TROPICAL PEAT SWAMPS

Safe-Guarding a Global Natural Resource

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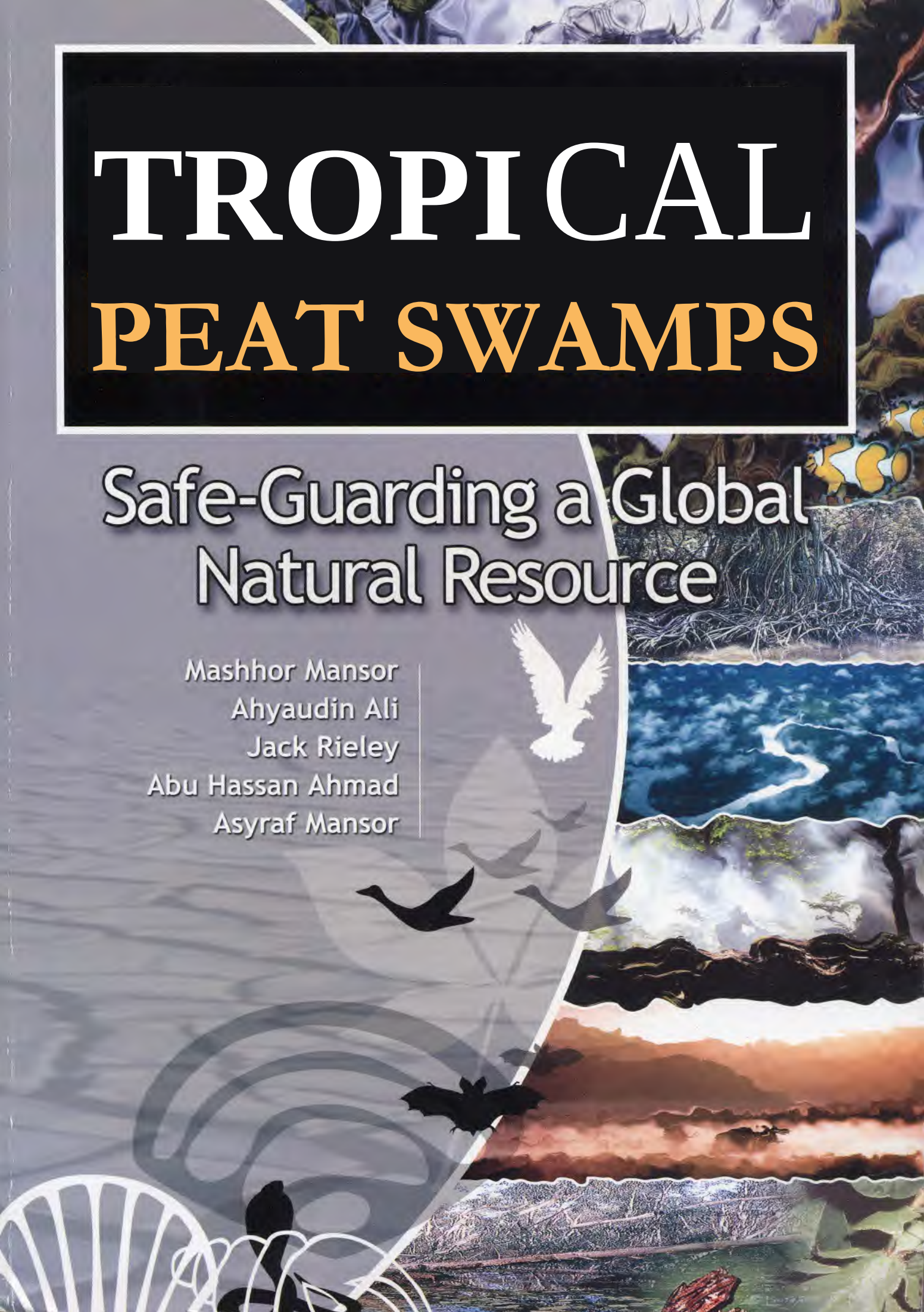

APPLICATION OF REMOTE SENSING AND GIS TO SURVEY AND EVALUATE TROPICAL PEAT

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ABSTRACT

Remote Sensing (RS) is a powerful tool to monitor the surface of the earth in different spectral bands, for example, in the visible, in the infrared and the Radar-frequencies. The changes of the relevant interesting areas can be easily detected over a time period. The Radar sensors in satellites have the advantage to penetrate active the electromagnetic rays through the clouds, while the passive optical sensors need a cloudfree or low cloud weather condition. Sensor-fusion increases the information level achieved by image processing.

For many projects, a Geographical Information Systems (GIS) is used to store geocoded raster sensor data in different levels to show information's of tropical forests, for example, vegetation, soil, water bodies including. hydrology, forest types, clear cuts, slash and burn, streets, rivers, channels, settlements, GPS-tracks, fires, animal habits, photos, short videos, etc.

In this presentation, this tools is applied for tropical forest in Central Kalimantan where Peat Swamp Forest (PSF) grows in the wetlands north of the Java Sea (see Figure 1). In that area a landuse conversion, 1 million ha Mega-Rice-Project (MRP) for rice cultivation including transmigration was started by the Indonesian government with a feasibility study and, in April 1996, with the digging of the irrigation channels into the peat swamp. The development of an area of one million hectares in Central Kalimantan, situated between the Sebangau River in the west, Kahayan River, Kapuas River and Barito River in the east and the Java Sea in the South was planned and partly realised. The total area of impact is 1.4 million ha for the Blocks A, B, C, D and E. The project faces problems of peat domes with a height up to 10 m between the main rivers. Satellite-images of the heavy forest fires in Autumn 1997 in Central Kalimantan has been processed too.

To undertake global monitoring/ survey in a short time, it was essential to use LANDSAT Thematic Mapper, SPOT and ERS1 / 2 Radar images, linked to a programme of field checking of forest, peatland development and peat condition. Remote sensing technology was used for all survey, monitoring and planning tasks. This paper presents some of the results from LANDSAT, SPOT, ERS1 and ERS2 image processing activities from aerial surveys on 13 and 27 June and 3 November 1998, as well as from several ground truth campaigns in 1997 and 1998. This evaluation takes place in the next three years (1999-2001) within the framework of a European Union project with 6 international partners, Natural Resource Functions, Biodiversiy and Sustainable Management of Tropical Peatlands.

INTRODUCTION

Central Kalimantan covers an area of 153,564 km^2 which is 28% of the total area of Kalimantan. The southern part of the province consists of lowlands and wetlands (mostly peatland), constituting a total of 36,716 km^2 or 24% of the total extent of the province. This area comprises 812 km^2 of coastal plains, 12,392 km^2 of alluvial plains (including flood plains), 1,027 km^2 of tidal swamps, and 22,485 km^2 of peat swamps (Report 1885). The middle and northern belts of the land vary from low-altitude uplands to rolling hills with a height of up to 2,500 m (the Schwaner and Muller Mountains at the northern boundary see Figures 1 and 2).

According to a 1995 statistics (Biro Pusat Statistik 1996), Central Kalimantan has a total population of 1,627,000 and a population density of 11 per km^2 — very little compared to an average density of 101 per km^2 for the total of Indonesia. Up to the beginning of this decade it had huge pristine and (secondary) logged peatland areas which are changing quickly.

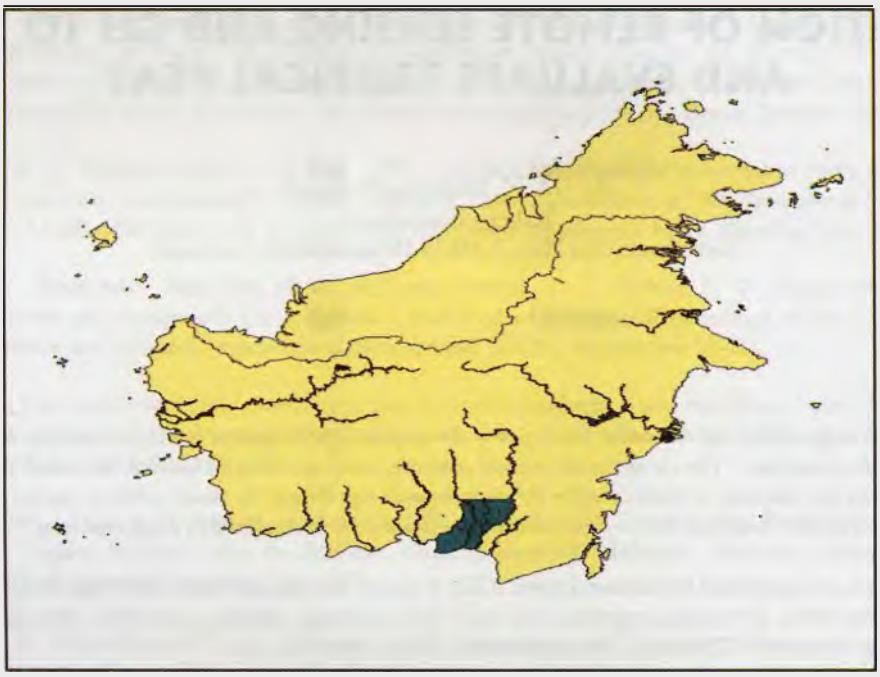

Figure 1. Map of Kalimantan/Borneo. The green area shows the area of the Mega Rice Project in Central Kalimantan with the Blocks A, B, C and D.

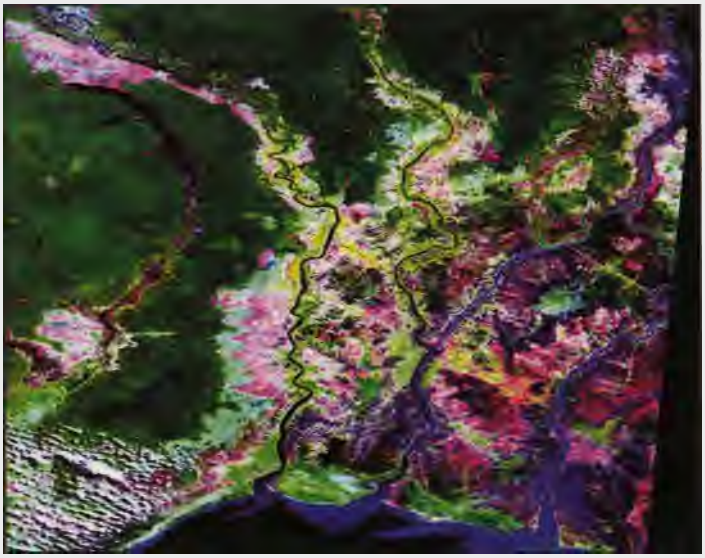

Figure 2. LANDSAT TM image (118-62, 10 May 1996, RGB = 542, Image size 125 km x 150 km) showing the PSF area and the 1 Million ha rice project, the transmigration areas and the four rivers Sebangau, Kahayan, Kapuas and Barito (from left to right). This channel combination enhances agricultural land use classes. The city of Banjarmasin is located at the lower right corner of the image (pink colours). Note the irrigation channels between the rivers Kahayan, Kapuas and Barito. Small Dutch made irrigation channels are visible near Lamunti, Dadahup and Palingkau.

A Presidential Decree in June 1995 (No. 82/1995) established the conversion of the PSF of Central Kalimantan into a rice production area called Mega Rice Project (MRP). This project violates the governments own regulations. Firstly, reclamation of peat deeper than three metres is prohibited by Presidential decree No. 32/1990. Secondly, the Environmental Impact Assessment (EIA) legally required before implementation of any project work was not started before April 1996, almost half a year after the excavation of a huge channel system had begun and forests were being cleared. Drainage is already affecting the entire area and damaging its ecology. This Presidential Degree was replaced (superseded) by the new Presidential decree 80/1999 of July 1999: "General planning guidelines and management of peatland development area in Central Kalimantan".

Thick peat is a part of wetland characteristic and functions as a buffer zone, and must be protected. Only shallow peat (< 3 m) in alluvial wetland is allocated for wetland agriculture. Sustainable development, with social empowerment and prosperity should be achieved for the local ecosystem.

Droughts, forest fires and famine were logical results. In 1997, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire. The MRP was a major location of "hot spots" because burning for land clearance had been started at the onset of the dry season. In June 1997, months before fires and smog had become a serious health hazard to millions of people in Southeast Asia, the areas upstream of the reclamation project already suffered serious food shortages. A marked drop in the water-level of major rivers, combined with poor visibility due to smog hindered food transport, and lack of water for irrigation made the planting of crops impossible. By September/October 1997, famines were reported in the entire area.

SURVEY AND GROUND TRUTH CAMPAIGN

The purpose of the survey and ground truth campaign was to verify the classified signatures of the satellite images in peatland areas of Central Kalimantan and to monitor the rapid changing of the landscapes. Intensive ground truth checking is necessary for an accurate impression of the landscape, its vegetation, animal life and human inhabitants.

The peatland area around the province capital Palangkaraya (see Figures 4, 5, 6) is largely extended and the forest type is PSF. PSF is positioned mainly on quartz sand (podzol) from the Java Sea up to the heath forest belt in the northern area, covering a band of approximately 150 km to 200 km. The landscape is very flat and partly affected by coastal flood plains, in which the northward tide from the Java Sea is felt inland up to 50-80 km. Where the soil changes and the ground becomes hilly, highland dipterocarp forests start. Along the main rivers are *ladangs* (slash and burn) built by Dayaks for rice cultivation on alluvial soil in slash and burn technique. In general, the forest is secondary logged and many areas clear-cut. Only the northern mountain region has greater locations of unaffected primary tropical forests.

The different areas of interest can be reached by the rivers and the existing streets, some of them in very poor condition due to rain and flood. With a permit, the forest concession and the interior of the PSF types can be reached by rail-lorry. The parallel structure of these rails are visible on the satellite images. Better and easier survey is possible from a plane—birds' view compared to frog view from the ground. Photographs and/or video images of the different PSF types and forest quality have been stored for research work (see Figures 2 and 8).

GEOGRAPHIC AND ECOLOGICAL PROFILE OF THE PSF IN KALTENG, AERIAL OBSERVATION AND GROUND TRUTH CAMPAIGNS

Overview Over the PSF Area in Kalteng

Indonesia has a large amount of tropical peat (between 17 and 27 million ha), located mainly on the three islands Sumatra [8.2 (4.6) Mha], Kalimantan (6.8 Mha) and Irian Jaya [4.6 (8.7) Mha] (compare ref. 25). Peat age varies from several hundred years up to 10,000 years. In the last decades the size of the peat area has been shrinking continually due to conversion into land use. High amounts of stored carbon were thus released into the atmosphere.

Peat water is dark-brown to blackish and acidic (pH value 3 to 4). Peat accumulates in domes with a thickness of 12 to 15 meters and flows from water sheds to the main rivers. Peat forests have a specific atmosphere and many different animal sounds are heard. Large, undisturbed PSF still boast strong Orang Utan populations. Temperature inside the forests is moderate and under closed canopies seldom exceeds 28°C. There is noticeable wind circulation in the afternoons. Soil and water have a constant temperature of approximately 23-24°C. Tree types and fish species adapt to the acid water. Special roots stick out of the water to absorb oxygen.

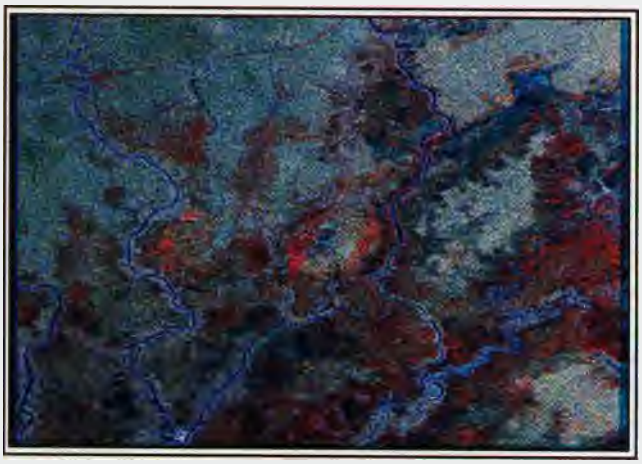

Figure 3. ERS Change Detection image (7 November 1996 and 18 September 1997) of the 1 million. ha rice project between the Kapuas and Barito rivers. Burnt scars appear in reddish colours. Compare aerial photos as indicated by arrows.

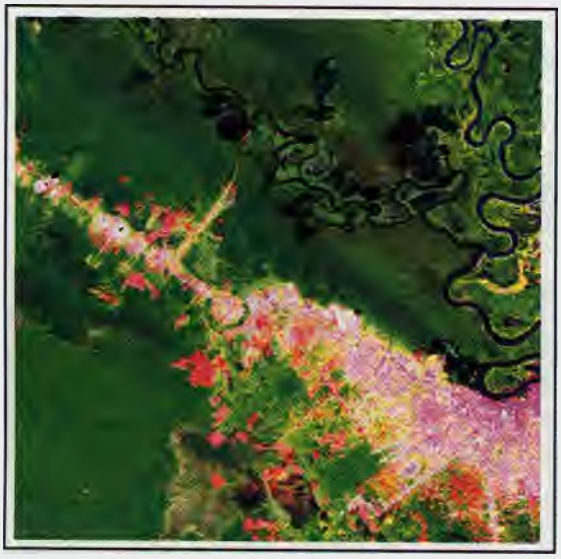

Figure 4. LANDSAT TM image (24 July 1994, RGB = 542) showing the province capital Palangkaraya with the rivers Kahayan and Rungan. Green indicated PSF, red indicated clear cuts. (Image size 15.4 km x 15.4 km)

According to LANDSAT, image in Figure 2, the size of the original PSF between the Katingan and Barito rivers can be estimated as covering approximately 1.8 million ha (1995). This amount has been drastically reduced within a few years by conversion into land use. The remaining, relatively untouched area is located between the rivers Katingan and Sebangau, but even there illegal logging caused lots of damage.

Blocks A, B, C and D faced the strongest changes in the last 30 months by clearcuts and forest fires (see Figures 1, 3 7, 9). Even in Block E (above the Parent Primary channel, connection between Kahayan, Kapuas and Barito), the construction of a 10 km long channel has started. A recommendation that this area be protected and conserved as refuge for animals (e.g., Orang Utan) and forest products has been forwarded to the Indonesian authorities (ref. 27).

It is now estimated that up to *one billion tons of carbon* were released during the fires of July—October 1997. This equals the entire European output of one year. Burning and oxidised peat is largely responsible for these huge releases. An estimated 2 to 4 *billion tons of carbon* is stored between peatlayers in the MRP. Research data show that carbon sequestration and storage in the forests of Central Kalimantan is among the highest recorded sustained values anywhere in the world. The rate of accumulation in tropical peat forests in Indonesia has been found to be between 228 and 668 gC/m^2 year (58% C). Indications are that

the erosion of peat in the MRP will irreversibly affect the climate of the whole of Kalimantan and will influence the world carbon budget in meteorological climate models.

Mega Rice Project (MRP) and Irrigation Channels

The development in Indonesia of wetlands for sawah rice cultivation is not new. Decades ago, coastal wetlands in Sumatra and Kalimantan were opened and settled by Bugis from South Sulawesi, Banjars from South Kalimantan and Malays from Riau, East Sumatra and West Kalimantan. They selected land along the broad, natural estuaries and avoided deep swamps and peat soils. Tidal movements in the estuaries were spread laterally by a network of simple, hand-dug channels. Using tidal movements, the indigenous people succeeded in cultivating sawah rice, albeit on a modest scale, on a 1-2 km wide strip alongside the estuaries. By present standards the yield was a meagre 0.8 Mg/ha harvest once a year. This Banjarese system became known as *sawah bayar.*

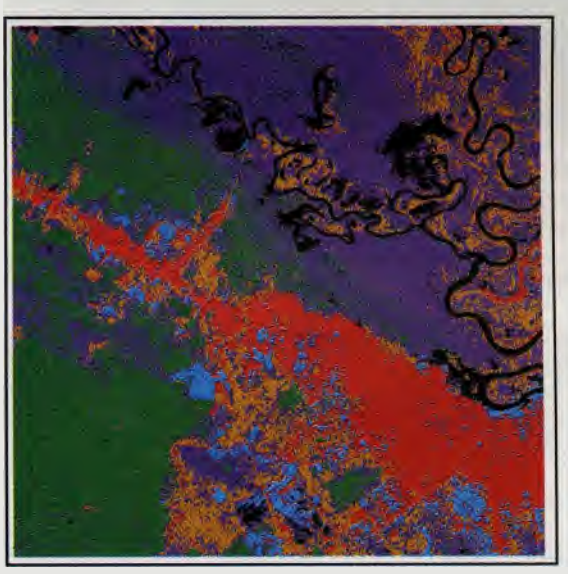

Figure 5. Classified LANDSAT TM image (24 July 1994). Processing with a neuronal net classifier shows six different classes: Green = water bodies/rivers (1); pink = primary/secondary PSF (2); blue = clear cut, open ground (3); light-blue = settlements (4); grey-blue = swamp area (5); brown = bush land/alang alang (6). (Image size 15.4 km x 15.4 km)

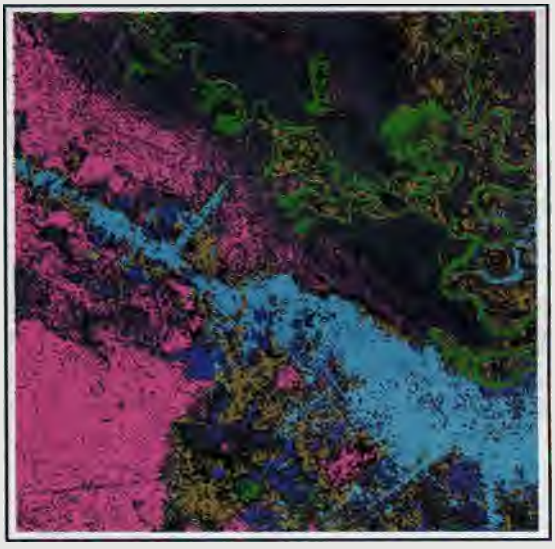

Figure 6. Classified LANDSAT image (24 July 1994). Processing with a minimum distance classifier shows six different classes: Black = water bodies/rivers (1); green = primary/secondary PSF (2); light-blue = clear cut, open ground (3); red = settlements (4); violet = swamp area (5); brown = bush land/alang alang (6). (Image size 15.4 km x 15.4 km.)

The success of this system attracted genuine interest in the Netherlands Indies government. Channels connecting big rivers such as Barito, Kapuas and Kahayan were built across their common delta plains. These channels were also meant to provide waterways and to make the area between the cities of Banjarmasin, Kuala Kapuas and Palangkaraya accessible. The first channel in Kalimantan, *Anjir Serapat (anjir* = channel), was finished in 1890, connecting the rivers Kapuas and Barito and spanning a distance of approximately 28 km. A second channel, *Anjir Basarang* and also approximately 28 km long, connects the rivers Kahayan and Kapuas.

The big scale sawah rice field MRP was initiated in 1995 by Presidential Decree No. 82. (Development of One Million Hectares of Peatland for Food Crop Production in the Province of Central Kalimantan, Peat Reclamation). It is also known as "Peat Area Project" or "Proyek Lahan Gambut — PLG". The settlement of 350,000 families into this area was planned by the Ministry of Transmigration. Up to now, approximately 15,000 families in the Dadahup—Lamunti region were settled, facing hard conditions clear-felled areas.

Parent, main, secondary, third and quarter level channels for irrigation and transport were built with high pressure from Spring 1996 to 1998. Over 4,000 km of channels were built in two years, using US$225 million from the Indonesian reforestation fund.

TABLE 1
CHANNELS OF THE MEGA RICE PROJECT

Parent Primary Channels	(PPC: 110 km)	2 X 25 m surface width, 15 m bottom width, 6 m deep
Main Primary Channels	(MPC: 1,129 km)	25 m surface width, 15 m bottom width, but only 5 m deep
Secondary Channels	(SC: 964 km)	15 m surface width, 10 m bottom, 3 m deep
Tertiary Channels	(TC: 900 km)	6 m surface width, 4 m bottom, 3 m deep
Quaternary Channels	(QC: 1,515 m)	4 m surface width, 3 m bottom, 3 m deep

Source: Taken from Notohadiprawiro (1998).

During our amphibious-plane flight on 13 June 1998 we passed the following points (Figures 7, 8 and 9) from Palangkaraya eastwards along the PPC (Blocks A and B) up to the Barito, then in a southerly direction to the Dadahup Transmigration Location, to Palingkau Lima and Baru, Kuala Kapuas, then westwards along the Anjir Basarang (Block D) to Pulang Pisau (with the Catchment Sungai Sebangau on the left side) and over Block C along the MPC back to the Kahayan at Palangkaraya. Total flight time: 2 h 30 min and 400 km flight distance.

The 110 km long Parent Primary Channel (PPC, actually consisting of two parallel channels) is located exactly alongside latitude 2°15' south; only towards the Kahayan it bends south and at the Barito it bends north. There are four sluices: one where it begins at the Kahayan, two at the crossing of the Kapuas, and one where it ends at the Barito. At present, they are not equipped with water-pumps for irrigation. Where possible, channels are used for transportation of tree trunks. The two channels were planned to have a width of 25 m at the surface and 15 m at the bottom, with a depth of 6 m. The reality is different. During flights and ground checking it became obvious that the PPC is not working properly. The difficult task of building channels through peat domes of up to 10 m high has not been mastered as yet. On several stages water-barriers were constructed in peat where sluices would have been necessary. At some points the water-level of the PPC is less than 2 m, as opposed to the required 6 m. The crossing of the PPC with the blackwater river Mentangai caused further problems. The opening of PSF in this area since 1995 changed the height of the water-table and the hydrology. It enabled loggers to cut ways into the remaining forest left and right of the PPC. Large parts of the forest burned during the 1997 fires, causing severe financial loss.

Figure 7. Irrigation channels of the 1 million ha rice project. **A:** Gamma map filtered ERS-image mosaic showing irrigation Channels (PPC, MPC, SC, TC) of the MRP at the Kapuas River region. (ERS images acquired 18 September 1997 and 2 September 1997.) **B:** Main Channel, 110 km long, **C:** Side channel filled with water near Kapuas river, **D:** Dried out side channel in the centre of the peat dome between Kahayan and Kapuas river. Burnt scars are visible along the channels.

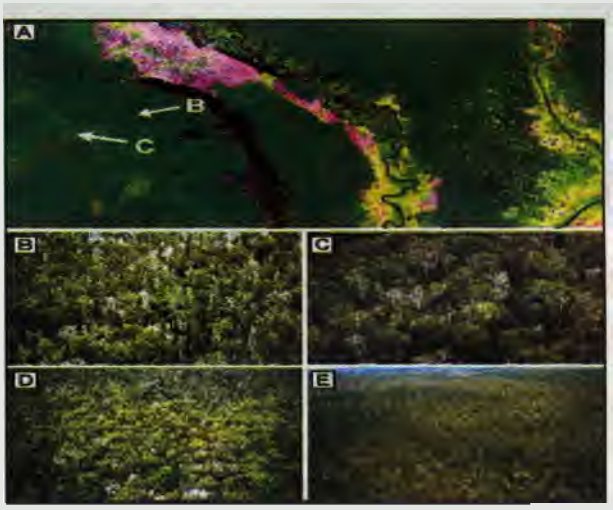

Figure 8. Different peat swamp forest types. A: LANDSAT TM image (118-62, 10 May 1996, RGB = 543) showing Palangkaraya and the surrounding PSF. A close look reveals different shades of green within the PSF, which can be related to different types of forest and likely to peat thickness. The arrows designate the location of the aerial photographs. **B:** Low pole forest (20 m high) near catchment of Sebangau River **C:** High PSF (40 m high) near the centre of the peat dome. **D:** Heath forest (20-30 m high). **E:** Mixture of PSF and heath forest to the north of Palangkaraya.

In dry and intermediate periods, even the combined waters of the main rivers are insufficient for irrigating the MRP; a waterflow of between 150-500 m^3 per second would be necessary. But such waterflow would be likely to damage channels built into peat. Furthermore, for agricultural purposes water quality would have to improve to a pH value of 5 to 6. Untouched PSF has an average value of pH 3.8. During the draught in autumn 1997 waters reaches an acidity of pH 2, unsuitable for drinking for humans and animals. Several people died.

Through the opening of PSF and conversion into paddy fields, peatdomes shrink and release oxidised carbon gas directly into the atmosphere. Peat itself, even with ample fertilisation, for example, volcanic ash (pugas) and limestone, sustains only pineapples and some types of oil-palms. Mineral storage capacity and water-table are the most important parameters in soil quality. Only alluvial regions with peat layers no

more than 2-3 m can be considered for yields of significance. Of the MRP area, no more than 30% meet these requirements.

After the May 1998 riots and subsequent change of government, a rethinking process has taken place within the Indonesian government and World Bank (see letter to Ministry of Public Works, ref. 11). An advisory commission (Timbalan Pengarah Pengembangan Lahan Gambut) has handed over a recommendation paper to President Habibie in early September 1998.

The MRP and many other transmigration sites are now disaster areas created by incompetence or greed on a level that is difficult to fathom. Action-plans to reverse inflicted damage would attract moral and financial support of many international donors.

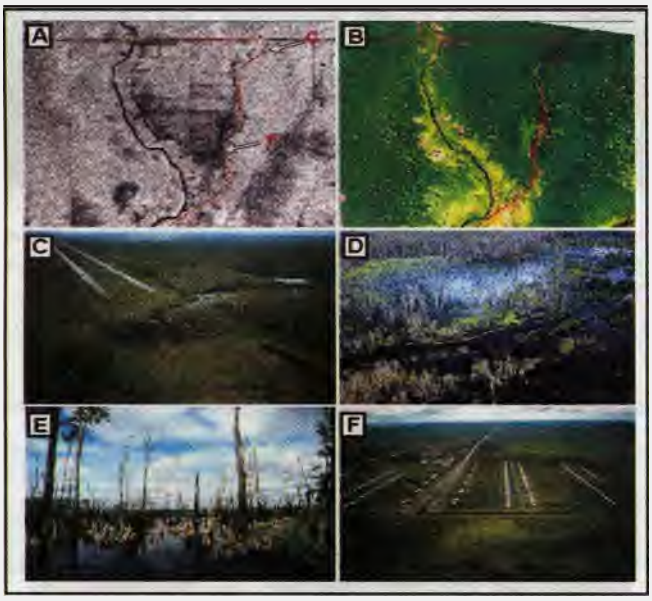

Figure 9. **A:** ERS-image (18 September 1997) showing the rivers Kapuas and black water river Mentangai, the new channels and the flight route from 3 November 1998 (dotted lines). **B:** LANDSAT-TM image (10 May 1996, RGB = 543) of the same area without channels. **C:** Mentangai River crossing the main channel, channel construction had to be interrupted. **D:** Illegal logging along Mentangai River. **E:** Dead trees along Mentangai River, remnants from the great fire in 1997. **F:** New Transmigration settlement established after the land clearing by fire in 1997 (compare LANDSAT image) not yet inhabited, location indicated by arrow in **A.**

Figure 10. LANDSAT-image (RGB = 543) taken from the MRP in Central Kalimantan at Dadahup on 29 May 1997 (30 km x 42 km). PSF is in green colour, clear-cut, see red colours and many new channels were dug. This image shows the situation before the huge fires in autumn 1997 and spring 1998. Now there are more than 4,000 km of channels in the MRP which has many problems in hydrology of draining instead of irrigating the land and in big peat layers which are not suitable for rice cultivation.

Bukit Tangkiling (River Rungan), Transmigration Area of Transsabangdep, River Tilap to the Edge of the Heath Forest

Bukit Tangkiling is a well-known area some 35 km along the main road from Palangkaraya. Six hills of intrusive young Alkali Granite from the Miocene age (27-28 million years old, ref. 3) grow unexpectedly out of the flat PSF region. They have an altitude of 125 m, 130 m, 135 m, 164 m, 174 m and 186 m. Indigenous people use tin-covered wood fires on the rock-surface to crack parts of the granite, subsequently broken into smaller pieces by children, for road and house construction. Ground, this material would make excellent fertiliser due to its good mineral composition (K^20). Even so, villagers around the hills enjoy good crops. The same is true for the area down to the blackwater river Rungan with the villages Tangkiling Harbour and Sei Gohong. North-east of the hills, the road that has been following the Rungan makes a sharp bend and leads through peat forest to the village of Kasongan, where a big metal bridge crosses the Katingan. From there, the road leads further to Sampit, Kalteng's second biggest town. At km 38 from Palangkaraya a big transmigration plot was recently established that has already caused peat soil to degenerate.

TABLE 2
WATER PARAMETERS

Samples	1. Kahayan	2. Rungan	3. PSF	4. Rungan Sari	Limited values
pH-value	5.6	3.9	3.3	5.8	6.5 — 9.5
conductivity mS/m	2.1	2.2	6.5	2.2	?
Pb in μ_g/1	<10	<10	<10	<10	40
Cd in $_{\beta}$a.g/1	<2	<2	<2	<2	5
Cu in sg/l	<5	<5	<5	<2	approximately 2000
Ni in pg/1	<10	<10	<10	<10	50
Hg in $_{j}$i.g/1	<0.2	<0.2			1
Zn in $_{f\cdot}$tg/1	10	5	9	4	2000

The pH-value was measured by Ralf Trenkle, München , on four sample plots. Water samples from: (1) Kahayan at Palangkaraya, (2) Rungan at Sei Gohong, (3) PSF between Tangkiling and Palangkaraya, and (4) the Nursery of Rungan Sari.

Notice the variation in pH-value from 5.8 at Rungan Sari (clear water) to 3.3 in PSF Mercury (Hg) values are very low in the rivers Kahayan and Rungan, thus only few small scale gold miners are attracted to the area. Small amounts of Zn are present in the water.

Approximately 5 km south of the hills and 5 km from the main road the transmigration village of Transsabangdep was constructed in 1993 on relatively shallow peat between 10 cm and 2 m in height. Nephentes pitcher plants are growing everywhere. The village is built in rectangular shape, criss-crossed by small water channels. The inhabitants are poor. We visited the area several times in 1996, 1997 and 1998. Since 1996 many villagers have left the area. By now, the remaining ones earn half their income by felling trees. Behind the village, an area was cut into the forest that looks like a hammer (see LANDSAT image from 8/7/94, ref. 2, 3). In the ERS image of 2 September 1997, the clear-cuts sharp edges have already become diffuse. This change is caused by numerous new cuts into the PSF using rail techniques. On 1 November 1998 we saw new logger camps and sawmills along railroads used for the transport of trunks out of swampy forest. This activity provides basic income for concessionaires and local indigenous people.

On 2 November 1998, a trip was undertaken to the village of Petakbahitang, where the small river Tilap flows into the bigger Rungan. We wanted to examine the fine structure of the river net left of the Rungan seen on an ERS Satellite image from 1993 and on LANDSAT images from 1991 to 1994. These had suggested that here is the border between peatland and heath forest.

At a bridge 19 km north of the junction Palangkaraya/Kasongan, we hired a boat and a crew of three. We followed the Tilap, a small blackwater river, 10 km up. The water level was high due to the rain period. Every now and then, we had to avoid floats, gently pulled by motorboats and guided with sticks by skilled workers, which came down the narrow river. When the canopy above us opened the sun came through, but soon heavy rain stared. We had to protect our photo apparatus and S-VHS-video camera. The Garmin GPS 12 was working excellently even in these conditions. Later we followed a side-arm of the stream to

the north west for 2 km and then went by foot into mixed PSF alternating with heath forest for approximately 1 km. The air was humid and hot, and insects and birds made typical sounds. On the map we saw a dark-coloured peat dome but could not reach it because of heavy rain. Back at the bridge, we took our Jeep and followed the road north to Tumbang Talaken and Tumbang Jutuh for several km over bridges which cross many small blackwater rivers. On the way back we followed a new logging road on quartz sand for approximately 3 km parallel to our river. This was definitely heath forest. Selective logging was done everywhere, in some areas even clear-cuts.

PSF in Setia Alam Jaya Concession and Sebangau River

The Setia Alam Jaya Concession is located approximately 12 km south of Palangkaraya, opposite to the village of Kereng Bengkirai on the Sebangau catchment. It is the last remaining big secondary logged PSF area extending over the blackwater lake Bulan to the Katingan River, see Figure 8. Many orang-utan live here. Selective logging was officially discontinued in 1996, and unless regular repairs are undertaken, the rails will rot quickly and render them useless for EU research tasks.

This region west of Sebangau River is outside the MRP. However, Block C, east of the Sebangau river and at the edge of the fragile PSF has been opened by main and secondary channels (Figures 11 and 12). We recommend that the conversion of Block C be stopped immediately and Block C be used as a buffer zone to the PSF west of Catchment Sebangau.

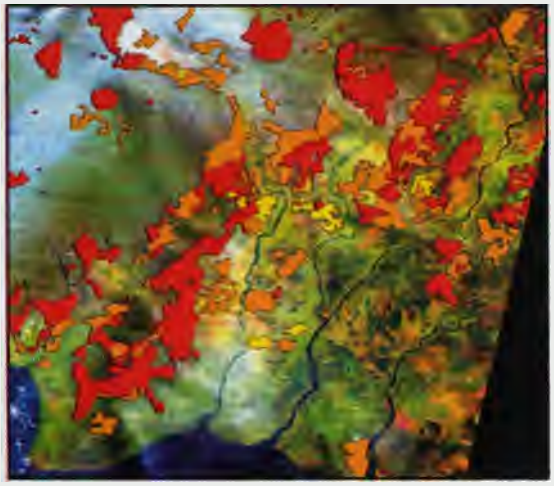

Figure 11. Visual classification of burnt scars in a cloudy LANDSAT-image from 29 March 1998 after the fires. The red colour are severe burnt scars, the olive medium and the yellow low burnt scars.

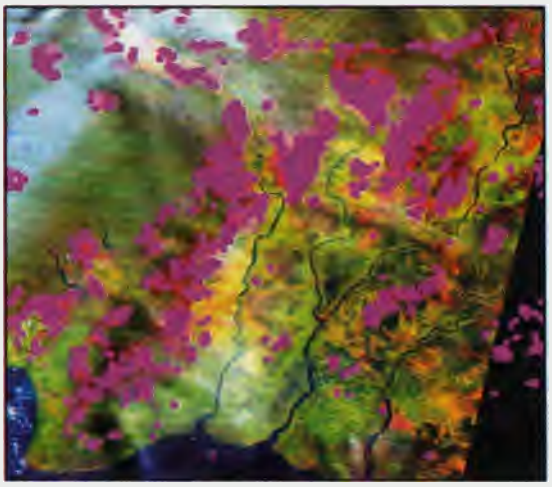

Figure 12. The same LANDSAT-image as in Figure 11. ATSR-Hot-Spot-Data from July – November 1997 are superimposed to the image.

Several PSF classes can be analysed in Figure 8A: Riverine Sedge Swamp (RSS), Mixed Swamp Forest (MSF), Low Pole Forest (LPF), Tall Interior Forest (TIF), Degraded PSF and clear-cuts. The catchment of Sebangau River shows up black. A granite hill is seen approximately 18 km south-west of the camp. Straight lines are logging rails in the PSF.

The area around *Camp Setia Alam Jaya* has been chosen by the EU-project as a natural laboratory. Many PSF data have been collected there by Dr. Jack Rieley (University of Nottingham), Dr. Susan Page (University of Leicester), Ir. Suwido Limin (University of Palangkaraya) and their students (ref. 3,22-26, 36). An old railroad leads more than 18 km into pristine peatland. A small granite hill shows many types of forest vegetation. These have been determined by ground checks and will be used for satellite image classification on a big scale. The camp also has potential for ecotourism.

Dadahup on Mengkatip and the Barito-Kapuas Murung Area

Apart from Lamunti, Dadahup is the main MRP area to be settled by transmigrates. Irrigation channels were started early 1996 (see Figures 3 and 10). On the ERS image from 18 September 1997, the MPC, the SC and the TC can be seen to be nearly completed. The draught of 1997 proved a good opportunity to clear the landscape for transmigration settlements by burning.

Aerial photos (Figure 7) show the many channels dug in connection with the MRP. All forest at Dadahup has been cleared and houses of transmigrates have been erected. During the ground truth campaign on 6 November 1998 we used a boat from Dadahup to follow the Mengkatip some kilometres south. We saw rattan left and right. Branching off into an SC necessitated a change of boat. After approximately 7 km we reached the junction with the 58 km long MPC. SC and MPC are separated by barriers and have slightly different water levels. Some new transmigrant villages on moderate peat layers are located along the 7 km long SC. These clear-cuts are a big disaster from the ecological point of view and repeat the damage experienced years ago in the nearby Pulau Petak region (between Kapuas Murung and Barito). The 1997 draught proved a good opportunity to clear the land for transmigration settlements. Systematic land-clearing by fire is, however, still in progress in 1998.

Fires and Drought Hazard, Burnt Scars in 1997

Rain forests often grow on very poor soils, which allow only 1-3 years farming every 20 years. If these forests are removed either by large scale cutting or by uncontrolled forest fires, as happened in 1982/83, 1987,1994, and 1997 in Kalimantan, it will take centuries until a new forest with a similar species diversity will regrow. In moderate climates, in contrast, a forest with similar species composition and diversity as before will regenerate within 10-30 years even after clear felling. In many areas the exploitation and conversion of tropical rain forest proceeds uncontrolled and with increasing rate. To analyse changing land use patterns, up till now mainly optical satellite images and aerial photos were evaluated. A major disadvantage of optical images for operational planning and monitoring is the frequent cloud coverage in tropical regions; the all-weather-capacity of SAR is a major advantage for land surface monitoring under these conditions.

In 1997, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire. The MRP was one major location of "hot spots" because burning for land clearance for the project started at the onset of the dry season. In June, several months before the fire and smog had become a serious health hazard to millions of people in Southeast Asia, the areas upstream of the reclamation project already suffered serious food shortages. A marked drop in the water-level of the major rivers combined with poor visibility due to the smog hindered food transport to communities and a lack of water for irrigation has made it impossible to plant crops. In September and October famine, forest fires and drought was reported in the area. Most of the fires were man made (compare Figures 11 and 12).

RECOMMENDATIONS AND FINDINGS

Peatland ecosystems are not only amongst earth's most important ecosystems, but are also well known for their extreme fragility. Their huge carbon storage is well known. Local communities have traditionally

cultivated rice in that part of Central Kalimantan for many years, but on shallow peatland and on a very limited scale and without significantly affecting the environment.

As a result of investigations and consultations with indigenous people conducted over a two year period, large number of Indonesian and international agricultural, soil and ecological scientists, it was concluded that:

1. Draining peat swamp will change the local climate and hydrology of the province in an undesirable way (e.g., periods of prolonged drought and flash floods).

2. The burning of peatland will release unacceptable amounts of carbon dioxide into the atmosphere.

3. Last year's peatland and forest fires in this part of Kalimantan are the logical result of the drying-out of the area due to draining the deep peat (between 2 and 20 m thick) and the use of fire as the cheapest method of land clearance.

4. The risk of similar fires — with the severe consequences for people's health, economic activity and the environment — will be increased in years to come.

5. The soil, hydrological, ecological and social conditions of the region make it highly unlikely that the planned production capacity of the area can ever be attained.

6. Rice cultivation will require massive inputs of limestone, fertilisers and soil supplements to counteract the acid, infertile soils.

7. The ability of farmers to pay for the large amounts of pesticides and other agrochemicals required is highly questionable.

8. The ill-planned drainage scheme makes the conservation of unique areas of PSF and their biological diversity impossible.

9. Reclamation work on this scale requires more thorough planning and sophisticated management to deal with inherent ecological constraints and to minimise environmental and socioeconomic risks than was hitherto applied.

10. For the conservation of the environment in Central Kalimantan it is best to fill in the PPC and establish a protected area in Block E. A buffer zone in Block C should be established to protect the PSF area in the west of Sungai Sebangau River. The *Setia Alam Jaya* area should be conserved as PSF ecosystem. The building of additional channels should be stopped.

CONCLUSIONS

Satellite images from 1997 compared to those from 1996, 1994, 1993 and 1991 show quick conversion of PSF areas into land use regions, some of which are left uncultivated. Roads and a system of irrigation channels with a total length of more than 4,000 km give loggers unprecedented access to cut every tree. After commercially viable trees have been cut, smaller ones of a diameter of 10-20 cm are not spared. Selective logging, although required by government law, is hardly observed. Countless floats transport timber over blackwater lakes and along channels and rivers. Huge areas of ecologically damaged peat landscape are visible from the air.

Draught and/or low water-table cause trees to die. Frequent fires give forests no time to recover and the tropical climate causes quick overgrowth by ferns and alang-alang, etc. Most of the Kalteng fires in 1997/1998 were man-made. Huge amounts of stored carbon were released into the atmosphere. Peatland destruction is an irreversible process.

The soil of the proposed MRP is largely unsuitable for the plantation of rice fields due to the big peat layers found there. The normal peat pH value is between 3 and 4. The huge peat domes between the main rivers Kahayan, Kapuas, Barito and Sebangau pose massive problems for the hydrology. The region is drying out, the water-table is low, questions of water-management remain unsolved. The big PPC between Kahayan, Kapuas and Barito (KaKaB) provides no irrigation and only has a draining effect. Since the 1960's, experiences in Kalimantan have shown the difficulty of creating agriculture on thick peat soil, especially without the acid-reducing influence of the tide, for example, in the following areas Pulau Petak, Pangkoh 1-9, Berengbengkel, Marang, more recently Transsambadep, Palingkau baru and km 38 at Tangkiling.

The eco-sociological aspects caused by large-scale transmigration are unsolved. Most transmigrates lack skills and experience with peatland. Furthermore, they are poor. They work under hard conditions and have no possibility to return to their origins. The MRP destroyed the habitat of many small and large animals. Planning was done by bureaucrats with disastrous results. US$225 million of the Central Government's reforestation fund were spent on the MRP. The winners were forest industry and channel construction companies. After the Indonesian economic crisis of 1997/98 the financial situation is much worse. Other public work projects, such as road construction between Kuala Kapuas and Palangkaraya, have been neglected. River crossings by ferries and car damage caused by pot-holes cost time and money; even though bridges have been constructed over the rivers Kapuas Murung, Kapuas and Kahayan.

The next step within the frame of the EU-project is to process, filter, geocoded and mosaic satellite images and to delineate forest types, agriculture areas, settlements, water bodies, burn scars, channels, etc. All satellite data and information is to be stored in the GIS. The result will be thematic maps. Workshops on LANDSAT and ERS SAR image processing and GIS application should be arranged for our Indonesian partners.

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ABBREVIATIONS

AVHRR	Advanced Very High Resolution Radiometer	Kaltim	Kalimantan Timor
		LPF	Low Pool forest
CIMTROP	Centre for International Co-Operation in Management of Tropical Peatland	MPC	Main Primary Channel
		MoF	Ministry of Forestry
CIFOR	Centre for International Forestry Research	MSF	Mixed Swamp Forest
		NOAA	National Oceanographic and Atmospheric Administration
DARTROP	Darwin project of Tropical Peatland		
DLR	Deutsche Luft- und Raumfahrt-Gesellschaft	ODA	Overseas Development Administration, now DFID
EIA	Environmental Impact Assessment	ORSTOM	Office de la Recherché Scien-tifique et Technique Outre-Mer
ENVI	The Environment for Visualizing Images		
ERS	European Remote Sensing Satellite	PLG	Proyek Lahan Gambut
ESA	European Space Agency	PPC	Parent Primary Channel
EU	European Union	PSF	Peat Swamp Forest
EUTROP	European Project of Tropical Peatland	QC	Quaternary Channel
FIMP	Forest Inventory and Monitoring Project	RGB	Red Green Blue
GIS	Geographical Information System	RS	Remote Sensing
GPS	Global Positioning System	RSS	Riverine Sedge Swamp
GTZ	Gesellschaft für Technische Zusammenarbeit	SAR	Synthetic Aperture Radar
		SC	Secondary Channel
HGI	Himpunan Gambut Indonesia	SPOT	French Electro-Optical Satellite
HTI	Hutan Tanaman Industri (forest crop industrial)	SW	Soft-Ware
		TC	Tertiary Channel
IDL	Interactive Data Language	TIF	Tall Interior Forest
IFFM	Integrated Forest Fire Management	TM	Thematic Mapper (LANDSAT)
IFM	International Monetary	TREES	Tropical Ecosystem Environment Observation by Satellite
IFRIS	Integrated Forest Resource Information System		
		UNPAR	University of Palangkaraya
INTAG	Inventarisasi dan tata guna hutan	UPT	Unit Pemukiman Transmigrasi (Transmigration settlement unit)
JERS	Japan Radar Satellite		
JRC	Joint Research Centre	4WD	Four Wheel Drive
KaKaB	Kahayan, Kapuas and Barito		
Kalbar	Kalimantan Barat		
Kalsel	Kalimantan Selatan		
Kalteng	Kalimantan Tengah		

TROPICAL PEAT SWAMPS

Safe-Guarding a Global Natural Resource

This publication, a compilation of papers presented in *The International Conference and Workshop on Tropical Peat Swamps,* should address the importance and significant value of peat swamp forests especially in this region. The cause of the destruction of many pristine peat swamps, which eventually created problems not only to human but also to other living organisms, are probably due to lack of knowledge of the ecological significant .of this ecosystem.

This publication should reach out to many people involved in wetland studies especially the peat swamp ecosystem. To name a few, engineers and scientists in the use of this natural ecosystem and sustainable management of the peat swamp forests. The idea of this publication is for the reader to gain more information and knowledge of the peat swamps. The five main topics discussed in this book ranging from studies on biodiversity, structure and function, water resources, socioeconomic and remote sensing of pristine and developed peat swamp forests in this tropical region. All of these are essential part in gaining broader point of view to this ecosystem. It is also hoped that this publication could provide some clear ecological concepts and better manage ment system in order to protect the undisturbed peat swamp forests and also to restore and manage the disturbed peat swamp ecosystem.

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