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Application of Remote Sensing and GIS to Monitor Peatland Multi-Temporal in Central Kalimantan

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Abstract

The study area of this 180 km × 360 km sized project lays between the Java Sea and the Schwaner Mountains of Central Kalimantan with the Province Capital Palangkaraya in the center. The technologies of Remote Sensing (RS) and of a Geographical Infomation System (GIS) are applied for multi-temporal change detection of the biomass between 1991 and 1998 using the satellite images/data from LANDSAT TM5, ERS1 + 2, SPOT and NOAA-AVHRR. In this area the main tropicial forest typs are Peat Swamp Forest (PSF) near the flat coastal region streching up to the north of Palangkaraya and Heath Forst in the north of Palangkaraya changing with Diperocarp Forest in the higher altitudes up to the mountain region (Sieffermann *et al.*,1988).The vegetation changes are processed for the time periode especially between 1991 and 1997 and between 1997 and 1998 with the huge fires in 1997 caused by the El Niño-Southern Oscillation (ENSO) event and man made fires.

The Government decided 1995 to convert Peatland into Paddy Fields by a one Million hectar project in the south of Palangkaraya. This project was unsuccessfully realised between 1996 and 1998 creating clear cuts and channels with more than 4000 km length into the PSF (Notohadiprawiro, 1998). The ecosytem was changed with the existing hydrology of the peatdomes and watersheds between the main rivers.

Several ground and aerial surveys (Boehm and Siegert, 1999) were performed for remote sensing verification between 1995 and 1999 using the tracks of a Global Positioning Sensor (GPS). By multi-temporal assessment of deforestation we found that the forest conversion between 1991 and 1997 was 16.3%, that equals to an average forest conversion rate of 2.7% per year. During the fire period the closed forest burned by 23.1% between May 1997 and March 1998 (LANDSAT TM analysis). It was found by the ERS analysis (images used before the fires until 10/97) that the burned area will be underestimated in the TM image by approx. 5.5%. This is because of the fast regrowth of vegetation (within 6 months, 10/97 and 3/98) in the area. A lot of Carbon was released during this period (Jaya *et al.* 2000, Page *et al.*, 2000).

The logging roads in the higher regions increased from 4419 km in 1991 to 6621 km in 1997 while the logging railways in the PSF changed from 7136 km in 1991 to 9406 km in 1997.

The main reasons of deforestation between 1991 and 1997 are:
- Logging operation, - Land clearing for small scale farming, and - Land clearing for plantations and between 1997 and 1998 the main reasons are: - Large scale land clearing for Mega rice project (MRP), - Man-made fires favoured by ENSO draught, and - Illegal logging operation. A professional EIA (Environmental Impact Assessment) study must be prepared for the new 2.8 Mha Kahayan, Kapuas, Barito (KaKaB) project before developing this additional area with its fragile soil.

Introduction

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 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, video-clips etc.

In this presentation this tools are applied for tropical forest in Central Kalimantan where PSF grows in the wetlands north of the Java Sea. 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, in April 1996, with the digging of 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 realised. The total area of impact is approx.1.4 million ha for the Blocks A, B, C, D and E. The project faces hydrological 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 have been processed too. During the 1997 ENSO event, the dry season spanned eight months from March to December, during which there was hardly any rainfall (Boehm, 1999; Boehm and Siegert, 1999; Siegert and Ruecker, 1999, Liew *et al.*, 2000, Siegert and Ruecker, 2000).

In the framework of the European Union project "Natural Resource Functions, Biodiversity and Sustainable Management of Tropical Peatlands" No.: ERB IC18-CT98-0260 and the TREES-project (Tropical Ecosystem Environment observation by Satellite): No. 14988-1999-05 F1EI ISP DE. this work is financed. Results will be presented of the MRP especially in the Dadahup area of Block A with processed LANDSAT TM, SPOT and ERS Radar images and aerial surveys in 1996, 1997, 1998 and 1999, as well as from several ground truth campaigns.

Materials and Methods

Data Processing

Basic image processing was done using ENVI 3.2. Raw image files were imported into ENVI and bands 3, 4 and 5 were selected to produce a colour RGB image. Band assignment was 5,4,3 = RGB (red, green blue). Each channel was interactively contrast enhanced in a reference LANDSAT TM image (118-61, 1991) in order to maximise overall image contrast.

This band combination proved to be the best in this region. It allowed to separate more than 20 vegetation and land use classes. Using the result of a histogram analysis of the reference image the adjacent scene (LANDSAT TM 118-62, 1991) was adapted in contrast and colouring to the reference image. This procedure was applied to all LANDSAT TM scenes.

The two adjacent scenes were mosaiked using 15 ground control points in the overlapping image parts. Initially we used 4 BAKOSURTANAL map sheets (scale 1:50.000) for georeferencing. However the results were not convincing. Therefore we used a set of more than 2000 GPS measurements (shp files) acquired during several ground and aerial surveys conducted in 1996, 1998 and 1999. GPS points were collected using the continuous track mode of the GPS acquiring measurements every 10s to 30s (aerial surveys) or 20s to 60s (ground surveys) (Fig. 1B).

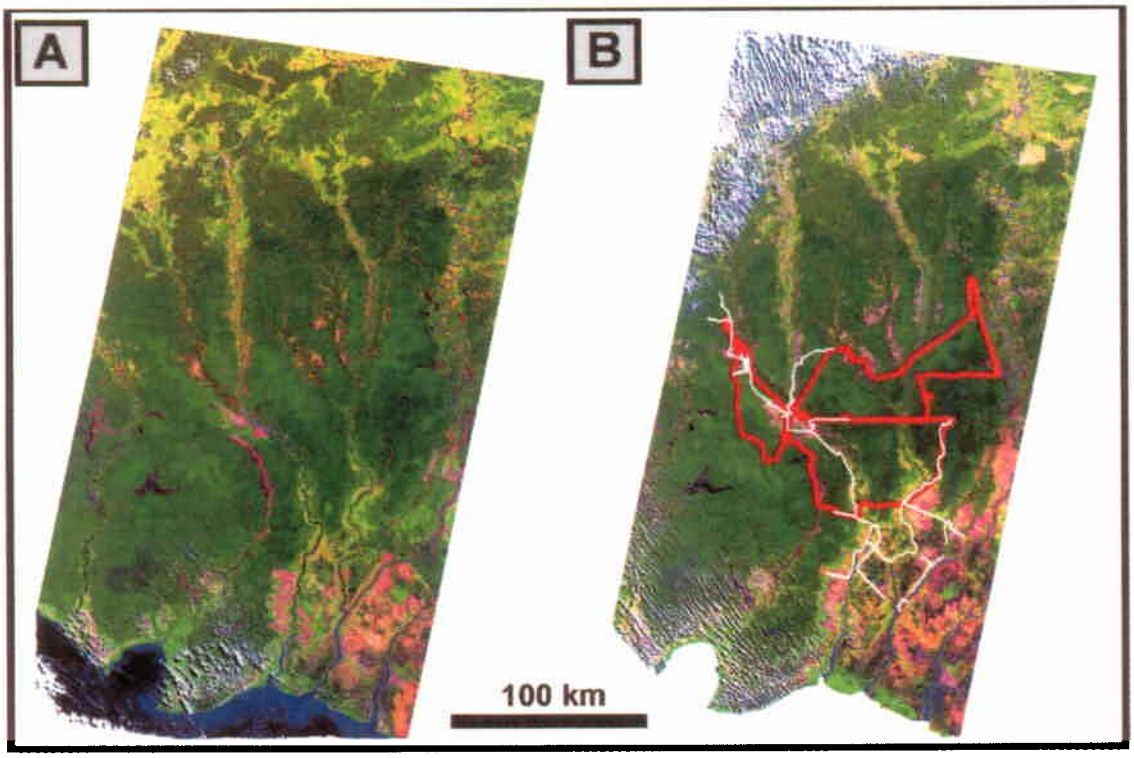

Fig. 1. Mosaiked TM images (118-61 and 62) of 30.6.1991 (A) and 29.5.1997(B). In (B) the GPS tracks of the 1998 ground (white) and aerial (red) surveys are shown. Peat swamp forests appear in dark green colours in the lower half of the image, heath forests in brownish colours, Dipterocarp forest in yellow-green in the northern area.

For georeferencing the enhanced, mosaiked LANDSAT TM reference image (118-62, 1991) was rotated by 8.5° clockwise before it was imported into ARCVIEW 3.2. In ARCVIEW the pixel size was set to 30 m. By using the ARCVIEW Image Scaler extension the image was then moved interactively into a position in which the GPS measurements matched unambiguous features like rivers, roads, channels etc. Thereby we achieved an accuracy of one pixel (30m) for most of the study area. The view was then projected as described in Table 1. The 1997 and 1998 LANDSAT TM scenes were registrated to the reference image from 1991 in ENVI using 35 Ground Control points - GCP's (mean RMS smaller than 1).

Test site description

Indonesia has a large amount of tropical peat (between 17 and 27 Million ha), located mainly on the three islands Sumatra, Kalimantan and Irian Jaya (Anderson, 1983; Rieley and Page, 1995). Central Kalimantan contains about 3 Mha of peatland, which is one of the largest joined tropical peatland areas world-wide. Approximately half of the study site (2 Mha) is covered by peatland that supports natural vegetation of peat swamp forest on top of peat that ranges from 0.5 m to more than 10 m thickness. Adjacent to the north there are large areas of heath forest, which grows on extremely nutrient poor siliceous soils. Further north typical lowland and hill Dipterocarp forest are found. Between 1991 and 1996 deforestation was related predominately to logging operations and land clearing along newly built roads.

Table 1. Map Information

Site	118-61 and 118-62	
Geographic extent	lat (°N)	long (°E)
TL	-0.57	113.73
TR	-0.79	115.21
BL	-3.10	113.18
BR	-3.57	114.62
Map series used		not used
Projection type		
name		UTM
ellipsoid *		GRS80
datum		WGS84
False easting		500,000 m
False northing		0 m
Zone		49
N or S		S
Central meridian		
Latitude of 1st standard parallel		
Latitude of 2nd standard parallel		

This changed in 1996, when a programme of massive peatland conversion, the so-called Mega Rice Project (MRP) was initiated in Central Kalimantan with the aim of converting one million hectares of peatland to agricultural use. Between January 1996 and July 1998 over 4000 km of drainage and irrigation channels were constructed throughout the area designated for the MRP and forest clearance on this land was initiated. After removal of the commercial timber, the remaining tree debris was removed by means of fire as the cheapest, most readily available land clearance tool (Fig. 2). During the 1997 ENSO event, the dry season spanned eight months from March to December, during which there was hardly any rainfall. At the start of the dry season in 1997 fires were started in order to clear land. Many of these fires spread into forest areas where they burned with greater intensity.

The total area of impact is approx. 1.4 (exact 1,589,629 ha) million ha for the Blocks A: 314,311 ha; B: 161,282 ha; C: 449,172 ha; D: 144,684 ha, and E: 510,513 up to Buntok.

Palangkaraya has: 9,667 ha: The Pristine PSF between rivers Sebangau and Katingan in the East res. West and the Java Sea in the South and the villages Kasongan and Tangkiling in the North: 855,265 ha.

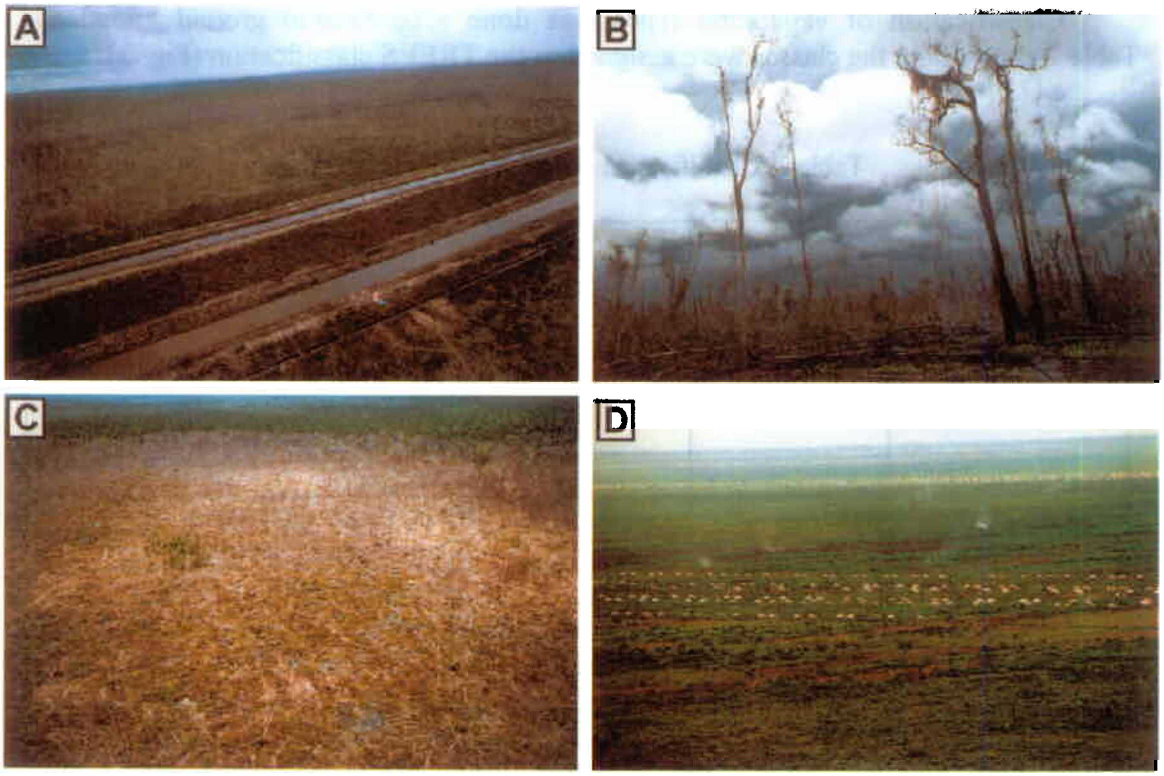

Fig. 2. Ground photographs of the study site in Central Kalimantan (A): Main irrigation canal near Palangkaraya. (B): Burned peat swamp forest. 100% of the biomass was killed by the fire, however substantial amounts of biomass remained unburned. (C): Aerial view of a burned scar. (D): Newly established Transmigration settlement on land cleared during the 1997 El Nino draught.

Ground and aerial surveys

Extensive ground surveys (see GPS tracks in ARCVIEW project) had been carried out prior to image interpretation in order to check land-use and vegetation (Boehm *et al.*, 1997; Notohadiprawiro, 1998). In the field we used a laptop computer in which the processed and georeferenced TM images (1991, 1997 and 1998) were stored. By connecting a GPS to the laptop we were able to ascertain our actual position in the georeferenced TM images at any time. Most importantly we were able to access specific areas which were ambiguous in the LANDSAT TM image. Post-fire ground-truthing was carried out both on foot and by low level aerial reconnaissance in April 1996, June and November 1998 and August 1999 to verify the existence and magnitude of burned scars.

Classification procedure

Image interpretation was done accordingly standard remote sensing procedures. The georeferenced image mosaics were visually interpreted on-screen using ARCVIEW 3.1. Interpretation was done at a resolution in order to comply with a final map scale of 1:100,000. Clouds, haze and non-overlapping areas were masked out. Area calculations were done with EXCEL 2000.

Classification of vegetation types was done according to ground knowledge. Table 2 shows how the classes were assigned to the TREES classification (Fig. 3).

Table 2. Classification of LANDSAT TM images

		Trees	Class No	Vegetation Land use
Natural forest	Closed	1	7	Medium peat
			8	Low pole peat
			9	Tall peat
			13	Heath forest
			16	Dipterocarp
			20	Heath peat forest
			21	Mangrove
	Open	2	17	Old logged dipterocarp
			18	New logged dipterocarp
	Fragmented	3	3	Freshwater swamp forest
			10	Degraded swamp forest
			22	Degraded mangrove
	Undefined	4		
Plantations		5	24	Agroforestry
Forest regrowth		6	19	Secondary forest
Non-forest vegetation	Mosaics	7	4	Shifting cultivation
			23	Strongly degraded mangrove
	Savannas and grasslands	8	2	Bushes, alang-alang
			11	Freshwater swamp (no forest)
			15	Old fire scars
	Agriculture	9	5	Permanent farmland
Unvegetated		10	1	Recent land clearance
Not visible		11	25	Clouds
No data		12	6	Blackwater lake
			12	Water
			14	Urban areas

Results and Discussion

Assessment of deforestation between 1991 and 1997

Table 3 shows an overview of the changes, which occurred in a 6 years period between 1991 and 1997. The total area analysed was 5.1 Mha. Taken together 7% of the area were cloud covered (1991 and 1997).

The highest rate was observed for closed forest: 8.3% decrease over a period of 6 years. The second largest figure is a 4.4% increase of unvegetated areas, i.e. land clearing. There were also substantial decreases in open forest (-1.6%) and forest mosaics (-1.9%).

The overall forest conversion rate is obtained if all conversion processes which lead to forest degradation or conversion are summed up (also considering forest regrowth). The forest conversion between 1991 and 1997 was 16.3%, that equals to an average forest conversion rate of 2.7% per year.

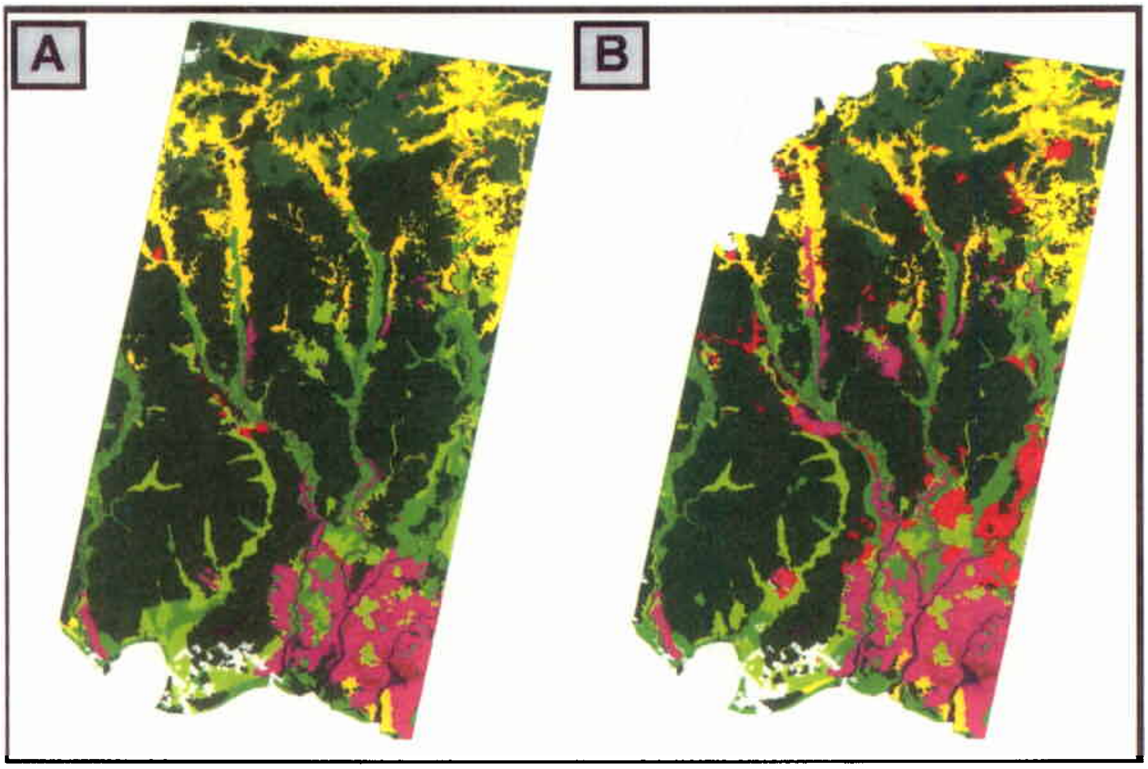

Fig. 3. Classification of the two TM mosaics of 1991 (A) and 1997(B). The colours indicate; dark green: closed forest; green: open, bright green: fragmented forests; brown-green: forest regrowth; yellow-green: grasslands; yellow: mosaics; red: unvegetated; purple: agriculture, brown: plantations; white: not visible in TM image.

Table 3. Overview of the changes between 1991 and 1997

Class	1991, ha	1997, ha	Change, ha	Change rate %
Closed forest	2,659,921	2,231,239	-428,682	-8.3%
Open forest	446,409	365,132	-81,276	-1.6%
Fragmented forest	515,773	494,471	-21,303	-0.4%
Forest Undefined	0	0	0	0.0%
Forest Plantation	28,590	29,244	654	0.0%
Forest regrowth	76,150	60,146	-16,004	-0.3%
Mosaics	578,607	477,875	-100,732	-1.9%
Grasslands, wood & shrub, non forest regrowth	381,959	354,900	-27,059	-0.5%
Agriculture	349,305	408,606	59,301	1.1%
Unvegetated	14,878	245,529	230,651	4.4%
Not visible	59,912	441,829	381,917	7.4%
No data	74,158	76,690	2,532	0.0%
Total	5,185,661	5,185,661	0	0.0%

In order to be able to assess forest conversion processes in detail one has to know about the type of conversion. This becomes evident in the following change matrix (Table 4). For example closed forest was converted into unvegetated, open and fragmented forest and into grasslands.

Table 4. Change matrix 1991-1997.

Scene P/R	1997	Natural forest				Planta-tions	Forest	Non-forest vegetation			Unvege-tated	Not visible	No data	Total
1991		Closed	Open	Frag-mented	Unde-fined			Mosaics	Savannas and grasslands	Agricult ure				
Natural Forest	Closed	2,209,789	60,19	69,960	0		1,258	8,564	47,756	7,06	129,45	125,41	475	2,659,921
	Open	2	304,00	0	0		345	3,683	109		13,16	124,94	156	446,409
	Fragnented	15,776		377,053	0	95	1,152	6,431	31,896	19,40	57,13	5,21	748	515,773
	Unidentified	0		0	0		0	0	0				0	0
Plantations		0		0	0	28,05	0	0	0	19			349	28,590
Forest regrowth		0		79	0		55,618	5,858	0	43	3,12	10,92	119	76,150
Non-forest vegetation	Mosaics	1,099	39	5,905	0		1,557	450,426	3,293	4,44	8,44	102,25	791	578,607
	Savannas and grasslands	2,695		38,335	0		215	1,347	268,554	29,75	24,77	15,68	605	381,959
	Agriculture	159		2,886	0	23	0	45	282	341,11	3,74		846	349,305
Unvegetated		3		242	0		0	0	3,008	5,73	5,39	49	1	14,878
Not visible		1.620	53	0	0		0	522	0	44	30	56.07	407	59.912
No data		96		10	0	1	0	999	2	2		82	72,193	74,158
Total		2,231,239	365,13	494,471	0	29,24	60,146	477,875	354,900	408,60	245,52	441,82	76,690	5,185,661

Assessment of deforestation between 1997 and 1998

Major factor of deforestation between 1997 and 1998 were fires which destroyed large areas of forest and other vegetation types in Indonesia. At the start of the dry season in 1997 many fires were started in order to clear land of vegetation prior to planting crops and trees. Many of these fires spread into forest areas where they burned with greater intensity. In Central Kalimantan fires spread into peatland where both the surface vegetation and underlying peat were ignited.

To investigate the extent of the fire affected area and to assess affected vegetation types and fire impact we evaluated a LANDSAT TM scene acquired 6 months after the end of the fire season (Fig. 4). Using band combination 5,4,3 (RGB) fire scars were clearly visible in the LANDSAT TM image. Table 5 shows the results of this analysis.

As a comparison we used ERS-2 SAR images to assess the burned area (Boehm, 1999; Boehm and Siegert, 1999; Siegert and Ruecker, 1999, Liew et al., 2000, Siegert and Ruecker, 2000). It was found by the ERS analysis that the burned area will be underestimated in the LANDSAT TM image by approx. 5.5%. This is because of the fast regrowth of vegetation (within 6 months) in areas where already degraded vegetation types have been burned completely by the fires. Fig. 5B shows that substantial areas which have been burned as indicated by ERS-2 SAR (red-brown areas) and by NOAA-AVHRR hotspot data (Siegert and Hoffmann, 2000, provided by IFFM/GTZ, Samarinda) are not recognizable in the LANDSAT TM image (Fig. 5C).

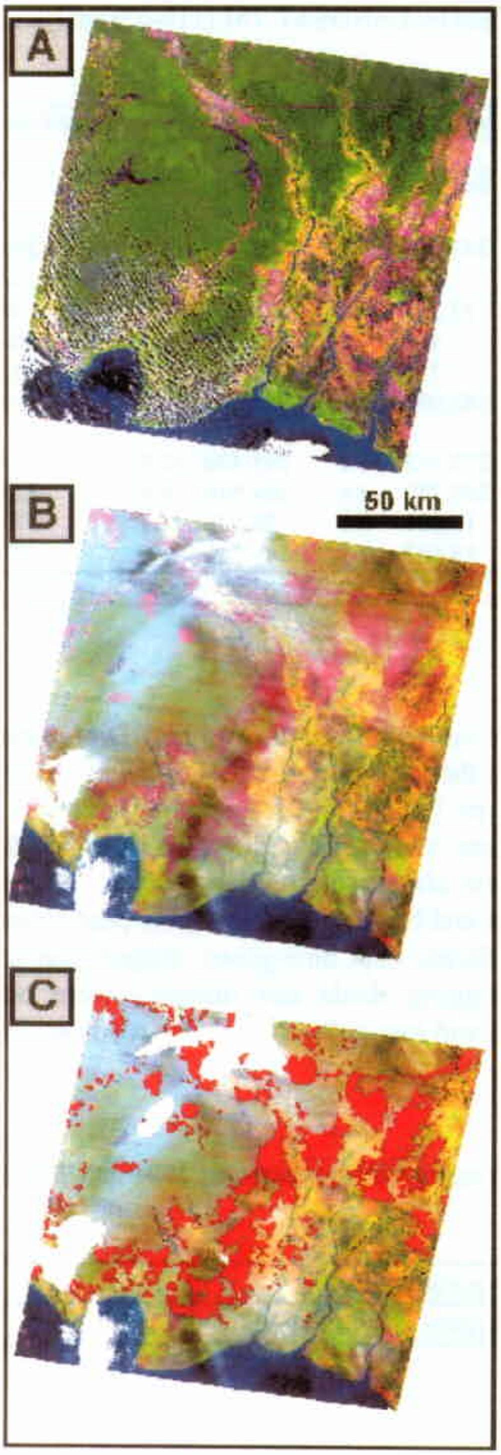

Fig. 4. LANDSAT TM image of 29 May 1997 (A) and 29 March 1998 (B). In (B) red colours indicate burned areas. (C) GIS layer of burned scars superimposed on TM image.

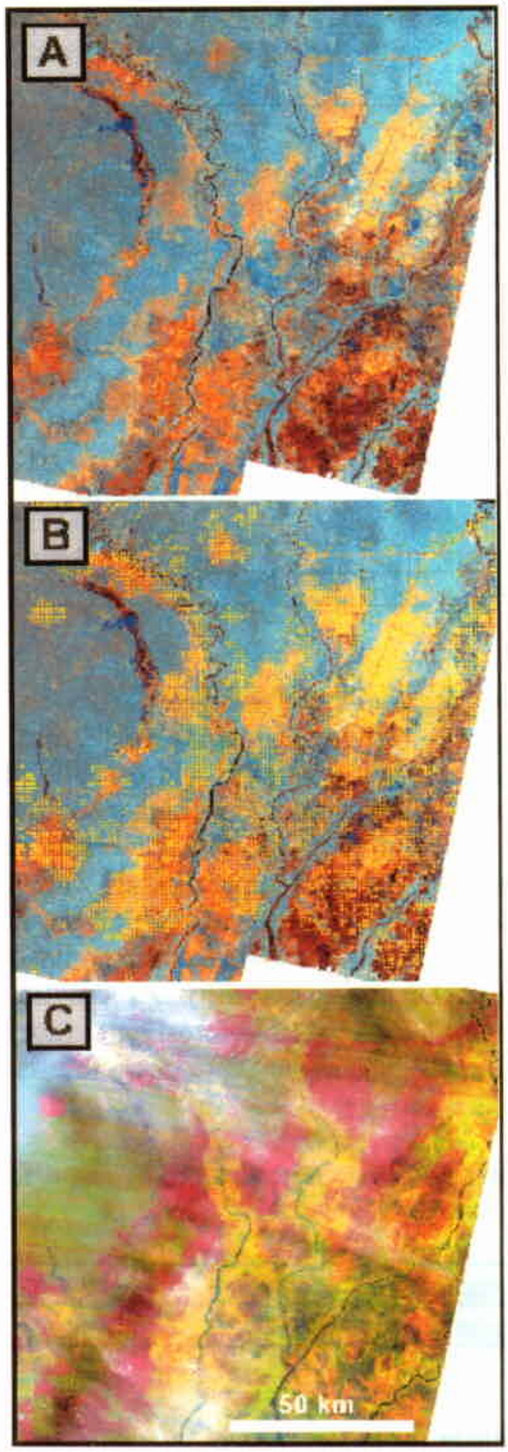

Fig. 5. (A) Multi-temporal ERS-2 mosaik of part of the study site before 1996/7 and after the fires 1997. Blue indicates unburned vegetation, orange to brown burned vegetation. (B) NOAA-AVHRR hotspots (yellow) acquired between August and October 1997 superimposed on multi-temporal ERS-2 mosaik. (C) Corresponding subset of the 29.3.1998 LANDSAT TM image. Note that substantial areas appear in green (unburned) although they have been burned as shown in (A and B).

Table 5. Burned areas and vegetation types processed by LANDSAT TM (118-62) analysis using the images from 5/1997 and 3/1998

	Clouds	Burned area		Unburned area		Total area		Burned area
Trees class	ha	ha	%	ha	%	ha	%	%
Closed forest	130,969	291,747	12.2	841,971	35.3	1,264,687	53.1	23.1
Open forest	0	0	0.0	0	0.0	0	0.0	0.0
Fragmented forest	22,695	62,413	2.6	243,348	10.2	328,457	13.8	19.0
Forest undefined	0	0	0.0	0	0.0	0	0.0	0.0
Forest plantation	0	1	0.0	13,222	0.6	13,222	0.6	0.0
Forest regrowth	0	2,875	0.1	452	0.0	3,327	0.1	86.4
Mosaics	237	450	0.0	715	0.0	1,402	0.1	32.1
Grasslands, wood & shrub, non forest regrowth	8,927	47,793	2.0	182,062	7.6	238,782	10.0	20.0
Agriculture	12,795	10,511	0.4	272,142	11.4	295,448	12.4	3.6
Unvegetated	4,996	54,190	2.3	105,330	4.4	164,516	6.9	32.9
Not visible	1,281	10,071	0.4	15,604	0.7	26,956	1.1	37.4
No data	6,309	4,476	0.2	35,507	1.5	46,292	1.9	9.7
Sum	188,210	484,526	20.3	1,710,353	71.8	2,383,089	100.0	20.3

Logging roads and railways

Fig. 6A shows the logging roads into the dry soil of heath forests and Dipterocarp forests in black for 1991 and in red for 1997. In the same Fig. 6A the logging rails into the PSF are shown in dark blue colour for 1991 res. blue for 1997, compare Table 6.

Fig. 6B has the same colours for the logging roads and logging rails as in fig. 6A, but here they are superimposed with the forest classification (dark green: tall peat swamp forest, green: medium peat swamp forest and bright green: low pole peat swamp forest, blue-green: logged over and intact heath forest, dark blue-green: logged over and intact Dipterocarp forest). As can be seen logging roads and railways were only established in valuable forest types (not in heath and low pole forest). The road network is especially dense in Dipterocarp forests.

Table 6. Change Detection of Logging roads and Logging railways between 1991 and 1997 of the study site.

Logging roads 1991	4419 km	Logging roads1997:	6621 km
Logging railways 1991	7136 km	Logging railways 1997:	9406 km

Causes for deforestation

Satellite images from 1998 compared to those from 1997 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.

Between 1991 and 1997:

- Logging operation
- Land clearing for small scale farming
- Land clearing for plantations

Between 1997 and 1998:

- Large scale land clearing for Mega rice project (MRP)
- Man-made fires favoured by ENSO draught
- Illegal logging operation

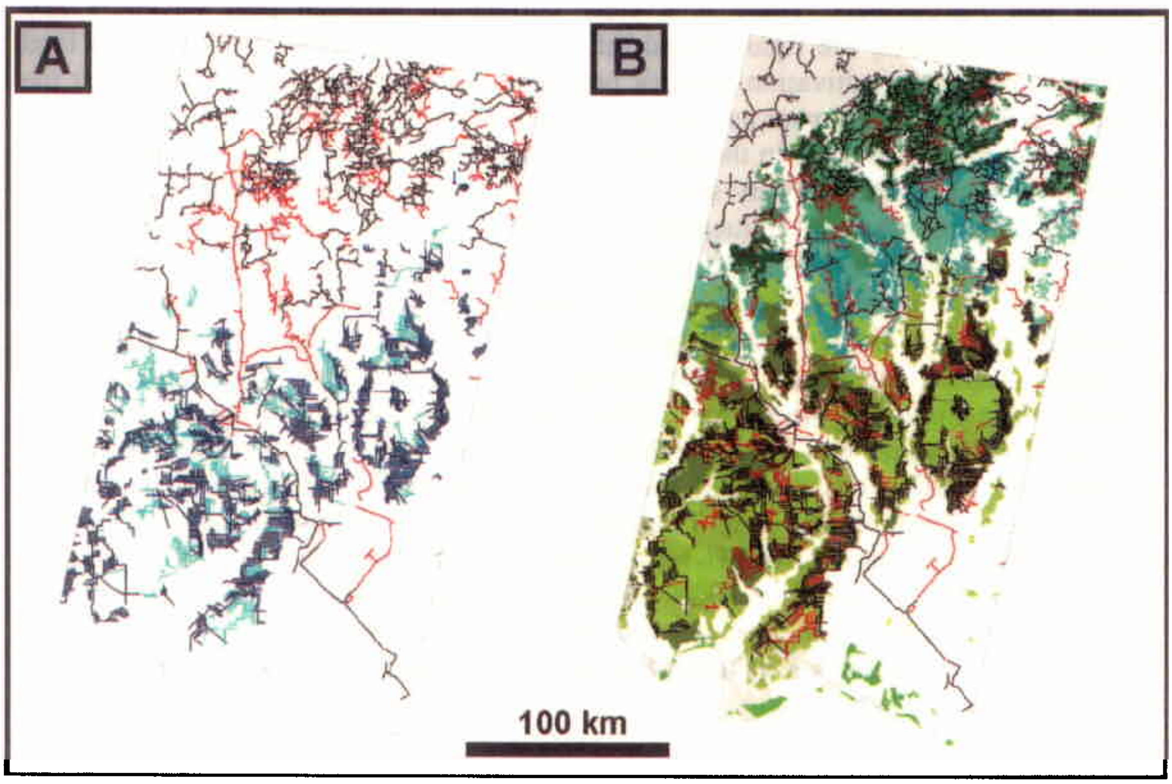

Fig. 6. A: Logging roads (black: 1991, red: 1997) and logging railways (dark blue: 1991, blue: 1997). B: Logging roads and logging railways superimposed on forest classification (dark green: tall peat swamp forest, green: medium peat swamp forest and bright green: low pole peat swamp forest, blue-green: logged over and intact heath forest, dark blue-green: logged over and intact Dipterocarp forest).

Fig. 7 shows a new geocoded SPOT image (41 km × 46 km) taken on 19 June 1999 from Block A of the MRP at Dadahup with the rivers Barito (green) and Mengkatip (black). The regrowth is ongoing between the new channels (light red colour) after the clear cuts and fires in 1997. Farmers observe new threats. Many mice are eating amounts of the rice. The SPOT image resolution is with 20 m per pixel high. Even houses and smaller channels can be made visible. The clouds are in white and the shadows in black colours. Below the splitting of rivers Barito and Kapuas Murung lies the island Pulau Petak that was developed some years before. On the right side of Barito also channels drain farmlands.

Fig. 8 shows a vegetation map from nearly the whole Block A based on the LANDSAT TM image from 1991. It includes the Lamunti and Dadahup region. The colours indicate different types of PSF, of bushlands and cultivated areas. The legend is: dark pink - clearings; light pink - shifting cultivation and farmland; pink - old fire scars; ochre - riverine ecosystem; green - medium PSF, blue green - low pole PSF; dark green - tall PSF; light blue - degraded swamp forest; purple - wetlands; light green - secondary PSF.

A digitised soil map is presented in Fig. 9 from the upper part of Block A. The soil map indicating the thickness of peat for Block A (digitised from Peta Penelitian Tanah dan Agroclimat). There is a clear correlation between peat thickness and agricultural activities, see figure 8 and ref. Jaya, 2000). Till 1997 there were no land clearings or shifting cultivation on thick peat. The peat thickness starts with 0 m at the rivers and reaches in the upper part up to 10 m and 12 m.

Tidal influenced areas in the south have a different soil content, e.g. pyrite (FeS_2) (Purnomo, approx. 1990). Peaty soil contains a little bit of peat material. In the lower part of the figure 9 the tidal influences the irrigation and drainage channels to water the paddy fields near the Java Sea. Reclamation of tidal swamp area with acid sulphate soil is well known since many years. Short channels (handils) were dug by the Banjars, which are approx. 4km to 9km long and grouped left and right to rivers Sebangau, Kahayan, Kapuas and Barito. Water management system called "Fork-System" from Gadiah Mada University are approx. 12km long, with right and left ponds (reservoir) at the end; which were built in the 1980th to store and remove oxidation products. A gradient of fertility occurs along the primary, secondary, tertiary and quaternary channels, e.g. Pangkoh-Kahayan, Tabunganen-Barito, and Barambai-Barito. The tidal water quality are measured in pH-value, electric conductivity (EC in μSi/m), sodium (Na^+), chloride (Cl^-), sulphate (SO_4^{2-}) and magnesium (Mg^{2+}) concentration; Na^+, Cl^-, SO_4^{2-} may come from sea water and Mg2- from the soil.

Fig. 10A-F contains a gallery of aerial photos taken during the flights 11 April 1996 and 13 June 1998.

Fig. 7. SPOT image acquired on 19 June 1999 showing regrowth of secondary vegetation in bright red. The image shows with high resolution the MRP area in Block A at Dadahup area between rivers Mengkatip, left (black) and Barito, right (bright green). Transmigration settlements are resolved beside the channels. Red means vegetation and green cleared areas. The white and black areas indicate clouds res. shadows.

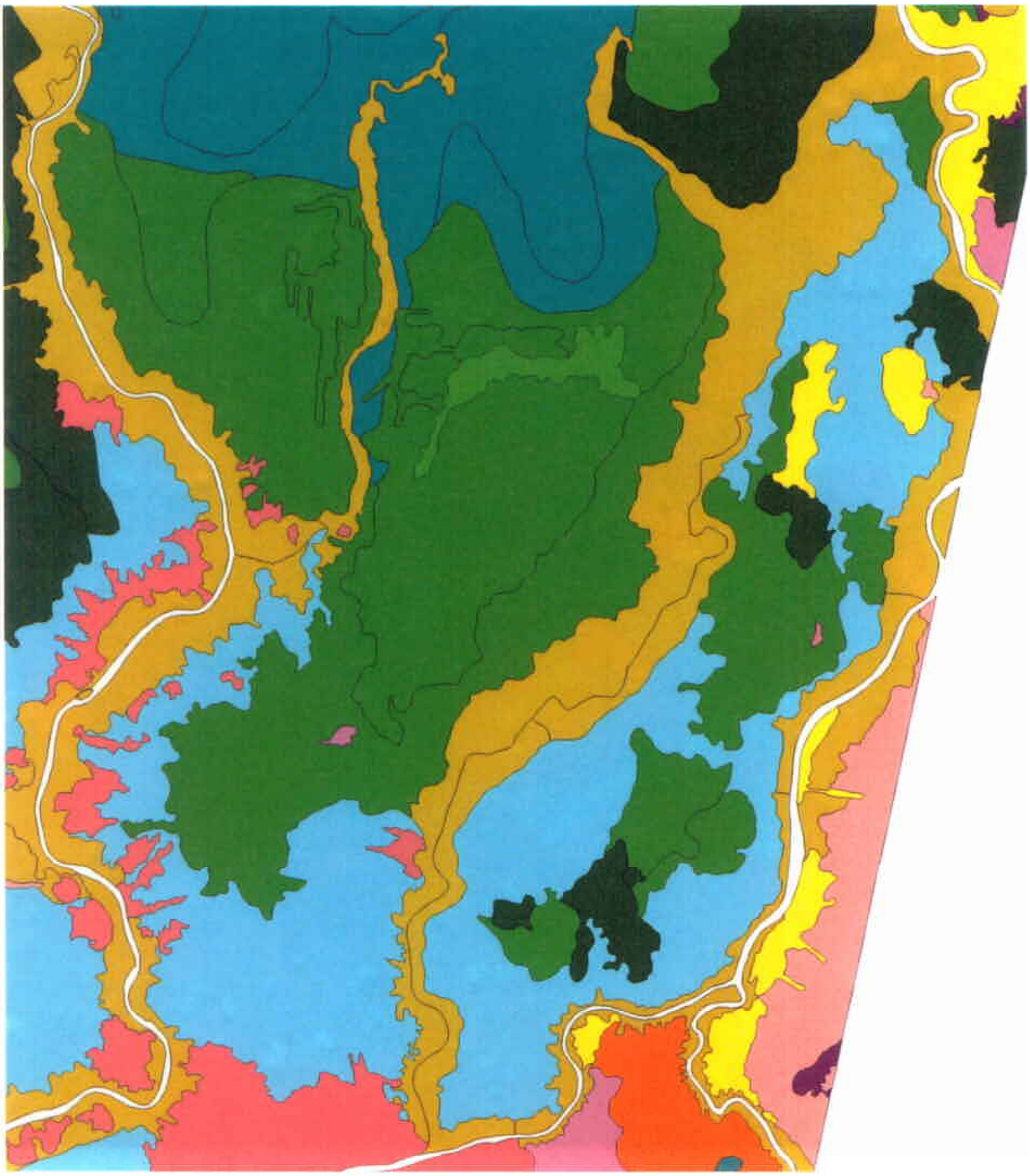

Fig. 8. Vegetation map from MRP- Block A with villages Lamunti and Dadahup between rivers Kapuas and Barito. The map based on the LANDSAT TM image from 1991. The legend is: dark pink - clearings; light pink - shifting cultivation and farmland; pink - old fire scars; ochre - riverine ecosystem; green - medium PSF, blue green - low pole PSF; dark green - tall PSF; light blue - degraded swamp forest; purple - wetlands; light green - secondary PSF.

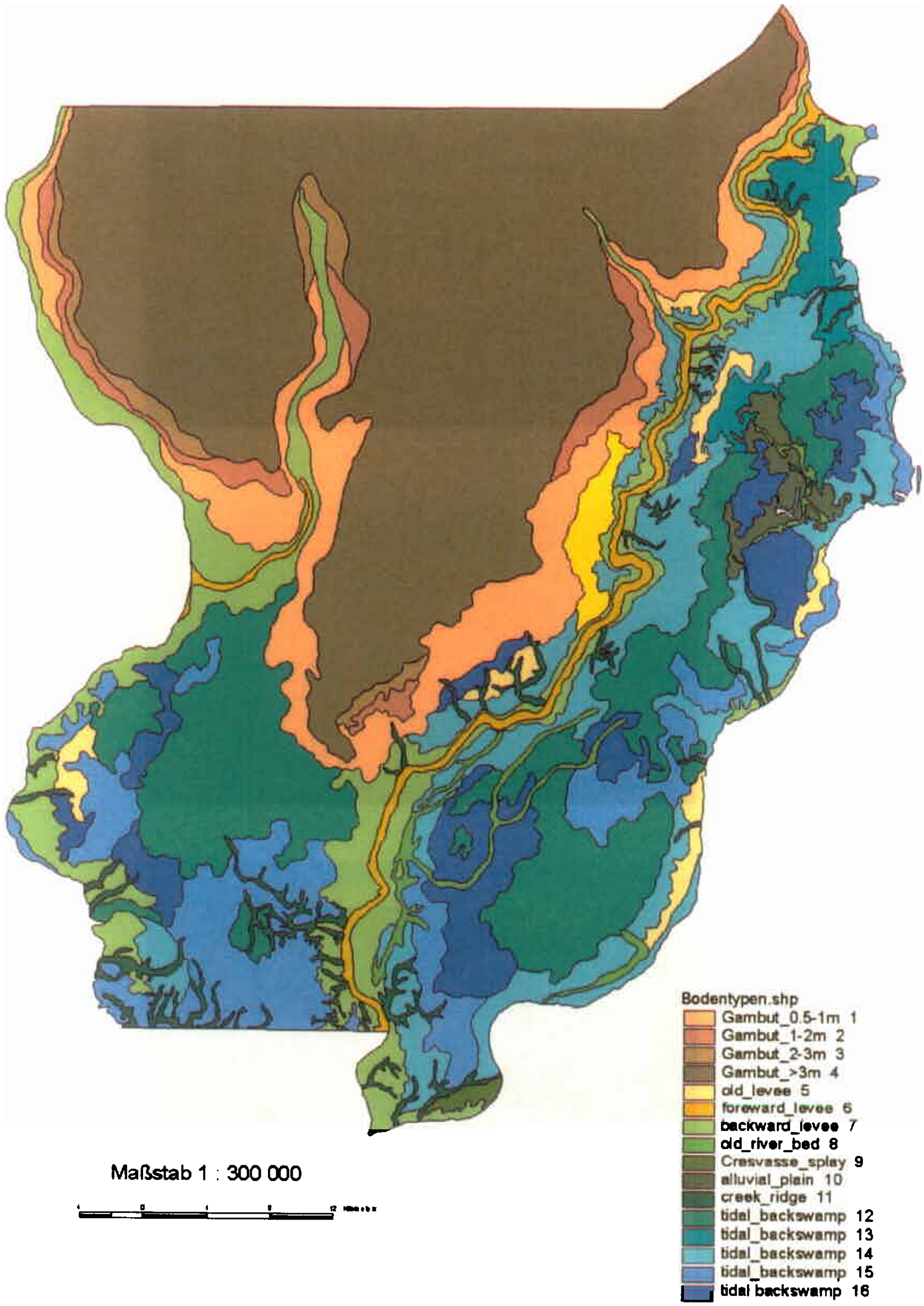

Fig. 9. Soil map from MRP- Block A with Dadahup and Lamunti. The soil map indicating the thickness of peat for Block A (digitised from Peta Penelitian Tanah dan Agroclimat). There is a clear correlation between peat thickness and agricultural activities, see Fig. 8 and ref. Jaya, 2000. Till 1997 there were no land clearings or shifting cultivation on thick peat.

A

B

C

Fig. 10. Gallery of aerial photos.

(A) Pristine Peat Swamp Forest with black water at river Sebangau. Aerial photo taken on 11 April 1996; (B) Rice fields near river Kahayan in the south of the MRP where the tidal influence occur. Aerial photo taken on 11 April 1996; (C) Preparation work for a secondary channel into PSF of the Mega Rice Project at Lamunti, river Kapuas. Aerial photo taken on 11 April 1996.

D

E

F

Fig. 10. Gallery of aerial photos (continued).

(D) The double channel with black peat water at river Barito. Main sluices and secondary PSF is visible. Aerial photo taken on 13 June 1998; (E) Double channel crossing the black water river Mentangai. Without sluices no irrigation is possible. Burnt PSF is the result of ENSO effect combined with man made fires. Aerial photo taken on 13 June 1998; (F) Double channel with big sluices at river Kahayan. In the foreground is the black water river of Kalampangan Area leading into Kahayan. Aerial photo taken on 13 June 1998.

Future Perspectives

There is a very high risk that most of the peat swamp forest resource will be destroyed within a very short period of time. NOAA-AVHRR hotspot data indicate that land clearing continues although the Government has stopped the MRP. Another major reason of forest degradation is illegal logging, which occurs all over the area with a strong increase since the economic crisis. Logging and the drainage of the peat swamp (by the canals) highly increases the risk of recurrent fires. Using hydrological models, current land use patterns and accessibility (logging roads and railways) may simulate the future development.

A bigger project of 2.8 million ha incl. the 1 million ha of MRP is released by presidential degree in the Kahayan, Kapuas, Barito (KaKaB) region of Central Kalimantan. This must be planned better and according to professional EIA (Environmental Impact Assessment).

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