and causing flooding downstream. In contrast, in the dry season, the presence of drainage channels ensures that water levels, that are already lowered, continue to fall causing drought conditions and crop failure (Annex 2). One consequence of the failed Mega Rice project in Central Kalimantan has been increased flooding of the only road linking Palangka Raya, the provincial capital with Banjarmasin, the principal city near the coast of South Kalimantan. As a result, a concrete causeway has had to be constructed, at considerable cost, to enable transport to continue along this essential route during the rainy season.

Regulation of catchment hydrochemistry:
Tropical lowland peatlands in Southeast Asia are mostly domed, ombrotrophic systems to which the only source of water and chemical elements is rainfall (Chapter 2). Marginal areas may be flooded periodically by river water but, since this flows over nutrient poor mineral substrates, there is not the same degree of enrichment that occurs to some boreal and temperate peatlands. In the Sungai Sebangau peatland of Central Kalimantan, for example, the chemistry of rainfall is slightly higher than that of the surface peat water that, in turn, is higher than that of the river (Page *et al.,* 1999). Recent research on nutrient dynamics of the Sungai Sebangau peatland in Central Kalimantan suggests that, over a 12 month period, the amount of essential plant nutrient elements (Ca, Mg, K) flowing out of the peatland in runoff is less than the amount that enters as rainfall, suggesting that peat accumulation is still taking place with storage, not only of carbon but other elements as well (Sulistiyanto, 2004).

Once developed, the chemistry of peat and peat water changes as greater amounts of chemical elements and potentially toxic compounds (humic acids) are either added (N and P fertilisers and lime), or released. In order to maintain soil fertility on developed tropical peatland, ameliorants have to be added constantly, especially lime to raise the pH, and fertilisers to maintain crop productivity. Farmers on tropical peatland are poor and have little or no money with which to purchase chemical ameliorants and, consequently, enrich their peat soil with ash obtained by burning organic farm residues (crop remains and animal manure) together with the surface peat on their land. This practice, however, speeds up peat subsidence and leads to flooding, followed by abandonment of homesteads. It also contributes to the ‘haze’ that has occurred in recent dry seasons as a result of extensive forest and peatland fires.

Regulation of soil conditions:
The vast expanses of tropical peatlands protect their underlying mineral substrates from erosion and toxification. Development practices (tree felling, drainage, cultivation, burning) speed up the loss of peat and its subsidence. Once the peat disappears the underlying mineral substrate is prone to erosion, which may reveal potential acid sulphate soils and cause siltation problems downstream.

Information functions

Social amenity and history functions:
Little is known about this aspect of tropical peatlands but indigenous people have been familiar with them for many centuries and used them as sources of water, food, shelter and a range of materials to supplement their life style. In Kalimantan the Dayak people revered some peat swamps and established holy places and shrines in them.

Recreation and aesthetic functions:
Tropical peatlands have a limited potential for appropriate recreation. Tropical peatlands and the rivers and streams draining from them are well established fishing locations and this could be expanded and improved. The ‘Natural Laboratory’ of tropical peat swamp forest that is located in the upper catchment of Sungai Sebangau in Central Kalimantan is an important resource to enable local people, especially children, to learn about their natural surroundings in a way their ancestors took for granted but of which they are either ignorant or suspicious. There is scope

to extend this use of tropical peatlands. It would not be welcomed to find speed boats towing water skiers on the peatland rivers of southeast Asia but some form of regulated ecotourism could be financially beneficial to both local communities and the peat swamp forest ecosystem.

Tropical peat swamp forest is a beautiful, exciting, tranquil yet awe-inspiring ecosystem that either captivates the imagination or terrifies. It is one of the most wonderful places on this planet and it brings the individual in contact with one's self and inner thoughts. It leads to a greater appreciation of the natural and dynamic nature of remote places and it should be respected and protected. It is a wonderland that brings together tropical rain forest and tropical peatland in a coexistence that is virtually impossible to believe, never mind understand. The aesthetic beauty of this place can only be understood by those who have visited and stayed within its tall trees and coolness and experienced the sights and sounds!

Symbolization, spirituality, and existence functions:
Virtually nothing is known about these functions of tropical peatlands but indigenous people revered their animals and plants and used some in their ceremonies. Christian-humanist Dayaks hunted and killed orang utan, for example, and used animal fur and bird feathers in ceremonial robes and head dresses (hornbill). It is likely that indigenous people worshipped their gods in peat swamp forest, to which they accorded spiritual values.

Signalization and cognition functions
Until recently, little systematic, structured research was carried out on tropical peatlands, although a large body of information existed on what happens after their development. This has now been addressed in part through the efforts of teams of scientists, especially from Europe, Indonesia, Malaysia and Japan, as a result of which much new information is available on the ecological, hydrological and natural resource functions of lowland tropical peatlands of southeast Asia. In addition, the impacts of fire and land use change have been documented and the socio-economic dependency of local people determined (see Chapters 3 and 5).

In common with boreal and temperate peatlands, tropical peatlands are reservoirs of chronological, climatic, cultural, geochemical, palynological and stratigraphical information (Page *et al.,* 1999; Weiss *et al.,* 2002; Page *et al.,* 2004). This resource, however, has hardly been tapped and only limited data are available from very few locations on these important topics.

Transformation and option functions

Tropical peatlands have the potential to be used as educational and teaching resources and information should be included in school and college curricula at all levels. Practical experience in the field will add to the usefulness of and benefit to be gained from peat swamp forest. Comparisons can be made between natural peat swamp forest and developed tropical peatland together with information on the impacts of fire and land use change. As a result, local people can be introduced to one of their most important ecosystems and, through a better understanding, can participate in its wise use.

Conservation and economics of tropical peatland

Conservation and economic values of peatlands are derivations of and combinations of various instrumental values and, in the case of conservation, also of different approaches to intrinsic values (Joosten & Clarke 2002). Conservation involves a wide range of motives with respect to instrumental and intrinsic values and it is necessary to be aware of these complex relationships in order to undertake a systematic analysis of the wise use of peatlands.

Peatland resources can provide long-term support to the economy of local communities and to the economic growth of developing tropical countries. The planning for wise use of tropical peatland, however, requires an understanding of the necessity for both development and conservation of tropical peatland, and the ability to choose management methods to balance the two optimally. In developing countries in the tropics these two apparently opposing requirements have failed, largely because they have been directed from 'top down' and funded and propelled by outside funding agencies, governments and international NGOs. As a result local people have become enmeshed in the 'poverty trap' and resort to over-exploitation of natural resources that places consequential stress upon environmental functions and processes.

Values and conflicts

The concept of 'Wise Use' incorporates complex environmental, economic and social concerns that require integrated decision-making (Joosten & Clarke, 2002). Different values may be interconnected in complicated ways and some may be mutually incompatible. Even if they are compatible, the allocation of benefits that are derived from them can be disputed. Before making decisions, mutually exclusive values need to be identified, conflicting claims have to be evaluated and procedures created for determining priorities. This process is neither obvious nor easy because there are major constraints to the degree to which different values and competing claims can be compared. There has to be a rational framework for presenting different opinions and coming to conclusions that will be acceptable, at least to the majority of stakeholders. This should enable all relevant points of view to be expressed and debated with reference to mutually agreed principles, e.g. conventions, guidelines, knowledge, legislation.

Joosten & Clarke (2002) present an excellent analysis of different types of conflicts and their origin with respect to peatlands. Firstly, they stress the difference between human 'needs' and 'wants' and divide conflicts into two components, those dealing with 'facts' and those dealing with 'choices'. Conflicts of 'facts', relating to understanding and judgement, can be resolved relatively easily since information is available that can be compared and conclusions reached in a rational way. It is more difficult to resolve conflicts of 'choices' since different stakeholders give greatly differing weightings to peatland values and favour actions that are often incompatible with others. In the formulation of wise use strategies 'needs' should prevail over 'wants'.

In this document, it is unnecessary to reiterate the background concepts enunciated by Joosten & Clarke (2002) but to apply these where appropriate to tropical peatlands in order to provide a framework for wise use activities. This more pragmatic approach is necessary because the situation affecting tropical peatlands at the present day is not the same as pertains to boreal and temperate peatlands in the northern hemisphere. The latter have been utilised for many purposes for hundreds of years and the legal frameworks for their current management (planning, utilisation, restoration, conservation) are well developed and more or less enforced. In developing tropical countries peatland utilization is a much more recent phenomenon that is part of the economic engine to generate capital and improve livelihoods and the legal procedures are less refined. Many developments have taken place in tropical peatlands without detailed planning or prior environmental impact assessments and have been driven by money and profit rather than proven benefits to economies or people. This has usually been at the expense of environmental quality and sustainability.

There is an urgent requirement to provide strategies for the wise use of tropical peatlands based upon sound knowledge of their ecological and natural resource functions, balanced against the needs of people to escape the poverty trap and obtain sustainable livelihoods. For those tropical peatlands on which inappropriate and unsuccessful land developments have taken place it is important to provide a framework that will lead to their restoration and rehabilitation of either natural ecosystem or sector development or both. In the case of future developments on tropical peatland it is essential to have available a guide to their wise use and strategies for its implementation in order to ensure sustainable management at minimal environmental stress.

Constraints to wise use of tropical peatland

Numerous inappropriate and ill-advised land development programmes have taken place on tropical peatlands over the last 30 years leaving a legacy of landscape degradation and continued impoverishment of local communities. In addition, especially in Indonesia, uncontrolled resource exploitation on lowland peatland (e.g. illegal logging, trapping, hunting and non-timber product removal) is threatening the current viability and future sustainability of this ecosystem. These problems are exacerbated by frequent, intense and widespread forest and peat fires that are making it virtually impossible to implement strategies for the wise use of tropical peatland in that country.

Illegal logging

Four decades of timber extraction in Indonesia through the Government promoted ‘concession’ system (HPH) has not improved the livelihoods of local communities surrounding peat swamp forest (Limin, 2000). The official system of cutting commercial trees in ‘blocks’ identified in a forest inventory and planned over the lifetime of the concessions (20 years) was followed only rarely, if at all, owing to corruption and the need to pay both Government and Government officers money in order to operate. In addition, legal taxes had to be transferred to the Provision for Forest Natural Resources (PSDH) and Reforestation (DR) Funds. As a result, peat swamp forests (in common with all forest in Indonesia) were overexploited and logged illegally since logging companies were forced to exceed their official quotas in order to meet their financial outlays. The forests became susceptible to fire, downstream flooding increased, water quality decreased and fish populations were affected adversely. Local people (Dayak) experienced difficulty in obtaining wood to build their houses and boats, while their ability to hunt for food was curtailed.

In order to survive many local people resorted to Illegal logging linked to large official logging companies and supported by individuals from Government Departments, the military and police. Consequently, implementation of law enforcement and prevention of illegal logging became very difficult. The Government of Indonesia has estimated that about 80% of illegal loggers in Central Kalimantan come from outside of the province (including transmigrants) and this has been confirmed by a survey carried out on the upper catchment of Sungai Sebangau (Limin 2004) that showed that 18 out of 20 groups of illegal loggers were new incomers to the region (Javanese and Banjarese).

Inappropriate development

There are numerous examples of poorly planned, badly implemented and mismanaged development projects on tropical peatland but the most disastrous is the Mega Rice Project carried out in Central Kalimantan (Muhamad & Rieley, 2002) (Annex 2).

In 1995 more than a million hectares of wetland, mostly of peatland, in Central Kalimantan were allocated by the Indonesian Government to promote a huge project to establish the biggest rice producing area in Indonesia. This project was known popularly as the "Mega Rice Project" (*Proyek Pengembangan Lahan Gambut*).

It took a very large amount of Indonesian financial resources in the attempt to establish this ambitious project because foreign aid money was not sought for its implementation. It was planned that within five years the project would be producing more than 5 million tonnes of rice each year (WALHI, 1999) from up to 200,000 households inhabiting the area (TTPLG, 1997). In the early stages of the project, many scientists doubted the feasibility of the project and predicted that it would be unsuccessful unless it was planned carefully. The political situation in the country at the time, however, prevented people from speaking against this favoured project of the then President of Indonesia, Suharto, and it was started without first undertaking an independent EIA and regardless of the views of indigenous communities.

Land conversion by draining peat for human settlement and irrigating for rice cultivation made the area unusually dry since excavation of deep drainage and irrigation ditches led to water flowing out of this area and did not provide the water reservoirs necessary for irrigation. As a result, widespread fires in the second year (1997) devastated most of the area bringing the project to a stop. A study that embraced most of the Mega Rice Project area estimated that the amount of carbon released from peat combustion was in the range of 0.167 to 0.367 Gt (Page *et al.,* 2000) within a few months only.

By December 1998 more than 15,000 migrants were living within Block A of the Mega Rice Project (Simatupang, 1999). Although the project was not stopped officially until 1999, the fire disaster of 1997 prevented further transfer of migrants into the project area. Even though the settlement of people was halted, channel excavation work continued and was completed throughout the project area as originally planned. Political uncertainty and the economic crisis in Indonesia, during 1997 and 1998, caused the project to be set aside from the top national agenda.

In 1998 the Transitional Government led by President Habibie ordered the complete cessation of the Mega Rice Project replacing it with a potentially more destructive scheme (*Kapet das Kakab*) that transferred the ex-MRP project area into a new development area twice the size of the failed project. This new Presidential Decree has not been annulled officially yet (2005), although the Government gave their word that further development of the area would not proceed and that amelioration of the damage caused by the ex-Mega Rice Project would be promoted. There is, of course, very little money available from Indonesian Government sources to promote this essential peatland rehabilitation and restoration process.

In 2002 an 'Ad Hoc' Committee was established under the Indonesian Central Planning Agency (BAPPENAS) to review the Mega Rice project, the reasons for its failure and to make suggestions for restoration and rehabilitation of the landscapes affected by it. This committee reported its conclusions and recommendations in October 2004 (Annex 2).

Fire

Forest and peatland fires have been a recurring problem since the early 1980s when conversion of peat swamp forest in Indonesia to agricultural use increased in scale, promoted by the Indonesian Government's transmigration programme. Fire became the principal tool of deforestation for land conversion projects in addition to its regular use to dispose of unwanted tree material every year during the dry season by both small farmers and large plantation owners. The occurrence of extended periods without rain in El Niño years, however, provided drier conditions for longer periods when burning could be achieved for several months at a time. This intensified the use of fire and gave rise to poor environmental conditions, especially 'haze' (smoke combined with fine particles of soot) that affected not only people locally but extended over distances of several thousands of kilometres across the Southeast Asian region. Since much of the forest area being cleared was located on peat, large amounts of carbon and other chemical compounds were transferred to the atmosphere (Page *et al.,* 2002) (Chapter 4).

The combination of an extremely long El Niño of 8 months in 1997, linked with the planned conversion of over one million hectares of peatland for the MRP led to the severest and most damaging fire event ever experienced in Indonesia. The fires returned in 2002 when once again they ran out of control and devastated large areas of forest and peatland in Indonesia.

The solution to the recurring fires on tropical peatland lies in awareness and prevention, combined with prohibition or strict control of the use of fire as a land clearance tool. If these are not achieved, similar disasters will occur with increasing frequency, coincident with dry periods and exacerbated by El Niño events, and the livelihoods of local people and the quality of regional and global environments will continue to decline. Implementation of fire control measures necessitates an integrated multidisciplinary, multilateral approach combining scientists, technologists and engineers with policy makers, decision takers, stakeholders and funding organisations. There is, however, already sufficient scientific information on natural peat swamp ecosystems and the impact of land use change and fire upon them to assist in formulating the decisions that need to be made. The principal way forward is to prevent fires from starting in the first place but this requires both public awareness and understanding, and official enforcement of existing laws and regulations.

Socio-economic implications

Peatland ecosystems play an important socio-economic role in some tropical developing countries. This is especially so in Indonesia, which contains more than 50% of the world resource (Maltby, 1997). While, in many parts of that country peatland still contains many natural attributes, development programs have increased greatly during the last 10 years. There has been a major change in the official attitude to peat swamps that were once widely considered as marginal land and thought to be useless for agricultural development and non-agricultural uses. This has been brought about by the growing need for more food, clothing, shelter and cash income to enhance the prosperity of the nation's growing population linked to technological progress to ease the physical effort of manual logging. Simultaneously, there has been increased pressure on peat swamp forest both through official, but corrupt, excessive concession timber extraction and unauthorized illegal logging, both of which usually operate without effective check or serious penalty.

In this situation, systematic, concerted efforts are necessary to promote strategic management to sustain ecological as well as social benefits of peatland ecosystems. Environmentally sound sustainable development must mean promoting wise use of the ecosystem for the welfare of local people, enhancing provincial and national prosperity while, at the same time, keeping ecological functioning and socio-cultural integrity intact. Evidence shows that tropical peatland ecosystems provide greater intangible benefits or indirect use values compared to tangible economic benefits associated with direct use values (Sjarkowi, 2002; Safford & Maltby, 1998). Strategic sustainable management of tropical peatland should promote social as well as official responsibilities in providing local, provincial, and national capacity to balance every formal and informal economic endeavour against the ecological dynamics of the ecosystem.

Failure to promote sustainable management strategies that recognize local social dimensions would be regrettable and could lead to social entropy (e.g. social disharmony and enmity) that could become harmful to both local communities and the peatland environment. Social entropy is defined as *'the negative outcome of social change that reduces social welfare, social cohesiveness, and social responsibility necessary to sustain ecosystem benefits following a social and economic development process'*. For the sake of efficiency and effectiveness, strategic management must of course rely upon more relevant and locally oriented sociological and ecological information (BMZ, 1995). The so-called 'SESA' (socio-entropy system approach) could become an effective interface for bridging the information gap between social forces and ecological dynamics that threatens valuable natural peatland ecosystems.

Problem Issues

More scientific observations and field work on individual tropical peatlands are needed in order to come to a better understanding of appropriate methods of sustainable management of tropical peatland ecosystems in general (Silvius & Giesen, 1996). This is particularly true when attention is being given to an ecosystem in a region that belongs to hundreds of indigenous tribes, namely the Dayaks and Banjarese in Central Kalimantan (Riwut, 1979). Much investigation of biogeophysical dynamics of tropical peatland natural functions and utilization has been carried out in recent times (Rieley & Page, 1997), but there is still very little comprehensive knowledge of socio-economic, socio-cultural or socio-ecological aspects of the peatland ecosystem. In response to this information gap, the following problematic issues have now been taken into consideration to provide clear direction for effective field observations.

Socio-Economic Aspects:

(a) the perception of socio-economic interaction between the communities of different ethnic background, for example, whether or not indigenous Dayaks and Banjarese, Javanese and Madurese migrants interact for their earning activities within the spirit of synergism or antagonism.

(b) how each particular earning activity that is natural-resource based differs from each other in terms of future trends of supply and demand and their potential impacts on the carrying capacity of the peatland ecosystem to provide these resources in a sustainable manner.

Socio-Cultural Aspects:

(c) the degree of intensity and prospect of social culturisation and social conflicts as they relate to future trends of increasing intensity of natural resource utilization, and how these influence socio-economic progress of local communities.

(d) which traditional rights (adat) are still effective and not ruled out by previous homogenous enactment of Central Government legislation and development policies, and what would be the social implications of instituting social institution reform to back-up a sustainable management strategy for the peatland ecosystem.

Socio-Ecological Aspects:

(e) model an environmentally-sound allocation of peatland resources in a region that optimise the economic benefits without sacrificing ecological integrity and ecosystem potential, and determine which technical and socio-ecological measures need to be taken into consideration.

(f) anticipate the future trends of social conflict that might follow peatland resource crisis and environmental risks owing to a lack of environmental concern, and identify which socio-ecological criteria could be used as an early warning system

Future direction and prospects

Study of the Sebangau peatland ecosystem suggests that partial utilisation of the natural resources is possible within a pre-determined strategy of multiple wise use. The Sebangau peatland could be sustainable if peat swamp forest conversion for alternative land use is not more than 13% of the whole area of the ecosystem, apart from some 1.7% that should be dedicated as a buffer zone. A 2% rate of annual (legal) deforestation would support legal logging activities for about 6.5 years. In order to extend this logging period (e.g. to 13 years) without removing more trees or clearing additional land will require decision makers and the regional development agency to inject technology and appropriate management through a special community development program. If the process is not controlled, serious social disruption might occur, especially if social productivity and local welfare are not improved as early as possible. The socio-economic dimension is clearly of fundamental importance in promoting environmentally sustainable development of tropical peatland and this should be positioned as the main gateway for policy implementation. For example, when parts of a peatland ecosystem have been destroyed by illegal logging and by man-made forest fire a socio-economic approach becomes crucial in order to bring success in implementing technical measures needed to promote reforestation. As population growth in Central Kalimantan is expected to be high in years to come (2.53%), the fate of natural forest resources will still be exposed to socio-economic forces that promote forest conversion and illegal logging. Therefore wise use strategies for sustainable management have to be taken seriously into consideration and implemented by provincial and local governments.

Governmental responsibilities

There is no Ministry or other Government body that specifically manages peatlands or oversees their development in Indonesia or Malaysia. In the former, their management depends on the designation of their land-use. Forested peatland comes under the auspices of the Ministry of Forestry, peatland converted to agriculture is the responsibility of the Ministry of Agriculture but the prior processes of ‘opening’ and ‘settlement’ come under the Ministry of Public Works and Ministry of Manpower and Transmigration, respectively. Since the demise of the Suharto regime and the promotion of decentralization through increased regional autonomy the Ministry of Regional Development has had a say and local management is in the control of Provinces and Regencies.

In Sarawak (Malaysia) several Ministries have responsibilities for peatland activities including the Ministry of Natural Resources and Environment, Ministry of Science, Technology and Innovations and Ministry of Agriculture. Peatland management is regulated by several policies including National Biodiversity Policy, National Forest Policy and National Agriculture Policy although additional national policies for wetlands and water are being formulated.

Balancing conservation and development of tropical peatland

Development of peatland in tropical countries has been promoted mostly without adequate knowledge of the ecological and natural resource functions of the peat swamp ecosystems or an understanding of their environmental and socio-economic importance (see Chapter 3). This has led to conflict with their global and regional environmental roles in carbon and water cycles and their wildlife conservation importance. The long term value of tropical peatlands can be optimised through sustainable use that involves an assessment of the economic and social as well as ecological and natural resource function values, together with a cost-benefit analysis of alternative development options. A combination of several small scale, but complimentary uses (multiple wise use strategy) that maintain the hydrological integrity of the area, may maximise benefits for minimum cost.

Implementing wise use of tropical peatland

The key to implementing sustainable multiple wise use of tropical peatland is the adoption of an integrated approach to planning and management that necessitates stakeholders and sectors working together to formulate and operate an integrated ecosystem or landscape scale management plan. This is a complex process that requires the use of several new concepts, methods and techniques that are still being developed and refined including, collaborative or joint management, consideration of the socio-economy and culture of local people, creation and involvement of multidisciplinary advisory teams, restoration and rehabilitation of degraded peatland, and changes to government policies and legislation. There is no universal 'wise use' management plan and every tropical peatland landscape requires its own unique version determined by the needs of the societies reliant upon it and the nature of the ecosystem itself.

Guidelines to planning and management of tropical peatlands (based on Safford & Maltby, 1998)

When planning use of tropical peatland, governments and development agencies should operate within national biodiversity and wetland management policies or strategies (see Box 6.1), which may need to be strengthened to take account of the special characteristics and properties of this ecosystem. National wetland policies should include the following components with respect to peatlands:

- formulating and implementing national policies and strategies for tropical peatlands;
- ensuring that peatland wise use is incorporated into sectoral policies, programmes and projects;
- increasing knowledge and awareness of peatlands and their values;
- carrying out inventories of peatland in different categories (classes and degrees of use or degradation);
- applying an internationally agreed classification system for peatland types;
- identifying actions to address problems affecting nationally important peatlands;
- reviewing the status and identifying priorities for peatland wise use nationally;
- protecting, using and expanding traditional knowledge of peatland use and management;
- promoting public awareness of the functions and values of peatland, through education and the media; and
- establishing or strengthening peatland-related institutions.

Box 6.1: Existing policy frameworks for wise use of peatlands in Indonesia and Malaysia

Indonesia

Article 33, paragraph 3 of the National Constitution 1945 states that “Land and water and natural resources contained therein, are owned by the State to be used for the utmost for the welfare of the people”. Specific laws and other legal instruments relating to wetland management, including peatlands, have not yet been enacted, although an Act on the Basic Provision for Environmental Management (4/1982) envisaged that, in principle, the management of the environment should be based upon maintaining the capability to support sustainable development for the improvement of human welfare. In reality, peatland development and management are regulated by policies specified in the Spatial Planning Act (24/1992) that are based upon principles of sustainable utilization to ensure integrated management that addresses harmony, conformity and equality between development needs and environmental functions.

Peatland ecosystems and their biodiversity should be managed in accordance with the Conservation of Biological Resources and their Ecosystems Act (5/1990) whilst Presidential Decree 32/1990 mentions explicitly the criteria for the designation of peatlands as protected areas. As a result of this decree peatlands with a peat thickness of more than 3 metres, located in the upper parts of river catchments, the outflows from which run through cities or other important sites, should be designated as protected areas.

Other relevant legislation/regulations include Regulation 27/1986 on Environmental Impact Assessment and Decree 5/2001 of the Minister of Environment on Guidelines for Environmental Impact Assessment of Wetland Developments. The latter states that the objective of peatland protection is to maintain hydrological integrity to ensure water conservation, flood control, fire control and protection of specific economic resources within the area. Regulation 4/2001 on Environmental Degradation and Pollution Control Related to Forest and Land Fires prohibits the burning of land and forest, including peatland and outlines the authority and responsibilities of Central Government, Local Government and other stakeholders in controlling fire.

Malaysia

The principal Government Agencies involved in peatland management are The Ministry of Natural Resources and Environment, Ministry of Science, Technology and Innovations, and Ministry of Agriculture. The first is responsible for conservation and management (policy and coordination), environmental impact assessment and open burning, establishment and management of National Parks and Wildlife Reserves, forest management, forest research and river and water resources management. The second embraces the Meteorological Services Department (fire danger rating and warning system) and the Malaysia Centre for Remote Sensing (remote sensing and monitoring of peatland). The last promotes agricultural development and research on peatland.

<u>Integrating peatland conservation and wise use into the planning process</u>

Integrating peatland conservation and wise use into planning requires:

- placing responsibility for peatlands, as far as possible, under the control of a single government ministry or department;
- undertaking and concentrating more research at provincial and local levels;
- formulating sectoral and economic policies and planning to implement strategies
- identifying existing policies and plans that impact upon peatlands and updating them to take account of peatland functions and values and obligations of sustainable wise use;
- anticipating conflicts and resolving them;
- consulting, agreeing and coordinating management policies with all sectors and stakeholders at every scale (national, regional, local);
- planning cross-sectoral uses, especially of water resources, forestry, agriculture and peat extraction;
- implementing land use planning using catchment area boundaries and integrated resource management (ecosystem approach); and
- ensuring that site-specific project planning considers off-site effects and involves local communities and other stakeholders.

The Integrated Catchment Management (ICM) approach takes into account the impact of activities taking place elsewhere (e.g. upstream deforestation or mining) and the consequences, especially downstream, of on-site operations (e.g. flooding and ground water recharge). This involves consideration of:

- ground waters and any effects of their manipulation;
- floodwater regime and routing;
- linkage to coastal and marine ecosystems;
- impact of upstream land use changes;
- effects of pollution on the site (effluents) and produced by or on it (water acidification, fire);
- non-hydrological requirements (e.g. migratory species and people); and
- adoption of regulatory controls over specific interventions (which would require impact analysis) and processes (such as spontaneous settlement).

In addition to these considerations, there are others that operate at the regional and global levels and which are not covered adequately by local or site-specific planning and policy procedures but which must be incorporated into the wise use approach. These include considerations of national, regional and global diversity and climate change.

Since much of the funding for land use change activities on tropical peatland is derived from development agencies these have a responsibility to produce internally consistent policies specific to tropical peatland that include:

- developing mechanisms for long term financing of sustainable wise use projects for peatlands;
- committing to support wise use and to discouraging activities likely to damage peatlands and their users;
- promoting peatland issues, threats and sustainable use among agency staff; and

- ensuring that peatland issues that are identified during Environmental and Health Impact Assessments are addressed during project planning and implementation.

Strategies for wise use of tropical peatlands
Owing to the unique characteristics and nature of peatlands there are certain actions that should not be undertaken or, if they are, adverse consequences should be mitigated. For example, water fluxes and water levels determine peatland functioning, and hydrological integrity should be maintained as an utmost priority for management. The potential short, medium and long term effects of human impacts on tropical peatland should be assessed and taken into account before permission for any activity is given. Management should be adjusted accordingly and buffer zones of appropriate extent should separate impacted areas from those of resource conservation. In particular:

- Ecosystem composition (biodiversity of habitats and species) should be maintained as far as possible. Activities that maintain natural hydrology and conserve peat soils should be favoured.

- Management must take into account the inter-relationships between tropical lowland peatlands and other hydrological, ecological, social and economic systems within the catchment (e.g. river systems, Dipterocarp forest, mangrove, urban and rural communities).

- Sustainable wise use of tropical lowland peatlands must be based on recognition and inventory of societal benefits (products and services), derived from peatlands in their natural state.

- Local people must be willing to cooperate and become involved in all stages of planning and management, and mechanisms should be established to involve stakeholders in sustainable wise use of peatlands affected by planned development projects.

- The rights of stakeholders to tenure and utilisation of tropical peatland must be well defined and respected, otherwise these must be compensated fully.

- Development of deep peats (normally exceeding 2 metres thick) should be avoided, except in exceptional circumstances, because of the inherent physical problems of their management, extreme vulnerability to change and overall importance of their ecological and natural resource functions.

- The environmental and economic costs of peatland management, and the benefits arising from environmentally sound strategies, should be apportioned fairly; effects may be experienced far from the management area. Compensation should be provided if peatland benefits are lost (environmental, ecological, economic, social).

- Large peatland landscapes should not be developed piecemeal because this results invariably in problems of water management and maintenance of the peat soil. It is virtually impossible to conserve only part of a peatland landscape since differences in water table requirements and water management practices will make different land uses incompatible. Proposed development can be evaluated adequately only if the peatland is considered as a whole within its ecological boundaries.

- Unauthorised settlement of tropical peatland should be prevented.

- Intensive and widespread deforestation should be avoided since it leads to degradation of peat soils and loss of biodiversity and function. Deforested land is frequently left fallow, or if converted to agriculture it may be abandoned subsequently owing to a lack of economic viability. Abandoned peatland is subject to continued degradation with loss of carbon and increased risk of fire.

- Environmental and conservation objectives should be incorporated into the socio-economic decision making process and existing development plans should be reassessed and modified to take account of peatland functions, values and wise use.

Implementation of wise use strategies for tropical peatland should be based upon understanding and acknowledgement of:

- the Precautionary Principle, which determines that policy makers should proceed cautiously when planning changes to the natural environment, in order to safeguard against unexpectedly severe costs in the future;
- carrying and cropping capacities;
- sustainable extraction rates;
- maintenance of goods and services;
- resilience of the ecosystem and its ability to recover from damage;
- likelihood of effects on different functions; and
- likelihood of off-site effects.

Important components of sustainable wise use of tropical peatland

There are several key activities, measures and operations that are necessary to ensure successful implementation of wise use of tropical peatland, namely:

- climatological, ecological, hydrological and socio-economic studies;
- management direction and implementation jointly with developers and users, stakeholders and local communities;
- monitoring to record success and change;
- formulation and implementation of specific targeted peatland management plans;
- strengthening of institutional capacity and human resource training;
- preparation of action plans and monitoring their progress; and
- project-specific education and awareness programmes using school and higher education curricula and media.

Impact of development on functions and values of tropical peatland

The values of tropical peatland ecosystems can be maintained only if they are identified, their importance and susceptibility to change is understood and steps are taken to maintain them. This can be achieved by:

- assessing functions, products and attributes and ranking them; consulting with peatland stakeholders to document and evaluate peatland uses;
- identifying areas of optimum importance for each function, product or attribute;

- specifying all activities that may lead to changes in the nature of the peatlands;
- establishing mutual compatibility of proposed activities;
- establishing compatibility between proposed activities and maintenance of functioning;
- identifying possible trade-offs whereby one function may be preserved or enhanced while another is reduced or lost;
- prescribing operational limits to activities.

Various tools are available to assist in the assessment process, especially:

- Strategic Environmental Impact Assessment (SEIA) and Environmental Impact Assessment (EIA);
- Functional assessment;
- Rapid assessment methods as a substitute for functional assessment, using checklists of questions;
- Economic evaluation (Barbier *et al.* 1996);
- Cost-Benefit Analysis (CBA), which should take into account the length of time that peat swamp forest resources take to renew, and discounting. Sensitivity analysis should be used to evaluate best and worst case scenarios, especially where discount rates are uncertain.

The economic techniques and methods for valuing wetlands, including peatlands, rely on ecological and hydrological as well as economic data. Research is still needed on the production of rapid assessment and economic evaluation techniques, especially for social costs and benefits, although use should be made in the meantime of those already available.

Problems for management of tropical peatland

The need for action to support the sustainable wise use and integrated management of lowland tropical peatlands, arises from at least six key factors (Maltby, 1997):

- Recognition of the magnitude and extent of the tropical peatland resource;
- Rapid rate of loss and degradation of tropical peatlands;
- Increasing knowledge of their relative importance in the livelihoods of local communities;
- Significant biodiversity;
- Their role in the maintenance of environmental quality;
- Increasing pressure from the development and conservation community for resource management guidelines.

There is widespread and increasing conversion of tropical peatlands usually for single sector purposes, especially agriculture and forestry but to a lesser extent for aquaculture, energy and horticulture (see Chapter 5). Much of the land cleared for agriculture has been abandoned subsequently for a number of reasons which derive from their physical and chemical characteristics and socio-economic limitations to sectoral development.

Drainage of peatland, and subsequent water management, is essential to grow intensive agricultural crops but this gives rise to surface subsidence owing to physical collapse and compaction of the dehydrated peat and loss of organic matter as a result of biochemical oxidation (see Chapter 2). Drainage and overall site hydrology of tropical peatlands are very difficult to manage. Subsidence is a particular problem for perennial crops such as oil and coconut palms, which suffer from root exposure and stem collapse if grown on thick peat.

Tropical peats are also associated frequently with potential acid sulphate substrates and drainage and oxidation results in high acidity with pH values below 3.0. Under these conditions it is impossible to grow economically viable crops, while water quality and human health deteriorate (Maltby *et al.,* 1996). Economic agriculture on developed peatland requires regular application of agrochemicals and soil ameliorants. The level of investment required is generally beyond the capacity of individual farmers and their families and returns may be substantially less than can be achieved from exploitation of natural peat swamp forest.

Maintaining ecological and hydrological functions

Hydrology (water fluxes and water levels) is vital to the ecological functioning of tropical peatlands but is vulnerable to a wide range of human activities and impacts. These can be generated on- or off-site. They may be direct or indirect. The effects can be abrupt or gradual and, in most cases, are progressive, unpredictable and irreversible. In addition, the area of peatland affected will always be greater than the actual location of the activities owing to the hydrological connectivity within a peatland and between it and other ecosystems. All development activities on tropical peatland involve a lowering of water levels through drainage, canalization, ground and surface water abstraction, logging, road building, leading to ecosystem degradation, irregular water runoff and peat surface subsidence. As a result, the frequency and severity of adjacent and downstream flooding increases with serious consequences for the economies and infrastructure of rural and urban communities.

Natural water levels in tropical peatland should be maintained as far as possible by:

- Applying principles of Integrated Catchment Management;
- Basing management decisions on appropriate scientific and socio-economic information; with additional data collected where necessary;
- Recognising that every peatland has its own unique ecological and hydrological characteristics, which should be reflected in the management plan;
- Understanding that the effects of peatland drainage may extend far beyond the limits of the activity causing the drainage, and the area of peatland affected can increase for many decades after drainage is implemented;
- Separating conservation areas from drained areas by buffer zones of sufficient size and on which land use is regulated strictly.

Maintaining biodiversity

Lowland tropical peatlands harbour a rich biodiversity that is of global importance. Wise use should involve formulating comprehensive strategies to conserve and maintain as much as possible and these guidelines should be incorporated into specific peatland management projects. In particular, it is important to:

- Carry out inventories and determine biodiversity conservation priorities (e.g. rare, endangered and Red Data Book species) that can be used to identify critical peatlands in, or connected hydrologically to, project areas. The impact of project management on biologically diverse peatlands should be assessed;
- Zone project areas according to their functional importance, including maintenance of biodiversity. Areas of greatest importance for biodiversity

should be protected by restrictions on, or prohibition of, development activities. Restrictions should be enforceable and designed specifically to facilitate biodiversity maintenance whilst optimising sustainable benefits arising from it (see Annex 3);

- Maximize biodiversity through appropriate management strategies applied throughout the project area, not only in protected areas;
- Consider alternatives or redesign projects that will have significant negative impacts on tropical peatland biodiversity;
- Withdraw gradually ('managed retreat') inappropriate land uses from sensitive peatlands; and
- Improve awareness of the values and importance of biodiversity.

Single sector development

Single sector development is proposed frequently on tropical peatlands as determined by National policies. These are based on the *unsuitability* for a particular sector rather than the *suitability* of another. Information used to support sector land use decisions is often out of date and development objectives over ambitious and unachievable. Current policies often conflict with one another and they are linked to incentives or subsidies that support unsustainable development. Policies that are currently damaging to tropical peatlands should be replaced by alternative ones that promote wise use. The problems and consequences of sector development of lowland tropical peatlands are summarised by Safford & Maltby (1998) (Box 6.2).

Additional factors to consider are:

- Shallow peats (<2 m thick) have reasonable prospects of development only under very carefully managed farming systems and require considerable economic investment. Thicker peats can support a few crops, including oil palm and pineapple, but at even higher investment, maintenance and cropping costs. In addition, in many lowland tropical peatlands the mineral soil interface is at, near or below sea level, a feature that will lead eventually to flooding unless countered by expensive construction schemes.
- Agricultural development and maintenance costs are high and productivity is usually low;
- Production forestry, if carried out intensively, is very difficult to manage sustainably and most peat swamp forests in Indonesia have been degraded severely as a result of illegal logging;
- Peat extraction for use as fuel is rarely economic;
- Peat is not a renewable resource over human time scales, because deposits take millennia to accumulate.

Box 6.2: Sectoral policies damaging to tropical peatlands

Damaging policy or initiative	**Alternative neutral or enhancing measures**
Agriculture	
1. Direct incentives to reclaim and drain peatlands	Redirect incentives to alternative means of production
2. Supplying seed, fertilizer and lime	(a) research mixed systems less reliant on artificial inputs (b) Encourage growth of traditional wetland crops
3. Price subsidy; preferential support for limited number of crops	Broaden the support to encourage farm diversification as well as off-farm opportunities
4. Large scale drainage; large scale irrigation	Review sector policies and carry out Cost-Benefit Analysis
5. Poorly sites resettlement projects	(a) Identify land that has greater potential to support diverse rural livelihoods (b) Change project objectives to harness benefits of peatlands (c) Review impact of organized resettlement on spontaneous settlement
Fisheries	
1. Support for large scale fish farming	Examination of the role of artisanal fisheries in the supply of protein
2. Unregulated fish farming	Apply regulations stringently
Forestry	
1. Short term concessions	(a) Alter regulations to increase life of concession to encourage better management (b) Alter stumpage charges
2. Designation of conversion forest using outdated criteria	Review land designation on the wider functional importance of swamp forest – not its suitability for plantation
3. Concession controls	Strengthen controls for dealing with illegal logging
Water resources	
Investment in multipurpose drainage and/or irrigation, flood protection and supply schemes	Re-examine the potentials of harnessing natural functional roles of swamp forest without major engineering
Health	
Drainage to control vector borne disease	Improve preventative health care
Energy	
Peat mining	Capitalize on renewable energy sources

The wisdom of further, intensive development of tropical peatlands for agriculture, forestry and peat extraction needs to be questioned seriously. Several choices are available:

- Abandon single sector development proposals and pursue options for integrated or multiple wise use;
- Continue with single sector development but take steps to maintain ecosystem functioning as far as possible by conserving peatland biological, chemical and physical properties, biodiversity, and environmental services by:
  - Introducing mitigation or compensation (e.g. reforestation), or
  - Ensuring that local or forest-dependent people obtain alternative sources of livelihood supported by finance and training;
- Undertake biodiversity and habitat conservation as the only land use and identify alternative funding mechanisms to support these in collaboration with stakeholders (Annex 3)

Multiple wise use of tropical peatland

Multiple wise use of tropical peatlands aims to optimise the economic, social and ecological value of peatlands by harvesting renewable resources at an economically and environmentally sustainable level, whilst conserving non-renewable resources and maintaining attributes and functions. If the functions of a tropical peatland are not protected, its carrying capacity will collapse, together with the sustainable harvests and the economies it supports.

Multiple wise use of tropical peatlands is very different from the traditional sector development approach and it requires:

- increased support for agencies that traditionally have been weak in safeguarding tropical peatlands (e.g. forestry and environmental protection);
- cooperation between sectors;
- consideration of the economies, societies and cultures of people occupying areas affected by or supporting peatland.

Since this is a new approach to landscape management it requires, inevitably, further research, especially into:

- suitability and compatibility of activities;
- tolerance of new or greater impacts;
- carrying capacity or limits to use; and
- tolerance and reaction to environmental change.

<u>Components of multiple wise use of tropical peatlands</u>

The uses most suitable for inclusion in a sustainable multiple wise use management plan are those that provide direct benefits and, when managed appropriately, have minimal effect on the functioning of the peatland ecosystem. The fundamental principles of multiple wise use are largely those for peatland management in general, for which it is necessary to:

- identify the ecosystem components;
- understand ecosystem functions, productive uses and non uses;
- ensure compatibility of uses;

- establish limits of acceptable change;
- anticipate and make allowance for natural and man induced hazards;
- establish a basis for conflict resolution.

In order to determine the impact of developments on hydrological functions, it is necessary to:

- identify the area affected, paying particular attention to water routing;
- acquire data that assist the understanding of hydrological functioning (e.g. surface and ground water in- and out-flow, precipitation, evapotranspiration);
- monitor areas representative of the entire peatland and off-site impacts over long periods, in order to understand the nature and rates of change;
- monitor water levels in ecologically sensitive areas including, ideally, the centre of peat domes, marginal areas and critical locations outside of but near to the peatland.

Managing extractive uses of tropical peatland
The level of extraction of resources (forest products, peat, water) from tropical peat swamp forest must be determined by its potential to provide a sustainable yield, rather than by the demand for the resource. Selective forestry is probably the most directly valuable use of peat swamp forest resources at the present time and, if managed appropriately, will cause minimal damage to the hydrology of the peatland in the long term. Unfortunately, it is not known if selective cutting regimes are truly sustainable since peat swamp forest requires at least 50 years to regenerate sufficiently before providing another economically viable timber harvest, during which time the ecological and hydrological integrity of the ecosystem must be maintained. Large channels and small canals must not be used to extract timber from tropical peatlands and, instead, light-weight railways should be employed.

Multiple wise use projects on tropical lowland peatlands should consider:

- participatory management that includes involvement of stakeholders and co-management;
- removal of most products should be controlled and, in some cases, prohibited;
- enforceable restrictions on exploitation of particular species are needed, and must be based on rigorous assessment of sustainable yields that do not cause unacceptable changes in the status of other species or in the functioning of the ecosystem;
- demand for water removal may be high, but should not be satisfied by drainage or re-alignment of natural water courses. Once water is drained from a peatland ecosystem, the system itself becomes unstable. Extensive peat domes may provide a ground water base flow which is beneficial to surrounding land;
- before ground water abstraction begins the volume of water that the peat swamp can supply on a sustainable basis must be determined, with consideration given to the length of dry periods and droughts and the impact of these on the relative position and amplitude of the water table. These characteristics should be monitored. Excessive water removal will contribute to extended droughts and lowered water tables with impacts beyond the boundaries of the peatland;
- suitable zones may be set aside for fuel wood collecting and hunting;
- selective logging may be permissible where regeneration is proven and practical, but large-scale commercial logging should be avoided;

- primary forest must be maintained for small scale exploitation of minor products (e.g. latex);
- silvicultural measures should be applied in order to sustain forest exploitation;
- criteria and indicators for sustainable forest management need to be identified and tested; and
- peat extraction for energy, horticulture and other uses should be permitted only after the most rigorous environmental impact assessment and cost-benefit analyses.

Managing conversion uses

Using tropical peatland for agriculture involves removal of the natural peat swamp forest and its complement of biodiversity. It normally requires drainage, which should be avoided if (a) the base of the peat is below sea or river level, otherwise flooding will occur and (b) if the peat is underlain by potential acid sulphate soil since loss of the peat layer will expose the underlying mineral soils. In a multiple wise use approach, limited areas of the peatland are likely to be converted to support small-scale agriculture. In such cases:

- areas selected should have minimal impact on ecosystem functioning;
- agricultural use should be accompanied by carefully controlled, shallow drainage;
- the organic soil and its properties must be conserved in order to ensure continued environmental functions of the peatland as well as agronomic viability;
- the suitability of a crop for peatland cultivation should be determined using criteria that reflect its effect on soils as well as its productivity; and
- lessons from indigenous cultures should be considered for research, refined where appropriate, and incorporated into sustainable agriculture systems.

Restoration and rehabilitation of degraded tropical peatland

Virtually nothing is known about restoration of impacted, damaged or utilized tropical peatland. In the tropical zone there has not been the historical utilization of peat and peatland, supporting local communities, that has been a traditional land use throughout Europe and other parts of the northern hemisphere for centuries where peat has long been used as a domestic fuel by remote communities and to support agriculture and forestry. Consequently there has been no need to consider either their after use or restoration until recently.

Utilisation of peatland in the tropics is of much more recent origin and for different reasons. There was no, or little need (except in highland zones) to dig peat for domestic heating or as a fuel for cooking because the climate was generally much warmer and easier energy sources, i.e. firewood from forests, abounded. Wetlands, including peatlands in Southeast Asia were first drained by the British in Peninsular Malaysia and the Dutch in parts of Indonesia using techniques employed in Holland to regulate water levels and supply. Drainage of tropical peatland and its utilization for market orientated purposes has not been a success because this substrate presents problems that are not encountered in the land use conversion of dry land ecosystems. As a result of inappropriate developments and mismanagement many peatland areas in the tropics are experiencing severe peat degradation and peatland landscape restoration[3] and natural resources rehabilitation should be considered. Once a large area of tropical peatland has been damaged severely it is impossible to return it back exactly to its former condition, at least within human timescales (see Annex 2).

In its strict sense peatland restoration consists of three distinct but overlapping stages, namely, rewetting, renaturation and regeneration (Wheeler & Shaw, 1995).

The main reasons to justify the rehabilitation of tropical peatland are to:

- restore ecological functioning, as far as possible;
- reduce off-site impacts, for example downstream acidification and flooding; and
- reduce pressure on undeveloped land (e.g. primary peat swamp forest) by enabling more effective use of degraded land.

Degraded peatlands may be rehabilitated for various uses, for example, forestry, agriculture, agroforestry, wildlife conservation, multiple use.

Forestry:
Forestry based systems will be most appropriate for areas that have been logged or are close to, or are linked hydrologically to natural forests; the capacity to support minor, non-timber product uses should also be considered.

Agriculture:
Rehabilitating tropical peatland for agriculture is extremely difficult, and should be considered only where investment is sufficient to guarantee a long term increase in sustainable rural livelihoods without reducing environmental quality.

Agroforestry:
If few resources are available for rehabilitation, agroforestry options including crops such as sago, rattan and fruit trees that do not require drainage or fertiliser, should be considered.

Plantations:
These are an obvious use of degraded landscapes, but are no substitute for natural forests because they lack the biodiversity that confers resilience and stability and provides multiple benefits to communities. Industrial plantations are needed to supply cellulose and wood, and the feasibility of establishing them on some degraded peatland should be investigated.

Wildlife conservation:
Ideally, this option is to be preferred since it involves restoring habitat functioning and attributes to as near a natural condition as possible and then maintaining these in perpetuity. In reality, relatively small areas will qualify owing to competition with land for development and the cost of undertaking conservation in the absence of sustainable income; in addition, local communities must be agreeable and involved and for this to be successful alternative sources of income must be found (Annex 3).

Multiple use:
This should be considered if a diverse resource base can be sustained.

The principle ecological requirements for restoration of lowland tropical peatlands are:

[3] Restoration implies an attempt to return a degraded landscape to its former condition as far as possible and is a rather strict definition; rehabilitation implies a less specific re-creation of natural resource functions and wildlife interest

- availability of an adequate supply of rainfall of appropriate quality and its retention at the peat surface in order to provide effective rewetting;
- availability of suitable colonising plant species to consolidate rehabilitation and bring about ‘renaturation’.

There are several reasons why these conditions cannot always (perhaps never) be met in the tropics even when a large reservoir of peat remains:

- the peat surface may not retain precipitation in the dry season because the surface runoff is too rapid (owing to drainage) and it may flood quicker and more severely in the rainy season owing to subsidence following land use change and/or fire, because its capacity for hydrological self-regulation has been lost;
- deep land drainage on the periphery and around the peatland may affect its water balance;
- groundwater abstraction from a permeable substratum beneath or adjacent to the peatland may affect the water balance substantially;
- peatland plants may not be able to rehabilitate owing to mineralization of the peat surface following degradation, although a vegetation cover may be able to regenerate eventually as a result of longer term successional processes;
- the seed bank and potential for vegetative reproduction is lost as a result of peat fires;
- atmospheric pollutants may be detrimental to the growth of some peatland plants (e.g. following fire);
- lack of species for rehabilitation because of their destruction previously.

The following guidelines should be observed in tropical peatland restoration and rehabilitation projects:

- assess changes in ecosystem functioning and estimate economic and social costs and benefits;
- maintain a flexible approach and avoid specificity of the ultimate goal;
- optimise ecosystem value and accelerate rehabilitation by using fast-growing nurse species;
- maximise ecosystem complexity in order to optimise availability and flexibility of site resources;
- protect against, or control, damaging influences such as fire;
- conserve soil;
- re-establish plant (especially tree) cover and hydrological integrity, e.g. to reduce acidity and prevent further acidification and peat oxidation; and
- where replanting is needed, choose seed and other propagule sources to give best growth characteristics.

Implementing strategies for wise use of tropical peatland

Managing tropical peatland requires a change from traditional sectoral priorities to a multiple wise use approach in which consideration is given to the potential impacts on the landscape as a whole. Several strategies should be applied when formulating and implementing a management plan for the multiple wise use of tropical peatland using an integrated approach.

Collaborative or co- management
The degree of stakeholder participation can range from consultation to the devolution of management authority, resulting in collaborative or co- management of the peatland resources. This should mean that the objectives of the management plan are determined collectively by the stakeholders, and the plan itself implemented by, or on behalf of, the stakeholders. In general, the greater the livelihood dependence by local stakeholders, the stronger is the case for a stakeholder to take on responsible roles in the management process.

Participatory project management has several technical problems as it is more complex to manage than a single sector project because the number of stakeholders may be large and dispersed widely. All stakeholders must appreciate the trade-off between conservation and development of peatland resources, and jointly ensure that the management plan balances the two. The economic and political links between the local situation and the national and international ones need to be understood, acknowledged and managed strategically.

Respect for the economy, society and culture of local people
The planning process must consider the society and culture of the local inhabitants, for example, whether they are indigenous people or immigrant settlers. Indigenous communities tend to utilise peatland resources effectively and sustainably while new settlers and developers believe that new technologies can overcome the lack of productivity of peat soil. Cultural and social differences inhibit the exchange of information between old and new inhabitants.

Multi-disciplinary advisory teams
Predicting and comparing the consequences of different management options on the peatland ecosystem as a whole (including the human population that relies upon it) is an essential part of identifying management objectives. This is a complex process, however, that requires knowledge of the geology, hydrology and ecology of the peatland, the socio-economics of the resident populations, and the interaction between people and the peatland (especially the use of resources). Multi-disciplinary advisory teams can provide advice that single sectors cannot provide alone. Members should include representatives of the different stakeholders (resource users), socio-economists, scientists, hydrologists, and representatives from government sectors.

Restoration and rehabilitation of degraded peatland
Previous inappropriate management may have resulted in peatland degradation in which case strategies for restoration and rehabilitation should be included in the management plan.

Implementation tools
The first stage of implementation should be to initiate a process of stakeholder participation that will form the basis of collaborative planning and management. This may result in the involvement of a large number of stakeholder groups. A survey of the peatland should be carried out and inventory of its functions and benefits established to enable decisions to be made concerning the likely effects of present and proposed human use and to understand the sensitivity of the peatland to natural and human-induced impacts. If collected systematically and explained appropriately, it should be possible to use this information to formulate and agree management objectives to the satisfaction of all stakeholders.

Integrated Catchment Management (ICM) is a useful tool in this process aided by Strategic Environmental Impact Assessment (SEIA) and Environmental Impact Assessment (EIA). Once a management plan has been agreed, action and monitoring plans can be established to enable activities to be undertaken and problems to be identified quickly and resolved. A crucial factor to the success of implementing wise use management strategies is the legislative framework of the country involved.

Peatland inventory and information

Peatland inventories provide information required for SEIA and EIA procedures relating to conservation and/or development policies. If not already available it can take some time to carry out survey and inventory of tropical peatland landscapes and it may be appropriate to develop conservation policies prior to the acquisition of new field data in order to avoid unnecessary delay in commencing implementation. Traditionally, inventories have concentrated on habitat features, especially of ecology, hydrology and soils, certain geographic characters, ownership, land tenure and use and threats. More recently, information that peatlands provide have been included (e.g. cultural and historical).

Institutions responsible for the planning and management of tropical peatlands are often unaware of, or lack information on and knowledge of, the values of peatlands. In addition, resources can be wasted because responsibilities are spread amongst various sectors and tasks may be duplicated. The main problem is that information on how peatlands function and their vulnerability to specific threats is not available.

Integrated Catchment Management (ICM)

ICM is the management of rivers and their catchments as an integrated whole. Planning management at a catchment scale facilitates understanding of how even remote ecosystems can be affected by the demands from distant urban areas in the region and from countries of the developed world (e.g. trade). ICM is useful in identifying and solving river basin-wide problems, resolving sectoral conflicts and cross-boundary questions in management of a water-based resource. ICM is therefore useful in managing lowland tropical peatlands because they are sensitive to problems arising elsewhere in the catchment, and can affect adversely large areas outside their immediate area when they are developed inappropriately (e.g. impact on regional and global climates) (Figure 6.1)

Predicting the impact of and monitoring management plans

Environmental Impact Assessment (EIA) has been the main method used to assess the environmental implications of a development project or intervention. Many countries have a legal requirement for EIA to be undertaken before projects are allowed to proceed. Draft guidelines for the preparation of environmental impact assessment (EIA) for developments on tropical peatland have been prepared by Universiti Malaysia Sarawak and the Sarawak Natural Resources and Environment Board (NREB) in conjunction with the EU STRAPEAT Project. This information is intended to provide guidance to those involved in the preparation of EIA reports for development projects on peatland areas. It highlights issues that need to be examined while carrying out EIA studies for prescribed activities in the unique and fragile peatland environment. The 'guidelines' ought to be used with flexibility, depending on the nature, location and size of the project. It is by no means a complete guide book. Expert judgement of environmental consultants is expected to identify all the pertinent significant impacts and also to propose effective mitigating and management measures best suited for the predicted impacts. Innovative ideas and incorporation of recent advances in research and field knowledge are equally useful for the purpose of planning, conducting the EIA studies and writing quality reports. The guidelines should be treated as a supplement to the Handbook of the Policy and Basic Procedure of Environmental Impact Assessment (EIA) in Sarawak issued by the NREB (Murtedza, 2004).

The first stage of EIA is 'scoping' to decide which are the most important environmental characteristics of an area, and of those, which are likely to be affected by the proposed development and require further investigation. In tropical peatlands, relevant characteristics are hydrology, biology and ecology and socio-economic aspects. Whenever a project exceeds a certain minimum specified area (say 50 ha) it should be subjected to an EIA. Traditionally, EIA has been applied to individual projects but this limits their value in efforts to minimise environmental damage. These limitations have led to a change in the level at which EIA is being used in the development process. Rather than being used only in the final stages of a development strategy (when individual projects have already been formulated), it is being used at much earlier stages in the development planning process, to evaluate the environmental impacts of a whole policy, plan or programme. In such cases it is described as Strategic Environmental Impact Assessment (SEIA).

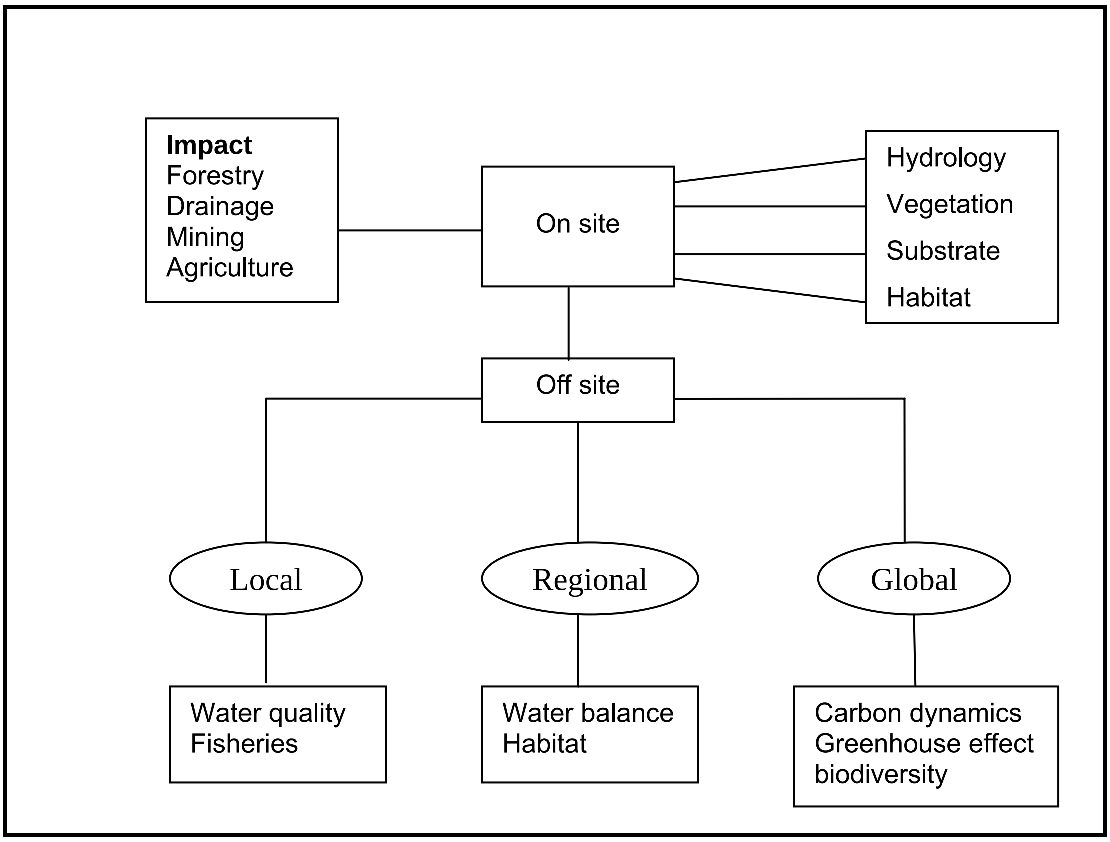


Figure 6.1: diagrammatic representation of effects of impacts on tropical lowland peatlands. The effects may extend over several different scales. From Maltby (1997).

Action plans and monitoring progress

Action plans are being used increasingly for environmental management in developed countries and could be used to great effect in the implementation of multiple wise use of peatland in the tropics. They may be divided into long-term (20 years), medium-term (5 years) and short-term (1 year) plans. Implementation and monitoring should be based on prioritized activities (see box 6.3)

Box 6.3: Outline action plan for sustainable multiple wise use of lowland tropical peatland

1. Classify and map peat resources.
2. Identify the nature and scale of current utilisation and possible alternative developments.
3. Evaluate the local, regional, national and international significance of peatland ecosystems in relation to:
   - Ecosystem, community or hydromorphological type
   - Ecological, chemical, biophysical, hydrological processes
   - Production and natural resource functions support
   - Wildlife
   - Research, educational, recreational and heritage values
   - Genetic reservoir
   - Other values
4. Define the nature and scale of permitted sustainable uses, i.e. uses that do not impair essential functions.
5. Identify those peatlands that must be retained for functional and conservation purposes.
6. Define terms for non-sustainable use of peatland before development begins.
7. Define terms for stakeholder participation and steps towards the most effective community-based management system.
8. Advise on strategies necessary for the sound management of peatland resources.

Indicators of wise use and sustainable management of tropical peatland

It is necessary to have a platform of indicators of multiple wise use and sustainable management of tropical peatlands against which to monitor progress and gauge success. A list of possible indicators is presented in Table 6.3

Management support system

A Management Support System (MSS) has been developed to assist planners and managers in the wise use of these tropical peatlands (Grobbe, 2003). This MSS, which is based on a GIS application, combines a groundwater model with expert knowledge of subsidence, land use and water management. The MSS can be used to predict the long-term effects of different types of land use, e.g. peat swamp forest, sago or oil palm plantations, on the lifetime and associated CO_2 release of these tropical peatlands. The type of land use dictates the required depth of the groundwater table which, in turn, has a significant effect on the sustainability of the peatland. The MSS helps to improve the decision-making process by showing the long-term consequences of selecting specific types of land use. To facilitate the communication between planners, farmers, plantation owners, decision-makers and other stakeholders the consequences of the proposed land use changes are visualized using various methods showing the effects of subsidence and CO_2 release over time. Data from Central Sarawak, Malaysia are used to test and refine these methods (Ritzema *et al.,* 2004). By visualization of the effects, the MSS helps to make better decisions on the implementation of sustainable management practices for tropical peatlands.

Table 6.1: Examples of positive indicators of sustainable multiple wise use of tropical peatland (based on Safford & Maltby, 1998)

Geophysical	Biophysical	Economic	Social
• Low incidence of flooding • Minimal intervention necessary to prevent siltation and tidal intrusion • Low incidence of fires • High water quality • Maintenance of high water table	• High rate of regeneration of production forest • High number of species • Large area of closed canopy • Continuous yields of forest products • Low frequency of animal disturbance on agricultural areas near peatlands	• Indigenous people with sustainable livelihood • Settlers economically self sufficient • Government subsidies to households low or absent • Good support to economic sectors	• Low emigration from settlement projects • Good employment opportunities and enterprise arising from forest wise use • Presence of effective local institutions for co-management • Racial conflicts resolved

Table 6.2: Instrumental values of peatland (from Joosten & Clarke, 2002)

<table>
<tr><th colspan="4"></th><th>Examples</th></tr>
<tr><td rowspan="14">Present day aspects</td><td rowspan="3">Material life support functions</td><td colspan="2">1. Production functions</td><td>Providing water, food, raw materials, energy, labour</td></tr>
<tr><td colspan="2">2. Carrier functions</td><td>Providing space and substrate for habitation, cultivation, energy generation, conservation, recreation</td></tr>
<tr><td colspan="2">3. Regulation functions</td><td>Regulating climatic, water, soil, ecological, and genetic conditions</td></tr>
<tr><td rowspan="9">Non-Material life support functions

(=informational functions)</td><td rowspan="4">4. Proxy functions</td><td>4a. Social-amenity functions</td><td>Providing company, friendship, solidarity, erotic contact, cosiness, respect, home, territory, employment</td></tr>
<tr><td>4b. Recreation functions</td><td>Providing opportunities for recreation, recupe-ration, stress mitigation</td></tr>
<tr><td>4c. Aesthetic functions</td><td>Providing aesthetic experience (beauty, arts, taste)</td></tr>
<tr><td>4d. Signalization functions</td><td>Providing signals (indicator organisms, status, monetary price, taste)</td></tr>
<tr><td rowspan="5">5. Identity functions</td><td>5a. Symbolization functions</td><td>Providing embodiments of other functions (mascots, status symbols, money)</td></tr>
<tr><td>5b. Spirituality functions</td><td>Providing reflection and spiritual enrichment (religion, spirituality)</td></tr>
<tr><td>5c. History functions</td><td>Providing notions of cultural continuity (history, heritage, descent, ancestors)</td></tr>
<tr><td>5d. Existence functions</td><td>Providing notions of ecological and evo-lutionary connectedness</td></tr>
<tr><td>5e. Cognition functions</td><td>Providing opportunities for cognitive development (satisfaction of curiosity, science)</td></tr>
<tr><td colspan="2" rowspan="2">Future aspects</td><td colspan="2">6. Transformation (=educational) functions</td><td>Providing a change of preferences, character building</td></tr>
<tr><td colspan="2">7. Option (=bequest) functions</td><td>Providing insurance, heritage</td></tr>
</table>

Table 6.3: Overview of functions of peatlands for humans (those marked with an asterisk (*) are relevant to tropical peatlands of Southeast Asia (based on Joosten & Clarke, 2002)

Production functions:
(a) Peat extracted and used ex situ as/for,
- (aa) Humus and organic fertiliser in agriculture*
- (ab) Substrate in horticulture*
- (ac) Energy generation*
- (ad) Raw material for chemistry
- (ae) Bedding material*
- (af) Filter and absorbent material
- (ag) Peat textiles
- (ah) Building and insulation material
- (ai) Balneology, therapy, medicine, and body care
- (aj) Flavour enhancer

(b) Drinking water*
(c) Wild plants growing on mires and peatlands for/as
- (ca) Food*
- (cb) Raw material for industrial products*
- (cc) Medicine*

(d) Wild animals for food, fur, and medicine*
(e) Peat substrate in situ for
- (ea) Agriculture and horticulture*
- (eb) Forestry*

Carrier functions: space for
(f) Water reservoirs for hydro-electricity, irrigation, drinking and cooling water, and recreation*
(g) Fish ponds*
(h) Urban, industrial, and infrastructure development*
(i) Waste deposits / landfill
(j) Military exercises and defence
(k) Prisons
(l) Transport and herding*

Regulation functions:
(m) Regulation of global climate*
(n) Regulation of regional and local climates*
(o) Regulation of catchment hydrology*
(p) Regulation of catchment hydrochemistry*
(q) Regulation of soil conditions*

Informational functions:
(r) Social-amenity and history functions*
(s) Recreation and aesthetic functions*
(t) Symbolisation, spirituality, and existence functions*
(u) Signalisation and cognition functions for
- (ua) personal awareness and satisfaction*
- (ub) science*

Transformation and option functions: as/for
(v) education programmes*
(w) outdoor experiences*
(x) social and management skills*

Glossary

To return to the text, press CTRL and click on the respective term.

Acid sulphate soil: A soil containing pyrite, which upon oxidation will result in very low pH values.

Acidity: A property of (soil) water characterised by a pH below 7.

Acrotelm: The surface layer of a peatland that is above the limit of permanent saturation. In a little damaged bog it refers to the active layer, comprising the living plant cover, passing onwards into recently died plant material and then into fresh peat. It forms the largely oxygenated surface layer with high hydraulic conductivity, within which the water table fluctuates and the main water movement occurs.

Adat: traditional rights of indigenous peoples

Alluvial plain: A plain bordering a river, formed by the deposition of alluvium eroded from areas of higher elevation.

Aquifer: water bearing strata

Ash content: Weight of a volume of peat after it has been burned.

Available soil water: The quantity of water available to plants, defined as the quantity of water retained in the soil between field capacity and permanent wilting point. Also see plant available water.

Base flow: Water flow appearing in a river or stream as a result of groundwater discharge, with a characteristic delayed reaction to recharge. Most clearly visible after direct runoff has stopped.

Base saturation: The proportion of the exchange capacity that is saturated with cations

Biodiversity: The frequency and variety of living organisms found within a specified geographic region

Biomass: total weight, volume or energy equivalent of organisms in a given area

Biorights: an initiative to create a financial system which will pay people to protect their natural resources and to develop sustainable ways of using them

Biosphere: The part of a planet and its atmosphere in which living organisms exist or that is capable of supporting life

Blackwater: water rich in humic acids and with low nutrient concentrations

Bog: general term for ombrotrophic mires

BPPT: Indonesian Agency for the Assessment and Application of Technology

Bulk density: The mass of soil per unit volume in an undisturbed condition. Normally equivalent to the dry bulk density (i.e. when only the dry soil mass is considered), but sometimes to the wet bulk density (i.e. when the mass of water present is also considered).

Carbon trading: see emission trading.

Catchment: the entire area drained by a natural stream or artificial drain in such a way that all flow originating in the area is discharged through a single outlet.

Catena: a sequence of soil types and their vegetation that is repeated in a corresponding sequence of topographical sites.

Cation exchange capacity: the extent to which exchangeable cations can be held in a soil.

Catotelm: the lower "inert" layer of the peat of an undamaged ombrotrophic bog. The catotelm underlies the acrotelm, and is permanently water saturated, mainly anoxic and of low hydraulic conductivity.

Chelation: the formation of heterocyclic ring structures that contain metal cations. A natural reaction in most soils, it is enhanced by organic matter, especially humus.

Compaction: the change in soil volume produced artificially by momentary load applications such as rolling, tamping, or vibration.

Compression: the change in soil volume produced by the application of a static external load.

Consolidation: The very rapid subsidence after virgin peat swamps are drained resulting in compression of the permanently saturated peat layers. Consolidation occurs as water and/or air are driven out of the voids in the soil.

Declaration on Environment and Biodiversity: also known as the “Rio Convention”, that was held in Rio de Janeiro in 1992

Decomposition: metabolic degradation of organic matter into simple organic and anorganic compounds, with consequent liberation of energy

Degraded peatland: Peatland that has been affected by human activity or natural phenomena to such an extent that functioning, products and attributes are reduced along with the capacity to recover.

Discharge hydrograph: A graph or a table showing the flow rate as a function of time at a given location in a stream.

Drainage: The removal of excess surface and subsurface water from the land to enhance crop growth, including the removal of soluble salts from the soil.

Drainage base: The water level at the outlet of a drained area.

Drainage by gravity: drainage in an area with variable outer water levels, so that drainage can take place by gravity when outside water levels are low.

Drainage system: (1) A natural system of streams and/or water bodies by which an area is drained. (2) An artificial system of land forming, surface and subsurface drains, related structures, and pumps (if any), by which excess water is removed from an area.

Ecosystem: A dynamic arrangement of plants and animals with their non-living surroundings of soil, air, water, nutrients, and energy.

Ecotourism: a low impact, culturally sensitive land-use with the potential for generating income for local people

Electrical conductivity: Indirect estimate of the solubility of ions required in plant nutrition, expressed in $\mu S\ cm^{-1}$.

Elevation head: The vertical distance to a point above a reference level.

El Niño: Southern Oscillation (ENSO): warm ocean current that periodically flows along the western coast of South America, usually around December - January.

Emission trading: a market mechanism that allows emitters (countries, companies or facilities) to buy emissions from or sell emissions to other emitters. Emissions trading is expected to bring down the costs of meeting emission targets, by allowing those who can achieve reduction less expensively to sell excess reductions (e.g. reductions in excess of those required under some regulations) to those for whom achieving reduction is more costly (http://www.pewclimate.org)

Enrichment planting: supplementary tree planting inside a natural forest following logging or natural depletion, in order to increase the potential for future commercial forestry.

ENSO (El Niño Southern Oscillation): temporary reversal of airflows and surface ocean currents in the equatorial Pacific region. This results in abnormal warming of the surface waters off the coast of Peru, and in the disturbance of global weather patterns. This abnormal situation occurs every 2 - 10 years and can last for more than a year.

Environmental impact: The effect on the environment of a certain human interference (e.g. artificial drainage).

Environmental Impact Assessment (EIA): Study undertaken in order to assess the environmental effects of a proposed development project

Evaluation: The assessment of the degree of success of a planned project or process, often undertaken at a specific moment (e.g. upon completion).

Evaporation: (1) The physical process by which a liquid (or solid) is transformed into the gaseous state. (2) The quantity of water per unit area that is lost as water vapour from a water body, a wet crop, or the soil.

Evapotranspiration: The quantity of water used for transpiration by vegetation and lost by evaporation from the soil.

Excess rainfall: That part of the rain of a given storm which falls at intensities exceeding the soil's infiltration capacity and is thus available for direct runoff.

Feasibility study: A study of the existing and future parameters of a drainage or other project in such detail that a reasonable estimate of its profitability can be made.

fibric peat: relatively young peat that is only partially decomposed, with a fibre content > 66 %. It is characterized by high water retention, low pH, low bulk density, and little ash

Field capacity: The volumetric water content of a soil after rapid gravity drainage has ceased. It usually occurs about two days after the soil profile has been thoroughly wetted by precipitation or irrigation.

Functions: The beneficial effects of one entity upon another entity and which can be studied scientifically.

GBHN: Garis-garis Besar Haluan Negara, Guidelines for State Policy

Greenhouse effect: Gasses such as CO, CO_2, CH_4 and N_2O which enter the upper atmosphere from the soil surface, allow solar radiation of short wavelength to reach the Earth but retain longer wavelength radiation of. This causes warming of the atmosphere.

Groundwater: Water in land beneath the soil surface, under conditions where the pressure in the water is equal to, or greater than, atmospheric pressure, and where all the voids are filled with water.

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Rand: outward sloping margin at the periphery of a peat dome

Reconnaissance survey: An initial, exploratory survey of the conditions affecting an existing problem. Its results should allow the extent of the problem to be weighed, and possible solutions in general terms to be found.

Rehabilitation: A less specific re-creation of natural resource functions and wildlife interest as compared to restoration.

Restoration: Attempt to return a degraded landscape to its former condition as far as possible.

Return period: The time in which a hydrological event is estimated to re-occur according to a selected statistical criterion. It is the reciprocal of an estimated frequency.

Rio Convention: see Declaration of Environment and Biodiversity

Runoff: That portion of excess rainfall that becomes overland flow.

Saltwater intrusion: movement of saline sea water into the freshwater zone of a coastal aquifer.

Sapric peat: most decomposed type of peat, with a fibre content of < 33 %

Seepage: (1) The slow movement of water through small cracks, pores, or interstices of a material, in or out of a body of surface or subsurface water. (2) The loss of water by infiltration from a canal reservoir or other body of water, or from a field.

Selective cutting (logging): logging technique where only trees that meet specific criteria (such as a minimum harvestable diameter) are harvested.

Shrinkage: the volume reduction of peat above the groundwater level due to irreversible loss of water at highly negative water pressures.

Simulation: The representation of a physical system by a device such as a computer or a model that imitates the behaviour of the system; a simplified version of a situation in the real world.

Social entropy (e.g. social disharmony and enmity)**:** Negative outcome of social change that reduces social welfare, social cohesiveness, and social responsibility necessary to sustain ecosystem benefits following a social and economic development process.

Soil classification: The organisation of types of soil in a systematic and meaningful way, based on practical characteristics and criteria.

Soil fertility: The capacity of a soil to supply the nutrients needed for the growth of crops.

Soil horizon: A layer of soil or soil material approximately parallel to the land surface, and differing from adjacent genetically-related layers in physical, chemical, and biological properties or characteristics (e.g. colour, structure, texture, consistency, or degree of acidity or alkalinity).

Soil profile: The vertical sequence of soil layers, from the soil surface downwards, as affected by soil formation.

Soil survey: The systematic examination of soils in the field, including the laboratory analysis of specific samples, their description, and mapping.

Soil texture: The relative proportions of the various sized groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand below 2 mm in size (fine earth fraction).

Soil-water content: The volume of water in a soil as a fraction of the total soil volume. Normally determined by drying a soil sample to a constant weight at a standard temperature. Sometimes expressed as a mass fraction.

Spatial variability: The phenomenon that a property does not have a constant value within a certain area, but that individual values depart from a central tendency.

SRTM: The Shuttle Radar Topography Mission, carried out by NASA in 2000, obtained global elevation data to generate a high-resolution digital elevation model (DEM) of the earth.

Stakeholders: a single individual or a group of individuals that may be affected by, or express a strong interest in, the resources or management of an area (Claridge & O'Callaghan 1997). A more restrictive definition is individuals or groups that share the 'risk' involved in management of an area and who will bear the cost of mismanagement of resources or environmental degradation. An important factor determining the success of stakeholder participation is whether or not stakeholders believe that the natural resources are held in trust for future generations and for other people in the community and elsewhere.

Steady state: (1) A condition in which the input energy equals the output energy. (2) A fluid motion in which the velocities at every point of the field are independent of time in either magnitude or direction.

STRAPEAT: EU-INCO Project "Strategies for Implementing Sustainable Management of Tropical Peatland" (2001-2004)

Strategic Environmental Impact Assessment (SEIA): while Environmental Impact Assessments (EIA) take place at the project level, Strategic Environmental Assessments focus on decision making at the more strategic level of programmes and policies.

Subsidence: The continuing lowering of the level of the land surface, as a combined effect of (i) compaction and compression; (ii) consolidation; (iii) oxidation; and (iv) shrinkage.

Subsistence living: producing enough food to meet the needs of the farmer/agriculturalist and family, but no cash crops

Subsurface drainage: The removal of excess water and salts from soils via groundwater flow to the drains, so that the water table and root zone salinity are controlled.

Sulphidic soils: soils characterized by the presence of oxidisable sulphur, mostly in the form of pyrite (FeS_2)

Sungai: Indonesian for river (short: Sg.)

Surface drainage: The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by the shaping and grading of land surfaces to such channels.

Surface runoff: Water that reaches a stream, be it large or very small, by travelling over the surface of the soil.

Surjan: traditional Indonesian practice to utilize acid sulfate soils, consisting of with broad ridges and shallow furrows, and into and out of which water flows as a result of tidal movement.

Sustainable utilization: Human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Swell: Opposite of shrinkage.

Tg = Teragram = 10^{12} grams = 10^{6} metric tons = 1 billion tonnes

Throughfall: part of the rainfall that is not intercepted by the canopy

Tidal swamps: A swamp whose water level is influenced by tidal water level fluctuations over a considerable distance.

Tide: The periodic fluctuations of the sea-water level that results from the gravitational attraction of the moon and the sun acting upon the rotating earth.

Topogenous peat: Peat formed under the influence of fluctuating levels of river flood water.

Transmigration: Departure from one's native land to settle in another

Transpiration: The quantity of water evaporating via the cuticula and the stomata of a dry crop canopy to the outside atmosphere.

UNFCCC: UN Framework Convention on Climate Change

Values: Independent entities in their own right.

Voids: Small cavities in the soil, occupied by air or water or both.

Water balance: Equating all inputs and outputs of water, for a volume of soil or for a hydrological area, to the change in storage, over a given period of time.

Water-holding capacity: See field capacity.

Waterlogging: The accumulation of excessive water on the soil surface or in the root zone of the soil.

Water management: The planning, monitoring, and administration of water resources for various purposes.

Water quality: A judgement of the chemical, physical, and biological characteristics of water and of its suitability for a particular purpose.

Watershed: See catchment.

Water table: The locus of points at which the pressure in the groundwater is equal to atmospheric pressure. The water table is the upper boundary of groundwater.

Wetlands: Land where the saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

Wise use of peatlands: Uses of peatlands for which reasonable people now and in the future will not attribute blame.

Glossary

To return to the text, press CTRL and click on the respective term.

Acid sulphate soil: A soil containing pyrite, which upon oxidation will result in very low pH values.

Acidity: A property of (soil) water characterised by a pH below 7.

Acrotelm: The surface layer of a peatland that is above the limit of permanent saturation. In a little damaged bog it refers to the active layer, comprising the living plant cover, passing onwards into recently died plant material and then into fresh peat. It forms the largely oxygenated surface layer with high hydraulic conductivity, within which the water table fluctuates and the main water movement occurs.

Adat: traditional rights of indigenous peoples

Alluvial plain: A plain bordering a river, formed by the deposition of alluvium eroded from areas of higher elevation.

Aquifer: water bearing strata

Ash content: Weight of a volume of peat after it has been burned.

Available soil water: The quantity of water available to plants, defined as the quantity of water retained in the soil between field capacity and permanent wilting point. Also see plant available water.

Base flow: Water flow appearing in a river or stream as a result of groundwater discharge, with a characteristic delayed reaction to recharge. Most clearly visible after direct runoff has stopped.

Base saturation: The proportion of the exchange capacity that is saturated with cations

Biodiversity: The frequency and variety of living organisms found within a specified geographic region

Biomass: total weight, volume or energy equivalent of organisms in a given area

Biorights: an initiative to create a financial system which will pay people to protect their natural resources and to develop sustainable ways of using them

Biosphere: The part of a planet and its atmosphere in which living organisms exist or that is capable of supporting life

Blackwater: water rich in humic acids and with low nutrient concentrations

Bog: general term for ombrotrophic mires

BPPT: Indonesian Agency for the Assessment and Application of Technology

Bulk density: The mass of soil per unit volume in an undisturbed condition. Normally equivalent to the dry bulk density (i.e. when only the dry soil mass is considered), but sometimes to the wet bulk density (i.e. when the mass of water present is also considered).

Carbon trading: see emission trading.

Catchment: the entire area drained by a natural stream or artificial drain in such a way that all flow originating in the area is discharged through a single outlet.

Catena: a sequence of soil types and their vegetation that is repeated in a corresponding sequence of topographical sites.

Cation exchange capacity: the extent to which exchangeable cations can be held in a soil.

Catotelm: the lower "inert" layer of the peat of an undamaged ombrotrophic bog. The catotelm underlies the acrotelm, and is permanently water saturated, mainly anoxic and of low hydraulic conductivity.

Chelation: the formation of heterocyclic ring structures that contain metal cations. A natural reaction in most soils, it is enhanced by organic matter, especially humus.

Compaction: the change in soil volume produced artificially by momentary load applications such as rolling, tamping, or vibration.

Compression: the change in soil volume produced by the application of a static external load.

Consolidation: The very rapid subsidence after virgin peat swamps are drained resulting in compression of the permanently saturated peat layers. Consolidation occurs as water and/or air are driven out of the voids in the soil.

Declaration on Environment and Biodiversity: also known as the "Rio Convention", that was held in Rio de Janeiro in 1992

Decomposition: metabolic degradation of organic matter into simple organic and anorganic compounds, with consequent liberation of energy

Degraded peatland: Peatland that has been affected by human activity or natural phenomena to such an extent that functioning, products and attributes are reduced along with the capacity to recover.

Discharge hydrograph: A graph or a table showing the flow rate as a function of time at a given location in a stream.

Drainage: The removal of excess surface and subsurface water from the land to enhance crop growth, including the removal of soluble salts from the soil.

Drainage base: The water level at the outlet of a drained area.

Drainage by gravity: drainage in an area with variable outer water levels, so that drainage can take place by gravity when outside water levels are low.

Drainage system: (1) A natural system of streams and/or water bodies by which an area is drained. (2) An artificial system of land forming, surface and subsurface drains, related structures, and pumps (if any), by which excess water is removed from an area.

Ecosystem: A dynamic arrangement of plants and animals with their non-living surroundings of soil, air, water, nutrients, and energy.

Ecotourism: a low impact, culturally sensitive land-use with the potential for generating income for local people

Electrical conductivity: Indirect estimate of the solubility of ions required in plant nutrition, expressed in $\mu S\ cm^{-1}$.

Elevation head: The vertical distance to a point above a reference level.

El Niño: Southern Oscillation (ENSO): warm ocean current that periodically flows along the western coast of South America, usually around December - January.

Emission trading: a market mechanism that allows emitters (countries, companies or facilities) to buy emissions from or sell emissions to other emitters. Emissions trading is expected to bring down the costs of meeting emission targets, by allowing those who can achieve reduction less expensively to sell excess reductions (e.g. reductions in excess of those required under some regulations) to those for whom achieving reduction is more costly (http://www.pewclimate.org)

Enrichment planting: supplementary tree planting inside a natural forest following logging or natural depletion, in order to increase the potential for future commercial forestry.

ENSO (El Niño Southern Oscillation): temporary reversal of airflows and surface ocean currents in the equatorial Pacific region. This results in abnormal warming of the surface waters off the coast of Peru, and in the disturbance of global weather patterns. This abnormal situation occurs every 2 - 10 years and can last for more than a year.

Environmental impact: The effect on the environment of a certain human interference (e.g. artificial drainage).

Environmental Impact Assessment (EIA): Study undertaken in order to assess the environmental effects of a proposed development project

Evaluation: The assessment of the degree of success of a planned project or process, often undertaken at a specific moment (e.g. upon completion).

Evaporation: (1) The physical process by which a liquid (or solid) is transformed into the gaseous state. (2) The quantity of water per unit area that is lost as water vapour from a water body, a wet crop, or the soil.

Evapotranspiration: The quantity of water used for transpiration by vegetation and lost by evaporation from the soil.

Excess rainfall: That part of the rain of a given storm which falls at intensities exceeding the soil's infiltration capacity and is thus available for direct runoff.

Feasibility study: A study of the existing and future parameters of a drainage or other project in such detail that a reasonable estimate of its profitability can be made.

fibric peat: relatively young peat that is only partially decomposed, with a fibre content > 66 %. It is characterized by high water retention, low pH, low bulk density, and little ash

Field capacity: The volumetric water content of a soil after rapid gravity drainage has ceased. It usually occurs about two days after the soil profile has been thoroughly wetted by precipitation or irrigation.

Functions: The beneficial effects of one entity upon another entity and which can be studied scientifically.

GBHN: Garis-garis Besar Haluan Negara, Guidelines for State Policy

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Ramsar Convention on Wetlands: Intergovernmental convention established at Ramsar, Iran, in 1991, to promote conservation of wetlands globally.

Rand: outward sloping margin at the periphery of a peat dome

Reconnaissance survey: An initial, exploratory survey of the conditions affecting an existing problem. Its results should allow the extent of the problem to be weighed, and possible solutions in general terms to be found.

Rehabilitation: A less specific re-creation of natural resource functions and wildlife interest as compared to restoration.

Restoration: Attempt to return a degraded landscape to its former condition as far as possible.

Return period: The time in which a hydrological event is estimated to re-occur according to a selected statistical criterion. It is the reciprocal of an estimated frequency.

Rio Convention: see Declaration of Environment and Biodiversity

Runoff: That portion of excess rainfall that becomes overland flow.

Saltwater intrusion: movement of saline sea water into the freshwater zone of a coastal aquifer.

Sapric peat: most decomposed type of peat, with a fibre content of < 33 %

Seepage: (1) The slow movement of water through small cracks, pores, or interstices of a material, in or out of a body of surface or subsurface water. (2) The loss of water by infiltration from a canal reservoir or other body of water, or from a field.

Selective cutting (logging): logging technique where only trees that meet specific criteria (such as a minimum harvestable diameter) are harvested.

Shrinkage: the volume reduction of peat above the groundwater level due to irreversible loss of water at highly negative water pressures.

Simulation: The representation of a physical system by a device such as a computer or a model that imitates the behaviour of the system; a simplified version of a situation in the real world.

Social entropy (e.g. social disharmony and enmity)**:** Negative outcome of social change that reduces social welfare, social cohesiveness, and social responsibility necessary to sustain ecosystem benefits following a social and economic development process.

Soil classification: The organisation of types of soil in a systematic and meaningful way, based on practical characteristics and criteria.

Soil fertility: The capacity of a soil to supply the nutrients needed for the growth of crops.

Soil horizon: A layer of soil or soil material approximately parallel to the land surface, and differing from adjacent genetically-related layers in physical, chemical, and biological properties or characteristics (e.g. colour, structure, texture, consistency, or degree of acidity or alkalinity).

Soil profile: The vertical sequence of soil layers, from the soil surface downwards, as affected by soil formation.

Soil survey: The systematic examination of soils in the field, including the laboratory analysis of specific samples, their description, and mapping.

Soil texture: The relative proportions of the various sized groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand below 2 mm in size (fine earth fraction).

Soil-water content: The volume of water in a soil as a fraction of the total soil volume. Normally determined by drying a soil sample to a constant weight at a standard temperature. Sometimes expressed as a mass fraction.

Spatial variability: The phenomenon that a property does not have a constant value within a certain area, but that individual values depart from a central tendency.

SRTM: The Shuttle Radar Topography Mission, carried out by NASA in 2000, obtained global elevation data to generate a high-resolution digital elevation model (DEM) of the earth.

Stakeholders: a single individual or a group of individuals that may be affected by, or express a strong interest in, the resources or management of an area (Claridge & O'Callaghan 1997). A more restrictive definition is individuals or groups that share the 'risk' involved in management of an area and who will bear the cost of mismanagement of resources or environmental degradation. An important factor determining the success of stakeholder participation is whether or not stakeholders believe that the natural resources are held in trust for future generations and for other people in the community and elsewhere.

Steady state: (1) A condition in which the input energy equals the output energy. (2) A fluid motion in which the velocities at every point of the field are independent of time in either magnitude or direction.

STRAPEAT: EU-INCO Project "Strategies for Implementing Sustainable Management of Tropical Peatland" (2001-2004)

Strategic Environmental Impact Assessment (SEIA): while Environmental Impact Assessments (EIA) take place at the project level, Strategic Environmental Assessments focus on decision making at the more strategic level of programmes and policies.

Subsidence: The continuing lowering of the level of the land surface, as a combined effect of (i) compaction and compression; (ii) consolidation; (iii) oxidation; and (iv) shrinkage.

Subsistence living: producing enough food to meet the needs of the farmer/agriculturalist and family, but no cash crops

Subsurface drainage: The removal of excess water and salts from soils via groundwater flow to the drains, so that the water table and root zone salinity are controlled.

Sulphidic soils: soils characterized by the presence of oxidisable sulphur, mostly in the form of pyrite (FeS_2)

Sungai: Indonesian for river (short: Sg.)

Surface drainage: The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by the shaping and grading of land surfaces to such channels.

Surface runoff: Water that reaches a stream, be it large or very small, by travelling over the surface of the soil.

Surjan: traditional Indonesian practice to utilize acid sulfate soils, consisting of with broad ridges and shallow furrows, and into and out of which water flows as a result of tidal movement.

Sustainable utilization: Human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Swell: Opposite of shrinkage.

Tg = Teragram = 10^{12} grams = 10^{6} metric tons = 1 billion tonnes

Throughfall: part of the rainfall that is not intercepted by the canopy

Tidal swamps: A swamp whose water level is influenced by tidal water level fluctuations over a considerable distance.

Tide: The periodic fluctuations of the sea-water level that results from the gravitational attraction of the moon and the sun acting upon the rotating earth.

Topogenous peat: Peat formed under the influence of fluctuating levels of river flood water.

Transmigration: Departure from one's native land to settle in another

Transpiration: The quantity of water evaporating via the cuticula and the stomata of a dry crop canopy to the outside atmosphere.

UNFCCC: UN Framework Convention on Climate Change

Values: Independent entities in their own right.

Voids: Small cavities in the soil, occupied by air or water or both.

Water balance: Equating all inputs and outputs of water, for a volume of soil or for a hydrological area, to the change in storage, over a given period of time.

Water-holding capacity: See field capacity.

Waterlogging: The accumulation of excessive water on the soil surface or in the root zone of the soil.

Water management: The planning, monitoring, and administration of water resources for various purposes.

Water quality: A judgement of the chemical, physical, and biological characteristics of water and of its suitability for a particular purpose.

Watershed: See catchment.

Water table: The locus of points at which the pressure in the groundwater is equal to atmospheric pressure. The water table is the upper boundary of groundwater.

Wetlands: Land where the saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

Wise use of peatlands: Uses of peatlands for which reasonable people now and in the future will not attribute blame.

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Annex 1: ESTIMATES OF UNDISTURBED PEATLAND AREAS IN TROPICAL COUNTRIES

(modified from Immirzi and Maltby, 1992)

COUNTRY	AREA (ha)	SOURCE/NOTE
CENTRAL AMERICA		
Belize	90,000	[1]
British Honduras	68,000	Andriesse (1988)
Costa Rica	22,000	FAO
Cuba	450,000-767,000	FAO; Kivenen & Pakarinen (1981)
El Salvador	9,000	FAO
Honduras	453,000	FAO
Jamaica	14,500-21,000	Andriesse (1988)
Nicaragua	371,000	Miller (1985), FAO
Panama	787,000	FAO
Puerto Rico	10,000	Andriesse (1988)
Trinidad and Tobago	1,000	Andriesse (1988)
TOTAL	2,599,000 (MAX)	
RANGE	2,276,000-2,599,000	
MEAN	2,437,000	

COUNTRY	AREA (ha)	SOURCE/NOTE
SOUTH AMERICA		
Bolivia	900	Andriesse (1988)
Brazil	1,500,000	Bord na Mona (1984) [2]
Chile	105,000	FAO
Columbia	33,000	FAO
French Guiana	162,000	FAO
Guiana	814,000	Andriesse (1988)
Surinam	113,000	FAO
Uruguay	3,000	Andriesse (1988)
Venezuela	1,000,000	Andriesse (1988)
TOTAL	4,037,000	

COUNTRY	AREA (ha)	SOURCE/NOTE
AFRICA		
Angola	10,000	Andriesse (1988)
Burundi	14,000	Kalmari and Leino (1985)
Congo	290,000	Andriesse (1988)
Guinea	525,000	Andriesse (1988)
Ivory Coast	32,000	FAO
Liberia	40,000	
Madagascar	197,000	FAO
Malawi	91,000	FAO
Mozambique	10,000	Andriesse (1988)
Uganda	640,000	Andriesse (1988)
Zaire	40,000	Shier (1985)
Zambia	1,106,000	FAO
TOTAL	2,995,000	

COUNTRY	AREA (ha)	SOURCE/NOTE
ASIA (MAINLAND)		
Bangladesh	60,000	Andriesse (1988)
China	1,000,000-3,000,000	[3]
India	32,000	FAO
Israel	5,000	Andriesse (1988)
Sri Lanka	2,500	Andriesse (1988)
Thailand	68,000	FAO
Vietnam	183,000	FAO
TOTAL	3,346,000 (max)	
RANGE	1,351,000-3,351,000	
MEAN	2,351,000	

COUNTRY	AREA (ha)	SOURCE/NOTE
ASIA (SOUTHEAST)		
Brunei	10,000	
Indonesia	17,000,000-27,000,000	[4]
Malaysia	2,250,000-2,730,000	[5]
Papua New Guinea	500,000-2,890,000	[6]
Philippines	104,000-240,000	[7]
Thailand	68,000	FAO
TOTAL	32,938,000 (max)	
RANGE	19,932,000-32,938,000	
MEAN	26,435,000	

COUNTRY	AREA (ha)	SOURCE/NOTE
THE PACIFIC		
Fiji	4,000	Andriesse (1988)
Australia (Queensland)	15,000	Andriesse (1988)
New Zealand	17,000-26,000	[8]
TOTAL	45,000 (max)	
RANGE	36,000-45,000	
MEAN	40,000	

NOTES:

[1] classified as coastal swamp (Shier, 1985).

[2] based on satellite data

[3] the China figure excludes 682,000 ha of buried peatland. Zhang *et al.* (1992) reported 7.1 million ha of which 21% are tropical.

[4] The figures for Indonesia cause the greatest variation in estimates for the tropical region as a whole. Andriesse (1988) suspects that the figures, based upon aerial photographs, are over-estimates.

[5] Numerous sources indicate similar, rounded figures but without classification.

[6] Shier (1985) and FAO (1974) provide the lower estimate, Wayi and Freyne (1992) the higher.

[7] Oraveinen *et al* (1992)

[8] Total amount of peat in New Zealand was estimated at between 169,000 and 260,000 hectares by McGrevy (1979), cited in Kivinen and Pakarinien (1981); this is substantially more than acknowledged by Bord na Mona (1984). Most is temperate peat and a figure of 10% of this has been included for the tropical peat resource; this may be incorrect.

Annex 2: THE MEGA RICE PROJECT IN CENTRAL KALIMANTAN, INDONESIA 1995-1999

Introduction

The Mega Rice Project (MRP) was initiated by Presidential Decree 82/1995. The official, complete title of the project is *"Pengembangan Lahan Gambut untuk Pertanian Tanaman Pangan di Wilayah Propinsi Daerah Tingkat I Kalimantan Tengah Seluas Satu Juta Hektar"* (Development of One Million Hectares of Peatland for Food Crop Production in the Province of Central Kalimantan). It was a very ambitious undertaking, promoted by over-simplified, over-pragmatic reasoning by which agricultural production, in particular rice padi (later on changed to food in general) was the ultimate goal. The Mega Rice Project was established to address the challenges that were facing Indonesia at that time. The concept of this project stemmed from an *ad hoc*, reactive approach, characteristic of Indonesia's basic policy of national development (Subandi 1992). The rationale was based on the following:

- Rice self-sufficiency that had been achieved in 1984 as a result of the green revolution had disappeared by 1993. To fulfill the national demand for rice, Indonesia was compelled to import up to 2 million tons a year (by 2000 it had inflated to 3.1 million tons) (Kleden *et al.,* 1999).
- Rice yields from existing sawahs, through the application of pre- and post-harvest technology, were beginning to level off, so that the opportunities for further agronomic intensification were limited.
- The best sawah lands in Java were being lost gradually owing to conversion to non-agricultural use. The rate of loss has been estimated at 15,000-20,000 ha a year during the 1990s (Notohadiprawiro, 1995).
- Farmers considered rice cultivation much less attractive in terms of profit making than other crops, notably horticultural plants. (Domestic trade in rice is rigidly controlled by the Indonesian Government.)
- Sufficient new agricultural land was needed to substitute for the estimated loss of one million hectares in Java to commercial and industrial development to replace the import of 2 million tons a year.
- In order to save expenditure on irrigation infrastructures the choice was for wetlands (peatlands) where the water needed would already be available.

Central Kalimantan was selected as the location for the Mega Rice project because:

- The land was in State ownership but its allocation to ten logging concessionaires (HPH) under the spatial land zoning at the time made its procurement for the MRP relatively easy;
- The clear cutting rights of the HPH obviated the need to take into account other land rights or potential compensation payments;
- the region was sparsely inhabited making it ideal for transmigration.

The implementation and planning phases of the Mega Rice Project highlighted a number of serious flaws in the decision making process. Although the region does not produce common agricultural crops, it yields natural products such as timber, rattan and fish that are important to sustain the livelihood of the indigenous inhabitants and support the national and provincial economy (See Chapter 5). Wetlands, including peatlands, perform significant environmental functions, which cannot be apprehended by the untrained mind (see Chapter 3). A Java-centric way of thinking about land idleness and emptiness should not have been applied to regions such as Kalimantan where the physical conditions and social situation are quite different.

Box A1.1: Soils of the Mega Rice project

Physiographically, 24% of Central Kalimantan, or 36,716 km^2, consists of wetlands and lowlands of which coastal plains make up 812 km^2, tidal swamps 1,027 km^2, alluvial plains 12,392 km^2 and peat swamps 22,485 km^2 (RePPProT, 1985). (There is good reason to believe that this is an underestimate of peat swamp forest area (Rieley *et al.* 1996)). The area of peat swamps (the total of all peat soils) affected by the Mega Rice Project are 9,191 km^2, which is 41% of the total area of all peat swamps in Central Kalimantan.

The soil composition can be roughly described to consist of:

- Fine textured mineral soils with a histic epipedon of less than 40 cm thick. They cover 466,250 ha or 32% of the total area of the site. The soils are classified as sulfaquents, fluvaquents, tropofluvents, tropaquepts, dystropepts and hapludults.
- Thin peat soils with a peat layer of 40-130 cm. They cover 225,750 ha or 15.5% of the site, consisting of sulfihemists, tropohemists and troposaprists.
- Medium peat soils with a peat layer of 130-300 cm. They cover 269,620 ha or 18.5% of the project area. The soils are classified as tropohemists and troposaprists.
- Deep peat soils with a peat layer of 300-1,200 cm covering 423,690 ha or 29.1% of the site. They consist of tropohemists and troposaprists.
- Coarse textured mineral soils (quartz sand) covering 71,750 ha or 4.9% of the site. They are classified as quartzipsamments.
- 61.3% of the MRP area was classified as peatland.

Sulfaquents and sulfihemists pose a serious problem of potentially extreme soil acidity and soil-associated water owing to a defective water regime regulation causing air to enter the existing underlying pyritic layer. This has happened in many places because of ill-designed and ill-aligned canals or channels. In addition, hemists in general are poor media for plant growth because of their high fibre content (low effective root contact). Deep peat soils and the deeper members of medium peat soils are physically and chemically unsuitable for agriculture. In Indonesia they are commonly ombrogenous, thus poor in nutrients. They should be conserved for water storage and regulation. Hemists and saprists have a water storage capacity of more than four times their own weight. Quartzipsamments are unsuitable for agriculture and make the landscape unfit for habitation. Fluvaquents, tropofluvents, tropaquepts and hapludults provide the best prospects for crop production. The latter may be suitable for perennials using artificial drainage if needed. With good water and nutrient management dystropepts may be used profitably.

Site Description

The total area of the mega-project was 1,457,100 ha located in the southern part of the province of Central Kalimantan (Figure A 2-1). The site borders the River Sebangau to the west, the main road connecting the provincial capital of Palangka Raya on the River Kahayan and the trading town of Buntok on the River Barito to the north, the river chain Barito-Kapuas, Murung-Kapuas to the east and the Java Sea to the south. The major drainage system of the site consists, from west to east, of the rivers Sebangau, Kahayan, Kapuas, Kapuas Murung, Mangkatip and Barito. Kapuas Murung is a short river connecting the Barito and the Kapuas. Mangkatip is a tributary of the Kapuas Murung. Unlike the other rivers, which have large catchment areas in the uplands of Borneo, the River Sebangau originates from a relatively small forested catchment covered in thick peat.

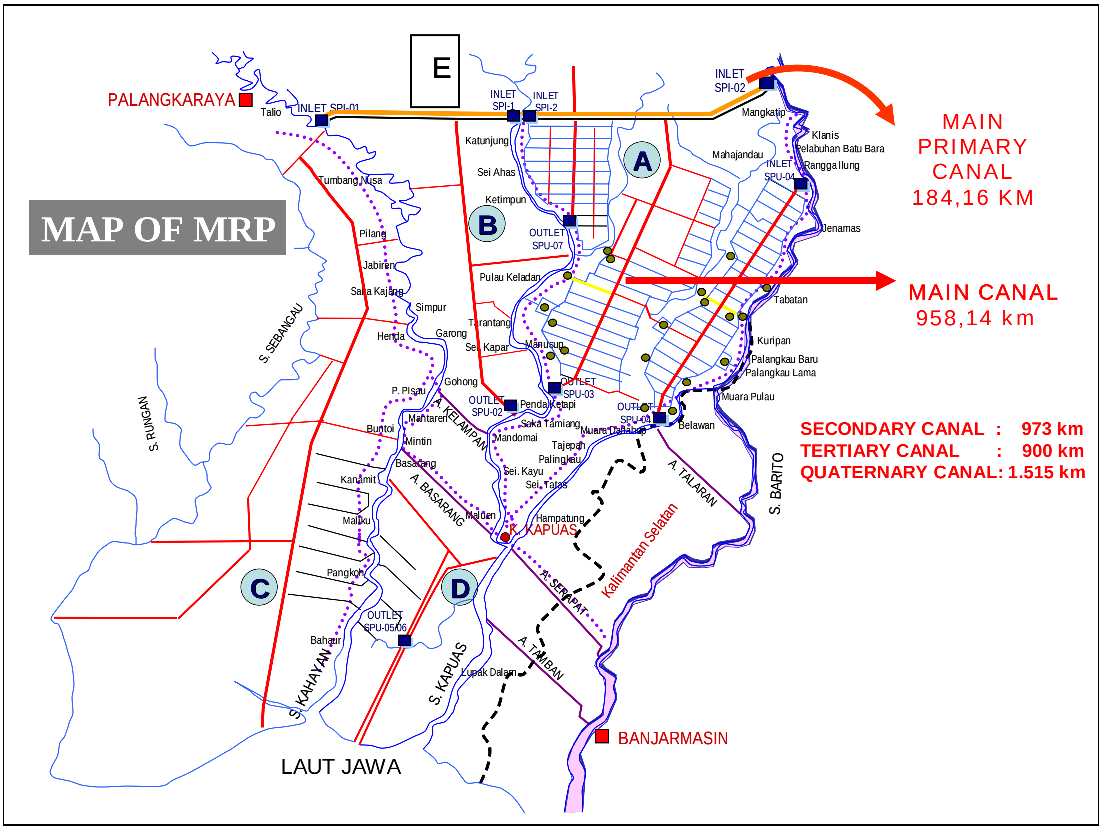


Figure A 2-1: Map of the Mega Rice Project, Central Kalimantan, Indonesia showing major settlements and the location and layout of the drainage and irrigation channels.

Prior to the development phase, the Mega Rice Project was divided into five working Blocks (Figure A 2-1): A of 227,100 ha located between the Kapuas and the Barito rivers, B of 161,480 ha between the Kahayan and the Kapuas rivers, C of 568,635 ha between the Sebangau and the Kahayan rivers, D of 162,278 ha between the Kahayan and the Kapuas rivers at the downstream side of B, and E of 337,607 ha between the Palangka Raya-Buntok main road and the Parent Primary Canal (PPC) connecting the Kahayan and the Barito and crossing the interflowing rivers of Kapuas and Mangkatip.

The PPC was planned to function as the key-control system of the hydrology of the entire project site, directly or indirectly, through regulation of the water flow in the lower category canals and by modifying the water regime of the existing rivers and streams. The PPC branched out into several Main Primary Canals (MPC), some of which modified the courses of rivers. MPCs branched out into many Secondary Canals (SC) that led to lower category Tertiary and Quaternary channels (TC and QC), which were to form the basis of the on-farm channel systems.

Figure A 2-2: Main Parent Channel, 120 km long

Figure A 2-3: Drying out Secondary Channel, Block B MRP.

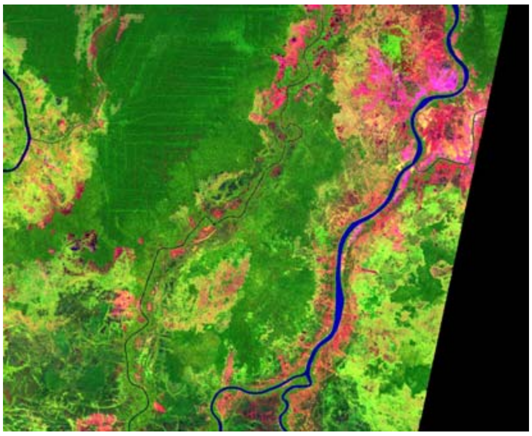
The obvious impact of the canal system on the site hydrology was to increase the drainage intensity. The total length attained by the canals and channels when completed was 4,618 km consisting of 110 km PPC, 1,129 km MPCs, 964 km SCs, 900 km TCs and 1,515 km QCs. The dimension of the PPC is 25 m surface width, 15 m bottom width and 6 m deep. The MPCs have the same dimensions except for the depth, which is 5 m. The measurements in the order surface width-bottom width-depth of SCs, TCs and QCs are respectively 15-10-3 m, 6-4-3 m and 4-4-3 m. The erroneous reasoning behind the design and alignment of the canals/channels was the fundamental cause of the failure of the Mega Rice Project.

Performance of the Mega Rice Project

It has been estimated that only 46% of the Mega Rice Project area had any prospect for agricultural use and habitation, provided that soil and water conservation for reclamation and, subsequently, for amelioration were strictly observed. The best areas are located mostly near to the main rivers and crop production should have been discouraged on the interior watersheds.

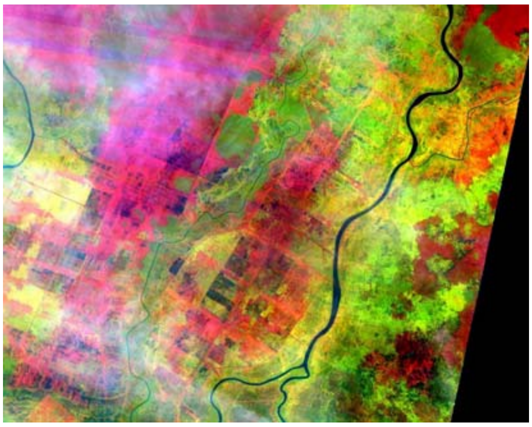
Except for Block E, channel excavation of MPCs and SCs was mostly completed by the end of 1998 (Figure A 2-2). Only a small part of Block A of slightly less than 50,000 ha has been fully equipped with water controlling devices and settled with 13,500 families of local people and transmigrants. In the first three years of operation it was evident that the project was very low in its achievement (figure A 2-4 b). Only about 3% of the whole physical plan reached the final stage. In 1997 the entire MRP area was affected severely by fire (figures A 2-3 and A 2-4 d-f).

The extreme drought which led to the widespread peat and forest fires in 1997/98 was not solely the effect of El Niño as commonly claimed but it was intensified by



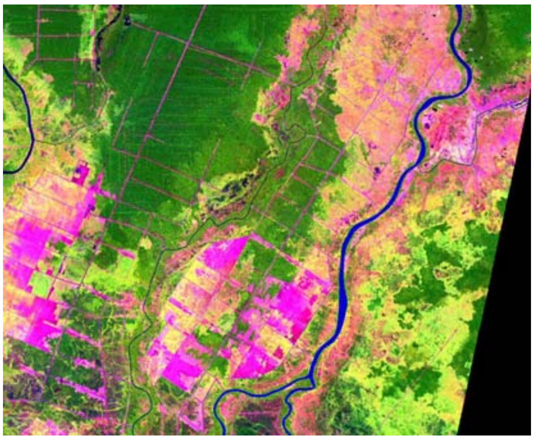
(a) Block A of the MRP: 1995, before the implementation of the MRP project.

(b) Channel construction in 1997, Block C**.**



(c) 1997 shortly after the establishment of the drainage channels; and shortly before the disastrous forest and peat fires**.**

(d) hole caused by burning peat.



(e) 6 months after the fire disaster of 1997. (dark green: peat swamp forest, red: fire scars). Scale: 50x 35 km.

(f) burnt forest in 1998, Block B.

Figure A 2-4: the Mega Rice Project from space and from the ground. (a), (c) and (e) show a time series of LandSat TM satellite images.

the over-draining of Kalimantan's wetlands. Land subsidence is a major result of drainage (see Chapter 2). Uncontrolled drainage may result in unpredictable changes in surface levels as a result of variations in peat characteristics (e.g. bulk density, water holding capacity, subsidence potential). A drainage scheme that is adapted to the initial landscape relief may become progressively less and less functional while controlled drainage can lead to over drainage. These problems are encountered frequently in wetlands, especially peatlands, where they can lead to several additional problems especially when a single drainage approach is applied uniformly throughout an extensive area and where large differences in soil/substrate/peat characteristics are likely to occur. This was the case with the Mega Rice Project (Figure A 2-3).

What made the situation worse was that a very large proportion of the Mega Rice Project area was acquired from land designated as Forest Concession Right (Hak Pengusahaan Hutan [HPH]) and also Timber Estates (Hutan Tanaman Industri [HTI]) that were controlled by large private companies interested whose main interest was in making profit as quickly as possible. The result was that vast peatland landscapes were left entirely bare, denuded of trees or, at best, covered with ferns and shrubs or scattered secondary stands of small trees. The most dominant secondary growth trees in severely damaged forests is galam (*Melaleuca leucadendron*) that is a prime survivor of forest fires and is highly resistant to acid soil and water conditions.

Box A1.2: Constraints to the success of the Mega Rice project

Many problems had to be faced, some of which were internal, or what may be called "self-inflicted", while others stemmed from unforeseen field situations. The internal constraints are the consequences of absence of good planning and the optimizing principles of land development. In particular:

- The project was hastily executed, without time taken to prepare a well constructed database of environmental information and collect the required base-line data on soils, hydrology and environment. Channels were aligned and excavated without factual knowledge about the area, especially the surface levels of the peat-covered landscapes (figure A 2-2).
- The core-planners were strongly convinced that wetlands and peatlands were just other kinds of land to which theories and actions derived for terrestrial landscapes could be applied without modification. The irrigation engineers developed water management systems that consisted of two conventional components only, namely irrigation (water supply) and drainage (water disposal) both to be operated by gravity. They were unaware of the reclamative and ameliorative functions of water management on soil and water itself (quality control), which are most important in wetlands and peatlands.
- The PPS and the MPCs were designed to perform the additional function of water reservoirs, supplying water to the lower category channels. The water kept in the lower category channels was intended to maintain the groundwater and the soil moisture in balance all year round by influent seepage during the dry season and by effluent seepage during the wet season. For this purpose water movement in the channels had to be slowed down by installing a series of water gates across the channels. None of these structures ever functioned as planned (figures A 2-3, A 2-6, A 2-7).

Figure A 2-5: deforested and burnt peat swamp landscape

Figure A 2-6: dried out, inoperable primary channel

Figure A 2-7: subsiding secondary channel

Figure A 2-8: fire prone secondary vegetation

The fate of the Mega Project

Considering the wide-spread, strong discontentment among academics and NGOs with the Mega Rice Project, the State Minister/Head of the National Development Planning Agency (BAPPENAS) in his capacity as Chairman of the MRP Steering Committee established an Expert Team on September 16, 1998. This Team was composed entirely of university scientists, with the mandate to re-evaluate the MRP (background, initial concept and planning, execution, etc.).

Findings of the Expert Evaluation Team

The principal findings of the Expert Evaluation Team that was composed of scientists from Bogor Agricultural Institute (IPB) and Gadjah Mada University (UGM) in parts of Block A, i.e. Dadahup, Lamunti, and Palangkau, where 13,500 families were settled, can be summarised as follows (UGM, 1997; IPB, 1998; UGM, 1998a, 1998b, 1999):

- The areas surrounding Dadahup, Lamunti, and Palangkau have the best prospects for agriculture. Even so most of this land is only marginally suitable for annual food crops such as upland rice, corn, soybeans and peanuts. The soil response to fertilizers and lime is weak. Of the entire area of 227,100 ha, only 120,008 ha (53%) is suitable for growing food crops.
- The land is permanently unsuitable (cannot be improved by cultural measures) for perennial crops such as coconut and oil palm owing to the presence of a pyritic layer.
- 80% of the land is higher than river level so that none of the channels can supply irrigation water by gravity as planned. In order to produce crops, irrigation pumps would have to be installed, which is uneconomical, otherwise the gravity irrigation system has to be changed into a rain-fed system with consequent reduction in the cropping intensity.
- The macro water management system (off-farm system) is functioning more for flood control and acid water leaching than for irrigation. It falls short of ensuring good water circulation for effective dilution of acid water and for the protection of the land from flooding. The intended use of the Barito and Kapuas waters for neutralizing acids formed as a result of pyrite oxidation and peat decomposition cannot be accomplished.
- There are clear indications of a correlation between soil nutrient leaching and acid water removal. It is obvious that land reclamation by drainage opposes the objective of soil improvement. The high channel density has accelerated the deterioration of the landscape hydrology and, consequently, the decline in soil fertility.
- Peat conservation, especially in catchment areas (hydrology commanding areas), for water reserve maintenance, was never part of the water regulation design.
- The soils are very heterogeneous over short distances and their reaction to treatment is therefore diverse, and their influence upon water chemistry is consequently very variable. A single land management scheme cannot be applied to the whole area.
- Long-term observation is required in order to obtain a representative picture of the cyclic behaviour of the hydrometeorology of the area and the hydraulic phenomena at the soil-water interface. The entire database used in the processing of the Mega Rice Project was therefore inadequate as it was constructed using very short-term estimations. This is evident from the great

variations in the measured values during the time interval of the evaluation study.

- The major constraints for development are flooding by heavy rains, drought during the dry monsoon and rodent pests. The latter is quite serious and up to now no solution has been found.
- The human health aspect is never taken into consideration when designing water management schemes. All surface waters become highly unsuitable for domestic use. Water-borne diseases are beginning to show up. The outbreak of stomach and skin disorders may become serious.

Conclusions and recommendations of the Expert Team

The Expert Team for Evaluation of Integrated Wetland Development came to the conclusion that:

- The Mega Rice Project in its original form must be terminated and Presidential Decrees 82/1995, 83/1995, and 74/1998 must be rescinded.
- The imposition of dry land development models upon wetland was a major reason for the collapse of the Mega Rice Project. When these simplistic and distorted views were allowed to shape the development planning, they contributed largely to the downward spiral in which the wetland ecosystem was caught. Unless this can be reversed, the future of Indonesia's peatlands is at serious risk.
- The reversal of the spiral calls for reform of the powerful underlying structures of knowledge, political power, social organization, and economy that control the direction of resources development in Indonesia. The pragmatic thinking that shapes reactive, and *ad hoc* development models must be challenged and replaced with new approaches based on optimizing concepts through critical observation and analysis,
- Activities in all Blocks, except in parts of Block A where people have already been settled, must be stopped and the land rehabilitated to its previous, natural eco-functions.
- Settlements in Block A, although inadvertently placed there by the Mega Rice Project, should be saved if possible as they concern the life of human beings. They involve 13,500 families inhabiting some 30,000 ha of land. The salvation plan consists of consecutive stages of rescue, survival, consolidation, and development.
- In Blocks B, C, and D rehabilitation should be restricted to old transmigration settlements established in the 1970s under a previous project called Proyek Pengembangan Persawahan Pasang Surut (P4S; Tidal Rice Paddy Development Project). Because of poor planning and execution of water control and soil productivity maintenance, most farming activities have already ceased. In addition, the channel works associated with the Mega Rice Project have caused severe damage to the older canal/channel systems. The restitution of livelihood and the land's agricultural potential require reinstatement of the old channels in order to reactivate farming. The problem farms cover an area of 80,000 ha, including traditional farmlands and swamplands for fish catching by indigenous people.
- Wetlands should never be developed separately from the whole hydrological regime that they form part of, and this includes the upstream catchment zone. The approach to development and management should be founded on a holistic concept forming a comprehensive, optimizing approach toward a wise, sustainable use in which economic and ecological goals are complementary. Thus, wetlands must be seen as an integral part of the whole hydrological regime.

Response of the Government of the Republic of Indonesia

Responding to the growing pressure, in July 1999, President Habibie revoked the Soeharto Presidential Decree that established the Mega Rice Project and replaced it with a regional development plan, the ***Kapet Das Kakab,*** which gave much of the management authority to the newly established local government. This new strategy, however, did not include any procedures to ensure landscape and wildlife protection and embraced a much larger area of 2.8 million hectares (Muhamad & Rieley 2002).

A further ironical twist to this catalogue of peatland disasters occurred in March 2000 when the Indonesian Minister of Regional Development, Erna Witoelar mothballed the *Kapet* and set the situation back to that prior to 1996. The difference being, of course, that more than one million hectares of wetland containing around 900,000 hectares of peatland, including peat swamp forest with its wildlife, had been destroyed forever. There is now a vacuum in which there is uncertainty about how to proceed. The forces of development and business still view the peatland areas of Central Kalimantan as major opportunities to make large profits at the expense of the environment and its resources. The destruction of peat swamp forest is still being promoted through illegal logging that the authorities seem unable or unwilling to stop.

There are still active logging concessions operating in the area of the former MRP even though logging activities should have stopped because of the termination of that project. Conversion to agriculture has occurred in part of Block A while, in Blocks B, C and E, most of the forest has been removed or degraded. Since the use of fire was applied for land clearing, especially using the main channels for access, the devastating fires of 1997 and 2002 will be repeated in the future (Page *et al.,* 2002).

There is a lack of expertise in Indonesia to advise on the best courses of action to solve the problems created by the MRP. The international donor community is remarkably muted about the whole affair and appears to be disinterested. This is in spite of the fact that much of one of the most biodiverse ecosystems and largest carbon stores on this planet is disappearing rapidly and the remainder is becoming unsustainable. This is the largest ecosystem restoration problem that has beset this planet in recent times. The magnitude of this challenge has to be met by the involvement of international scientific, donor agencies and aid organizations. The first step was a meeting sponsored by the British Ambassador to Indonesia on 26th September 2002 that was attended by Indonesian local and national Government officials, NGOs, international scientists, especially those with experience of peatland restoration, and the donor community, e.g. World Bank, Asian Development Bank and aid-giving Governments of developed countries. This was followed by a subsequent meeting of Mega Rice project restoration stakeholders in the office of the Governor of Central Kalimantan in August 2003 to take the process to the implementation stage. In December 2004 the Netherlands Government announced it was going to provide 45 million € over 5 years for the restoration of peatland in Indonesia. Things may at last be starting to move in the right direction.

Indonesian Government solution to the ex-Mega Rice Project problem

The failure of the project was attributed to:

- **problems of ecology and natural resource functions** (exploited but unused land, decreasing food production, over drainage, forest and peat fires and flooding);
- **problems of infrastructure** (irrigation network not optimal, insufficiency of settlement infrastructure);
- **problems of socio-cultural suitability and support** (high risk of failure owing to lack of harvesting technology and absence of product markets, insecurity, reorientation of transmigration jobs, lack of capability of people in peat soil management.)

In order to solve the problems caused by the MRP, Presidential Decree 80/1999, specified “Guidelines for a Mitigation Plan for the ex-MRP Area”, based upon management of peat >3 metres thick for conservation and economic development of peat < 3 metres through spatial land use planning.

An *Ad Hoc* team and Core Team for Mitigation of the ex-MRP (The Core and Ad Hoc Team - TCAHT) was established by the Minister of Acceleration & Development of KTI in 2002 to implement the guidelines. Members of the *Ad Hoc* team were government officials, scientists, and university and professional associations. The tasks of the *Ad Hoc* team were:

- evaluation and mitigation of the ex-MRP;
- formulation of a concept for rehabilitation of the ex-MRP;
- formulation of a concept for the mechanism of mitigation, and
- formulation of recommendations with alternatives.

Steps taken by the TCAHT towards formulating an integrated plan for the ex-MRP area included study, collecting, compiling all previous studies of the MRP (including research project reports), evaluating approaches and strategies, combining the available data into an integrated framework, constructing a matrix model for mitigation and developing a “grading” system for the ex-MRP area.

Six approaches were identified by the *Ad Hoc* team:

- legal aspects,
- spatial arrangement aspects,
- development of river area aspects,
- institutional aspects,
- production aspects, and
- conservation aspects.

The *Ad Hoc* core team proposed five mitigation plans for the ex-MRP area:

- development of production,
- management of the conservation area with peat >3 meters thick,
- management of the production area with peat <3 meters thick,
- spatial arrangement, water management and fire control, and
- revitalization of the transmigration programme, increasing socio-economic prospects and improving human health.

A grading system for the ex-MRP area, based on an impact and evaluation matrix, was developed by TCAHT as a tool to guide the planning of the rehabilitation programme. Advantages of the grading and matrix applied to the ex-MRP area are integration of approaches and options, data co-ordination, monitoring and evaluation, and understanding of the entire ex-MRP area as a holistic entity. TCAHT concluded that there can still be prospects for future development of the ex-MRP area by changing the principles of the approach to development of the area following some of the recommendations of the Pontianak Workshop on Tropical Peat (2004), namely:

- Restoration of hydrological functions on peat areas needs urgent attention.
- Development of tropical peat areas must be in accordance with the wise use experience of indigenous people.
- Development of tropical peat must be based on scientific and socio-economic data, otherwise it should not be undertaken until adequate information is available.
- Development of peatland in parallel with learning about its characteristics and properties is the wrong approach.
- There should be no more transmigration programmes on the ex-MRP area, while existing transmigrants are unable to obtain sustainable livelihoods.
- Illegal logging must be stopped because it causes not only destruction of the forest, but it also leads to the permanent disappearance of tropical peat through fire and oxidation.
- Fire must be controlled and prevented.

The Current Situation

Many of the 50,000 people settled on part of the MRP area were still there in 2005 although some are reportedly starving and suffering many privations. In 1997 80% of the MRP area burned in the El Niño promoted fires, liberating more CO_2 to the atmosphere in 3 months than is released from fossil fuel burning in the European Union in a year. Since then peat in this area continues to degrade, releasing more of its carbon, because the surface is exposed and the hydrological condition that was maintained under natural forest cover has been changed dramatically. The whole former MRP area has become a major fire hazard that will burn again in future extreme dry periods (figure A 2-8).

The MRP and its associated fires are the largest landscape disaster in recent times anywhere in the world. Half a million hectares of prime peat swamp forest were removed to fuel pulp mills; large sums of money were paid to contracting companies. In the event not a single blade of commercial rice was grown and the MRP is in a degraded and dangerous condition, unable to retain the large amount of water that falls upon it in the rainy season whilst it has become dangerously fire-prone in the dry season. No one has had to address a problem of this magnitude before.

The Province of Central Kalimantan inherited the problem of the Mega Rice Project from the Central Government of Indonesia. It is a legacy of the old order imposed by President Soeharto and the authorities in Kalteng cannot even begin to address the difficulties or even understand their magnitude. It is a global problem, however, that can only be tackled by international action for which a lead is required to initiate the process.

A Way Forward

- There is an urgent need for a co-ordinating agency in Indonesia to integrate all aspects of peatlands.
- There is an urgent need for international advice, think tank expertise and aid.
- There is an urgent need for assistance from a developed countries with experience of peatland problems and knowledge of tropical peatlands, e.g. Canada, Finland, Ireland, United Kingdom.
- The best scientific expertise in the world on tropical peatlands is already available through the EU funded INCO-DC, INCO-DEV and INCO D-DEV and JSPS research consortia and their information should be used to promote 'wise use of tropical peatland'.
- This knowledge and experience needs a lead from a major developed country Government in order to encourage the Government of Indonesia to take action to resolve this problem and to co-ordinate international assistance and funding.

Chronology of the land use change associated with the Mega Rice project in Central Kalimantan .

November 1985, Soeharto's achievement
President Soeharto received an award from FAO for successfully bringing Indonesia to self-sufficiency in rice production. In 1985, Indonesia produced 26.3 million tonnes of rice, more than the demand of 19.8 million tonnes (Kleden *et. al.,* 1999). The success story didn't remain long; Indonesian rice production dropped drastically in later years largely because one million hectares of the best rice growing land in Java was sold progressively for industrial and urban development.

June 1995, Soeharto meets 8 ministers
President Soeharto met with 8 ministers to discuss his plan to open new rice production areas that supposedly would produce 5.1 million tonnes of rice per annum (Kleden *et al.* 1999; Walhi 1999). From the original plan of 5.8 million hectares in Central Kalimantan, only 1.7 million hectares was finally agreed by Soeharto's ministers (Kleden *et al.,* 1999), and the Mega Rice Project was born.

December 1995, Mega Rice Project Decree issued
An Executive Team (Tim Pelaksana), chaired by the Minister of National Planning (BAPPENAS) and consisting of several other Ministers, was formed to oversee the implementation of the Mega Rice Project under Presidential Decree No 82/ 1995. A Technical Team responsible for day-to-day management was established under the chairmanship of the Minister of Public Works with members drawn from Directorates General of the main Ministries involved.

January 1996, first physical work of the Mega Rice Project
The first physical work was carried out in Block A of the five designated working areas. This work included construction of the main channels and preparation of land and settlement for 22,500 households. This was done without a prior Environmental Impact Assessment. The Ministry of Public Works adopted a 'plan as you go' approach in the development of the Mega Rice Project (Ministry of Public Works, 1999), a ludicrous decision for a project of this size.

April 1996, feasibility study started

First meeting of the feasibility study group established by the Agricultural University Bogor (IBP) was held. By this time the channel design was completed and being used by *PT. Sumatera Timur Indonesia* to build the primary channel.

July 1996, independent EIA completed

An independent EIA carried out by *Wetlands International* was completed five months after the project started. The Ministry of Transmigration (Walhi, 1999) acknowledged the lack of EIA.

January 1997, IPB EIA completed

Study by the EIA research team of IPB (*Tim AMDAL Pusat Penelitian Lingkungan Hidup IPB)* was completed. The result showed that only 30% of the Mega Rice Project area was suitable for agriculture. The Ministry of Environment agreed with the EIA but continued to support the project by issuing a Ministerial Decree that acknowledged the EIA results but praised the development plan and regional environmental monitoring plans for the Mega Rice Project (Walhi, 1999).

May 1998, decree no 82/1995 amended

President Habibie amended Decree No 82/1995 to Decree No. 74/1998, by adding the Minister of Transport (*Menhub*) into the Steering Committee and the Governor of Central Kalimantan as Second Deputy Chairman in the Technical Team.

August 1998, re-evaluation results presented

The Head of Bappenas commissioned a re-evaluation of the Mega Rice Project, through decree No. *Kep. 286/K/9/1998*, which was chaired by Prof. Dr. Ir. Gunawan Satari (Padjajaran University). The results and proposals of the re-evaluation team were presented at the National Seminar of Environmental and Social Impact from the Development of the One Million Hectare Project in Jakarta (Walhi 1999). The study shows that only 10 per cent of the area could be used for new rice production (Kleden *et al.,* 1999). The seminar concluded that the basic idea, strategy, planning and implementation of the Mega Rice Project had been wrong from the start and the development violated the concept of land use management as stipulated in regulation *UU No 24/1992 (Penataan Ruang)*.

September 1998, KAPET DAS KAKAB established

The Integrated Economic Development Zone (*Kawasan Pengembangan Ekonomi Terpadu - KAPET*) Kahayan Kapuas Barito Embankment Areas (*Daerah Aliran Sungai - DAS - Kahayan Kapuas Barito - KAKAB*) was established by Presidential decree No. 170/1998. The *Kapet* concept is copied from Japanese experienceThe area included within this integrated development zone was 2.77 million hectares (18% of the area of Central Kalimantan) of which 1.5 million hectares had been involved in the Mega Rice Project.

August 1999, Walhi's law suit

Yayasan Wahana Lingkungan Hidup Indonesia (Walhi) filed a civil law suit against the President of the Republic of Indonesia and 9 Ministers on the grounds that:

1. The Mega Rice Project violated the land use management concept.
2. The Mega Rice Project used the Reforestation Fund of the Department of Forestry illegally.
3. The Mega Rice Project was started before an Environmental Impact Assessment was agreed by the Bapedal EIA Commission.
4. The Mega Rice Project ignored traditional wisdom in the development of natural resources in the project location.

5. The Mega Rice Project caused degradation of environmental quality in the project location.

Walhi in its lawsuit demanded that:
1. Decree No 82/1995, Decree No. 74/1998 and Decree No. 83/ 1995 be revoked;
2. 2. All regulations and technical policies that were issued as a consequence of Decree No 82/1995, Decree No. 74/1998 and Decree No. 83/ 1995 be revoked;
3. All main channels in the working areas A,B,C,D and E be closed;
4. The area is rehabilitated to its original state;
5. Stop issuing IPKs (rights for land clearing).

The Government fulfilled Walhi's first demand with the issuance of Presidential Decree No. 80/1999 regarding the General Guidelines on Planning and Management of Peatland Development Areas in Central Kalimantan (Pemda TK1. Kalteng, 1999). This decree gives the local government of Central Kalimantan the authority to coordinate land management outside of the conservation zones in Blocks A and D of the Million Hectare Project for development. Land with peat over 3 metres thick was designated for 'conservation' under the management and coordination of the Minister of Forestry and Estate Crops.

March 2000, demise of the Kapet Das Kakab
The Minister of Regional Development cancelled the orders establishing the Integrated Development Programme (Kapet) for Central Kalimantan pending its confirmation in a Presidential Decree.

***2002* An *Ad Hoc* team and Core Team for Mitigation of the ex-MRP (The Core of Ad Hoc Team - TCAHT) were established**
These were set up by the Minister of Acceleration & Development of KTI to prepare guidelines for rehabilitation of the former MRP area. Members of the *Ad Hoc* team were government officials, scientists, and university and professional associations.

2004 The Ad Hoc Team published its conclusions and recommendations.
As of June 2005 these have not been implemented.

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Annex 3

FINANCIAL MECHANISMS FOR POVERTY-ENVIRONMENT ISSUES

The case of Central Kalimantan (II)

BioRights

This project has been carried out:

- with financial support from the Dutch Ministry of Foreign Affairs (DGIS) under the Partners for Wise Use of Wetlands Programme managed by Wetlands International
- with financial support from DGIS to the Global Peatland Initiative, steered by Alterra, (Wageningen-UR), the International Peat Society (IPS), the International Mire Conservation group (IMCG), the International Commission on Irrigation and Drainage (ICID) and IUCN-NL and Wetlands International.
- "STRAPEAT" project , with financial support of the European Union under the INCO-DEV budget line

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FINANCIAL MECHANISMS FOR POVERTY-ENVIRONMENT ISSUES

The case of Kalteng (II)

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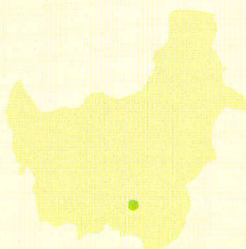

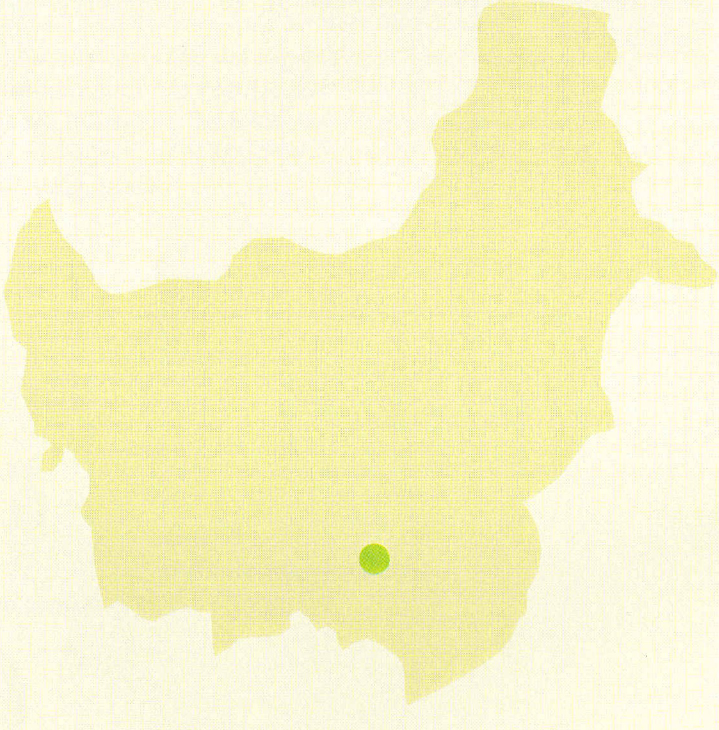

TABLE OF CONTENTS

1. INTRODUCTION

Conventional strategies to escape rural poverty emphasize the need for increasing productivity in agriculture, livestock and forestry activities or, failing that, population migration. Despite some notable successes in the so-called "favoured areas", however, productivity increases are by no means universal with income levels in agriculture and forestry decreasing in many of the so-called "less favoured areas" of the developing world[1]. Even in developed countries, rural incomes depict a decreasing trend, despite heavy subsidies and other types of income support. Migration in (and from) developing countries has proven to be a selective and costly process. As a result, many rural people in developing countries have to exist on very low incomes and are unable to escape the so-called poverty trap.[2]

To break free from this downward spiral, new pillars for the rural economy are needed. One potentially promising option consists of payment for environmental services through already established mechanisms such as carbon credits and new ones, for example, Bio-rights.

The Bio-rights concept (explained below) will, in combination with other environmental services, be tested in three areas of the world, namely, Central Kalimantan (Kalteng), Indonesia, the Inner Niger Delta, Mali and the San Juan - La Selva Biological Corridor, Costa Rica.

This booklet focuses on the application of the Bio-rights concept and other environmental services and products and their potential for raising the income of people in Central Kalimantan,

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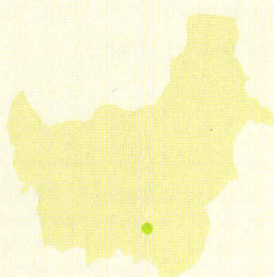
[2] Silvius, M.J. et al., 2002. Financial mechanisms for poverty-environment issues: The Bio-rights system. Alterra Report No. 617, Wageningen, The Netherlands. 19pp, ISSN:1566-7197.

Indonesia. The perspective of traditional agricultural commodities such as palm oil to provide environmental services (rather than being associated with forest destruction) is also discussed.

The Government of Indonesia and local authorities in Kalteng are looking currently to improve income from the traditional sources of agriculture and forestry but, as prospects especially for forestry are declining, new opportunities for rural development in this poverty-trapped region are needed. So far the income generated from forestry has not prevented this province being one of the poorest in Indonesia.

Indonesia decentralized government after the Suharto era and whilst, on the one hand, this provides another opportunity for sustainable development, on the other hand, peoples' incomes are still declining. There is a major need to find financing mechanisms that can convert environmental values into cash flows while, at the same time, generating income for those caught in the poverty trap.



2. THE BIO-RIGHTS CONCEPT

The principle behind the Bio-rights concept is that safeguarding biodiversity could be the subject of a business contract between the global community and local people in rural areas of developing countries. The global community recognizes the value of the biodiversity in the areas concerned and offers financial compensation for the costs (i.e. lost income or local opportunity costs) that have to be made in order to maintain the biodiversity. This typically involves converting actual (and unsustainable) land use into sustainable land use while, at the same time, creating income and job opportunities to stimulate economic development.

The idea of paying for the maintenance of biodiversity is not new. In the industrialized world, as well as in some developing countries such as Costa Rica, various systems are already in operation, based on either paying landowners to maintain (or increase) environmental services and, where necessary, compensate them for lost income, or by using tax deduction or debt reduction (dept for nature swap) for the same purpose.

There are two new elements inherent in the Bio-rights concept. Firstly, compensation payments are given a sustainable, enduring character by establishing a permanent endowment fund, which uses the revenues exclusively for making the payments. In developing countries, which are often confronted with a serious lack of alternative job opportunities, reliable long-term contracts are considered a necessary condition for sustainable rural development. Secondly, compensation payments are not necessarily paid to individual farmers (as is usually the case in industrialized countries) but rather to the local community, without a-priori specification of how the money should be spent.

3. DEVELOPMENT IN KALTENG

The Province of Central Kalimantan (Kalteng) occupies over 153,000 km≈ in the Indonesian part of the island of Borneo. Peatland covers around 40,000 km≈ of this area much of which is covered in peat swamp forest rich in biodiversity.

Before 1970 most land was virgin forest including the forested peatlands and about 50% of the 1.8 million inhabitants lived mostly along the banks of the major rivers that flow distances of up to 600 km from the interior mountains to the Java Sea. Traditionally, and significantly, the indigenous Dayak population did not live on the peatlands. Population patterns in the peatland districts were changed, however, by Indonesian Government sponsored transmigration (resettlement from Bali, Java and Madura to outer, thinly populated provinces). The first official transmigration settlement was started in 1969 with Balinese people. From 1979 until the mid 1980s most transmigration areas were allocated on peatland under the Southern Kalimantan Land and Water Resources Development Project.

During Dutch colonial rule, Central Kalimantan was part of East Kalimantan. The province of Central Kalimantan was formed in 1957 a decade after Indonesia gained its independence. Subsequently, the population increased rapidly owing to the influx of transmigrants from Java. In the 1980s this reached an annual growth rate of 3.9 %, which was nearly twice the national growth rate. Transmigration ceased after the Suharto era leading to a decrease in population growth rate.

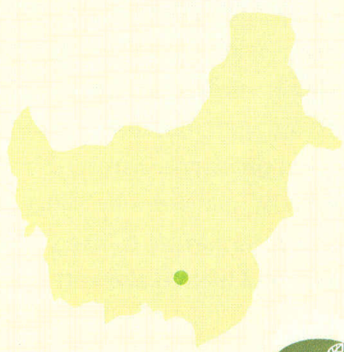
During Government promoted transmigration living standards in Kalteng did not improve, although forestry generated large windfall profits. Poverty in the province (about 10 US$/ month per capita) is 34% and well above the national level of 23% (1999 figures). In peatland districts the incidence of poverty is as high as 45%.

Over 50% of the labour force in Central Kalimantan works in agriculture and forestry, generating 667 million dollars equivalent to 47% of the gross regional domestic product in 2002.

Income from forestry is declining throughout Indonesia and the sustainable basis for timber based forestry in the future is slim. Income from (oil palm) plantations, however, is increasing. In 1998 and 2002 forestry generated 53% and 33% of the gross agricultural (plus forestry) income. Over the same period the income from plantation crops increased from 18% to 37%.

Revenue generation from forestry, although unsustainable, will continue to provide a source of income but at a cost to the resource itself. Whether or not the income from plantations will increase further depends on future market demand. If the demand for palm oil increases, oil palm could be used to rehabilitate degrated land and provide a source of 'green energy'.

Money generated from Bio-rights, carbon credits and green energy have the potential to provide a substantial, regular revenue for Kalteng. This could provide new labour opportunities and income for local people while, simultaneously, conserving biodiversity of global interest and protecting climate processes.



4. NATURAL RESOURCES IN KALTENG

Tropical peatlands in the lowlands of SE Asia are characterized by a special type of rain forest, peat swamp forest, which covers about 30 million hectares of landscape in Borneo, Indonesia, Malaysia, Thailand and Vietnam. Most of this undecomposed 'organic' resource (peat) occurs in Indonesia (20-27 Mha) and a major proportion is located in Central Kalimantan (at least 4 Mha) where it achieves a thickness of up to 20 metres forming a 'dome' shape on the watersheds between adjacent rivers.

Some of the peat in Kalteng has been accumulating for more than 20,000 years but the rate was most rapid during periods of climatic wetness and slow or non-existent during periods of drought. Over their life span, however, these tropical peatlands increased in thickness, millimetre by millimetre causing the surface to rise slowly, higher and higher, above the adjacent mineral ground. During this time these peatlands also stored the highest amounts of organic carbon found anywhere in the world (dry peat is around 50%-60% carbon by weight), which has major implications for global climate processes. Forested tropical peatland is a 'dual' ecosystem, peatland and rain forest, in which both components are dependent upon each other for their formation and survival. The peat swamp forests of Central Kalimantan are hotspots of global biodiversity and contain, amongst a large range of endangered, endemic and rare animals and plants, the largest extant population of orang utan in the world.

The tropical peatlands of Central Kalimantan, in common with those elsewhere globally, are under threat, especially when they are targeted for inappropriate major land development projects. A strident example is the one million hectare 'Mega Rice Project' to convert peat forest to rice (padi fields) in Central Kalimantan (1996-1998) that failed because it was ill conceived, mismanaged and not subject to EIA before it was initiated. This vast area has now lost most of its natural capital of biodiversity (including several thousand orang utan), its ecological and natural resource functions are seriously impaired, probably beyond recovery, and it is now subject to frequent fires causing its carbon store to disappear. Carbon gas emission from the latter is having a significant effect on carbon dioxide levels in the global atmosphere and is a major factor in climate change.

Central Kalimantan, especially the Sebangau catchment, is one of the most important areas in the world for the conservation of the Bornean orang utan. It is estimated that over 6,000 individuals live in that area, which is approximately 15% of the total population of this endangered species and the largest single contiguous population remaining in the world. Orang utans occur throughout this catchment, with the majority found in mixed swamp forest. This forest occurs on the margins of the peat domes near the rivers. Unfortunately, this puts the population in direct threat from human pressures such as hunting and illegal logging.

In 1996, the Sebangau population of orang utan was estimated to be 10,000 in 6573 km2 of peat swamp forest. Since then, 790 km2 has been lost to fire (=12% in 6 years), and logging has continued in the remaining forest. The current total population estimate of 6,300 individuals corresponds to a 36% decline in numbers since 1996. Hunting and compression effects (overcrowding in poor quality habitat) caused by illegal logging are thought to be responsible for 70% of this decline. Nevertheless, the Sebangau catchment still contains one of the most important populations of orang-utans in the world today.

5. ENVIRONMENT SERVICES AND PRODUCTS

Environmental or green services could become new pillars to support sustainable rural development in developing countries. In Central Kalimantan the emphasis is on new options for payments for biodiversity conservation (combined with maintenance of landscape scenery) through the introduction of a system of bio-rights and payments for maintaining peat swamp forest carbon sequestration and preserving the peatland carbon store. In addition, profitable land use options such as oil palm cultivation could, under certain conditions, help to promote sustainable development, directly and indirectly. In fact, oil palm already contributes to economic development and provides jobs, whereas there is a new opportunity to decrease deforestation rates by re-allocating expansion of oil palm to already deforested and degraded landscapes instead of destroying the remaining natural areas (see next chapter).

BioRights

6. BIO-RIGHTS

6.1 Fire prevention

Forest fires occur all over the world and under dry circumstances are notoriously difficult to fight in either developing or developed countries. Fires in Central Kalimantan are no exception to this problem, but the experiences from the University of Palangka Raya (CIMTROP) and the results from projects carried out by WWF and Wetlands International indicate that fire prevention through village participation is a distinct possibility. Moreover, local techniques have been developed that are effective. International links to share experiences and formulate joint strategies on fire prevention are being established within ASEAN.

Tropical peatlands are highly susceptible to fire in the absence of rainfall during dry spells regardless of the water table but, especially, if they have been effected by selective logging or clearfelling . From a technical point of view human control is the basic element in fire prevention during dry periods. Raising water tables, which is probably very difficult and costly, is desirable but not a first necessity.

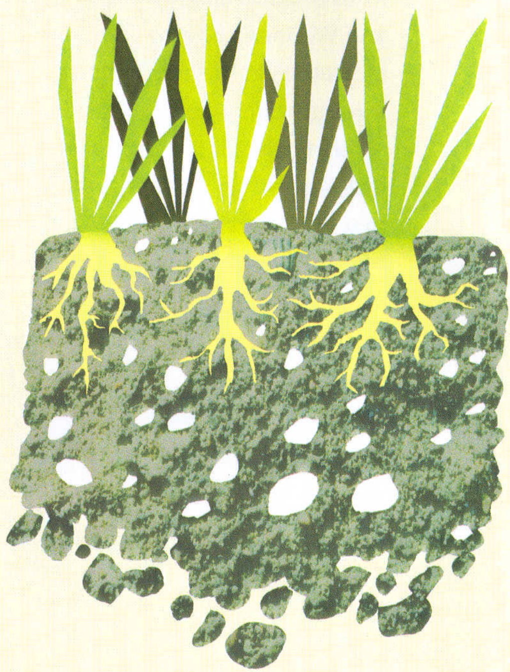
Fire prevention and combating fires is possible and requires relatively low investments,

particularly in manpower. It is a pre-requisite for payments through either carbon credits/rights or a Bio-rights system. It is pivotal for any protection of biodiversity and implementation of natural resources management. Fire protection also provides jobs in the villages, that participate in the fire prevention system. The costs of such a system are relatively cheap and the benefits/costs ratio is huge.

6.2 Rehabilitation of water resources

Rehabilitation of water resources in peatland areas is difficult to achieve and there is little information on this topic or proven methodology. It is clear, however, that rehabilitation of the Mega Rice Project area of 1.5 million hectares is also of importance for maintaining water tables in adjacent forested areas with their high biodiversity. What are the prospects of investments, which may come from e.g. Biorights? There are three issues involved, which are now under consideration by Indonesian authorities.

1) Construction of dams to restore water tables is a proven technique for elevating water tables in temperate bogs, but may be less effective in tropical forested peatland where the hydraulic conductivity of the surface peat is much higher. In other words temperate bogs retain water like a sponge, whereas tropical peats loose their water rapidly. Cascades of dams could help out, but whether or not this system will be able to raise water tables in tropical peatlands during dry spells is not yet proven and needs to be tested in field trials.



The theory of tropical bog hydrology indicates that, except in positions where there is still forest in the highest parts of the bog, the prospects are not bright. This suggests that rehabilitation of the former Mega Rice Project area, especially negation of the larger channels, will not be easy and may be impossible. This issue requires further study by hydrology experts before action is taken. Chances of success in places may be higher where only small drainage canals have been constructed in still forested peatland. But even in this case the permeability of the peat may obstruct a rapid success. It is known that in the Sg. Sebangau catchment many small canals have been excavated by illegal loggers as the means to transport their logs out of the forest. These are bleeding the peat swamp to death and must be filled in if the peat swamp forest and its biodiversity are to be saved.

2) A second problem with respect to rehabilitation is related to the functioning of canals as a means of transport. The support and participation of local people who are using canals for transport is therefore crucial.

3) A third issue is the sustainability of efforts to rehabilitate the water levels in the peat. There is a need to make the peatland profitable in order to make sure that fire prevention is also in the interests of the owner of the crop. In this respect tree plantations probably do not provide enough return on investment. In the present development phase other crpos such as oil palm, which may provide quicker revenues on investments could be used. If it comes to restoration of forest resources, the priority should be on conserving existing forested areas.

Here Biorights make constitute a plausible mechanism fo sustainable development and corservation, especially if fire prevention can be achieved.

6.3 Empowerment of Human Resources

There is an urgent need in Central Kalimantan to enforce the local government including the province and districts (kabupaten) in order to capture the new opportunities for sustainable development created by decentralization of Government in Indonesia. Funding is needed to empower the various levels of local government to deal with poverty-environment issues effectively.

Civil society, including the private sector and non-governmental organizations have to play a role. The University of Palangka Raya and its International Centre for Collaboration in Management of Tropical Peatland (CIMTROP) are very important in this respect through linkages to the international scientific community with projects such as the European Union-funded STRAPEAT project ('Strategies for Implementing Sustainable Management of Peatlands in Borneo'), the Japanese Society for Promotion of Science project ('Sustainable Management of wetlands in Southeast Asia') and the Global Peatland Initiative. There is already a long term commitment by a consortium of international and Indonesian Universities (Universities of Leicester and Nottingham, UK, University of Helsinki, Finland, University of Wageningen, Netherlands, University of Hokkaido, Japan, Universities of Gadjah Mada and Sriwijaya, Indonesia) to develop human resources and institutional capacity in the University of Palangka Raya so it can become a engine driving forward sustainable development in Kalteng, especially in the peatland areas. In the ASEAN context the ASEAN Peatland Initiative and GEF projects through the Global Environment Centre are also relevant.

The University of Palangka Raya has a field research centre (the 'Natural Laboratory for Peat Swamp forest) devoted to research and monitoring of this complex and vulnerable ecosystem. With assistance from international funding agencies and the support of WWF this facility could become the most prominent international research centre focusing on tropical peat and peatland. In addition, the Natural Laboratory could, through deployment of Biorights revenues, assist in the establishment of ecotourism in and around the Sebangau catchment in Kalteng. Control of fire and restoration of the ecological and natural resource functions of converted and degraded peatland is a pre-requisite for any form of sustainable management and also of habitat and wildlife conservation in Kalteng. These vital issues are already being addressed by the international scientific consortium and several NGOs that are trying to determine how to undertake peatland rehabilitation and implement the most appropriate management regime to achieve its sustainable 'multiple wise use'. Restoration of hydrological integrity and water management are fundamental to these activities. It is also significant that a process has been initiated at Indonesian National Government level, through the National State Planning Agency (BAPPENAS) linked to Kalteng Provincial and Local Governments, to find the most appropriate way(s) to rehabilitate the 1-1.5 Mha of peatland that were deforested, drained and later abandoned in the ill-fated Mega Rice Project of 1996-1998. The co-ordination team for this major task is chaired by Bambang Setiadi of the Indonesian Agency for Assessment and Implementation of Technology (BPPT in the Ministry of Research and Technology) and is an interdisciplinary, cross-sectoral ministry approach to try to solve a major economic, environmental and social problem.

6.4 Orang utan as an indicator of peat swamp forest sustainability

Peat swamp forest is a rare, endangered and unique wetland ecosystem that performs a large range of landscape functions and has considerable socio-economic and environmental values. It is a major reservoir of the Earth's biodiversity and the quality and sustainability of this forest as a habitat is of vital importance to a Biorights funding programme. The size and sustainability of the resident orang utan population in peat swamp forest is obviously a major indicator of the success of a biodiversity conservation effort, although other ecosystem attributes could also be used. Orang utan monitoring data have been collected in the Sg. Sebangau catchment for almost ten years with detailed population density information available from 1995/96. As a result, it has been

peat swamp forest for orang utan then this ecosystem will be available for future generations of earth inhabitants (local people, ecotourists and orang utan) to enjoy and be fulfilled.

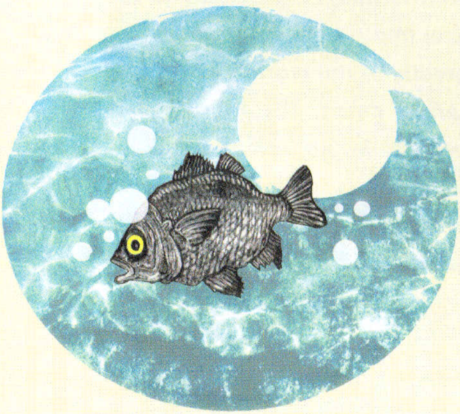
possible to determine changes in population number in different types of peat swamp forest related to logging pressure and fire between then and 2002 and this will provide benchmarks for future evaluation. Without the peat swamp forest the wild orang utan would have no future in Central Kalimantan where it makes up probably at least one third of the remaining world population. The density change patterns of orang utan and their overall numbers are a surrogate measure of the overall health of the peat swamp forest ecosystem and can be used as an overall indicator of its sustainability and compliance with Biorights funding conditions and obligations for local people.

If local people, local government and NGOs (e.g. WWF) in Kalteng focus on maintaining and monitoring the carrying capacity of

6.5 The role of peat swamp forest in maintaining fish resources

The rivers of the Southeast Asian peat swamp forests have long been considered to have a low fish biomass, productivity and diversity owing to their low pH, low oxygen concentrations, toxicity from plant-derived chemicals, lack of transparency, and depauperate invertebrate communities. In the last decade, however, the fish communities of these habitats have been reassessed and many species new to science have been discovered. In the blackwater rivers and pools of the Sebangau catchment, for example, studies carried out in 1994 and 1996 resulted in the collection of 44 species from 17 families, plus up to

10 other specimens which may be new species or subspecies. These, and more recent studies, are beginning to demonstrate that the blackwater rivers and peat swamps of Southeast Asia have a higher degree of fish endemism than alluvial rivers in the region. Many of these fish species utilize the peat swamp forest when it is



flooded for spawning and nursery areas following which they move into the rivers where they can become important commercial species of the riverine and shallow marine environments. As such they are an important source of income to local people that lasts only as long as the peat swamp forests survive.

6.6 Sustainable oil palm

Palm oil is a plant-derived commodity that has a high economic demand on the world market. It is the most productive oil-producing crop in the world and it has an even greater potential in the future. Oil palm is not only a very important crop for satisfying the increasing demand for edible oil in the world, but it has also a potential as a lubricant and could be used for bio-diesel fuel. Oil palm is one of the few crops that have a sustainable future, even though its price fluctuates, because it could contribute to many aspects of environmentally sustainable development. In Indonesia there is a nucleus and plasma concept to make sure that not only plantation owners but also smallholders can grow oil palm, in a way that the crop not only provides profits, but also supports the livelihood of the rural population.

You might ask, quite rightly, 'what about the environmental aspects?' There are claims that oil palm plantations are a major cause of deforestation and it is not possible to go into all aspects of these allegations in this short document. It is true that large areas of forest in Southeast Asia have been converted to oil palm plantations. It is also a fact that more land is probably needed for an expanding oil palm market and, whether we like it or not, forest land is attractive for oil palm as the standing timber provides investors with an initial windfall profit on capital invested. This situation has nothing to do with current proposals to plant oil palm on deforestated and degraded tropical peatlands, where costs of establishment are higher than on forest land. But, there is indeed a large amount of unused, deforested land, especially in Indonesia, which could be an alternative to forest land for future oil palm cultivation. The problem is that short-term costs are involved in making this latter land suitable for oil palm plantation (i.e. land preparation and planting, time delay to first cropping and lack of windfall profits from forest timber). Moreover, various agronomic aspects of peatlands for oil palm have yet to be discussed with the international science community and the authorities.

In relation to Biorights, it is important to note that oil palm, as a long-term crop can be used, to provide land stabilization and help prevent erosion. In the case of peatlands oil palm could make a contribution to reduce the risk of peatland fires, especially in Kalimantan and Sumatra. For many years these fires have been contributing considerably to the Greenhouse Effect by adding greatly to the world's emissions of carbon gases. The authors of this booklet would welcome the opportunity to discuss with potential Biorights investors additional opportunities to use oil palm not only as a means to provide jobs and contribute to incomes, but also how to mobilize oil palm to help protect global biodiversity. The use of oil palm to combat carbon emissions is very relevant in this respect. It is noted that there are new options for discussing its role in the recently in Kuala Lumpur established business initiative in co-operation with WWF : the Round Table on Sustainable Palm Oil.

7. CARBON

The Kyoto Protocol (KP) aims at reducing the concentrations of greenhouse gases in the atmosphere. The Clean Development Mechanism (CDM) is defined in Article 12 of the KP as a flexible procedure for assisting developed countries to achieve their emission reduction commitments and contribute to sustainable development in developing countries. This provides the opportunity to generate funding for investments in sustainable development in developing countries while helping the developed countries to reduce their emissions of greenhouse gases in a cost-effective way.

The options by which changes in land use can contribute to lower concentrations of greenhouse gases in the atmosphere include the following:

1. Avoidance of emissions via preservation of existing carbon stocks. Improved management of forest, cropping and pasture activities, usually involving the use of improved production technologies such as agro-forestry, can reduce emissions and preserve existing carbon stocks. (Avoidance)

2. Capturing and storing carbon in soil and biomass in forest, cropland, grassland and agro-forestry systems. (Sequestration)

3. Substituting fossil fuel with bio-based products, e.g., biofuel. (Substitution)

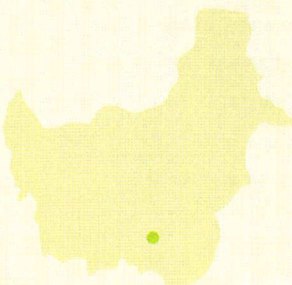
In the CDM activities related to land use, land use change and forestry (LULUCF) are limited to sequestration via forestation and reforestation. Using biomass to replace fossil fuel is not part of the LULUCF but is eligible via the energy paragraph of the KP.

Building up carbon in agricultural soils is not included in the CDM for the first commitment period. Managing soil organic matter can, however, greatly contribute to the carbon balance of a country. Moreover, increasing organic carbon in soils has several other benefits as well, including improving the soil's fertility status, increasing its water holding capacity while preventing soil erosion.

It is anticipated that carbon accumulation in forest, but also agricultural land such as improved pasture, might provide revenues in future, which could add to income generated through Biorights, provided that both financing mechanisms are accepted as complementary mechanisms.

Avoidance of carbon emission by fire prevention is most cost effective in tropical peatlands. Peat fires contribute significantly to global emissions (Page et al. Nature 2003).

Prevention of peat fires could avoid emission rates of over 200 ton of carbon per hectare. Preliminary cost estimates indicate that benefit/cost rates are excellent.



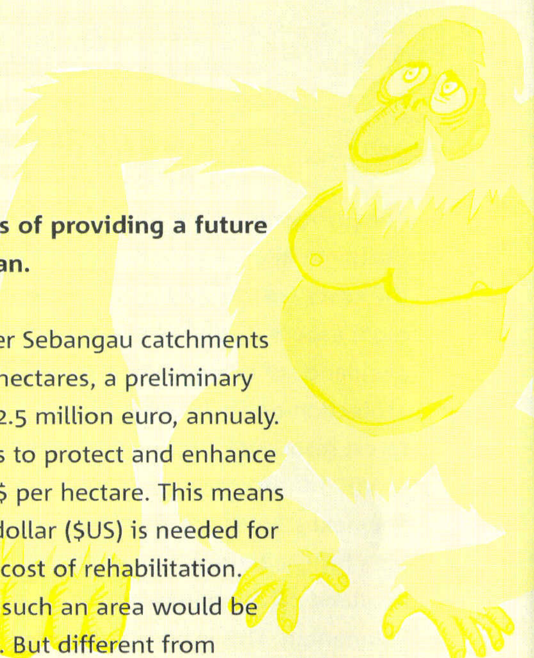
8. WHAT NEXT?

Fire prevention in tropical peatlands should get priority as the costs are low and benefits are high, especially with respect to avoidance of carbon emission and protection of biodiversity and forest resources.

The next step is to make a business plan for the greater Sg. Sebangau peatland catchment in Central Kalimantan. This is one of the last remaining large areas of peat swamp forest wilderness in Indonesia that still has a vast reservoir of biodiversity. This plan should contain an inventory of what it contains in general terms, including, rare and endangered plants and animals, ecological and natural resource functions, socio-economic uses and values and impacts upon these as a result of land use change (e.g. transmigration), fire and unauthorized activities (e.g. illegal logging and hunting).

In addition, opportunity costs arising from restriction of human use of the area should be calculated and the cost of providing alternative jobs and income must be determined. The potential revenue that could be generated to the provincial and local government and local communities from alternative sustainable development mechanisms and the jobs they would create has to be assessed. In this respect it is noted that WWF Indonesia is also facilitating a process to designate about 650,000 hectares of the Sebangau catchment area as a conservation area to save the critical habitat of the orang utan population. Acceptance and support of the relevant stakeholders in the province is considered as crucial.

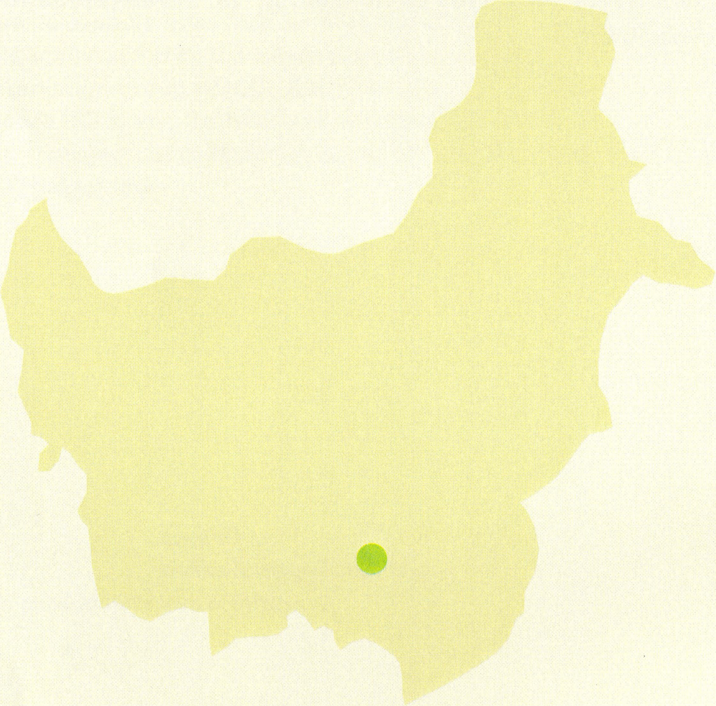
The second stage is to make a similar plan for the 1.5 million hectare former Mega Rice Project area with its devastated, fire-prone degraded peat covered landscape. This is an even a greater challenge!



Example of the economic aspects of providing a future for orang utan.

With respect to conserving the greater Sebangau catchments and watersheds of about 2.5 million hectares, a preliminary estimate of the opportunity costs is 2.5 million euro, annualy. Management costs of the forest areas to protect and enhance biodiversity are estimated to be 2 US$ per hectare. This means that an annual capital of 7.5 million dollar ($US) is needed for 2.5 million ha of land apart from the cost of rehabilitation. Direct costs in Europe for conserving such an area would be 200 million dollar on an annual basis. But different from Kalimantan the income generated by investments in forest conservation in Europe is still much higher compared to these high costs. So the costs involved in Kalimantan cannot be considered peanuts from an investment point of view. But there is hope. There is already a lot of money around for the conservation of biodiversity but so far this has resulted in minimal impact on the survival potential of orang utan. Biorights, however, is about performance and delivery of a successful outcome is everything!

In Indonesia Local and National Government, NGOs and the scientific world have already made a commitment and issued a challenge linked to an excellent idea. The international financial sector and institutions could become involved in this challenging and innovative program on how to promote a sustainable world, by making sure that investments perform and realize a real return for the survival of the life support systems on this planet



Annex 4: STATEMENT ON WISE USE OF TROPICAL PEATLANDS

THE WISE USE OF TROPICAL PEATLANDS

Darwin Initiative, EU-EUTROP Project, International Peat Society and International Mire Conservation Group

In this document, the Darwin Initiative, EU INCO-DC EUTROP Project, International Peat Society (IPS) and International Mire Conservation Group (IMCG) highlight the nature, importance and values of tropical peatlands and identify problems resulting from impacts upon them. Suggestions are made on how these problems may be resolved through application of the "wise use" approach.

Wise use of peatlands[1] is defined as those uses of mires and peatlands for which reasonable people now and in the future will not attribute blame.

Wise use is essential to ensure that sufficient area of this resource remains to carry out vital natural resource functions while satisfying essential requirements of people now and in the future. It involves evaluation of their functions, uses, impacts, and constraints so that, by assessment and reasoning, we are able to highlight priorities for their management and use, including mitigation of past and future damage.

The challenge is to develop mechanisms that can balance the conflicting demands on the tropical peatland heritage to ensure its continued survival to meet the needs of humankind.

WHAT ARE PEATLANDS?

Peatlands are characterized by the unique ability to accumulate and store dead organic material originating from plants that, in the lowland humid tropics, is mostly trees, under waterlogged conditions. Peatlands are the most widespread wetland types in the world, representing 50 to 70 percent, and covering more than four million km^2 (3 percent) of the land and freshwater surface of the planet. They exist on all continents, from tropical to polar zones, and from sea level to high altitude. Peatlands are natural systems performing local, regional and global functions that can mean different things to different people.

In the tropics peatland occurs on mainland East Asia, Southeast Asia, the Caribbean, Central America, South America and southern Africa, wherever rainfall and topography are conducive to poor drainage, permanent waterlogging and substrate acidification all of which slow down organic matter decomposition. The total area of undeveloped tropical peat is estimated to be between 30 and 45 Mha, which is approximately 10-15 per cent of the global peatland resource (Immirzi & Maltby, 1992; Lappalainen, 1996; Page *et al*., 2000).

[1] It is understood in this Statement that the term "peatland" is inclusive of "mire." A peatland is an area of landscape with a naturally accumulated peat layer on its surface. Mire is a peatland on which peat is currently forming and accumulating. All mires are peatlands but peatlands that are no longer accumulating peat would not be considered mires anymore.

Peatlands may be considered as land, wetland, geological deposit, water body, natural habitat, grazing meadow or forest. In some cases, they may be several of these at the same time. Peatlands exhibit extremes of high water and low oxygen content, presence of toxic elements and low availability of plant nutrients.

WHY PAY ATTENTION TO PEATLANDS?

Peatlands provide a wide range of wildlife habitats supporting important biological diversity. They play an important role in maintaining freshwater quality and hydrological integrity, carbon stores and sequestration, and geochemical and palaeo- archives. Peatlands contain one-third of the world's soil carbon and 10 percent of the global freshwater volume. In addition, they contribute to social, economic and cultural values important to human communities worldwide.

Peatlands are used by many stakeholders for agriculture, forestry, industrial applications, pollution control, recreation, tourism, nature conservation, and scientific research, while also providing for the needs and life support of local communities.

HUMAN IMPACT ON PEATLANDS?

Since 1800, the global area of peatlands has been reduced significantly by between 10 and 20 percent. Human activities continue to be the most important factors affecting peatlands, both globally and locally. Human pressures on peatlands are both direct, through drainage, land conversion, excavation, inundation, fire and visitor pressure, and indirect, as a result of air pollution, water contamination, water removal, and infrastructure development.

PEATLANDS: A VITAL LOCAL, REGIONAL AND GLOBAL RESOURCE

Peatlands satisfy many essential human needs for food, fresh water, shelter, warmth, and employment. With the growing understanding of their ecological importance to the planet, conflicting uses of peatlands are rapidly becoming apparent and some examples are outlined below.

■ In Europe, agriculture has been the principal use of peatlands for several centuries, utilizing 125,000 km^2. Well-managed peatland soils are amongst the most productive agricultural lands available, providing essential food crops. Drainage and conversion of peatland to agriculture has been going on for centuries and continues in some parts of the world.

■ In the tropics, peatland utilization commenced later than in Europe, mostly after 1900, but with a considerable increase after the Second World War. The main impacts on peatlands in the tropics are through agriculture and human settlement by land drainage, forest removal, and fire.

■ It is estimated that nearly 150,000 km^2 of the world's peatlands, in many countries, have been drained for commercial forestry but this has not yet happened on tropical peatlands.

■ A small amount of peat is extracted and burned for its energy value in South Sumatra but other evaluations have indicated that this is not yet a viable, commercial source of energy in tropical countries.

■ Temperate peat is an ideal substrate for horticultural and silvicultural plant production, forming the basis of growth media that are readily available, easily processed, uniform, high-performance, and cost-effective. In 1999, nearly 40 million m3 of peat were used in horticulture globally but very little of this use is practiced in the tropics apart from a small horticultural industry for nursery propagation of forestry trees.

■ There are many other uses of peat and peatlands, including leisure and recreation, building and insulation systems, animal stable litter, beverages, environmental improvement and purification systems, balneology, therapy, medicine, and textiles but almost none of these is practiced in the tropics.

PEATLAND CONFLICTS

Peatlands have been depleted or degraded in many countries around the world, owing to short-term or single sector development strategies, which have led to conflicts between different stakeholders. For example:

■ Human impact on peatlands may destroy their nature conservation value;

■ Drainage of peatlands may affect their flood control functions, leading to damage of downstream valley farmlands, bridges and buildings;

■ Drainage of peatlands for agriculture may lead to loss of carbon storage and climate change mitigation functions;

■ Drainage of peatlands and planting them with crops or forests impacts on biodiversity and constrains their use for recreation, berry picking and hunting;

■ Strict nature conservation may impact upon the local socio-economic situation, especially in developing countries.

DECISION-MAKING CRITERIA

Clearly, criteria are needed to assist in land use decision-making involving peatlands. The following guidelines, designed to be applied in their entirety, are intended to promote their wise use.

■ If the use of a peatland resource ensures the availability of the same quantity and quality of that resource there is, except for side effects, no reason to refrain from using the resource.

■ Even when the supply of a peatland resource is decreasing, a particular use could be continued as long as that resource is abundant.

■ If that peatland resource is not abundant and becoming rare, it is unwise to use the resource to the point of exhaustion, as it might be needed for more urgent purposes in the future.

■ The use of a peatland for a specific purpose may have considerable side effects and all other functions must be taken into account in the full assessment of the suitability of a particular use.

■ With respect to side effects, a use could be considered permissible when:

(a) negative side effects will not occur, or
(b) resources and services affected will remain sufficiently abundant, or
(c) resources and services affected can be readily substituted, or
(d) the impact is easily reversible.

■ In all other cases, an integrated cost-benefit analysis should be carried out involving thorough consideration of all aspects of the proposed use.

IMPLEMENTING WISE USE

The EU EUTROP Project partners, International Peat Society and International Mire Conservation Group believe that wise management of tropical peatland ecosystems requires a change of approach from single sector priorities to integrated, holistic planning strategies, involving all stakeholders to ensure that consideration is given to potential impacts on the ecosystem as a whole.

The design of peatland resource management projects involving a wide range of stakeholders is a major challenge that must be met in order to guarantee benefits for future generations.

FUTURE PROSPECTS

Wise use of tropical peatlands will be enhanced by initiatives such as:

- Adoption and promotion of the Ramsar Convention's *Guidelines for Global Action on Peatlands* (GGAP) and implementation of its wise use themes.

- Publication and distribution of the joint IPS/IMCG report: *The Wise Use of Mires and Peatlands – Background and Principles*.

- Implementation of the Global Peatland Initiative (GPI), of which the IPS and IMCG are partners.

- Publication of a handbook of Wise Use Guidelines by the Ramsar Convention and its partner agencies as a means of delivering key aspects of the GGAP.

- Refinement of global criteria for identifying and protecting key peatland sites for conservation purposes.

- Promoting the certification of peat and peatland products.

- Refinement and standardization of peatland classification systems and terminology.

- Promoting targeted scientific and socio-economic research in order to formulate strategies for implementing sustainable management of tropical peatlands according to principles of wise use similar to the objectives of the Darwin Initiative, EU EUTROP and STRAPEAT Projects.

The preparation of this documents has been carried out with financial support from the Darwin Initiative Project: *"Impact of fire and land use change on biodiversity of peat swamp forest in Central Kalimantan, Indonesia"*, EU INCO-DC EUTROP Project: *"Natural resource functions, biodiversity and sustainable management of tropical peatland"* and the Dutch Ministry of Foreign Affairs (DGIS) under the Global Peatland Initiative, managed by Wetlands International in cooperation with the IUCN-Netherlands Committee, Alterra, the International Mire Conservation Group and the International Peatland Society.

For further information on the project activities promoted by the EU INCO-DC EUTROP Project please consult http://www.geography.nottingham.ac.uk/rieley/kalhome/index.htm.

For the complete IPS/IMCG report: *The Wise Use of Mires and Peatlands*, contact the International Peat Society at www.peatsociety.fi or the International Mire Conservation Group at www.imcg.net.

The International Peat Society (IPS) is an international organization of applied and academic scientists, engineers, and business people with a special interest in peat and peatlands about which information can be obtained at http://www.peatsociety.fi.

The International Mire Conservation Group (IMCG) is an international network of specialists having a particular interest in mire and peatland conservation.

Annex 5: GUIDELINES FOR GLOBAL ACTION ON PEATLANDS (GAP)

The Ramsar Convention on Wetlands

Guidelines for Global Action on Peatlands (GAP)

[Resolution VIII.17] [français] [español]

"Wetlands: water, life, and culture"
8th Meeting of the Conference of the Contracting Parties
to the Convention on Wetlands (Ramsar, Iran, 1971)
Valencia, Spain, 18-26 November 2002

Guidelines for Global Action on Peatlands (GAP)

Peatlands and the Ramsar Convention

1. Peat is dead and partially decomposed plant remains that have accumulated *in situ* under waterlogged conditions. Peatlands are landscapes with a peat deposit that may currently support a vegetation that is peat-forming, may not, or may lack vegetation entirely. The presence of peat or vegetation capable of forming peat is the key characteristic of peatlands.

2. In recent years peatlands have become increasingly recognized as a vital part of the world's wetland resources. Approximately half of the world's wetlands, spread across six continents, are peatlands such as bogs, fens, swamp forests and converted peatlands. They are found in all biomes, particularly the boreal, temperate and tropical areas of the planet.

3. Peatlands are recognized throughout the world as a vital economic and ecological resource, though until recently they have received little attention from the international conservation community. Peatlands are ecosystems contributing to biological diversity, the global water cycle, global carbon storage relevant to climate change, and other wetland functions valuable to human communities.

4. Peatlands, especially active peatlands that are accumulating peat, are irreplaceable palaeo-environmental archives from which to reconstruct past landscape change and previous climates, and determine human impact upon the environment.

5. There is a wide range of threats to peatlands that require urgent national and/or international action. The opportunities for wise use, conservation and management (hereafter referred to as 'wise use') of the world's peatland assets are constrained not only by limited scientific and technical information but also by the effects of economic, socio-cultural, and environmental factors. Contracting Parties and partners need to evaluate the significance of these constraints at various scales and within appropriate national frameworks. For example, peatlands in the high Andes of South America are modified by overgrazing, drainage for agriculture, trade in dry peat, and

It is understood in this document that the term "peatland" is inclusive of active peatland ("mire"). A peatland is an area of landscape with a naturally accumulated peat layer on its surface. An active peatland ("mire") is a peatland on which peat is currently forming and accumulating. All active peatlands ("mires") are peatlands but peatlands that are no longer

changes in the natural water courses for human use.

accumulating peat would no longer be considered "mires".

6. Peatlands have a wide international significance and their wise use is relevant to the implementation of the Ramsar Convention, the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and other international instruments and agreements.

7. Peatlands play a special role in conserving global biodiversity because they are the refugia of some of the rarest and most unusual species of wetland-dependent flora and fauna. The CBD-Ramsar Joint Work Plan provides the opportunity to highlight the global contribution of peatlands to biodiversity.

8. Peatlands globally have been identified as a major storehouse of the world's carbon, exceeding that of forests. Peatlands that are actively accumulating organic matter are carbon sinks. Both aspects are worthy of attention by the UNFCCC.

9. It is recognized that the ecosystem approach, underpinned by the Malawi Principles and adopted as a framework for implementation of the CBD, also provides a valuable approach for implementation of these *Guidelines for Global Action on Peatlands* (GAP). This would be consistent with Decision IV/15 at COP4 of the CBD and Resolution VII.15 of Ramsar COP7 referring to the use of an ecosystem approach.

10. In addition to their significance for biodiversity, in many parts of the world peatlands are the predominant wetland type for cultural heritage, notably through their capacity to preserve archaeological remains and the palaeobiological record under waterlogged and deoxygenated conditions. This has been recognized by the European Archaeological Council's 2001 Strategy and Statement of Intent for the Heritage Management of Wetlands, which drew attention to the importance of the wise use of wetlands and the Ramsar Convention for the preservation of these cultural features, and argued that there is much common ground in the wetland biodiversity and cultural heritage management of peatlands.

11. Ramsar Contracting Parties have recognized the global significance of peatlands through Recommendation 6.1 which called for further cooperation on the conservation of global peatlands. These *Guidelines for Global Action on Peatlands* have been developed from the draft Global Action Plan for the Wise Use and Management of Peatlands endorsed by Ramsar Recommendation 7.1. In line with Recommendation 7.1, the guidelines have been further developed through the work of the Convention's International Organization Partners, international peatland conservation organizations, notably the International Peat Society (IPS) and the International Mire Conservation Group (IMCG), and interested Contracting Parties, assisted and evaluated by the Convention's Scientific and Technical Review Panel (STRP) and its expert Working Group on Peatlands.

12. These Guidelines recommend a series of priority approaches and activities for global action on the wise use and management of peatlands under seven themes:

A. Knowledge of global resources
B. Education and public awareness on peatlands
C. Policy and legislative instruments
D. Wise use of peatlands
E. Research networks, regional centres of expertise, and institutional capacity
F. International cooperation
G. Implementation and support

13. The guidelines form the basis for the development of a global action plan for peatlands by Ramsar Contracting Parties, the Convention's bodies, and International Organization Partners and other organizations working to address peatland issues, so as to implement Operational Objective 3.2 of the Ramsar Strategic Plan 2003-2008.

14. The overall aim of the guidelines and their implementation is to achieve recognition of the importance of peatlands to the maintenance of global biodiversity and the storage of the water and carbon that is vital to the world's climate system, and to promote their wise use, conservation and management for the benefit of people and the environment.

15. Taken together the guidelines provide:

a) a framework for national, regional and international initiatives to promote the development of strategies for peatland wise use, conservation, and management;

b) guidance on mechanisms to foster national, regional and international partnerships of government, the private sector, and non-government agencies to fund and implement actions in support of such strategies; and

c) approaches to facilitate adoption and support for implementation of global action on peatlands through the Ramsar Convention, the CBD, the UNFCCC, and other appropriate national, regional or international instruments.

A. Knowledge of global resources

Development and application of standardized terminology and classification systems

16. Many classification systems for peatlands have been developed in different parts of the world, and there is a range of different terminologies that have been developed to define peatlands and peatland processes. When seeking to describe the character, extent and status of peatland resources worldwide, an essential step is to seek to compare and harmonize terminologies and classifications as the basis for achieving a globally consistent view of these resources.

Guidelines for action

A1. In order to review and standardize peatland terminology and classification systems, the Ramsar Convention is encouraged to establish a Working Group on Peatland Terminology, Classification and Biogeography, involving peatland conservation organizations, Contracting Parties, and other interested bodies.

A2. Regional and international workshops and symposia should be convened by the Working Group to review and build consensus on terminologies, classifications, and biogeography.

A3. To assist Contracting Parties and others in compiling information on peatland resources, the Working Group should develop and publish a *Glossary of Peatland Terms*.

A4. The Convention should review the Ramsar Classification System for Wetland Types with regard to peatlands in the light of the Working Group's report on standardized terminology and classification systems.

Establishing a global database of peatlands

17. Inventory and assessment information on peatlands varies from country to country. It is generally patchy, inconsistent, and often difficult to access for those needing to use this vital baseline material for ensuring the wise use of their peatlands. This hinders the recognition of the importance of the peatland resource, its values and functions, and the application by Contracting Parties of measures to ensure the wise use of their peatlands, including the identification and designation of peatlands as Wetlands of International Importance.

18. Ramsar Resolution VII.20 on priorities for wetland inventory urged Contracting Parties to give highest priority to undertaking inventory activities for those wetland types identified as at greatest risk or with poorest information in the *Global Review of Wetland Resources and Priorities for Wetland Inventory* (GroWI) report. The GRoWI report identified peatlands as a priority wetland type noting, in particular, that they are threatened by drainage for agriculture and afforestation in Europe, Asia and North America despite their importance as a global carbon sink and economic resource. Peatlands are poorly known in tropical regions such as Southeast Asia.

Guidelines for action

A5. In order to emphasize the importance of the peatland resource, and to provide the baseline information necessary to assist Contracting Parties and others in their delivery of Global Action for Peatlands, a global database of peatlands should be established and made widely accessible to Contracting Parties and others. The database should be compiled in the first instance from sources of existing information, brought into line with the agreed standardized terminology and classification systems for peatlands, and should include baseline information on the distribution, size, quality, ecological characteristics and biological diversity of the resource.

A6. Contracting Parties, based on national capacity, are urged to provide national information on carbon stored in their peatlands for incorporation in this database.

A7. Contracting Parties, through their National Reports, should report to each Conference of the Parties on their progress in contributing information to the global peatlands database.

A8. The data and information compiled in the global peatlands database should be made available to, and used by, Wetlands International in its role of advising the Convention on the application of the *Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance*. This advice should be designed to assist Contracting Parties in their identification and designation of peatlands as Ramsar sites, noting that peatlands have been identified by the Convention as under-represented in the Ramsar List and urged as a priority for future designations. To assist in such further designations, the database should include information on the biogeography of peatlands.

Detecting changes and trends in the quantity and quality of the peatland resource

19. Since peatlands have been recognized by the Convention as a particularly threatened wetland type, priority should be given to monitoring changes in their status and trends so as to assist Contracting Parties in taking the necessary actions to safeguard their wise use. In addition to on-the-ground assessment and monitoring, modern earth observation remote sensing techniques offer considerable potential for such appraisals over large geographical scales, using a variety of techniques.

Guidelines for action

A9. A standardized monitoring system should be established for use by Contracting Parties in determining the status of, and detecting change in, their peatland resource.

A10. Reporting the status and trends in national peatland condition should form an element of the triennial National Reports prepared by Contracting Parties for each Ramsar COP. Such information should be also made available by Contracting Parties for inclusion in the global peatlands database.

A11. Opportunities for developing remote sensing tools and analyses to assess large-scale status and trends in peatland quality and quantity should be explored with earth observation organizations and agencies, as well as others expert in this field.

A12. Based on the information provided on the status and trends in the peatland resource in National Reports, and the information available in the global peatlands database, regular summary reports of the status and trends of the global peatlands resource should be prepared for consideration by Contracting Parties.

B. Education and public awareness on peatlands

20. In order to ensure that the importance of peatlands as a global wetland biodiversity resource is fully understood, it is important to develop and implement environmental education, training and public awareness programmes focusing on peatlands. The Ramsar Convention's Communication, Education, and Public Awareness Programme (Resolution VIII.31) provides a comprehensive framework for the development and enhancement of wetlands education and public awareness through which peatland education and public awareness can be delivered.

Guidelines for Action

B1. National or sub-national agencies responsible for environmental education should incorporate peatlands as an environmental theme in education programmes targeted at formal, continuing and outreach education, business and industry, as an important element of their implementation of the Ramsar Convention's Communication, Education, and Public Awareness Programme.

B2. Teaching, learning and training resources on peatlands should be developed and promoted, which should explore the associated values of peatlands as well. The materials developed should include a broad base of understanding, experience and skills, with contributions from local communities, women and indigenous people, particularly in areas where peatlands form a significant component of the landscape and culture.

B3. Programmes focusing on peatlands should be developed and promoted for professional and in-service training of wetland planners and managers, at both practitioner and trainer levels, including through the development of training modules in the Ramsar Wetland Training Service, once established.

B4. Citizens should be provided with information and educational materials that will enable them to make informed choices concerning lifestyle and consumer behavior compatible with the wise use of peatlands.

C. Policy and legislative instruments

21. Ramsar Resolution VII.7 provides guidelines for reviewing laws and institutions to promote the conservation and wise use of wetlands (Ramsar Handbook no. 3). These guidelines are designed to assist Contracting Parties in ensuring that they have in place the appropriate legal and institutional framework for effective delivery of their commitments under the Ramsar Convention for the wise use of wetlands (which include, *inter alia*, peatlands), and that other sectoral measures, for example water management mechanisms and legislation, are harmonized and consistent with their wise use objectives.

22. Contracting Parties have recognized that peatlands are an under-represented wetland type in the Ramsar List of Wetlands of International Importance and have afforded priority to the designation of peatlands as Ramsar sites. To assist Contracting Parties in the identification and designation of such sites, COP8 has adopted additional guidance on their designation (Resolution VIII.11).

Guidelines for Action

C1. Contracting Parties should review their present frameworks of national policies, laws and incentive programmes relevant to peatlands utilizing the Ramsar *Guidelines for reviewing laws and institutions to promote the conservation and wise use of wetlands* (Ramsar Handbook no. 3) so as to identify the main barriers to, and opportunities for, making wise use of peatlands more effective. These measures should be strengthened where peatlands are at significant risk owing to resource development or other pressures.

C2. Contracting Parties should endeavour to ensure that national legislation and policies relating to peatlands are compatible with other international commitments and obligations.

C3. Contracting Parties should ensure that the particular importance and requirements of peatland wise use are fully incorporated into national wetland and biodiversity strategies and plans and land use planning instruments, and that national wetland policies developed in line with the guidelines adopted by Ramsar Resolution VII.6 (Ramsar Handbook no. 2) fully incorporate the implementation of the wise use of peatlands.

C4. Reviews of national networks of peatland protected areas should be undertaken. Where there is a currently incomplete network of peatland sites within a national system of protected areas, as appropriate, the number of peatland reserves, parks or other types of protected peatlands should be increased.

C5. The conservation of nationally, regionally and globally important and representative peatland types should be further secured through the expansion of the global network of Ramsar sites, applying the *Guidance for identifying and designating peatlands, wet grasslands, mangroves and coral reefs as Wetlands of International Importance* adopted by COP8 (Resolution VIII.11).

C6. Contracting Parties should, in line with Resolution VII.17, establish policies to implement peatland restoration and rehabilitation, where appropriate seeking the assistance of countries, and the private sector, with knowledge in these fields, utilizing the *Principles and guidelines for wetland restoration adopted by COP8* (Resolution VIII.16).

D. Wise use of peatlands

23. The wise use management of peatlands, including restoration and rehabilitation, should be treated as a priority by all Contracting Parties that have peatland resources within their territory. In order to assist Contracting Parties and all other bodies and organizations involved in peatland management and exploitation in ensuring that peatlands are used wisely, global guidelines for peatland wise use and management are being developed by a consortium of peatland organizations, including the International Peat Society (IPS) and the International Mire Conservation Group (IMCG). Such wise use and

management guidelines are recommended as a source of further information and expertise for ensuring sustainable peatland management.

24. Given that the biogeography of peatlands is often regional in nature, Contracting Parties and others should consider the need for management guidelines and action plans that can be developed and implemented at appropriate regional as well as national scales and also, where appropriate, at the scale of whole catchment basins, in line with the *Guidelines for integrating wetland conservation and wise use into river basin management* (Ramsar Handbook no. 4). Such implementation may be facilitated by the establishment of regional centres of expertise (see Guideline E4 below).

Guidelines for Action

D1. Peatland wise use principles should be applied through the acquisition of information on the effectiveness of various socio-economic incentive measures and by enabling instruments to facilitate the equitable sharing of the costs and benefits of different management options.

D2. Best management practices and peatland restoration should be promoted by Contracting Parties as an important input to Ramsar principles and other international conventions such as CBD and UNFCCC.

D3. In developing their strategies and policies for the wise use of peatlands, and in particular their management planning for Ramsar sites and other wetlands, Contracting Parties should ensure that the cultural heritage significance of peatlands is fully taken into account, and should work closely with their counterpart heritage management agencies and bodies to achieve this.

D4. The development of local and community-based peatland wise use initiatives and actions should be fostered through land use planning programmes, with the support of the development assistance agencies, particularly those programmes affecting, and to be implemented by, women, indigenous people, and local communities, utilizing the Ramsar Guidelines for establishing and strengthening local communities' and indigenous peoples' participation in the management of wetlands (Ramsar Handbook no. 5).

D5. Measures should be undertaken to restore peatland functions in those systems that have been degraded through human activity, drawing on experience and best management practices from different regions.

E. Research networks, regional centres of expertise, and institutional capacity

25. In order to improve implementation of the wise use of peatlands, it is necessary for countries to review and ensure that they have in place the necessary institutional capacity. It is also necessary to provide peatland managers and those responsible for policy related to the wise use and exploitation of peatlands with improved access to information and training facilities, in order to enhance their capacity.

26. The Ramsar Wetland Training Service being established by Wetlands International will provide a mechanism for developing training in peatland management and wise use, so as to support the priority afforded to peatlands under the Convention as a globally threatened wetland type that is under-represented in the Ramsar List of Wetlands of International Importance.

Guidelines for Action

E1. Networks for research and programme cooperation should be established, involving research institutes and other peatland scientific organizations so as to share knowledge and information and improve understanding of the biodiversity, ecological character, values, and functions of the world's peatlands.

E2. Research institutes and other peatland scientific organizations should seek opportunities for the development of cooperative scientific and management studies to fill the identified gaps in the knowledge required to implement peatland wise use. The GAP Coordinating Committee (see Guideline G1 below) should assist in this process by reviewing and identifying such gaps.

E3. Opportunities should be sought for cooperative research to further elucidate the role of peatlands in mitigating the impacts of global climate change, in line with the gaps in knowledge identified by the comprehensive review of "Wetlands and climate change: impacts and mitigation" submitted to Ramsar COP8.

E4. The creation of Regional Centres of Expertise in the wise use and management of peatlands should be promoted for training and the transfer of knowledge in order to assist developing countries and those with economies in transition to increase their capacity for implementation of wise use of peatlands.

E5. Peatlands suitable for restoration and rehabilitation should be identified following the procedures outlined in the *Principles and guidelines on wetland restoration* adopted by Ramsar COP8 (Resolution VIII.16), and research and transfer of technologies for peatland management and the restoration and rehabilitation of appropriate peatlands should be facilitated, particularly for local community use in developing countries and countries with economies in transition.

E6. Contracting Parties should encourage the establishment and activities of national and local organizations with expertise in peatland management.

E7. Research into, and development of, appropriate sustainable alternatives to peat in, for example, horticultural use, should be encouraged.

F. International cooperation

27. Peatlands are a widely distributed wetland resource worldwide, with many extensive systems crossing geopolitical boundaries. There is much to be gained by Contracting Parties and others sharing their knowledge and expertise in the wise use and sustainable management of this key component of the world's wetlands through international cooperation, in line with the *Guidelines for international cooperation under the Ramsar Convention on Wetlands* (Ramsar Handbook no. 9).

28. Furthermore, efforts towards the wise use of peatlands can contribute to the delivery of not only the Ramsar Convention but other multilateral environmental agreements, including the CBD, in particular its programme of work on the biological diversity of inland waters, and the UNFCCC.

Guidelines for Action

F1. Peatland wise use and management issues should be fully addressed in the discussions and resolutions prepared for the meetings of the Conference of the Parties and subsidiary bodies of the Ramsar Convention. These issues should also be taken into account, where appropriate, in other multilateral environmental agreements, notably CBD and UNFCCC, including consideration of joint action plans on peatlands.

F2. International cooperation between Contracting Parties and others for global actions developed to address peatland issues should be coordinated in cooperation with peatland stakeholders and other interested parties (see also guideline G1 below).

29. Implementation of Guidelines for Action E1-E5 above concerning cooperative action on research and technology transfer for peatland wise use also contributes to the delivery of international cooperation on peatland wise use.

G. Implementation and support

30. In order to assist and coordinate between Contracting Parties, the bodies of the Convention, specialist peatland organizations and others in developing actions for the implementation of these Guidelines for Global Action on Peatlands, it will be necessary to establish communication and coordination mechanisms, and for these to review regularly progress and future priorities for global action on peatlands under the Convention and report these to the meetings of the Conference of the Parties.

Guidelines for Action

G1. A Coordinating Committee for Global Action on Peatlands should be established, as resources permit. The Coordinating Committee should be chaired by the Ramsar Bureau and comprise governments and invited partner organizations and be geographically balanced.

G2. The GAP Coordinating Committee should develop a global implementation plan which specifies the actions needed for the implementation of these Guidelines, including initiatives and timetables to deliver the priority actions identified by the Guidelines, and track and review the progress of their implementation.

G3. Contracting Parties and others should assist the GAP Coordinating Committee in identifying sources of funding in order to implement the actions identified in the implementation plan for global action on peatlands.

G4. The Coordinating Committee should develop and implement a monitoring and reporting procedure to evaluate the effectiveness of implementation of these Guidelines for Global Action on Peatlands and their global implementation plan, and report to Ramsar COP9 on the progress, including the progress of the Working Group on Peatland Terminology, Classification, and Biogeography, once established (see Guideline A1 above), and improvements to knowledge of the global peatland resource (see Guidelines A7, A10 and A11).

G5. The GAP Coordinating Committee should review and prepare for COP9 recommendations on future priorities and implementation of these Guidelines for the 2006-2008 triennium and for subsequent meetings of the Conference of the Parties as appropriate.

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