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 e.g. 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 electro-magnetic 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 e.g. vegetation, soil, water bodies incl. 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 fig. 1. In that area a land-use 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 Rivers Sebangau in the west, River Kahayan, River Kapuas and River Barito in the east and the Java Sea in the South was planned and partly realised. The total area of impact is 1.4 million hectares for the Blocks A, B, C, D and E. The project faces problems of peat domes with a height up to 10m 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, Biodiversity and Sustainable Management of Tropical Peatlands.

1. Introduction

Central Kalimantan covers an area of 153,564 km² 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 km² or 24% of the total extent of the province. This area comprises 812 km² of coastal plains, 12392 km² of alluvial plains (including floodplains), 1,027 km² of tidal swamps, and 22,485 km² of peat swamps (RePPProT, 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 figs. 1, 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 km² - very little compared to an average density of 101 per km² 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.

A Presidential degree in June 1995 (No. 82/1995) established the conversion of the Peat Swamp Forest of Central Kalimantan into a rice production area called "Mega-Rice-Project". 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 (<3m) 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 "Mega-Rice-Project" 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 South-east 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.

2. 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 figs 4, 5, 6) is largely extended and the forest type is **peat swamp forest (P.S.F.)**. P.S.F. 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 approx. 150km to 200km. 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 50km – 80km. 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 P.S.F. 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 P.S.F. types and forest quality have been stored for research work, see figs. 2 and 8.

3. Geographic and Ecological Profile of the P.S.F. in Kalteng, Aerial Observation and Ground Truth Campaigns

3.1 Overview over the P.S.F. 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 P.S.F. 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 approx. 23 - 24°C. Tree types and fish species adapt to the acid water. Special roots stick out of the water to absorb oxygen.

According to LANDSAT image figure 2 the size of the original P.S.F. between the rivers Katingan and Barito can be estimated as covering approx. 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 Sungai 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 figs.1, 3 7, 9). Even in Block E (above the Parent Primary channel, connection between Kahayan, Kapuas and Barito), the construction of a 10km 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 peat-layers in the "Mega-Rice-Project". 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/m² year (58%C). Indications are that the erosion of peat in the "Mega-Rice-Project" will irreversibly affect the climate of the whole of Kalimantan and will influence the world carbon budget in meteorological climate models.

3.2 Mega-Rice-Project 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".

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 approx. 28km . A second channel, *Anjir Basarang*, and also approx. 28km long, connects the rivers Kahayan and Kapuas.

The big scale sawah rice field "Mega-Rice-Project" 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, approx. 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 4000km of channels

were built in two years, using 225 million US $ from the Indonesian reforestation fund.

Table 1: Channels of the Mega-Rice-Project

Parent Primary Channels	(PPC: 110km)	2x25m surface width, 15m bottom width, 6m deep
Main Primary Channels	(MPC: 1129km)	25m surface width, 15m bottom width, but only 5m deep
Secondary Channels	(SC: 964km)	15m surface with, 10m bottom, 3m deep
Tertiary Channels	(TC: 900km)	6m surface w., 4m bottom, 3m deep
Quaternary Channels	(QC: 1515m)	4m surface w., 3m bottom, 3m deep

Taken from Notohadiprawiro, T. (1998)

During our amphibious-plane flight on 13 June 98 we passed the following points (Figs. 7, 8 and 9): from Palangkaraya eastwards along the PPC (Blocks B and A) 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: 2h 30min and 400km flight distance.

The 110km long Parent Primary Channel (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 25m at the surface and 15m at the bottom, with a depth of 6m. 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 peatdomes of up to 10m 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 2m, as opposed to the required 6m. The crossing of the PPC with the black-water river Mentangai caused further problems. The opening of P.S.F. 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.

In dry and intermediate periods, the even the combined waters of the main rivers are insufficient for irrigating the "Mega-Rice-Project"; a waterflow of between 150 - 500m³ 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 P.S.F. 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 P.S.F. and conversion into paddyfields, peatdomes shrink and release oxidised carbon gas directly into the atmosphere. Peat itself, even with ample fertilisation e.g. 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 peatlayers no more than 2-3m can be considered for yields of significance. Of the "Mega-Rice-Project" 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 (Tim Pengarah Pengembangan Lahan Gambut) has handed over a recommendation paper to President Habibie in early Sept. 1998.

The "Mega-Rice-Project" 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.

3.3 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 35km 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 P.S.F. region. They have an altitude of 125m, 130m, 135m, 164m, 174m and 186m. 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^2O). Even so, villagers around the hills enjoy good crops. The same is true for the area down to the black-water 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. P.S.F.**	**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 µg/l	<10	<10	<10	<10	40
Cd in µg/l	<2	<2	<2	<2	5
Cu in µg/l	<5	<5	<5	<2	approx.2000
Ni in µg/l	<10	<10	<10	<10	50
Hg in µg/l	<0.2	<0.2	-	-	1
Zn in µg/l	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) P.S.F. between Tangkiling and Palangkaraya, 4) the Nursery of Rungan Sari.

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

Approx. 5km south of the hills and 5km from the main road the transmigration village of Transsabangdep was constructed in 1993 on relatively shallow peat between 10cm and 2m 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 Sept. 1997, the clear-cut's sharp edges have already become diffuse. This change is caused by numerous new cuts into the P.S.F. using rail techniques. On 1 Nov.1998 we saw new logger camps and saw-mills 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 Nov.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 and 1994. These had suggested that here is the border between peatland and heath forest.

At a bridge19km north of the junction Palangkaraya/Kasongan, we hired a boat and a crew of three. We followed the Tilap, a small black-water river, 10km 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 2km and then went by foot into mixed P.S.F. alternating with heath forest for approx.
1km. The air was humid and hot, and insects and birds made typical sounds. On the map we saw a dark-coloured peat dome but couldn't 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 black-water rivers. On the way back we followed a new logging road on quartz sand for approx. 3km parallel to our river. This was definitely heath forest. Selective logging was done everywhere, in some areas even clear-cuts.

3.4 P.S.F. in Setia Alam Jaya Concession and Sungai Sebangau

The *Setia Alam Jaya* Concession is located approx. 12km south of Palangkaraya, opposite to the village of Kereng Bengkirai on the Sebangau catchment. It is the last remaining big secondary logged P.S.F. area extending over the black-water lake Bulan to the Katingan river, see fig. 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 Sungai Sebangau is outside the "Mega-Rice-Project". But Block C, east of the Sungai Sebangau and at the edge of the fragile P.S.F. has been opened by main and secondary channels (figs.11, 12), . We recommend that the conversion of Block C be stopped immediately and Block C be used as a buffer zone to the P.S.F. west of Catchment Sebangau.

Several P.S.F. classes can be analysed in figure 8A: Riverine Sedge Swamp (RSS), Mixed Swamp Forest (MSF), Low Pole Forest (LPF), Tall Interior Forest (TIF), Degraded P.S.F. and Clear-Cuts. The catchment Sungai Sebangau shows up black. A granite hill is seen approx. 18km south-west of the camp. Straight lines are logging rails in the P.S.F.

The area around Camp *Setia Alam Jaya* has been chosen by the EU-project as a natural laboratory. Many P.S.F. 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 18km 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 Eco-Tourism.

3.5 Dadahup on Mengkatip and the Barito-Kapuas Murung Area

Apart from Lamunti, Dadahup is the main "Mega-Rice-Project" area to be settled by transmigrates. Irrigation channels were started early 1996 (see figs. 3, 10). On the ERS image from 18 Sept. 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 (fig. 7) show the many channels dug in connection with the "Mega-Rice-Project". 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 approx. 7km we reached the junction with the 58km 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 7km 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.

3.6 Fires and Drought Hazard, Burnt Scars in 1997

Rainforests 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 "Mega-Rice-Project" 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 South-east 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 Figs.11, 12)

4. 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 metres 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 peat-swamp forest 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 socio-economic risks than was hitherto applied.
10. For the conservation of the environment in Central Kalimantan it is best to fill in the parent primary channel (PPC) and establish a protected area in Block E. A buffer zone in Block C should be established to protect the P.S.F. area in the west of Sungai Sebangau. The Setia Alam Jaya area should be conserved as P.S.F. eco-system. The building of additional channels should be stopped.

5. Conclusions

Satellite images from 1997 compared to those from 1996, 1994, 1993 and 1991 show quick conversion of Peat Swamp Forest 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 4000km 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 black-water 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 "Mega-Rice-Project" is largely unsuitable for the plantation of rice fields due to the big peatlayers found there. The normal peat pH value is between 3 and 4. The huge peatdomes 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 1960ties, experiences in Kalimantan have shown the difficulty of creating agriculture on thick peat soil, especially without the acid-reducing influence of the tide, e.g. 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 "Mega-Rice-Project" destroyed the habitat of many small and large animals. Planning was done by bureaucrats with disastrous results. 225 Million US$ of the Central Government's reforestation fund were spent on the "Mega-Rice-Project". 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 Kapuas Murung, Kapuas and Kahayan rivers.

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.

6. References

1. **Antikidis, E., O. Arino, E. Janodet, F. Achard (1998).** ”Burned Forest Regional Map of Borneo”, presented on the International Conference on Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory, Jakarta, Indonesia, Oct. 26 – 29, 1998 organised by FIMP – EU/IFSSP and INTAG
2. **Böhm, H.-D.V., S. Haisch, E. Friauf (1995).** "Environmental Helicopter with Modular Sensor Concept: Example on Forestry Monitoring", presented at the Conference on Remote Sensing and GIS for Environmental Resources Management the Indonesian - European experience Jakarta, June 6 - 8, 1995, Session 15.
3. **Böhm, H.-D.V., S. Haisch (1996).** ”Report of ground truth campaigns incl. aerial survey in Kalimantan Tengah, 27th of March - 20th of April 1996”, Kalteng Consultants Report
4. **Böhm, H.-D.V., F. Siegert, J. Rieley, S. Limin, (1997).** "Land use planning and environmental monitoring in Kalimantan using remote sensing data", published in Economic & Business Review Indonesia No. 279, August 20, 1997
5. **Böhm, H.-D.V. (1998).** ”Satellite Images and Aerial Photos from the tropical Peat Swamp Forest in Central Kalimantan”, presented on the International Conference on Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory, Jakarta, Indonesia, Oct. 26 – 29, 1998 organised by FIMP – EU/IFSSP and INTAG
6. **Friauf, E. (1995).** "Untersuchung von Spektralsignaturen in Datensätzen abbildender Sensoren (Infrarot- TV-Kameras, LANDSAT Thematic Mapper und ERS-1 C-SAR Satellitensensoriken) durch Entwicklung und Anwendung von digitaler Bildanalyse-Software", Diplomarbeit bei EUROCOPTER Deutschland GmbH, München 19. Juli 1995, 167 pages
7. **Fuller, D. , M. Fulk (1998).** ”An Assessment of Fire Distribution and Impacts during 1997 in Kalimantan, Indonesia, using Satellite Remote Sensing and Geographic Information Systems”, report for the WWF, Indonesia
8. **Gutierrez, M.-L., S. Ramonteu (1997).** ”Front pionnier Banjar: Une agriculture entre terre et eau. Etude de cas sur le village de Palingkau province de Kalimantan Centre, Borneo, Indonesie” ORSTOM thesis
9. **Haberäcker. P. (1991).** ”Digitale Bildverarbeitung: Grundlagen und Anwendungen.”, München
10. **Hasjrul Junaid, Herman D. Rijksen, H.-D.V. Böhm (1998).** "The Mega-Rice Project Central Kalimantan Indonesia - An appeal for intervention to the International Community and IMF" a report
11. **Herman, T (1998).** ”Million hectare swampland project. Field visit observation and recommendations" The World Bank, Rural Development and Natural Resources Sector Unit, East Asia and Pacific Region, 10 pages. A report to Public Works.
12. **Hoffmann, A., F. Siegert (1998).** ”Integrated Forest Fire Management: The Use of Multisensoral Satellite Images”, Poster Abstract on the International Conference on Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory, Jakarta, Indonesia, Oct. 26 – 29, 1998 organised by FIMP – EU/IFSSP and INTAG
13. **Klinger, A. (1997).** ”Bildverarbeitung von Sensorbildern zur Erstellung thematischer Karten” ”Anwendung von klassischer Bildverarbeitung auf multispektrale and multitemporale Sensorbilder (LANDSAT TM, ERS-1, IR-Bilder) zur Klassifizierung und Erstellung von thematischen Karten”, Diplomarbeit (Thesis) bei EUROCOPTER Deutschland GmbH and FH-München, 14.7.97
14. **Kuntz, S., F. Siegert (1994).** "Evaluation of ERS-1 SAR data for tropical rainforest monitoring" Earth Observation Quarterly, No. 45 - September 1994

15. **Kuntz, S., C. Streck & F. Siegert (1995/6).** ”Multitemporal Evaluation Of ERS-SAR Data For Monitoring Deforestation of Tropical Rainforest”, Paper presented at the 2. ERS-1 Applications Workshop, 6.-8.12.1995, London, proceedings p.83 -93
16. **Levang, P. (1995).** "Tanah Sabrang - La terre dén face; La Transmigration en Indonésie: permanence dúne politique agraire contrainte”, These Montpellier
17. **Lillesand and Kiefer (1994).** "Remote sensing and image interpretation" J. Wiley & Sons, Inc., New York,
18. **Notohadiprawiro, T. (1998).** "Conflict between problem-solving and optimising approach to Land use resources development policies - the case of Central Kalimantan wetlands", presented at Symposium of International Peat Society, Proceedings page 14 - 24, Jyväskylä, Finland, 7 - 9 September, 1998
19. **ORSTOM and Dept. Transmigrasi (1981).** "Reconnaissance survey in Central Kalimantan. Phase I" 14 maps 1/250 000 and three reports, ORSTOM-Transmigrasi Project PTA-44. Dept. of Transmigration, Jakarta.
20. **Richards, J.A. (1993).** "Remote Sensing Digital Image Analysis - An Indroduction” ISBN 3-540-54840-8 2nd. Ed. Springer-Verlag Berlin Heidelberg New York
21. **Ridder, R.-M. (1996).** "Multitemporales und multisensorales Tropenwald-Monitoring integriert in ein Geographisches Informationsystem am Beispiel von Bukit Soeharto”, DLR-Forschungsbericht 96-20
22. **Rieley, J., R.G. Sieffermann, S.E. Page (1992).** "The Origin, Development, Present Status and Importance of the Lowland Peat Swamp Forests of Borneo", SUO 43(4-5), 241-244
23. **Rieley, J., S. Page (1993).** "The Ecology and Environmental Importance of the Peat Swamp Forest in the Sungai Sebangau Catchment, Central Kalimantan, Indonesia, July-Sept.1993, July-Sept. 1994", 146 pages, unpublished
24. **Rieley, J., S. Page, Suwido Limin, Sih Winarti (1995).** "The Peatland Resource of Indonesia and the Kalimantan Peat Swamp Forest Research Project", presented at the Peatland Convention, held in Edinburgh, Scotland 24-28 July 1995
25. **Rieley, J., S.E. Page (1995).** "Biodiversity and Sustainability of Tropical Peatland" Samara Publishing Limited, Tresaith, Cardigan SA43 2JG, UK, ISBN: 1873692102
26. **Rieley, J., H.-D.V. Böhm, S.E. Page (1999).** ”The Application of Satellite Imagery and Aerial Photography to the Classification of Peat Swamp Forest Vegetation and the Evaluation of Impacts upon the Ecosystem”, in preparation for journal of International Peat Society
27. **Rijksen, H.D., D. Offermans, J. Rieley, H.-D.V. Böhm, F. Siegert (1998).** ”Ecological values of the northern section (Blok E) of the KAKAB-PLG (peat Reclamation) area in Central Kalimantan” proposal for Bappenas, Public Works, MoF, Bappeda etc.
28. **Setiadi, Bambang (1996).** Kalau tidak seperti di Pulau Sambu bahayanya besar sekali, published in info ALAT No.13 Th. ke III p.38, 1996
29. **Sieffermann, G., M. Fournier, S. Triutomo. M.T. Sadelman, A.M. Semah (1988).** "Velocity of Tropical Forest Peat Accumulation in Central Kalimantan Province, Indonesia (Borneo)", VIII International Peat Congress in Leningrad, 90-98
30. **Sieffermann, G., J. Rieley and M. Fournier (1992).** "The Low-Land Peat Swamps of Central Kalimantan (Borneo): A Complex and Vulnerable Ecosystem", presented at the International Conference on Geography in the Asian Region, 31st Aug.- 3rd Sept. 1992, Yogyakarta, Indonesia
31. **Siegert, F., S. Kuntz, C. Streck, W. Bergbauer (1995).** "Land Use Planning and Monitoring Using ERS-1 Radar (SAR) Data", presented at the Conference on Remote Sensing and GIS for Environmental Resources Management, Jakarta, June 6 - 8
32. **Siegert, F., S. Kuntz (1998).** "Final Report - Land Use Monitoring and fire detection in Indonesia using ERS-1/2 and RADARSAT SAR images" Tropical Rainforest and Use of Land Investigation (TRULI), DLR (former DARA) Project Nr.: 50 EE 93125, ESA Pilot Project PP2-D11, 31. March 1998
33. **Siegert, F., S. Kuntz (1998).** ”Long term land use monitoring and forest fire detection in Indonesia using ERS-1/2 and RADARSAT SAR images”, presented on the International Conference on Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory, Jakarta, Indonesia, Oct. 26 – 29, 1998 organised by FIMP – EU/IFSSP and INTAG
34. **State Ministry for Environment (1998).** ”Forest and Land Fires in Indonesia, I. Factors, Impact and Evaluation of Efforts, II. Plan of Action for Fire Disaster Management” United Nations Development Programme (UNDP)
35. **Stibig, H.-J., F. Achard (1998).** ”TREES – Present Activities for Global and Regional Tropical Forest Cover Monitoring”, presented on the International Conference on Data Management and Modelling Using Remote Sensing and GIS for Tropical Forest Land Inventory, Jakarta, Indonesia, Oct. 26 – 29, 1998 organised by FIMP – EU/IFSSP and INTAG

36. UNPAR (1995). "International Symposium on the Biodiversity, Environmental Importance and Sustainability of Tropical Peat and Peatlands", Symposium Programme and Abstracts of Papers and Posters, Palangkaraya, Central Kalimantan, Indonesia, 4th - 8th September
37. Werner, C. (1996). "Digitale Klassifizierung und GIS-Analyse von MOMS-02/D2-Bilddaten eines tropischen Regenwaldgebiets in Mindanao, Philippinen", Berliner Geowissenschaftliche Abhandlungen Reihe D, Band 11., FU - TU - TFH - Berlin
38. Whitmore, T.C. (1984). "Tropical rain forests of the Far East" 2nd ed. Oxford University Press.

39. http://www.rhc.at/kalteng

7. Abbreviations

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

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.
(borneo.jpg)

Figure 2: LANDSAT TM image (118-62, 10 May 1996, RGB = 542, Image size 125km x 150km) showing the peat swamp forest 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.
(960510-542.jpg)

Figure 3: ERS Change Detection image (7 Nov.1996 and 18 Sept. 1997) of the 1 Million. ha rice project between the rivers Kapuas and Barito. Burnt scars appear in reddish colours. Compare aerial photos as indicated by arrows.
(970918-chan.jpg)

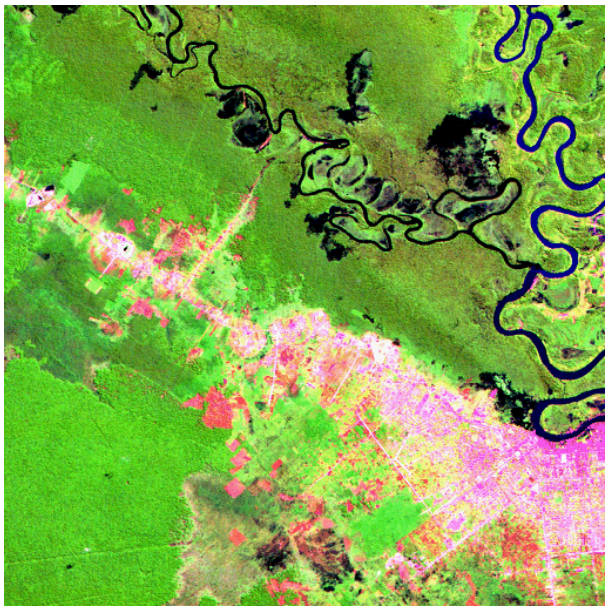

Figure 4: LANDSAT TM image **(**24 July 1994, RGB = 542) showing the province capital Palangkaraya with the rivers Kahayan and Rungan. Green indicated P.S.F., red indicated clear cuts. (Image size 15.4km x 15.4km).

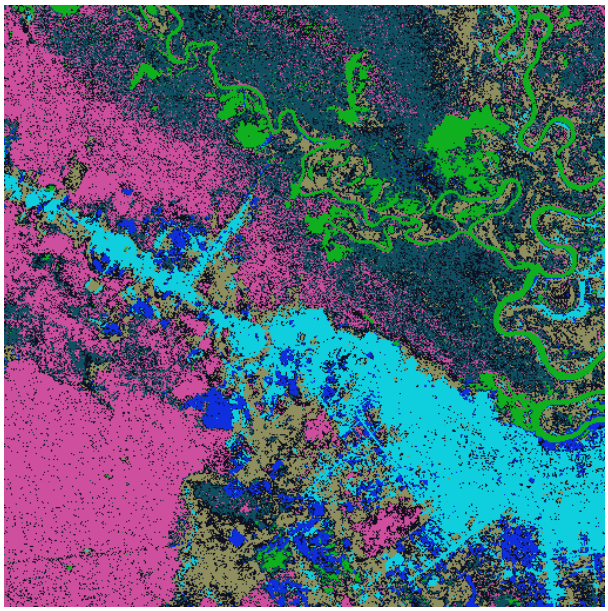

Figure 5: Classified LANDSAT TM image (24 July 1994). Processing with a neuronal net classifier shows 6 different classes: Green = water bodies/rivers(1); pink = primary-/secondary P.S.F. (2); blue = clear cut, open ground (3); light-blue = settlements (4); grey-blue = swamp area (5), brown = bush land/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

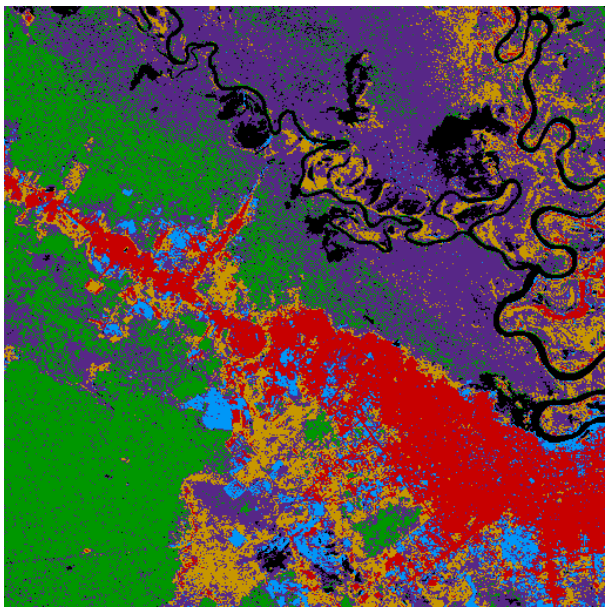

Figure 6: Classified LANDSAT image (24 July 1994). Processing with a minimum distance classifier shows 6 different classes: Black = water bodies/rivers (1); green = primary-/secondary P.S.F. (2); light-blue = clear cut, open ground (3); red = settlements (4); violet = swamp area (5), brown = bush land/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

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 "Mega-Rice-Project" at the river Kapuas region. (ERS images acquired 18 Sept. 1997 and 2 Sept. 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.

(chanal-2.jpg)

Figure 8: Different peat swamp forest types (P.S.F.). A: LANDSAT TM image (118-62, 10 May 1996, RGB = 543) showing Palangkaraya and the surrounding peat swamp forests. A close look reveals different shades of green within the peat swamp forest, 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 (~20m high) near catchment of Sungai Sebangau **C**: High peat swamp forest (~40m high) near the centre of the peat dome. **D**: Heath forest (~20-30m high). **E**: Mixture of peat swamp forest and heath forest to the north of Palangkaraya.

(forest-types.jpg)

Figure 9: A: ERS-image (18 Sept. 1997) showing the rivers Kapuas and black water river Mentangai, the new channels and the flight route from 3 Nov. 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.
(Black-Water.jpg)

Figure 10: LANDSAT-image (RGB = 543) taken from the Mega Rice Project in Central Kalimantan at Dadahup on 29 May 1997 (30km x 42km). 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 4000km 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.
(970529A.jpg)

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.
(burnt-scars98.jpg)

Figure 12: The same LANDSAT-image as in fig. 11. ATSR-Hot-Spot-Data from July - Nov 1997 are superimposed to the image.
(MEGA98-ATSR.jpg)