Chapter 6
Peatland in Kalimantan

Mitsuru Osaki, Bambang Setiadi, Hidenori Takahashi, and Muhammad Evri

Abstract Peatland area in Indonesia was about 14.91 million ha spread out in Sumatra 6.44 million ha (43 %), in Kalimantan 4.78 million ha (32 %), and in Papua islands 3.69 million ha (25 %). In 1995, Mega Rice Project (MRP) in tropical peatland launched in Central Kalimantan, of which project failed because of knowledge gaps, especially on peatland hydrology, water management, peat subsidence, impacts of long term drainage, mechanization problems on peatland and socio-economic consequences.

This paper focuses on the peatland ecosystem affected by climate change, specifically the rainfall, relating with the position of the Intertropical convergence zone (ITCZ), which has a strong influence on the seasonal variations, and the seasonal patterns of rainfall variation in different parts of Indonesia. Further, to gain a better understanding of El Niño related phenomena, we provide details of the relationship among the Southern Oscillation index (SOI), the rainfalls during dry season in Central Kalimantan, and the lowest annual groundwater level in the tropical peatlands.

Kalimantan, Indonesia side of Borneo Island, has two big water storage system in peatland near costal area and humid forest of Hurt of Borneo at central mountain area. In Kalimantan, there are Main Three River Basins: the Kahayan, Mahakam, and Kapuas Rivers, which connect the Heart of Borneo with the Mountain Ranges in Borneo (*Water Tower*) and peatland downstream (*Water Pool*). As both Heart of Borneo (*Water Tower*) and peatland (*Water Pool*) interact mutually, both ecosystems destruction will induce the reduction of resilience and increase of vulnerability.

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6.1 Introduction

Particulars of peatlands in Indonesia are estimated as 20.7 Mha of area (47 % of total tropical peatlands), 1138 Gm^3 of volume (65 % of the total tropical peatlands), 57.4 Gt of accumulated carbon (65 % of total tropical peatlands), and with an average 5.5 m thick peat layers (Page et al. 2011).

Kalimantan is the name given to the Indonesian portion of the large island of Borneo, the third largest island in the world after Greenland and New Guinea (MacKinnon et al. 1996).

Peatland area in Indonesia was about 14.91 million ha spread out in Sumatra 6.44 million ha (43 %), in Kalimantan 4.78 million ha (32 %), and in Papua islands 3.69 million ha (25 %). Thus, Kalimantan is one of key area for tropical peatland, which has been affected seriously on both human and climate change impacts.

6.2 Climate Conditions in Kalimantan

According to the Köppen classification system, the climate of a tropical rain forest (Class Af) is characterized by all 12 months having average precipitation of at least 60 mm. These climate zones are commonly distributed within 5–10° latitude of the equator. The climate in Indonesia is influenced by two monsoon periods, the Northeast “wet” Monsoon from November to February and the Southwest “dry” Monsoon from April to September. During the Northeast Monsoon, Australia and South-East Asia receive large amounts of rainfall, while the Southwest Monsoon normally brings relatively drier weather. The jet stream in this region splits into the southern subtropical jet and the polar jet streams. The subtropical arm directs northeasterly winds across south Asia, creating dry air streams which produce clear skies over India from the months of November to May. The Southwest Monsoon is drawn towards the Himalayas, creating winds blowing rain clouds towards India, which receive up to 10,000 mm of rain in some areas.

Intertropical Convergence Zone (ITCZ) Effect on Peatland In the Northern Hemisphere summer (July), the position of the ITCZ, which affects the tropical climate, stretches westward and northward from the Indian Ocean to approximately 30° north latitude, and reaches near the equator in the central Pacific Ocean, reaching the Himalayas and crossing southern China. In the Northern Hemisphere winter (January), it spreads to the south across Africa and reaches the Australian continent (Fig. 6.1). All of Indonesia lies in the annual fluctuation range of the ITCZ, and has a rainy season from October to April when the ITCZ passes across the country. However, the position of ITCZ is complicated due to the influence of the

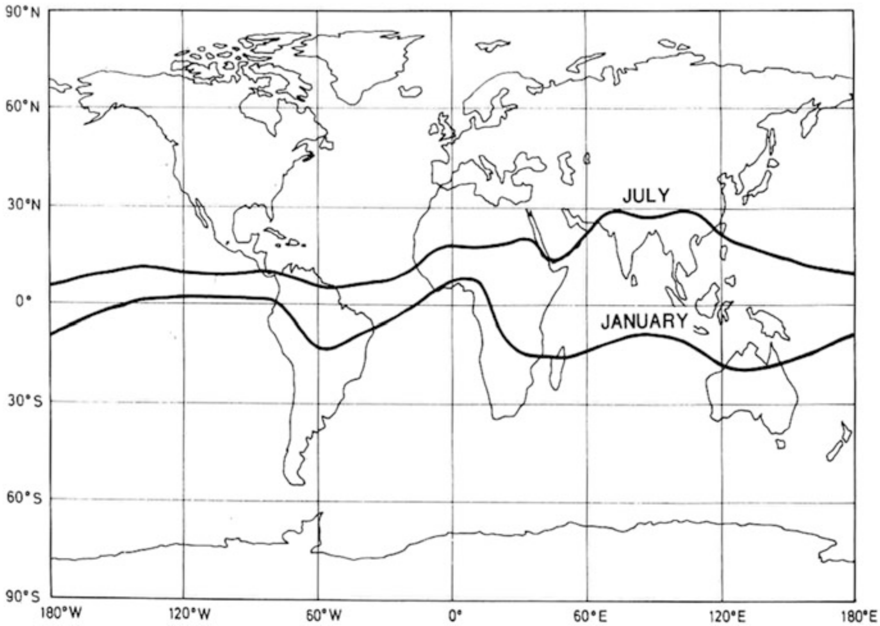

Fig. 6.1 Mean positions of the Intertropical Convergence Zone (ITCZ) in January and July (Henderson-Sellers and Robinson 1986)

land areas, from India to the Indochinese Peninsula, and different parts of Indonesia experience different intensities of rainy and dry seasons at different times of the year.

Figure 6.2 shows the seasonal fluctuations of rainfall at different locations in Indonesia based on data for the 10 years from 2001 to 2010 provided by the Indonesian Agency for Meteorology, Climatology and Geophysics. In Jakarta, Surabaya, Ujung Pandang, and Kupang, which are all located south of the equator, the monthly total amounts of rainfall is the lowest in July and August when the ITCZ is at the northern limit of its range. However, the monthly rainfall in July and August does not decrease extremely even when the ITCZ is at the equator or immediately to the north of the equator, and there is no distinguishable dry season at these locations. There are some areas including at Medan and Manado, where the average monthly rainfall decreases in January and February when the ITCZ is located to the south. Also, some areas such as at Pontianak, Pekanbaru, Padan, Palembang, and Palangka Raya, experience a mild dry season in February and March when there is some decrease in the rainfall, although it is a smaller decrease than in July and August.

According to the climate zones of Koepen, most parts of Indonesia excluding some parts of the mountainous regions have a Wet equatorial climate, *Af*, the mean temperatures in the coldest month are higher than 18 °C. At high altitudes, above 1500 m along the Kalimantan border between Indonesia and Malaysia, the climate is

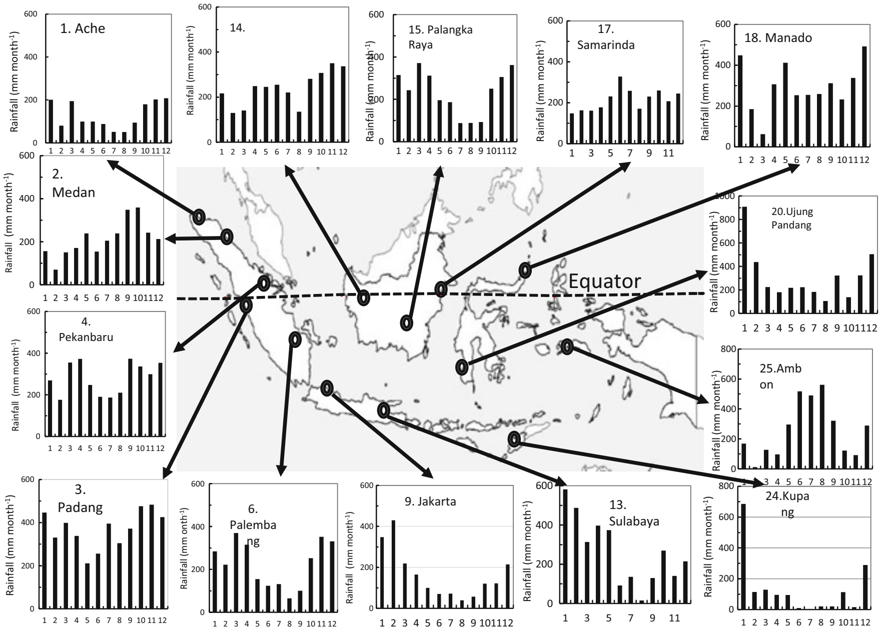

Fig. 6.2 Annual changes in monthly total amount of rainfall (mm), 10 year average from 2001 to 2010, in Indonesia (Data source: Rain data table of the Indonesian Agency for Meteorology, Climatology and Geophysics)

classified as Humid subtropical climate, Cfa. The eastern part of Jawa has relatively little rain, and some parts with Tropical savanna climate, *Aw*. Figure 6.3 plots climatic global peatland diagram that show the monthly mean temperature versus the total rainfall in Pontianak in west Kalimantan with this data for peatlands of various other parts of the world. Peatlands in Indonesia are clearly tropical, those in the Florida Peninsula in North America are subtropical, the wetlands in Kushiro and Sarobetsu are in cool temperate areas, and those in northern Siberia are cold temperate pleatlands.

Rainfall during the dry season and El Nino phenomena in Kalimantan Kalimantan can be divided broadly into five agroclimatic zones based on the mean monthly rainfall. About 43 % of the land area of Kalimantan is classified into zone A (wet season more than 9 months and dry less than 2 months), a large percentage of the peatland areas of Central Kalimantan are classified in zone C with 5–6 months wet and 2–3 months dry seasons. According to this classification, a month is considered “dry” when the mean monthly rainfall is less than 100 mm and “wet” when the mean monthly rainfall is more than 200 mm (MacKinnon et al. 1996). This is the zone where there is the combination of high temperatures (mean temperature of all months higher than 18 °C) and sufficient soil moisture for prolific vegetation growth. In South and Central Kalimantan rainfall generally increases northwards, inland from the coast.

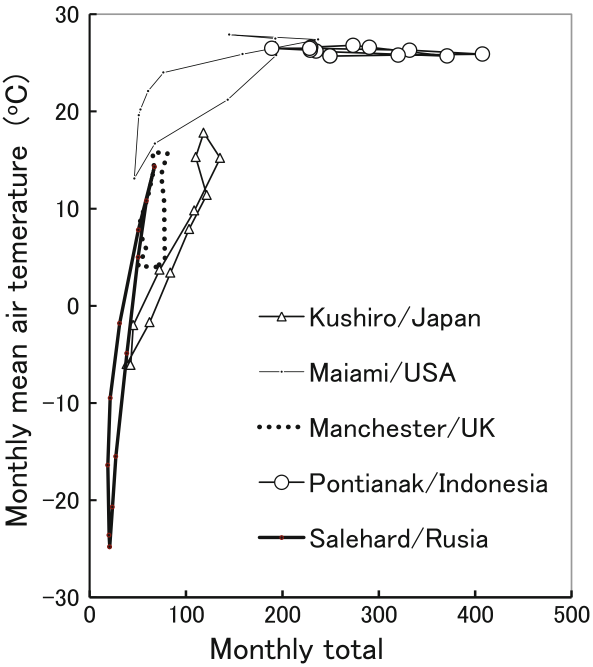

Fig. 6.3 Climatic global peatland diagram classified by monthly mean air temperature and monthly total rainfall

In the ocean upwelling area off the coasts of Peru, nutrient-rich cold water regularly rises to the surface, although the temperature of the surface is lower than the surroundings. However, every 3 or 4 years this upwelling flow weakens and warm seawater of the equatorial countercurrent flows into the area. Then the air layers warmed by this warm sea surface rises off the coast of Peru, and after flowing west across the South Pacific gives rise to a descending air current near Indonesia. Due to this descending air current Indonesia then suffers from a climate condition with little rain, resulting in a prolonged dry season (Fig. 6.4). This phenomenon is the so-called El Nino, and the intensity of the occurrence is determined by the Southern Oscillation index (SOI), which is computed from fluctuations in the surface air pressure difference between Tahiti in the South Pacific and Darwin, Australia. Anomalous dry seasons occurred frequently in this area due to the effect of ENSO events, such as in the years 1982, 1987, 1991, 1994, 1997, and 2002 (MacKinnon et al. 1996; Schimel and Baker 2002; Wooster and Strub 2002a, b; Aldhous 2004; Slik 2004), and there have been further ENSO events in 2006 and 2009.

Figure 6.5a plots the SOI for the 33 years from 1978 to 2010 versus the mean rainfall for the 5 months from June to October (Japan Meteorological Agency 2014) as it deviates from the total rainfall for the 5 months from June to October, the dry season in Palangka Raya, Central Kalimantan (Fig. 6.5a). The figure shows a clearly positive correlation between the SOI and the rainfall during dry season in Palangka Raya, with the coefficient of determination ($R^2 = 0.59$), indicating that El

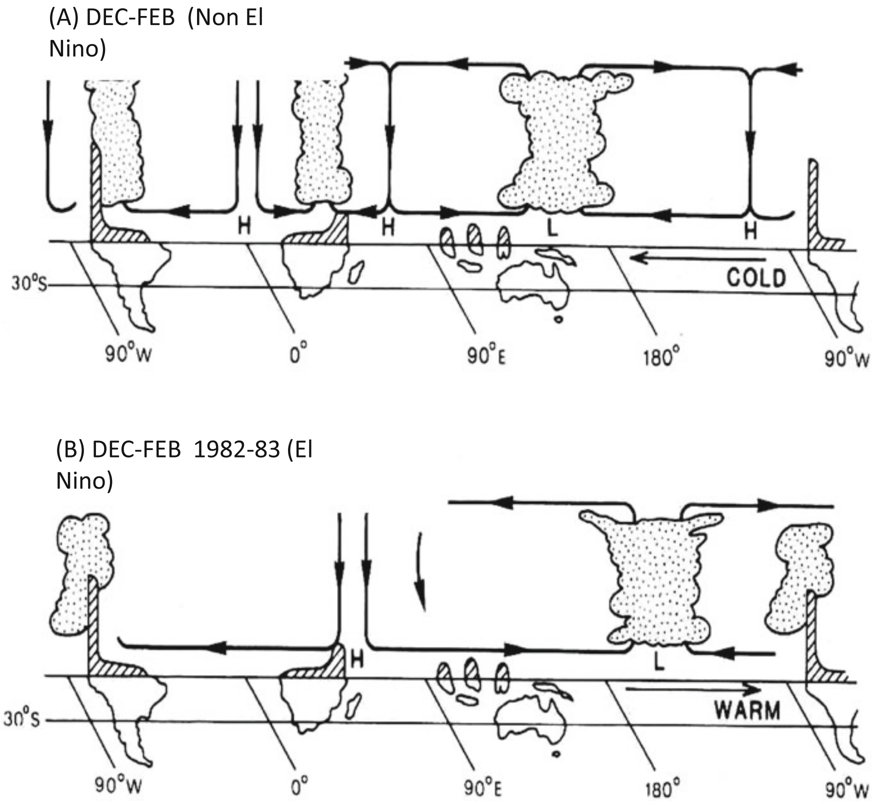

Fig. 6.4 Cross-sections of the walker circulation along the equator during non El Nino (**a**) and El Nino (**b**) events in 1982–1983 (Barry and Chorley 1989)

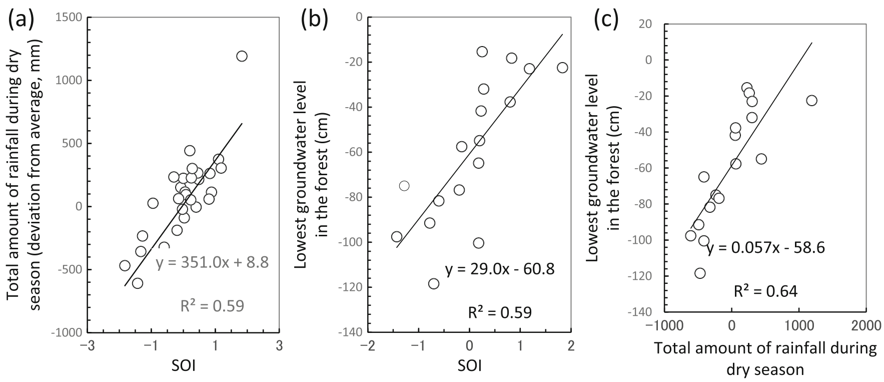

Fig. 6.5 Plot of (**a**) SOI versus the total amount of rainfall during the dry season at Palangka Raya, (**b**) SOI versus the lowest groundwater level in the tropical peatland/forest in Central Kalimantan, and (**c**) the total amount of rainfall during the dry season versus the lowest groundwater level in the tropical peatland/forest

Nino affects the rainfall during the dry season in Central Kalimantan. Figure 6.5b shows the annual lowest groundwater level in the tropical peat swamp forests in Central Kalimantan, recorded from 1993 (Takahashi and Yonetani 1997) and plotted against the SOI, this plot shows a significant correlation with the SOI, also with the coefficient of determination ($R^2 = 0.59$), and as shown in Fig. 6.5c there is a slightly higher correlation between the total rainfall during the dry season and the annual lowest groundwater level with the coefficient of determination ($R^2 = 0.64$).

The correlations among the SOI, the total rainfall during the dry season in Palangka Raya, and the annual lowest groundwater level in the tropical peat swamp forest strongly suggest that the rainfall during the dry season in Central Kalimantan decreases during El Nino events, and that this lowers the groundwater level of peatlands. The decrease in the groundwater level of the peatlands is a major cause of outbreaks of the peat fires in this area (Jaya et al. 2012).

6.3 Water Stock and Water Networks in Kalimantan

The water volume contained in the tropical peat in central Kalimantan is about 95 % when it is saturated at high groundwater levels, but it decreases to about 25 % and fire risks become high when droughts continue in the dry season in the drained areas (Takahashi, unpublished data). Assuming the potential retained water capacity as 95 %, the water retention capacity of Indonesian peat is about 1100 Gm^3, and this acts as a huge reservoir. For comparison the total reservoir capacity of dams in Japan is 20.4 Gm^3 (http://damnet.or.jp/cgi-bin/binranB/TPage.cgi?id=19). These data suggest that the water volume accumulated in tropical peat areas is huge, and changes in the water environment due to a terminal disturbance of this ecology will have a serious impact on global ecology and the environment. For this reason it is urgently important to conduct an analysis and modeling of the water flux of these areas because there is no adequate basic data at present.

The Heart of Borneo (HoB) Initiative is a conservation and sustainable development program aimed at conserving and managing the contiguous tropical forest in the island of Borneo (Fig. 6.6). The HoB covers approximately 200,000 km^2 of ecologically inter-connected rainforest in the provinces of Kalimantan (Indonesia), the states of Sabah and Sarawak (Malaysia), and Brunei Darussalam. The Heart of Borneo initiative has been developed and implemented to prevent unsustainable use of high economic value natural resources that are at serious risk by illegal and unsustainable activities from environmental and social aspects in the areas of jurisdiction of the three countries. An expression of commitment through a declaration entitled "*Three Countries*, *One Conservation Vision*" was announced in Bali on 12 February 2007.

The HoB program is a coordinating regional partnership providing equal responsibility and assigning roles among the three countries. The remaining tropical rainforest with high conservation value in the world is an important area for the global community and international institutional support is provided by priority

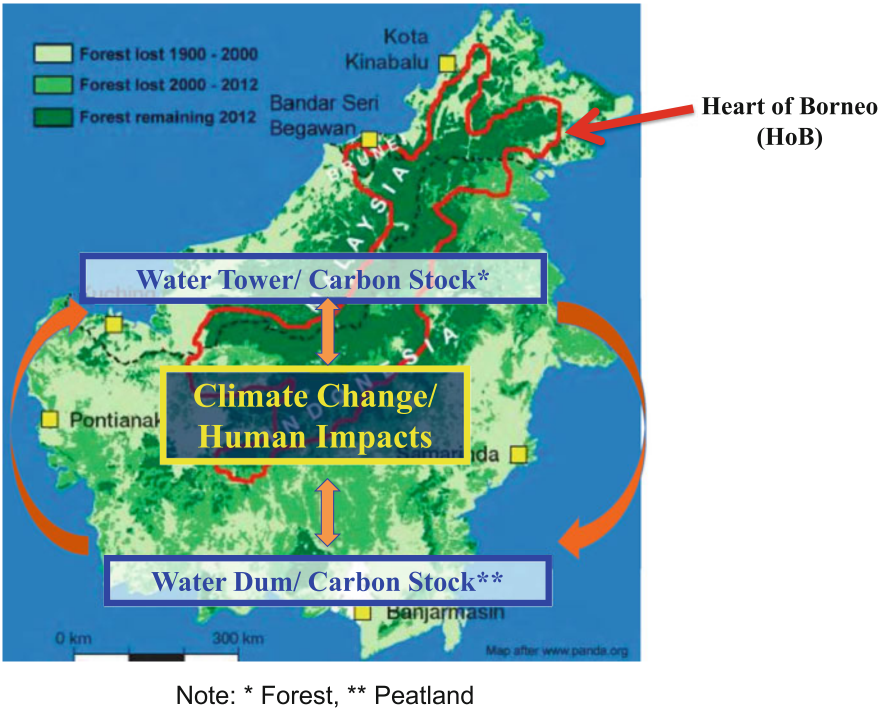

Fig. 6.6 Diagram of the carbon-water relationship in Kalimantan (the *red line* shows the Boundary of the Heart of Borneo (HoB))

programs such as: the Transboundary Management; Protected Areas Management; Sustainable Resources Management; Ecotourism Development; and Capacity Building.

In Kalimantan, there are Main Three River Basins: the Kahayan, Mahakam, and Kapuas Rivers, which connect the Heart of Borneo with the Mountain Ranges in Borneo (*Water Tower*) and peatland downstream (*Water Pool*) (Figs. 6.6 and 6.7). The Water Tower supplies water to the Water Pool through the water available in forests and rivers, and also the Water Pool supplies water by water cycling through rain. Thus, Human Impact and Biodiversity, and not only climate change also affect the Water Buffer and Water Cycle in the forest.

Kahayan River The Kahayan River, or the Great Dayak, is the largest river in Central Kalimantan, and the capital Palangka Raya of Central Kalimantan Province lies on this river, located close to the tropical peatland-forest area, and approximately 120 km from the Java Sea, at an elevation between 15 and 20 m above sea level (MacKinnon et al. 1996).

The inhabitants are mainly Dayaks, who practice slash-and-burn rice cultivation and pan for gold on the upper reaches of the river. The lower Kahayan flows through

Fig. 6.7 River network connecting the Heart of Borneo (HoB) and the Peatlands of Kalimantan (The three main rivers are: Kahayan, Mahakan and Kapuas rivers)

a rich and unusual environment of peat swamp forests, which has been severely degraded by an unsuccessful program to convert a large part of the area into rice paddies, and the degrading has been compounded by legal and illegal forestry. Central Kalimantan covers 153,800 km^2, with 82 % tropical rain forest and no more than 3 % agricultural land. The northern part of the province is mountainous, the central area has flat and fertile tropical forests and the southern area is swampy. The forests provide rattan, resin, and high-quality woods. The climate is hot and humid, typically around 30 °C throughout the year. Annual rainfall is between 2800 and 3400 mm.

The Kahayan River rises in the northern mountains, then meanders for 600 km southward through the plains to the Java Sea. Tidal effects are felt 50–80 km inland from the sea. A recent study found 28 species of fish in the river, 44 species in the Danau Sabuah Lake and 12 species in traditional fish ponds along the river. The riparian wetlands are the main spawning areas, however fishermen are recently reporting declining yields due to problems with the water quality. The lower reaches of the Kahayan River formerly flowed through a huge area of peat swamp forest, an unusual ecology that is home to many unique or rare species such as Orangutans, as well as to slow-growing but valuable trees. The peat swamp forest is a dual ecosystem, with diverse tropical trees standing on a 10–12 m layer of partly decayed and waterlogged plant material, which in turn covers relatively infertile soil. The peat swamp forests were being slowly cleared for small scale farming and plantations before 1997, but most of the original cover remained.

In 1996 the government initiated the Mega Rice Project (MRP), which aimed to convert 1 million ha of peat swamp forest to rice paddy. Between 1996 and 1998, more than 4000 km of drainage and irrigation channels were dug, and deforestation started in part through legal and illegal forestry and in part through burning. It turned out that the channels were draining the peat forests rather than irrigating them. Where the forests had often flooded up to 2 m deep in the rainy season, now the surface is dry at all times of the year. The government has therefore abandoned the MRP, but the drying peat is vulnerable to fires which continue to break out on a massive scale. Peat forest destruction is causing sulphuric acid pollution of the rivers. In the rainy seasons, the canals are discharging acidic water with a high ratio of pyritic sulphate into the Kahayan River up to 150 km upstream from the river mouth. This may be a factor contributing to lower fish catches.

Mahakam River The Mahakam River basin is considered to retain the biodiversity and health of the tropical Kalimantan riparian zone and logged over forest areas: it is evaluated as a reference to develop restoration practices that are adaptive to climate change. The Mahakam River rises at Cemaru in the mountains of Kalimantan, and flows about 650 km east-southeast to the Makassar Strait (MacKinnon et al. 1996). The Mahakam River is the largest river in East Kalimantan, with an approximately 77,100 km^2 catchment area. The Mahakam River flows meet the Kedang Pahu River, through the Mahakam lakes region, which is a flat tropical lowland area surrounded by peat land, and also connected with the Semayang and Melintang lakes downstream. There are about 76 lakes in the Mahakam river basin and about 30 are at the middle reaches of the Mahakam area, including the three main lakes. A wetland at the river mouth delta has been developing and holds Samarinda, the capital of Kalimantan Timur (East Borneo) province.

The Mahakam delta is a mixed fluvial-taidal delta. The delta covers about 1800 km^2, consisting of mangrove areas near the shore, Nypa swamps in the central areas, and lowland forest near the start of the delta. Recent fishery development in this area has converted a vast area of mangrove into shrimp ponds (tambak).

Kapuas River The Kapuas River is the largest river on the islands off South East Asia. The river rises in the Kapuas Hulu Mountains in the central part of the Kalimantan and flows 1143 km west-southwest, from 114° to 108° E., and reaches in a very large marshy delta west-southwest of Pontianak. The physical characteristics of the Kapuas River are flat, wide, and with many meanders. This majestic river is one of the important rivers that feed into the South China Sea, the largest marginal sea in the world.

About 350 km from the source, near the northern shore of the river, there is the Kapuas Lake group which is connected to the river by numerous channels. These lakes include the Bekuan (area 1268 ha), Belida (600 ha), Genali (2000 ha), Keleka Tangai (756 ha), Luar (5208 ha), Pengembung (1548 ha), Sambor (673 ha), Sekawi (672 ha), Sentarum (2324 ha), Sependan (604 ha), Seriang (1412) Sumbai (800 ha), Sumpa (664), and Tekenang (1564 ha) (MacKinnon et al. 1996). The delta is west-southwest of Pontianak, the capital of the province of West Kalimantan, which lies at the equator. The delta has five arms, of which the northernmost is the widest, the *Kapuas Besar* (Big Kapuas). The largest tributary is the Melawi River, which flows into the Kapuas River from the left near the city of Sintang, about 465 km from the mouth. Other major tributaries are the Landak, Kubu, Punggur, and Sekayam rivers (MacKinnon et al. 1996).

6.4 Peatland Eco-systems of Kalimantan

In Kalimantan, trees of the family Dipterocarpaceae dominate in terms of abundance, density and biomass (Appanah and Turnbull 1998). Slik et al. (2003) found that the ten most abundant tree families after Dipterocarpaceae were Euphorbiaceae, Myrtaceae, Sapotaceae, Lauraceae, Myristicaceae, Burseraceae, Anacardiaceae, Ebenaceae, Annonaceae, and Guttiferae.

Some commercial tree species from tropical peat-swamp forests can be utilized in reforestation programmes, for example: *Shorea balangeran*, *Dyera polyphyla*, *Gonystylus bancanus*, *Alsodophan* sp., *Alstonia pneumatophora*, *Calophyllum* spp., and others. Timber from the ecosystems here is used in building boats, furniture, and homes, as well as for firewood and for charcoal by the local population (Sosef et al. 1998). Some tree species are used for medical purposes because of their antimicrobial activity and the presence of other biologically active compounds such as coumarins, xanthones, and terpenoids. Recently, the *Calophyllum* species has received considerable attention from pharmacological interests because they contain compounds that strongly inhibit HIV (*human immunodeficiency virus*) reverse transcriptase (Reyes-Chilpa et al. 1997).

Tropical peat-swamp forest areas have diminished due to forest fires, overexploitation, and development of highways, industrial, and agricultural land, and also plantation estates (Phillips 1998). Today, degraded peat-swamp forests require extensive rehabilitation and an annual supply of high-quality seedlings. The major obstacle in the rehabilitation of peat-swamp forests is the slow growth and the high mortality of seedlings in the nurseries destined for reforestation.

About 258.650 higher plant species are recorded in the world and about 13–15 % of these are found in Indonesia (about 35.000–40.000 species). At least 5575 higher plant species were recorded in Kalimantan, 71 lichen species, 376 mosses, 235 fungi and other families (Widjaja et al. 2011).

From long term monitoring it has been recorded that the Kalampangan peat swamp forest before the onset of the wildfires was dominated by: *Combretocarpus rotundatus*, *Palaquium cochlorifolium*, *Callophyllum canum*, *Ctenolophon parvifolius*, and *Cratoxylum glaucum*, but the forest has degraded due to the building of man made canals and there were wildfires in December 1997 and September 2002. After the 2002 forest fire, the dominant species were: *Co. rotundatus*, *Cratoxylum arborescens*, *Palaquium gutta*, *Shorea teysmaniana* and *Syzygium ochneocarpum*. Of 1158 individual trees, 1102 were considered to have been established after the wildfires, while the remaining 56 individuals were pre-fire trees that survived the wildfires of December 1997, most belong to: *C. canum*, *Co. rotundatus*, *Dyera lowii*, *and P. gutta* species. In September 2002 wildfires burnt out all trees within the surveyed plot for the second time, leaving only two *Dyera lowii* trees still standing and producing new leaves in August 2004, and both these trees had also survived the first wildfires. In August 2004 or about 2 years after the second series of wildfires the floor of the peat land plot (after the second series of wildfires) was covered with plants on about 15.3 % of the area, on average by 12 species of herbs and seedlings, mainly ferns *Stenochlaena palustris* (Burm.f.) Bedd. and *Blechnum orientale*, which are found in 79 % and 73 % of the observed subplots, respectively.

The Mixed dipterocarps forest of Wanariset-Samboja in 1980 was dominated by *Pholidocarpus majadum* (Arecaceae), *Anthocephalus indicus* (Rubiaceae), *Shorea laevis*, *Shorea parvifolia*, and *Dipterocarpus cornutus* (Dipterocarpaceae), and since then the forests have degraded due to three series of wildfires. After experiencing the three series of wildfires, in August 2004, the forest was still dominated by *Pholidocarpus majadum* (Arecaceae), *Macaranga gigantea* (Euphorbiaceae), *Nauclea purfurascens* (Rubiaceae), *Dipterocarpus cornutus*, *Shorea parviflora* (Dipterocarpaceae), and *Mallotus paniculatus* (Euphorbiaceae). However, in number of individuals, the top five of the most frequently found species were pioneer secondary species of: *Macaranga gigantea* (Euphorbiaceae), *Mallotus paniculatus* (Euphorbiaceae), *Ficus uncinulata* (*Moraceae*), *Vernonia arborea* (Asteraceae), and *Macaranga pruinosa* (Euphorbiaceae) (Simbolon, *unpublished data*).

From a basic study of *ecosystem services* and the *biodiversity* survey it was recorded that 12 species of timber and 14 of medicinal plants were commonly used by the local population before the 1960s. A survey among Bawan villagers showed that: (1) since 2006 only six timber trees species and four medicinal plants were easily found in the forest. The populations of *Benuas* and *Meranti*, which were the main timber species during the 1960s had decreased. The tendency was similar for medicinal plants. (2) There was a pattern of decreasing timber production for the 40 years during the period from 1960 until 2006, due to forest degradation and land conversion to farming or plantation uses. (3) From 1968 until the 1980s, three private forest concessions were operating here with wood and rattan exploitation.

6.5 Traditional Peatland Utilization Practices in Kalimantan

The Dayak people have never used deep peat for agriculture; they have only utilized the shallow peat ("*petak luwau*") near the riverbanks, where there is mainly mineral soil. Therefore, the Dayak, whose livelihood depends on shifting cultivation and especially upland rice, have concentrated settlements in upstream areas of Central Kalimantan (Limin 1994, 1999; Limin et al. 2003, 2004). Consequently, the utilization of peatland for agriculture has been very limited, historically.

The "*handel*" based farming practices have been used by the local population in peatland and wetland areas. Dimensions of the "*handel*" canals are determined by farmers based on the volume of water to enter and flood the rice fields. By heeding natural condition, such as soil fertility as indicated by the kinds of plants growing, the farmers determine the feasibility of an area to support crop cultivation. They also factor in that the soil, water, and trees have the ability to contribute to the success of the cultivation. Therefore, at the end of the cultivation activities, the local population is grateful to the Lord, earth (including soil, water, and trees), and their ancestors.

The opening of forest area for rice fields ("*ladang*") is always determined by considering the season, especially the flooding level and the length of the dry season. The farmers follow a number of rules based on experience gained by their parents and ancestors. Generally, the procedures for establishing rice fields ("*ladang*") by Dayak people are as follows.

Season Determination Based on natural observations the Dayak farmers estimate when the following are likely to occur (1) a short dry season, (2) a long dry season, (3) absence of flooding, and (4) heavy floods. Based on this they use two criteria to choose a field's location, namely, (i) low land ("*petak pamatang*" or "*petak bahu danum*"), if a long dry season is predicted, and (ii) hill area ("*petak bukit*"), if a short dry season and heavy flooding are predicted.

Several natural signs that indicate the kind of growing season likely to occur in the following year include: (1) Moon and star positions when these can be observed, (2) Roots of trees (mangrove tree) and mushrooms e.g. "*kulat danum*" which grow near or beside the river, and (3) Behavior of certain animals, e.g. "*rihun*" (*Hexagenia bilineata*, Say), ants i.e. "*semut gatal*" or "*sansaman*" (*Dolichoderus bituberculatus* Mayr), and birds i.e. elang (*Spizaetus nanus*).

Choice of Location Farmers discuss among themselves to determine the location, because at least there need to be two families as neighbors in one place where they establish their rice fields ("*ladang*"). This strategy must be followed, because the main constraint on rice production will be natural pests, e.g. pigs, deer, monkeys, rats, and birds. To confirm the choice of location there is an important natural sign of luck called "*nantuani dahiang*". The farmers determine the success of their rice fields ("*ladang*") by: (1) dreams before and after visiting the location and (2) the sound of eagles when they leave and arrive at the location. Land fertility can be determined by the color of the top layer of soil by digging of soil using a knife ("*manejeb petak*"). If the topsoil is black (fertile) for around 10–20 cm, the area can be used for rice fields ("*ladang*"). The vegetation type is another indicator of soil fertility, e.g., the presence of "*kalapapa*" (*Euodia* sp.), and "*kalanduyung*" (*Mallotus* sp.).

Land Clearing and Land Preparation Land clearing and land preparation can be divided into four stages. Shrubs or small trees are first cut down, so burning will be clean. Tree branches and twigs are chopped up and used as biomass. In the burning stage, the farmers burn all of the biomass (grass, leaves, branches, and twigs), except for large timber. The success of the burning stage determines the success of the rice production. Using traditional burning methods, the fire does not spread outside the rice fields ("*ladang*"). To ensure this the farmers make a transect along the border of the rice field ("*ladang*") and many people join in the burning activities. Generally, the biomass is never all burnt away. Therefore, the farmers must collect the residual biomass material ("*mangakal*") and put in a pile ("*pehun*"). This heap of biomass is disposed of by burning of the heaps ("*mamehun*").

Planting ("*manugal*") and Land Management The Dayak always plant rice directly with seeds, especially in dry areas. Seeds are planted in holes made by sticks, 5–7 cm in diameter. The holes must be closed with soil or ash after the seed is placed in it.

Intensive weeding is carried out, commonly in the second and third year of the rice field ("*ladang*"). In the first year, weeding is not necessary, especially for rice fields ("*ladang*") just put into use from cleared primary forest. Weeds in the first growing year are very few owing to the previous burning of the rice fields ("*ladang*"). In the second year, weeds become very high and grow fast. Therefore, after the first or second year, farmers abandon the rice field ("*ladang*"), and move to a new area.

Traditionally, pest and disease protection involves the use of an extract of "tuba" and "*saing*", applied using a bamboo sprayer. "Tuba" (*Vatica albiramis*) and "*saing*" are local names of plants from which a paralyzing drug is obtained.

Harvesting Generally, harvest activities are conducted in three stages. First, in the young rice harvest stage ("*nyumput parei*") the Dayak make "*behas maru*" and "*kenta*" (looks like chips) from young rice. The maturity of the rice grain in this stage is less than 10 %, as indicated by its green color. The amount of rice harvested for "*behas maru*" is very limited, and provides food for only 1 or 2 days.

Next, the real harvest is carried out if all rice grains on 50 % of the stalks are mature, indicated by their yellow color. Finally, there is the remaining harvest ("*mamata*"), because some of the rice had not matured earlier. This activity also includes rice produced by new shoots.

Post-harvest All of the rice harvested is put in one place in buildings, close to the roof. The drying process is carried out every day by opening the roof, only closing it when it rains and at night. The rice grains are dry enough when they are easily released from the ear-stalks, and the release process is named "*mengirik*". Before the rice is placed in the rice barn ("*lumbung*") the drying process should be carried out till the grains become firm, and unhulled paddy is separated from the ear-stalks using a huller ("*kipas*") and winnowing basket ("*penampi*"). The rice barn may be in the rice field ("*ladang*") or in the houses in the village.

Festival for Celebrating and Blessing the Harvest The last activity in the rice growing ("*ladang*") practices is the celebration and blessing of the harvest ("*pakanan batu*"). This festival signifies the appreciation of the blessings of the Lord, support of the land, and functioning of equipment. The name of the celebration comes from "*batu*", a rock for sharpening the knives ("*parang*"), and "*beliung*" *and* "*gentu*", equipment used for preparing and working in the rice fields ("*ladang*") from the beginning of cultivation.

The celebration is held after finishing all the activities for the farming in the rice field ("*ladang*"). The Dayak express thanks to the Lord, nature (land and water), and their ancestors. They believe that successful farming practices of the rice fields ("*ladang*") must involve the three components above.

Utilization of Previous Rice Fields ("*ladang*") Usually the Dayak use previously farmed rice fields ("*ladang*") for growing other annual crops, e.g. rubber, rattan, and fruits such as cempedak (*Artocarpus chempeden*), durian (*Durio zibethinus*), and rambutan (*Nephelium* sp.). Planting the particular crop depends on future plans for the area. If the farmers want to open an area for rice fields ("*ladang*") in some years, other crops are restricted to only certain places or planted in widely spaced rows. The purpose of planting in widely spaced rows is to leave space to grow rice between the rows of plants. However, if there are no plans to use an area for rice fields ("*ladang*") in the future, all crops may be planted throughout an area. In this way, many Dayak have plantation gardens (rubber, rattan, and fruits) that were established by their grandfathers and even earlier. This is a strategy to maintain the carrying capacity of the land and to claim land ownership.

The re-utilization of formerly used rice fields ("*ladang*") does not take place after fixed periods of time; rather, rice fields are re-utilized only after there is sufficient vegetation to produce enough fertilizer when burned.

Local Knowledge of Peat Utilization The utilization of peatland by the Dayak people is limited to shallow peat. Shallow peat used for growing rice by the local population in upstream areas is called "*petak luwau*", while in coastal areas it is referred to as "*lahan pasang surut*".

The characteristics of the shallow upstream peat ("*petak luwau*") are as follows: (1) Peat thickness: 20–50 cm, (2) Decomposition condition: hemic to sapric, (3) Bottom material: clay, (4) Location: near river banks or between two hills, (5) Previous vegetation: dominated by grass, (6) Water supply: rainfall and river flooding, and (7) Soil condition after planting: muddy. Rice fields in "*petak luwau*" were farmed as follows by the local population: (1) Clearing land in the first year by cutting small trees and grass. After the first year for growing rice, all of the field becomes covered with grass, one kind with very sharp blades leaving itchy spots with the local name "*garigit*", teki (*Cyperus rotundus*) and also "*kumpai*" (*Ortoxylum ridicum*), (2) burning when the biomass is totally dry, (3) removing the biomass left and re-burning at specific places or places along the border to other farmers to ensure retention of water, (4) not tilling, since it is sufficient to cut the grass and burn, (5) planting rice plants grown in a nursery for 2–3 months, rather than planting seeds directly, (6) marking the border between farmers by digging small and shallow canals to either drain water from the field or collect water as necessary, (7) getting water needed for irrigating the rice fields from the river without a connecting canal from the river to the field, since the water needed comes from river flood water, (8) using the same planting schedule as for the rice field in the "*ladang*" farming, i.e. October to March, and (9) these areas must be unaffected by sea water tidal fluctuations. According to farmers with experience of "*petak luwau*", rice production depends on the hydrological conditions. If, in the generative growth phase, the rice field is not flooded for a long time, rice yields will be high. Productivity of the local rice variety is 1.75–3.00 t/ha (Limin 1994) and for the superior rice variety, 2.4–5.6 t/ha (Noor 2001).

Shallow Peat in Coastal Areas ("*lahan pasang surut*") The utilization of peatland was common using "*handel*" farming. A "*Handel*" is a small canal excavated from a big river to the interior or dome area of a coastal peatland. The size of canals limited to a width of 2–3 m, depth 0.5–1.0 m, and length 1000–2000 m. The characteristics of this land area are as follows: (1) it is influenced by sea water tidal movements pushing river water into the rice field and flooding it daily, (2) the rice field is located up to 2000 m from the river bank, (3) the maximum peat thickness is 1.0–2.0 m, (4) the material underlying the peat is clay, (5) the decomposition status is mostly sapric, (6) nutrients are provided constantly by the twice daily tidal movements, and (7) the soil condition after planting becomes muddy. Productivity of the local rice variety is 1.90–4.00 t/ha from one source and 2.0–2.8 t/ha from another, while the superior rice variety yields 3.4–5.5 t/ha (Noor 2001).

Canal Technology Establishment of the canal system in coastal areas by the Government of Republic of Indonesia is linked to the settlement of people arriving through transmigration. An area of the Basarang Canal, called "*Anjir Basarang*", still produces rice at a high productivity (around 4–5 t/ha), and many Dayak from upstream areas moved to this area to make rice fields there. The farmers are still making "*handel*" along the "*Anjir Basarang*". Extending "*handel*" into a larger canal ("*Polder*", "*Garpu*", "*Sisir*" and "*Kolam*") for the new transmigration settlement has led to a significant decrease in rice production. After that decrease, the Dayak returned to their original villages.

6.6 History of Peatland Development in Kalimantan

The traditional "*handel*" farming has been used by the local population in peatland and wetland, and is a superior farming method for peatland farming. However, the Development Sector of Government interpreted the reasons for the success of the local population in managing their farmlands with the "*handel*" system wrongly, leading to unfortunate results. The Development Sector of the Government attempted to apply this to much larger areas drained and irrigated by means of oversized canals. The history of development of the canal system by the Development Sector of Government can be summarized as follows: (1) "*Handel*" farming (traditional ways), (2) "*Anjir*" (1880–1936 by Dutch Colonial Authorities), (3) "Polder" system (1950 by Schophyus/Dutch Expert), (4) "*Garpu*" (fork) (UGM)/"*Sisir*" (comb) system (IPB and ITB) (1969–1982), (5) "*Kolam*" (pond) system (1980s), and (6) Giant canal system (1996, Mega Rice Project).

Upto the 1960s, development of the coastal areas in central Kalimantan started from the south Kalimantan state (capital Bandjarmasin), which is located in the east of Kalimantan on the Barito river, and advanced toward the west. In this project, two types of canals, Anjir and Handil played important roles, the former connecting rivers, and the latter as narrow waterways connecting to the Anjir canals. The construction of these canals was started by the local population (mainly Banjarese) when Kalimantan was a colony of the Netherlands. Currently, Anjir consists of six canals (16–35 km long) connecting to the Barito, the Kapuasu, and the Kahayan rivers, and their tributary streams, but there is no connection on the west, the right bank of the Kahayan river. Anjir canals are now large canals allowing passage of large barges, and playing an important role in the local shipping services although it was originally excavated to develop the economy of the surrounding area, and its waterways were as narrow as 2 m. The Handil canals serve as secondary waterways with 2 m in average width and 1.5 m in depth, excavated at right-angles to the Anjir Canals at intervals of about 500 m. The lengths of the Handil canals range from 5 to 11 km. The Handil canals are currently used mainly for drainage of farmland, and each waterway of the Handil canals has its own governing body for its operating practices run by the local population. These canals were originally excavated as traffic routes for settlement and cultivation. Because many of the areas with Handil canals are developed in the alluvial soil zone, they serve as a grain growing area of Kalimantan (especially for south Kalimantan and the adjacent central Kalimantan) (Osaki and Inoue 2000).

Since the 1970s, Indonesia has implemented an immigration policy (transmigrasi) aiming to increase food production, to achieve food self-sufficiency, and to alleviate the crowded population on Java and Bali Islands. There has been migration from Java and Bali Islands to the coastal areas of central Kalimantan. The settlers migrated to areas with trunk waterways (canals) connected to rivers, but these have proved a dead end inland without connections between rivers, unlike the case of the Anjir. Many of these new settlements are located in the shallow peatlands, where the peat layers have already disappeared from most of the farmland, and sulfuric acidic soil appeared from the subsoil, making it difficult to cultivate rice (Osaki and Iwakuma 2008).

Further, in 1995 it was decided that a large scale development project (a 1 million-ha peatland development project) would be carried out overlapping the same area. The former President Republic of Indonesia, President Suharto launched the Mega Rice Project by Presidential Decree no. 85 of 1995. The purpose of this project was to turn 1 million ha of swamps in central Kalimantan into paddy fields at one stroke to improve the rice self-sufficiency of Indonesia as well as to attract new settlers. In this project, the Department of Public Works, Department of Agriculture, and Department of Immigration managed the project planning and construction of basic irrigation facilities, land reclamation, and immigration relations, respectively.

The target region was from the south 2° 15′ south latitude, and encompassed the Kapuas, the Barito, and the Pulaupetak rivers, which connect the Kapuas and the Barito (east side), and the Sebangau rivers (west side). However, the project excluded some areas including the area surrounding Kuala Kapuas, where intensive development has already been completed. The target area was divided into four blocks, A–D, bordering on each river. The actual total project area was 1,134,000 ha, and about a half of the target area is peatlands with a peat thickness over 40 cm. The classification of the land include primary forest (25 %), forests to be cleared (40 %), denuded land such as moors (25 %), and land that have been cultivated (10 %). The project was launched by a presidential order issued in 1995, the work was initiated by 1996, and the excavation work of the trunk waterways and settlement in some parts were largely completed in 1997. However, the entire project has been put on hold from May, 1998 since Indonesia faced economic difficulties. In Block A, the project progressed with the construction of the trunk waterways and the land reclamation, and 13,500 households settled in three settlements in the block between October, 1996 and March, 1998.

The project failed because of knowledge gaps, especially on ecosystem function, peatland hydrology, water management, peat subsidence, impacts of long term drainage, mechanization problems on peatland and socio-economic consequences. The failure of the project can be attributed to: (1) Problems of ecology and natural resource functions (idle land, decreasing food production, over drainage, forest and peat fires and flooding), (2) Problems of infrastructure (irrigation network not optimal, insufficiency of settlement infrastructure), and (3) 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 more detail, the 1 million-ha peatland development project suffers from the following issues:

Deforestation Excavation for trunk waterways in 1 million ha of swamps made it easier to enter the inland forests that were not previously accessible, and accelerated large-scale deforestation. Specifically in the area between the Kahayan and the Sebangou rivers, which had been entirely undeveloped, there has been removal of large amounts of lumber along the banks of the Sebangau river.

Wild Fires in Peatland-Forests Due to the unusual droughts in 1997–1998 and the excessive drainage by the trunk waterways, wildfires broke out covering vast areas, destroying a wide range of peatlands and forests. The ignition loss (rate of decrease in weight of dry samples when heated at 700–800 °C) of tropical peat in the low, flat inland areas reaches values as large as about 98 %, showing that this peatland is composed of mostly carbon compounds, organic matter. As the volume density of tropical peat is approximately 0.1 g cm^{-3}, and the carbon content of the

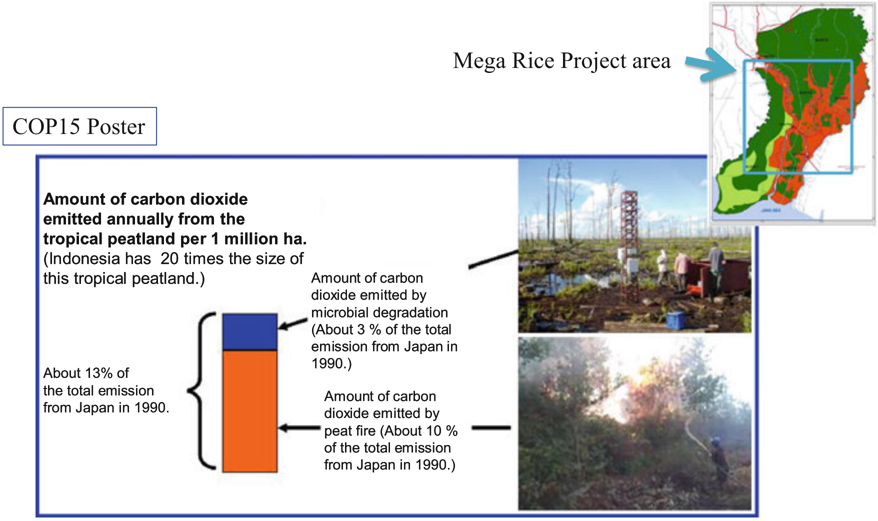

Fig. 6.8 CO_2 emission in Mega Rice Project area estimated in 2009 (presented at COP15 of Copenhagen in 2009). Recent (2013) estimation on C emission (MtC/Mha/year) in MRP: (a) By fire: 30.5 (fire)/312 (Japan C in 1990) = 0.098 = 10 %. (b) By microorganisms: 12 (peat degradation)/312 (Japan C in 1990) = 0.038 = 4 %

peat is approximately 50 %, 1 m^3 of swamp holds about 100 kg carbon. Assuming 10,000 ha peatland of 10 cm thickness has been burnt, this amounts to 0.5 Mt carbon emitted to the atmosphere. Page et al. (2002) reported that the area affected by peat fires occurring in the region of the Mega Rice Project in central Kalimantan in 1997 is 470,000 ha, and estimated that 150–180 Mt carbon was released.

Using the data from long term measurements by Hokkaido University, we calculated the annual average CO_2 emission from 1 million ha of the farmland of the Mega Rice Project and found that it significantly exceeded the carbon reduction targets of Japan, and that it was equivalent to 3 % (by biodegradation) and 10 % (by peat fire) compared with the annual total emissions of Japan in 1990 (Fig. 6.8). Further, as the overall area of tropical peatland in Indonesia is about 20 times this area, it was reported that extremely vast amounts of carbon were emitted by the development of the tropical peatlands (White Paper on Science and Technology 2010).

Appearance of Poor Soil Peatlands in tropical regions including Indonesia have faced the problem of appearance of poor soils. If peat layers disappear due to increased drainage and use for agriculture, quartz sand (mainly from Inland peat) which has lost nourishing substances and is a strongly sulfuric acid soil (mainly from coastal peat) will be generated from the lower layers. Such poor soil makes the farming and regeneration of vegetation difficult, resulting in abandonment of the land. Also, because water with extremely high acidity is discharged, water pollution

Table 6.1 Comparation of impact on the natural peatland/forest and the disturbed peatland of Mega Rice Project area

Natural peatland/forest	Disturbed peatland in mega rice project area
High biodiversity rain forest	Low biodiversity degraded landscape
Orangutan habitat	Orangutan killed or captured
Hydrology intact	Hydrology disrupted
Climate moderator	Climate extremes frequent
Chemical filter	Purification ability lost
Major carbon store	Major carbon losses
Fire resistant	Fire prone
Access difficult	Access facilitated
Good resources for local people	Only stealing trees
Sustainable	Unsustainable
Few illegal activities	Illegal activities promoted

From Rieley (1999)

is accelerated, causing damage to fisheries. Therefore, the development of peatlands cannot avoid being accompanied by problems in the lower soil layers, and it is necessary to deal with this issue with caution as long as we know of no effective measures to counteract it. The alternative is the creation of vast denuded land areas.

Thus, this tropical peat development project caused great damage to the environment and increased poverty of local people (Muhamad and Rieley 2002). Rieley (1999) compared key natural resource attributes of natural peat swamp forest and the area developed for the Mega Rice Project, which indicate great impact on ecology, environment, and economy (Table 6.1).

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