STRAPEAT STATE OF KNOWLEDGE REPORT

Monitoring land cover and impacts, Remote Sensing (RS) and GIS used for Kalteng and Sarawak Borneo

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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 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 the frame of EUTROP project this tools are applied for tropical forest in Central Kalimantan where peat swamp forest (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 1.4 million hectares 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 has been processed too.

In the framework of the European Union project “Natural Resource Functions, Biodiversity and Sustainable Management of Tropical Peatlands” No.: ERB IC18-CT98-0260 this work was 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.

For the STRAPEAT-Project (2002 - 2004) we have procured five Landsat images for Kalteng and Sarakak, see Figs. 10, in the time 1999 to 2000 (Figs. 10 -18). In a second timeframe, approx. 2002, we will analysis the land use and vegetation changes.

1. Data Processing

Basic image processing was done using ENVI 3.1. 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. 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 two ground and aerial surveys conducted in 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) (**Figure 1**).

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 30m. 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).

Map information		
SITE	*118-61 and 118-62*	
Geographic extent		
	LAT	LONG
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	*500000 m*	
False northing	*0 m*	
Zone	49	
N or S	S	
Central Meridian		
Latitude of 1st standard parallel		
Latitude of 2nd standard parallel		

Table 1. Map Information

2. Test side 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 (1,2). 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.

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 (**Figure 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.

3. Ground 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 (3,4). 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 June and November 1998 and August 1999 to verify the existence and magnitude of burned scars.

4. Classification procedure

Image interpretation was done accordingly standard remote sensing procedures. The georeferenced image mosaics were visually interpreted on-screen using ARCVIEW 3.2. 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.

Vegetation cover classification

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

5. Results – Vegetation maps of LANDSAT TM 118-61 and 118-62

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.

Table 3. Overview of the changes between 1991 and 1997

Overview Table: Change 1991 - 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.

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 (**Figure 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 (5-7). It was found 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. **Figure 5B** shows that substantial areas which have been burned as indicated by ERS-2 SAR (red-brown areas) and by NOAA AVHRR hotspot data (provided by IFFM/GTZ, Samarinda) are not recognizable in the LANDSAT TM image (**Figure 5C**).

Scene P/R	1997	Natural Forest				Plantations	Forest regrowth	Non-forest vegetation			Unvegetated	Not Visible	No data	Total
1991		Closed	Open	Fragmented	Undefined			Mosaics	Savannas and grasslands	Agriculture				
Natural Forest	Closed	2,209,789	60,190	69,960	0	0	1,258	8,564	47,756	7,061	129,452	125,416	475	2,659,921
	Open	2	304,009	0	0	0	345	3,683	109	0	13,160	124,943	156	446,409
	Fragmented	13,776	0	377,053	0	955	1,152	6,431	31,896	19,406	57,139	5,218	748	515,773
	Undefined	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantations		0	0	0	0	28,030	0	0	0	192	0	0	349	28,590
Forest regrowth		0	0	79	0	0	55,618	5,858	0	432	3,121	10,922	119	76,150
Non-forest vegetation	Mosaics	1,099	396	5,905	0	0	1,557	450,426	3,293	4,446	8,441	102,254	791	578,607
	Savannas and grasslands	2,695	0	38,335	0	0	215	1,347	268,554	29,758	24,771	15,680	605	381,959
	Agriculture	159	0	2,886	0	230	0	45	282	341,112	3,743	0	846	349,305
Unvegetated		3	0	242	0	0	0	0	3,008	5,738	5,395	490	1	14,878
Not Visible		1,620	537	0	0	0	0	522	0	442	307	56,078	407	59,912
No data		96	0	10	0	10	0	999	2	20	0	828	72,193	74,158
Total		2,231,239	365,132	494,471	0	29,244	60,146	477,875	354,900	408,606	245,529	441,829	76,690	5185661

Table 4. Change matrix 1991-1997.

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Table 5. Burned areas and vegetation types

	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

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

Causes for deforestation

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)
- Illegal logging operation

Figure 7 shows a new SPOT image dd. 19 June 1999 from Block A of the MRP. Figure 8 shows a vegetation map based on the LANDSAT TM image from 1991and figure 9 a digitised soil map.

6. Future perspectives and gaps

There is a very high risk that most of the peat swamp forest ressource will be destroyed within a very short period of time. NOAA AVHRR hotspot data indicate that land clearing continues although the MRP has been stopped by the Government. 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. The future development may be simulated by using hydrological models, current land use patterns and accessibility (logging roads and railways).

With Modis Satellite images of 250m by 250m pixel-resolution combined with knowledge of LANDSAT images the status of the hole peatland area of Borneo could by analysed.

7. References

1. **Anderson, J.A.R. (1983)** The tropical peat swamps of western Malesia. In: A.J.P. Gore, (ed) *Mires: swamp, bog, fen and moor, B. Regional studies*. Elsevier, Amsterdam, pp. 181-199
2. **Rieley, J.O., Page, S.E. (1995).** "Biodiversity and Sustainability of Tropical Peatland" Samara Publishing Limited, Tresaith, Cardigan SA43 2JG, UK, ISBN: 1873692102
3. **Böhm, H.-D.V., Siegert, F., Rieley, J.O., Limin, S., (1997).** "Land use planning and environmental monitoring in Kalimantan using remote sensing data", published in Economic & Business Review Indonesia No. 279, August 20, 1997
4. **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
5. **Böhm, H.-D.V., Siegert, F. (1999).** "Interim Report of Aerial Surveys and Ground Truth campaigns in 1997 and 1998 in Central Kalimantan, Indonesia - Peat Swamp Forest, Mega-Rice-Project and Fires", 25.2.1999, 49 pages incl. 22 colour figures
6. **Böhm, H.-D.V. and Siegert, F. (1999).** Remote Sensing verification by Aerial Surveys and Ground Truth Campaigns 1997 and 1998 in Central Kalimantan, Indonesia - Peat Swamp Forest, Mega-Rice-Project and Fires. *Workshop on Tropical Forest and Remote Sensing, the* Centre for Remote Imaging, Sensing and Processing, National University of Singapore, 5 March 1999; CD is available from CRISP
7. **Siegert, F. & Rücker, G. (1999).** Evaluation of the 1998 forest fires in East-Kalimantan (Indonesia) using multitemporal ERS-2 SAR images. *Earth Observation Quaterly*, 61, 7-12
8. **Siegert, F. & Rücker, G. (2000).** Use of Multitemporal ERS-2 SAR Images for Identification of Burned Scars in South-East Asian Tropical Rainforest. *Int.J.Rem.Sensing,* in press
9. **Siegert, F. & Hoffmann, A. (2000).** The 1998 Forest Fires in East-Kalimantan (Indonesia): A quantitative evaluation using high resolution, multitemporal ERS-2 SAR Images and NOAA-AVHRR hotspot data. *Remote Sens. Environ.*, in press
10. **Page**, **S.E., Rieley, J.O., Böhm, H-D.V., Siegert, F., & Muhamad, N.Z (2000). "**Impact of the 1997 fires on the peatlands of Central Kalimantan, Indonesia", prepared for the Millennium Wetland Event, Quebec 2000
11. **Jaya, A., Limin, S., Rieley, J.O., Böhm, H.-D.V. (2000).** "Peat depth in Block C of Mega Rice Project, Central Kalimantan" prepared for the Millennium Wetland Event, Quebec 2000
12. **Böhm, H.-D.V., Siegert, F. (2001).** „Land use change and (il)-legal logging in Central Kalimantan, Indonesia", held at Jakarta Symposium Proceeding, in proceeding on Peatlands for people natural resources function and sustainable management, 22-24 Aug 2001, p.132.
13. **Siegert, F., Böhm, H.-D.V., Rieley, J.O., Page, S.E., Jauhiainen, J., Vasander, H. and Jaya, A. (2001).** „Peat fires in Central Kalimantan, Indonesia: fire impacts and carbon release" in Jakarta Symposium Proceeding on Peatlands for people natural resources function and sustainable management, 22-24 Aug 2001, p. 142.
14. **Siegert, F., Ruecker, G., Hinrichs, A. and Hofmann, A.A. (2001).** „Increase damage from fires in logged forests during draughts caused by El Nino, Nature Vol.414, 22 November 2001.
15. **Pages S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., and Jaya, Adi (2002) "**Carbon released during peatland fires in Central Kalimantan, Indonesia in 1997" submitted to Letter to Nature

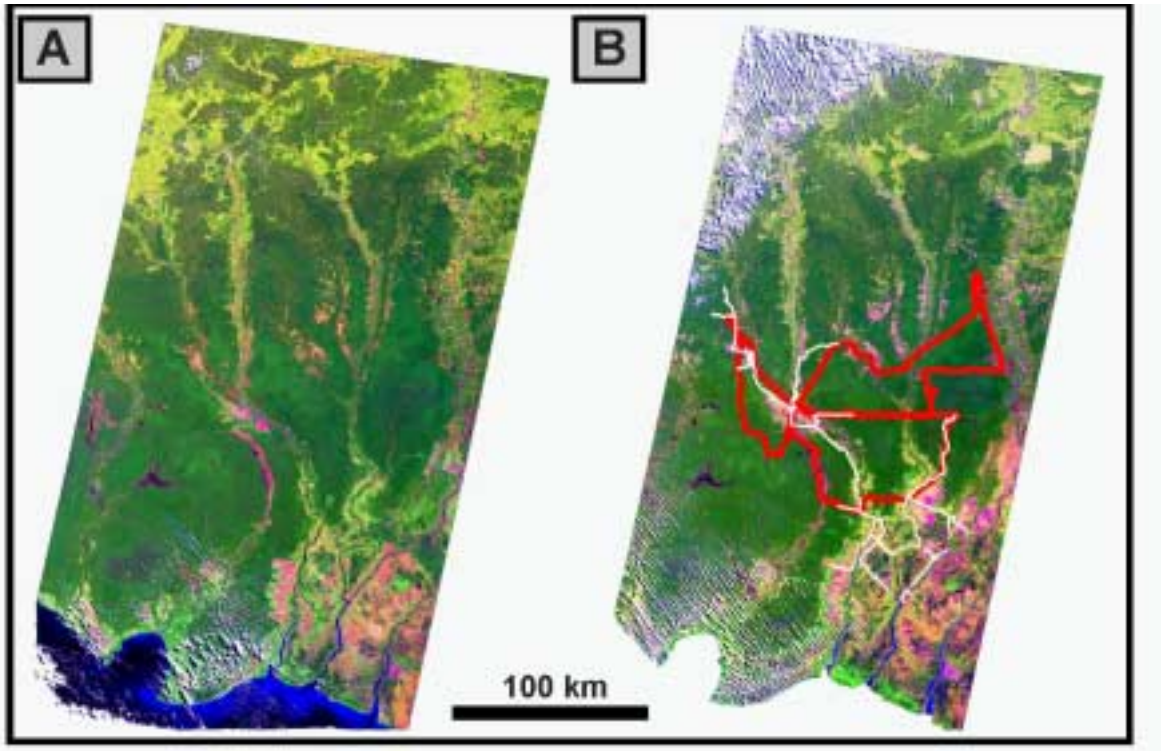

Figure 1. Mosaiked TM images (118-61 and 62) of 30.6.1991 (A) and 29.5.1997(B). In (B) the GPS tracks of the 1998 ground (white) and aerial (red) surveys are shown. Peat swamp forests appear in dark green colours in the lower half of the image, heath forests in brownish colours, Dipterocarp forest in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

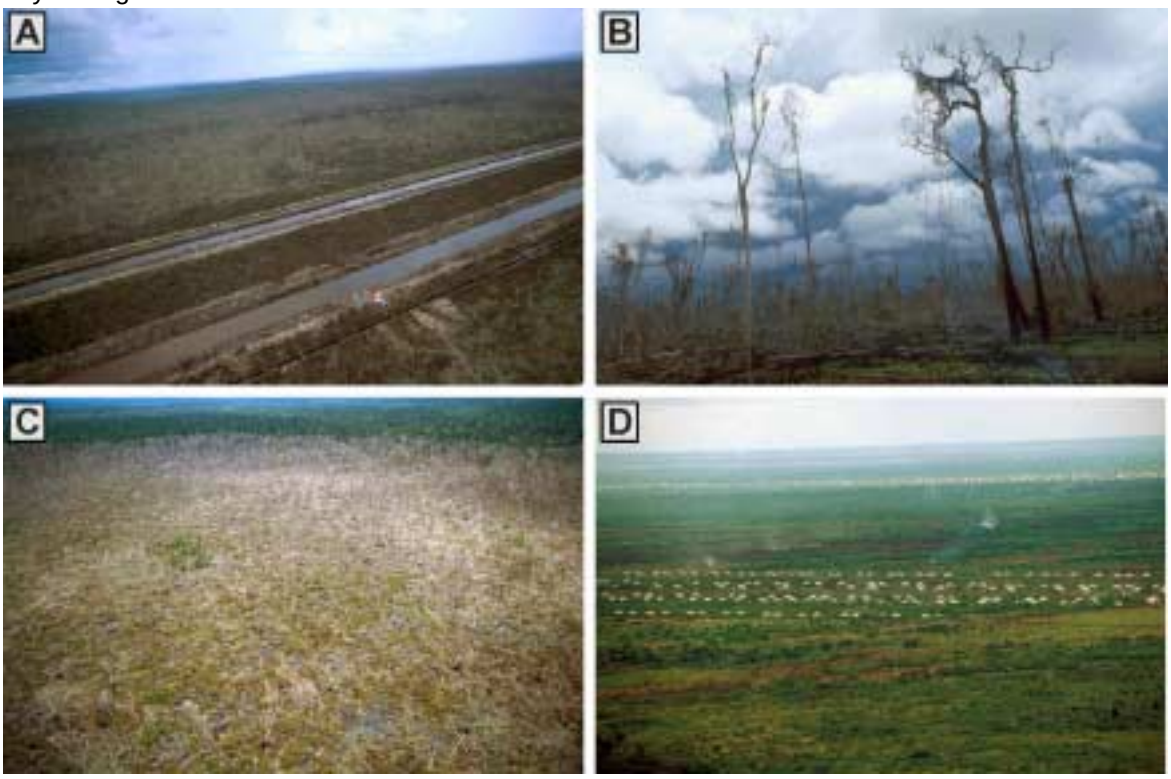

Figure 2. Ground photographs of the study site in Central Kalimantan (A): Main irrigation canal near Palangkaraya. (B): Burned peat swamp forest. 100% of the biomass was killed by the fire, however substantial amounts of biomass remained unburned. (C): Aerial view of a burned scar. (D): Newly established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

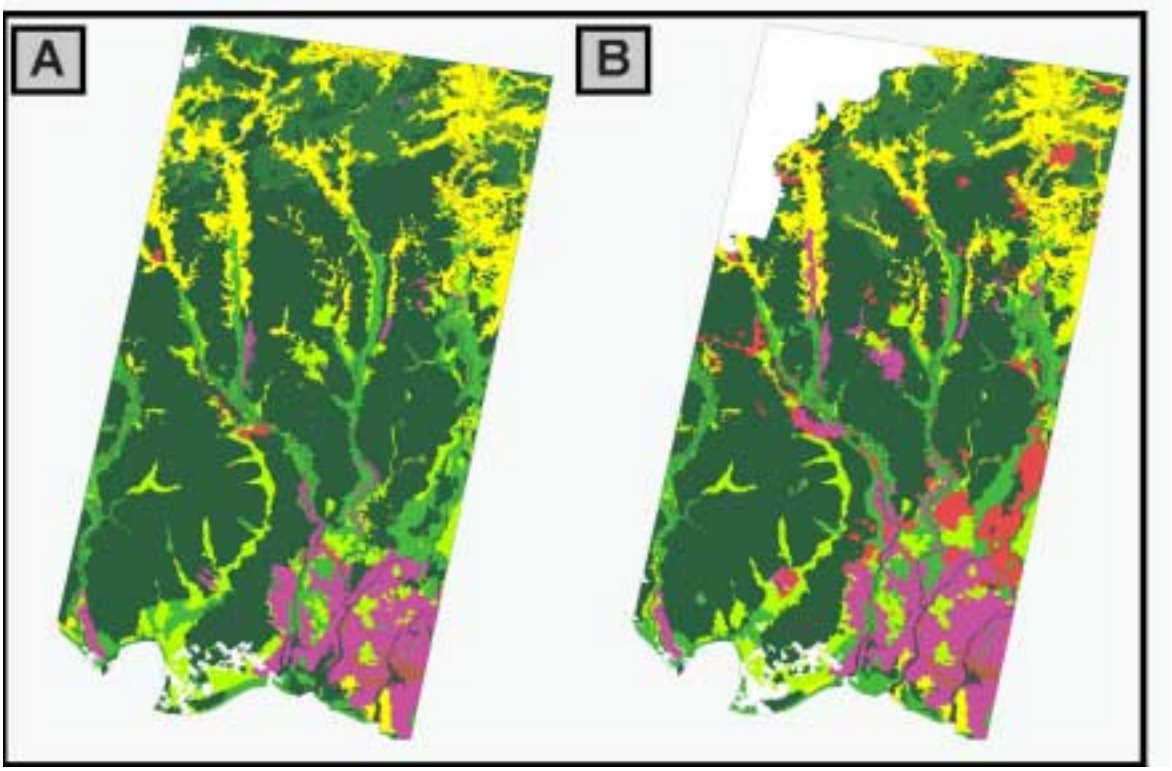

Figure 3. Classification of the two TM mosaiks of 1991 (A) and 1997(B). The colours indicate; dark green: closed forest; green: open, bright green: fragmented forests; brown-green: forest regrowth; yellow-green: grasslands; yellow: mosaiks; red: unvegetated; purple: agriculture, brown: plantations; white: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

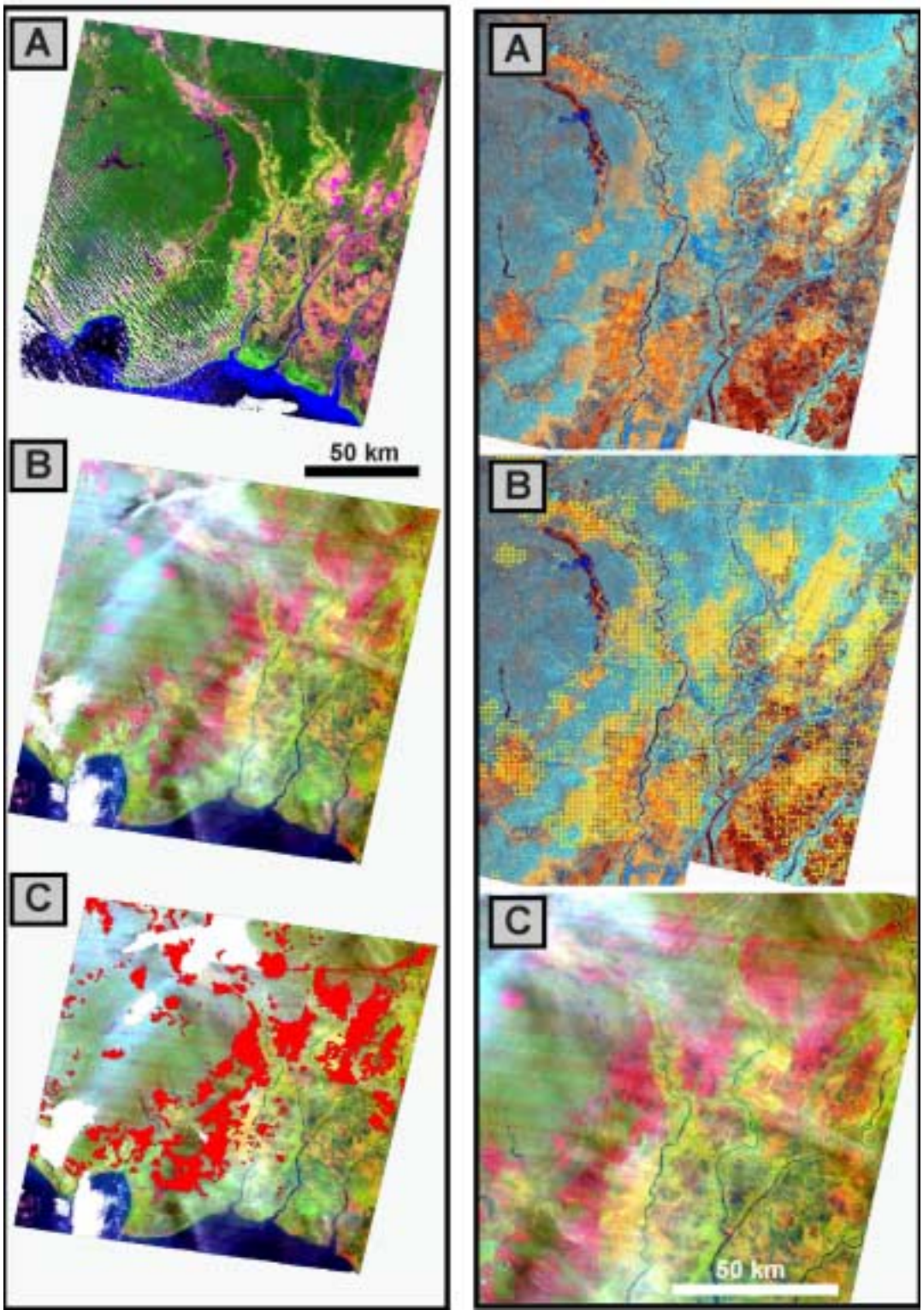

Figure 4 (left). LANDSAT TM image of 29 Mai 1997 (A) and 29 March 1998 (B). In (B) red colours indicate burned areas. (C) GIS layer of burned scars superimposed on TM image. **Figure 5 (right)**. (A) Multi-temporal ERS-2 mosaik of part of the study site before 1996/7 and after the fires 1997. Blue indicates 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).

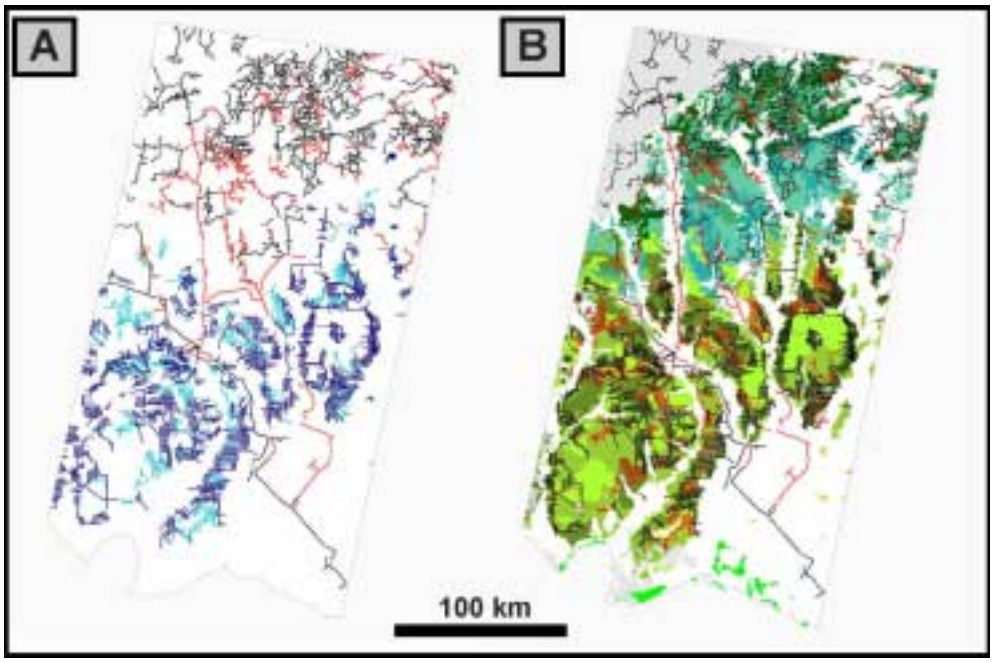

Figure 6. A: Logging roads (black: 1991, red: 1997) and logging railways (dark blue: 1991, blue: 1997). B: Logging roads and logging railways superimposed on forest classification (dark green: tall peat swamp forest, green: medium peat swamp forest and bright green: low pole peat swamp forest, blue-green: logged over and intact heath forest, dark blue-green: logged over and intact Dipterocarp forest). As can be seen logging roads and railways were only established in valuable forest types (not in heath and low pole forest). The network is especially dense in Dipterocarp forests.

Figure 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.

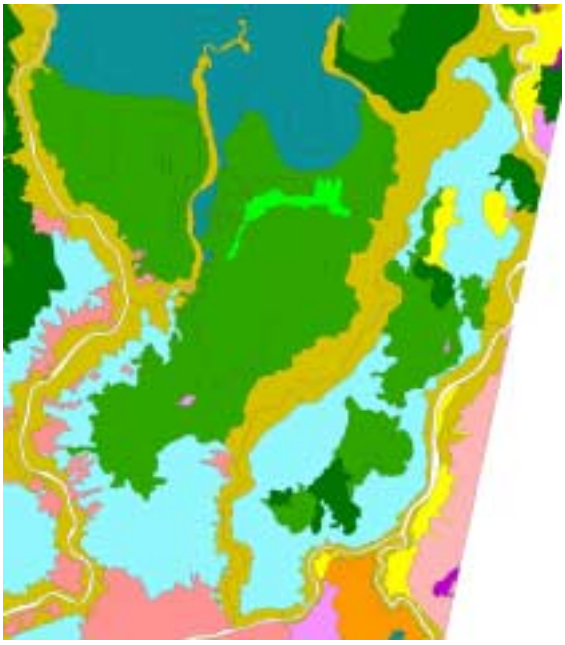

Figure 8. Vegetation map from MRP- Block A with villages Lamunti and Dadahup between rivers Kapuas and Barito. The map based on the LANDSAT TM image from 1991. The coloures indicates different types of PSF, of bushlands and cultivated areas.
Pink: clearings, farmland, yellow: bushland, alang-alang, light brown: riverine ecosystem, green: medium peat, dark green: low pole peat, green-blue: tall peat, light blue: degraded swamp forest, dark red: wetlands, orange: old fire scars

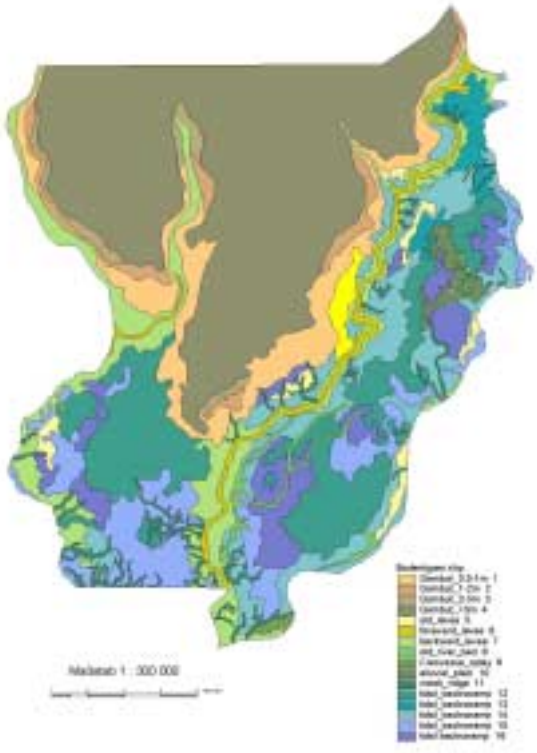

Figure 9. Soil map from MRP- Block A with Dadahup and Lamunti. The soil map indicating the thickness of peat for Block A (digitised from Peta Penelitian Tanah dan Agroclimat). There is a clear correlation between peat thickness and agricultural activities, see figure 8 and ref.12. Till 1997 there were no land clearings or shifting cultivation on thick peat.

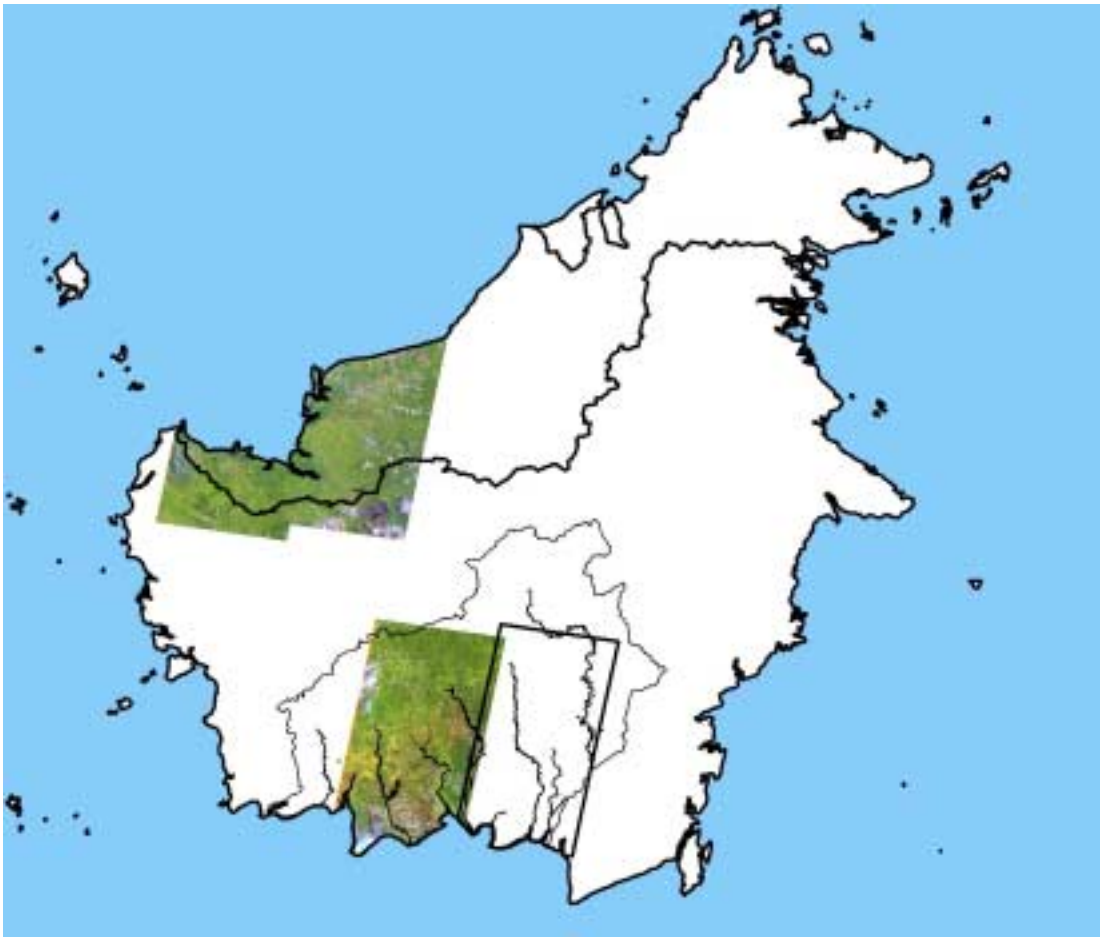

Figure 10 New Landsat ETM images for the STRAPEAT-Project for Kalteng and Sarawak.

119/061	26.11.1999	all bands	Kasongan
119/062	26.11.1999	all bands	Sampit
120/058	31.08.2000	all bands	Sibu on lower edge
120/059	31.08.2000	all bands	Sibu on upper edge
121/059	18.05.2000	all bands	Kuching

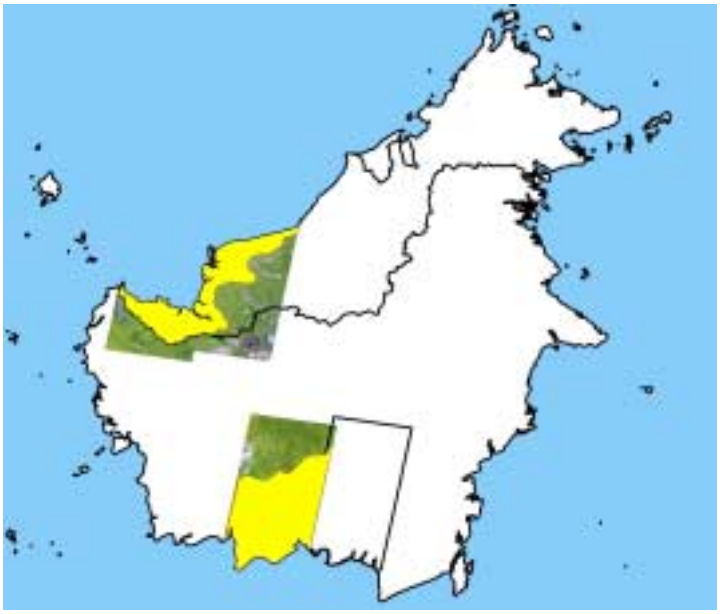

Fig. 11: STRAPEAT-Peatland-area to analyse in yellow colour. Transparent box (118-61+62)on the right side in Kalteng was studied and analysed in the EUTROP-project

Figure 12: STRAPEAT Landsat ETM 119-62 from 26.11.1999 with Sampit

Figure 13:STRAPEAT Landsat ETM 121-59 and 120-59 from 18.05.2000 res. 31.8.2000 with Kuching

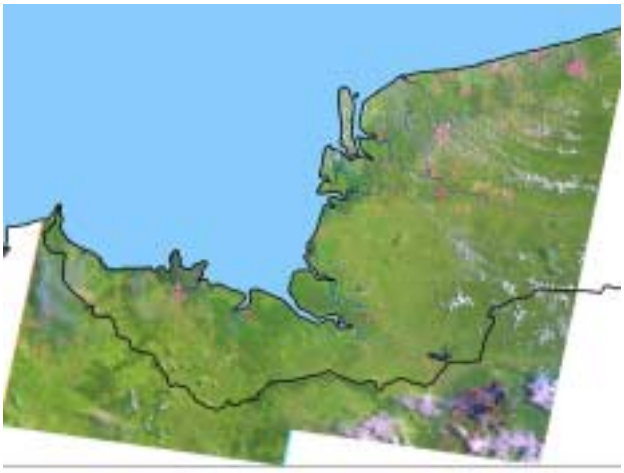

Figure 14: Three Landsat ETM images (120-58+59, 121-59) taken 2000 from Sarawak with Malaysian border to Kaltimantan of STRAPEAT-project

Figure 15: STRAPEAT Landsat ETM 120-59 with Delta of Rajang, peat-area

Figure 16: STRAPEAT Landsat ETM 120-59 with logging activities

Figure 17: Landsat ETM images of Borneo peatland with tracks in Kalteng and flight path from Jakarta to Palangkaraya, green. Black area was analysed in the frame of EUTROP project

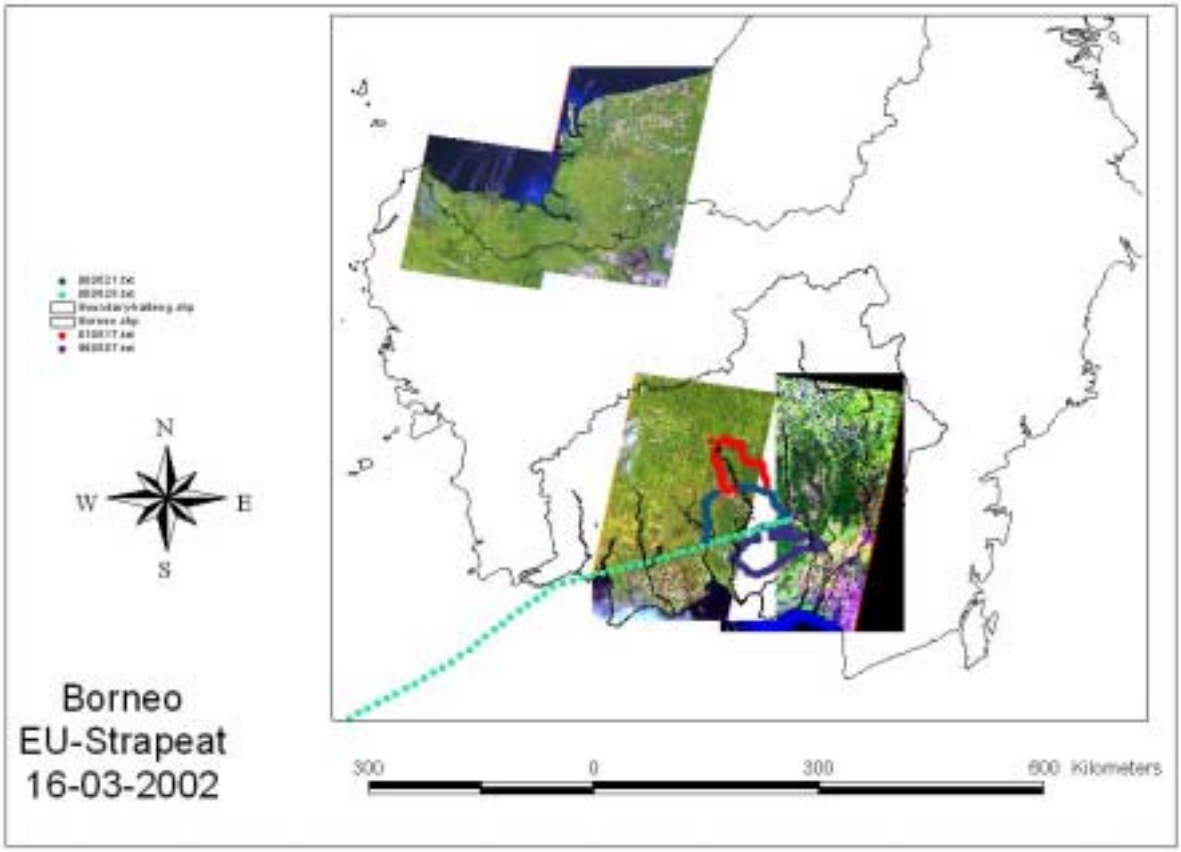

Figure 18: GPS-Tracks from the 3rd, 5th and 6th April 2002 in Sarawak: Kuching-Sibu-Bus-Tour, Sessang Tour to Mardi-Peat-Station and Boat-Tour back to Kuching