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# Land Use Change in Central Kalimantan over the Period 1991 - 2001 including Impacts of Selective and Illegal Logging, MRP Establishment and Fires

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## Abstract

In Central Kalimantan grows on plain areas a lot of Peat Swamp Forest (PSF) from the coast at the Java Sea up to the north of the provincial capital Palangkaraya. PSF is among the earth's most endangered ecosystem. Peatland has a huge carbon storage capacity and is extremely fragile (Page et al. 2000 and 2002). Local communities have used them extensively for centuries with no significant effect on the environment. This changed in 1995/1996 when a programme of massive peatland conversion, the so-called Mega Rice Project (MRP), was initiated with the aim of converting one million hectares of peatland into rice fields. Approx. 4000km of drainage and irrigation channels were constructed in the area designated for the MRP in two years (Notohadiprawiro 1998). Many people were able to access the previously inaccessible interior of this peatland landscape to exploit the residual timber resources, mostly doing this on illegal logging basis and using fire in the process. In summer 1997 deforestation was initiated by means of fire clearance as the most economical method. Enhanced by the El Niño Southern Oscillation (ENSO) in 1997, many of these fires set for land clearing spread into opened forest areas where they continued to burn with greater intensity.

The detailed multi-temporal analysis of eight LANDSAT TM images acquired between 1991, 1994, 1996, 1997 (before the fires), 1998, 2000 (2x) and 2001 shows the quick change of the sensitive peatland and high rates of deforestation. Two TM images, 118-61 and 118-62, with 5.4 million ha were compared for 1991, 1997, 2000 and 2001. It was found by Remote Sensing (RS) and Geographical Information System (GIS) technology that from the TM 118-62 with approx. 2.4 Mha in 6/1991 1.560.377ha (64.8%) was covered with forest while in 5/1997 1.377.442ha (57.5%); res. 7/2000 1.110.151ha (45.7%) was covered with forest. Strong logging and illegal-logging took place (Boehm and Siegert, 2001).

Legal/selective logging operation prepared the ground for further degradation of the forests by fire, illegal logging and farming. More than 11,000km of logging railways were mapped in an area of 25,000km². Illegal logging could be often discriminated from selective logging operation in Landsat ETM images by its specific spatial pattern. The logged over area increased by 44% between 1997 and 2000. Field and aerial surveys showed that most of this increase could be attributed to illegal logging. Additionally land use changes as shifting cultivation mosaics, dry and swamp grassland, plantations, bushland, rivers and urban areas will be reported in the paper. The reduction of the forest between 1991 and 1997 is approx. 1.9% / year. Between 1997 and 2000 logging is increased for this three years of approx. 6.5% / year, this includes the fires in 1997, the illegal logging and the MRP activities. As summery the deforestation between 1991 and 2001 is at average approx. 3.3% / year.

If the situation continues as for the years 1991 to 2001 there is a very high risk that most of the PSF resource in Central Kalimantan will be destroyed within few years with grave consequences for the hydrology, local climate, biodiversity and livelihood of the local people. Unless land use policies are changed to control logging and the drainage of the peatland will be stopped recurrent fires will lead to an irrecoverable loss of this unique rainforest ecosystem, compare the last strong fires in 2002 (Boehm et al. 2003).

## Introduction

Approximately half of the study site (2 million hectares) around Palangkaraya, the provincial capital, is covered by peatland that supports the natural vegetation of peat swamp forest. In recent decades the size of the peat area has been shrinking continually due to land-use conversion. High amounts of stored carbon were thus released into the atmosphere. Their huge carbon storage capacity is well known (Page et al. 2000 and 2002). The age of peat varies from several hundred years to 15,000 years (Anderson 1983, Sieffermann et al. 1988, Rieley et al 1996, Diemont et al. 1997).

Peat water is dark-brown to a murky black, and is acidic (pH-value 3 to 4). Peat accumulates in domes with a depth of 8 to 12 metres and flows from watersheds into the main rivers. Peat swamp forests (PSF) have a specific atmosphere and many different animal sounds are heard. Large, undisturbed PSF still contain strong Orang Utan populations. Temperatures within the forests are moderate and under closed canopies seldom exceed 28°C. There is a noticeable wind circulation in the afternoon. Soil and water have a constant temperature of approx. 23° - 24°C. Tree types and fish species have adapted to the acidic water. Special roots protrude out of the water to absorb oxygen (Rieley and Page 1996 and 1998, Boehm and Siegert 2000).

The peatland area around Palangkaraya is widely extended and the forest is of a PSF type if not cleared. The peatland is located mainly on quartz sand (podzol), from the Java Sea and up to the heath forest belt in the northern area, covering a PSF belt of approx. 150km to 200km (Sieffermann et al. 1988). The landscape is very flat and partly affected by coastal flood plains in which the northward tide from the Java Sea has effect up to 50km – 80km inland. Highland dipterocarp forests begin where the soil changes and the ground become hilly. Along the main rivers Dayaks exercise a slash and burn (ladangs) technique for rice cultivation on alluvial soil. The forest in general is secondary, logged and many areas clear-cut. Only the northern mountain region has greater locations of untouched primary tropical forests. Adjacent in the north are large areas of heath forest, which grows on extremely nutrient-poor siliceous soils. Further north in the direction of the Schwaner and Muller Mountains typical lowland and hill dipterocarp forest are to be found (Sieffermann 1988). Between 1991 and 1996 deforestation was predominately relegated to logging operations and land clearing along newly built roads.

Tropical rainforests often grow on very poor soils, which allow only 1-3 years of farming in 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, 1997 and 2002 in Kalimantan (Barber and Schweithelm 2000, Boehm et al. 2003), it will take centuries for a new forest with a similar species diversity to revive. In moderate climates, in contrast, a forest with a 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 by illegal logging and at an increasing rate (Rieley and Page, 1996, Boehm and Siegert, 2001). To analyse changing land use patterns to date mainly optical and radar satellite images and aerial photos have been evaluated. In this paper we compare optical Landsat images only.

The large-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” (Notohadiprawiro,. 1998). Local communities have traditionally cultivated rice in that part of Central Kalimantan for many years, albeit on shallow peatland, on a very limited scale and without significantly affecting the environment. This land-use conversion through the 1 Million ha (Mega)-Rice-Project for rice cultivation, including transmigration, was started by the Indonesian government with a feasibility study and, 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 River Sebangau in the west, the River Kahayan, River Kapuas and River Barito in the east, and

the Java Sea in the South, was planned and realised. The total area of impact is 1.5 million hectares within the Blocks A, B, C, D and E, see Fig. 3.
In 1997 and 2002, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire (Barber and Schweithelm 2000, Boehm et al. 2003). The "Mega-Rice-Project" was in a major location of "hot spots" because burning for land clearance had been started at the onset of the dry season. In June 1997, months before fires and smog had become a serious health hazard to millions of people in Southeast Asia, the areas upstream of the reclamation project already suffered serious food shortages. A marked drop in the water level of major rivers, combined with poor visibility due to smog, hindered food transport, and a lack of water for irrigation made the planting of crops impossible. Droughts, forest fires and famine were the logical results. Famine in the entire area was reported in September/October 1997 and in 2002.

We have used LANDSAT TM (Thematic Mapper) images. The project was funded partly by an European Union project with 8 international partners with the title: *Natural Resource Functions, Bio-diversity and Sustainable Management of Tropical Peatlands* and partly by a TREES-project (Tropical Ecosystem Environment Observation by Satellite).

## Methods

Multi-temporal LANDSAT TM images 118-61 and 118-62 were analysed for four time periods: 1991, 1997, 2000 and 2001, see Fig.1 and 2, to estimate with a Geographical Information System (GIS) land use classes, change detection and to calculate the deforestation rate. Objectives of the work is to get inputs for land use planning and conservation of the remaining peat swamp forest resources.
Basic image processing was done using ENVI 3.5. 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 TM5 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 TM5 118-62, 30.6.1991) was adapted in contrast and colouring to the reference image. This procedure was applied to LANDSAT TM5 scenes 29.5.1997, TM7 scenes 16.7.2000 and TM7 scenes 20.8.2001. Additional Landsat scenes 118-62 from 24.7.1994, 10.5.1996, 29.3.1998 (after the fires) and 7.2.2000 are available for analysis's.
The two adjacent scenes 118-61 and 118-62 were mosaiked using 15 ground control points (GCP) in the overlapping image parts. We used a set of more than 2000 GPS measurements (shp files) acquired during several ground and aerial surveys conducted in 1998, 1999 and 2000. 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).
40 Geographical Information System (GPS) measurements distributed across the Landsat TM scene were used for georeferencing the enhanced, mosaiked LANDSAT TM5 reference image (118-62, 1991) and stored into the GIS database ArcView 3.3. Accuracy was better than one pixel (30m) for the study area. The 1997, 2000 and 2001 LANDSAT TM5 res. TM7 scenes were co-registrated to the reference image from 1991 in ENVI using 35 GCP's (mean RMS smaller than 1).
To achieve higher resolution of images for this publication we have selected an area of 43.65km x 96km including Palangkaraya and the southern region for analysis.

## Results and Discussion

Figure 1 and 2 describe the location of the study area in Kalimantan on the island Borneo. In this quick look of Spot vegetation image the remaining forest are shown in green colour.
The elevation of the peatland rises gradually from the Java Sea to the north end of the MRP area by approx. 12m, which means that the channels essentially create paths for water from the peatland to drain into the sea. Tidal influences can be monitored to approx. 6m – 8m and have affected up to the north of Kuala Kapuas. In addition, water levels in the area's major rivers vary greatly and depend on domes of up to 8m – 12m high between the main rivers. In a cross-section Figure 4 explains the hydrological conditions of two large rivers with a watershed

between them, seen here as a high peat dome. Only sluices allow a proper irrigation system in the tropical rainforest. Big sluices are only built at the end of the main and secondary channels, but not in every 5 km. Distance. Fig. 3 shows the MRP and the peat drillings along the channels in block A, B and C done by the staff of University of Palangkaraya. Table 1 give some peat depth measurements along the main channel between Kahayan and Kapuas rivers (46km). More than 9m peat thickness was measured at the peat dome. The photos in figure. 5E highlights the problem of the channels in the MRP and show the many collected timber trunks in the Sebangau river from illegal logging.
Further analysis of the MRP channel system has revealed that rather than irrigating the peat areas, the channels have served to systematically drain moisture into the sea. The topography of the land was not taken fully into account during the project planning. As a result, the water table is falling, the remaining vegetation is dying off, and the peat is shrinking by 1cm to 2cm annually – releasing large volumes of carbon and increasing the risk of fire as the land dries out (Page et al. 2000 and 2002). In the rainy season, the water table now stays below the peat surface, and is much lower in the dry season. Water levels in the main rivers are either abnormally high or low. Clear-cut peatland never floods. Poor design, construction and maintenance have also resulted in the rapid silting of the channels, and many will be filled in with peat mud within the next few years. The deep peat close to the channels will subside rapidly and decompose. During the dry season, water levels are very low and the channels are partly without water (Fig 5E).

Illegal logging could be often discriminated from legal logging operation in Landsat ETM images by it's spatial pattern. Figure 5A shows the Landsat TM image from 7.2.2000 and 5B a detail from this image in the southern area between Katingan and Sebangau rivers. Figure 5C indicates the logging situation near the Bulan catchment in May 1997 while Fig. 5D does this for Feb. 2000. Legal logging operation by concessionaires involves investment in infrastructure such as logging roads and railways along which the logs are transported after tree felling (Fig.5C). Roads and railways are clearly visible in the Landsat TM images even after 10 years; railway routes visible in 1991 were still visible in 2000 and 2001 (Fig. 9A-1991, 10B-2000 and 10C-2001). The removal of trees by logging appears as a change in signature in the Landsat TM image because some of the reflectance comes from soil. Illegal loggers do not have the money and equipment to establish roads and railways and their access tracks the forest appear as irregular patterns and follow natural features like small streams or abandoned logging railways, see Fig. 5A-D.

Another difference between legal and illegal logging becomes evident from the pattern of harvesting. While in concessions all merchantable trees are harvested along approx. 500 m wide strips to both sides of the roads and railways, illegal loggers take only the most accessible trees. This results in an irregular pattern in the Landsat ETM image (Fig. 5B and 5D). Table 2 shows a comparison of the logged over area in 1997 and in 2000. This area increased by 44% in this 3 years. Most prominent was the increase in medium pole swamp forest (64%), while there was less activity in low pole peat forest, which contains only small numbers of merchantable trees. We estimate that this extreme increase can be attributed mostly to illegal logging. This was confirmed for 23 sites by field checks and aerial reconnaissance (Boehm et al. 2003). Another alarming information is that 2000 most logging activity occurred between Sebangau and Kahayan river, while there was hardly any activity in the MRP area. This can be attributed to the fact, that almost all valuable forests in the MRP Block A and B area have been destroyed by the 1997 fires. The area between the Sebangau and Katingan river is the last remaining large, continuous of PSF in block C of Central Kalimantan. As logging opens the canopy and leaves huge amounts of logging waste (illegal logging even more than legal operation) there is an extreme danger for another fire disaster in the future.

An overview of the vegetation changes and classes of land use, which occurred within a 9 years period between 1991, 1997 and 2000, is presented in Boehm and Siegert, 2001, with the TREES (Tropical Ecosystem Environment Observation by Satellite, an EC funded initiative) classification legend, Table 3 (Stibig et al. 2000) and Table 4. The total analysed area was 5.2 Mha. Taken together, 8.6% of the area was covered in accumulated cloud over the three LANDSAT TM images from 30.6.1991, 29.5.1997 (Fig. 6), 16.7.2000 and 20.8.2001 (Fig.7). The

clouds are subtracted from the GIS calculations. Classification of the TMs from 1991, 1997, and 2000 are manually delineated in the ArcView-GIS. In the Fig. 6 the results of classification is shown for 1991 and 1997, while Figure 11 shows this for the TM image of 2000.
To be able to assess peat swamp forest conversion processes in detail, one has to have knowledge of the type of conversion. The highest rate observed for closed, medium density peat swamp forest was a 7.5% (23.8%- 16.3%, 134b) decrease over a period of 9 years, 1991 - 2000. The second largest figure is a 4.3% (10.4%-6.1%, 134a) decrease of closed, high-density peat swamp forest followed by 3.8% (5.5%-1.7%, 111a) decrease of closed, high density, evergreen lowland forest. Increase of non-vegetated bush land areas for land clearing is 7.3% (1.7%-9.0%, 59) and increase of forest mosaics or other vegetation and forest is 5.0% (6.7%-11.7%, 23) over the time period 9 years.

For this publication we have selected a specific area of 43.65km x 96km including Palangkaraya and the southern region during six time periods: 30.6.1991, 10.5.1996, 29.5.1997 (Fig. 9), 7.2.2000, 16.7.2000 and 20.8.2001 (Fig. 10) with high resolution.
The TM image from 1991 (Fig. 9) shows a closed big area of PSF (green colour). Only along the rivers Kahayan and Kapuas we see the beginning of deforestation. In the TM image from 10.5.1996 we can see the beginning of the 10km long channel construction at Kapuas river, (Fig. 9) while the 1997 TM image presents in reddish colour much more open PSF for the channels. The opening of PSF from 1991 up to 1997 before the fires was done in moderate form. The TM images from 7.2.2000, 16.7.2000 and 20.8.2001 (Fig.10) shows the strong influence of the MRP, illegal logging and fires in 1997. Burnt scars are visible and the opened forest in Blocks A, B and C. The burnt scars area are partly regrowing by ferns visible in the 2001 TM image. In the 2001 TM image the plumes of fires are superimposed. Fig. 8 contains the classification for the area of 43.65km x 96km from the 20.8.2001 TM image. Table 5 contains the change detection of several TREES-classes in an area 43.65km x 96km south of Palangkaraya with Rivers Sebangau, Kahayan and Kapuas, see Fig. 8, 9 and 10, between 1991, 1997, 2000 and 2001.
Deforestation in this area shows a value of 33% in 10 years from 1991 - 2001 (from 338,041 ha PSF in 1991 reduced to 226,759.6 ha PSF in 2001). This is a **3.3% deforestation/year** in this chosen area inside in the former MRP with Blocks A+B+C partly. The closed, high density PSF has gone almost completely. The opened area No.59 bushland-clearcuts has increased from 54,914.4 ha in 1991 to 166,130.6 ha in 2001.

The reduction of the forest between 1991 and 1997 is approx. 1.9%/year and between 1991 and 2000 in average approx. 3.2%/year, Table 6. Between 1997 and 2000 logging is increased for this three years of approx. 6.5%/year, this includes the fires in 1997, the illegal logging and the MRP activities. Block D had already in 1991 not much forest. Major causes for deforestation between 1991 and 1997 were logging operation, land clearing for small scale farming and land clearing for plantations. This changed in the period between 1997 and 2001 where large scale land clearing by fire for MRP (Blocks A, B, and C) and legal and illegal logging operation were the major causes for deforestation (Fig 9 and 10).

## Conclusions

If the situation continues as it has for the years 1991 to 2001 there is a very high risk that most of the peat swamp forest resource in Central Kalimantan will be destroyed within a few years with grave consequences for the hydrology, local climate, biodiversity and livelihood of the local people (Page et al. 1998 and 2002, Boehm et al. 2000 and 2003). Peat layer up to 12m thickness have been measured in the MRP, with an average of 2.5m to 4m in the study area. The 4000km of channels from the MRP disturbs the hydrology of the peatland.
Land clearing is continuing although the Indonesian Government abandoned the MRP in 1998. Satellite images show a rapid conversion of peat swamp forest mostly into un-used fallow land. Roads and the irrigation system of the MRP allow loggers and farmers unprecedented access into otherwise highly inaccessible forests. During dry seasons they lit fires which create a lot of smoke and haze over the island Borneo and releases huge amount of carbon ($CO_2$) into the atmosphere.

Illegal logging occurs all over the area with a strong increase of 44% since the beginning of the economic crisis. Even when commercially viable trees have already been cut, illegal loggers take smaller trees of only 10cm – 20cm diameters. 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 and satellite imagery. Logging and the drainage of the peat swamp by the channels greatly increase the risk of fire. Drought and/or low water tables in peat areas cause trees to die and make the forests even more susceptible to fire. Recurrent fires e.g. in 2002 do not allow forests to recover and ferns and grasses invade (Boehm et al. 2003).
Unless land use policies are changed to control logging and the drainage of the peatland stopped recurrent fires will lead to an irrecoverable loss of this unique rainforest ecosystem.
The reduction of the forest between 1991 and 1997 is approx. 1.9%/year. Between 1997 and 2000 logging is increased for this three years of approx. 6.5%/year, this includes the fires in 1997, the illegal logging and the MRP activities. In average the deforestation is approx. 3.3%/year between 1991 and 2001.

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| BB10 | BB9A | BB8A | BB7A | BB6A | BB5A | BB4A | BB3A | BB2A | BB1A | BB0 | BB1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.93 | 2.92 | 5.05 | 2.53 | 1.29 | 3.92 | 3.10 | 3.14 | 3.17 | 6.40 | 9.34 | 5.67 |
| BB2 | BB3 | BB4 | BB5 | BB6 | BB7 | BB8 | BB9 | BB10 | BB11 | BB12 | BB13 |
| 5.40 | 5.53 | 6.13 | 4.02 | 2.10 | 0.82 | 2.67 | 4.75 | 3.34 | 1.14 | 0.81 | 0.41 |

**Table 1:** Peat depth (m) of Block B along the Main Parent Channel (46km) from Kahayan River to the middle of MPC at Kapuas River, see Figures 3, 4 and 5E.

| | **1997** | **2000** | **Total area** | **% increase** |
|---|---|---|---|---|
| | ***ha*** | ***ha*** | ***ha*** | |
| Low Pole Peat Forest | 3,056 | 3,649 | 189,257 | **20%** |
| Medium Peat Forest | 2,6371 | 43,293 | 698,559 | **64%** |
| Tall Peat Forest | 7,575 | 9,799 | 292,059 | **29%** |
| Total Area | **39,566** | **56,891** | **1,607,775** | **44%** |

**Table 2:** 44% increase of the logged over area between 1997 and 2000 in different types of peat swamp forest (PSF).

| **TREES Classification** | | | |
|---|---|---|---|
| 111a | Closed, high density, evergreen lowland forest.. | 170a | Closed, high density mangrove forest |
| 111b | Closed, medium density, evergreen. lowland forest | 170c | Open mangrove forest |
| 111c | Open evergreen lowland forest | 170d | Fragmented mangrove forest |
| 111d | Fragmented evergreen lowland forest | 210 | Shifting Cultivation Mosaic |
| 114a | Closed, high density, heath forest | 23 | Forest Mosaics, Other Vegetation & Forest |
| 114b | Closed, medium density, heath forest | 321 | Dry grassland |
| 114d | Open heath forest | 322 | Swamp grassland |
| 131a | Closed, high density, periodically inundated forest | 412 | Rain-fed arable land |
| 131d | Fragmented, periodically inundated forest | 420 | Plantations |
| 134a | Closed, high density peat swamp forest | 51 | Urban |
| 134b | Closed, medium density peat swamp forest | 59 | Bushland (Non-vegetated) |
| 134c | Open peat swamp forest | 62 | Rivers |
| 134d | Fragmented peat swamp forest | 81 | Clouds |
| 160 | Forest Regrowth | | |

**Table 3:** Trees Classification of Land use classes (Stibig et al. 2000)

| TM5 6/1991 | | | TM5 5/1997 | | | TM7 7/2000 | | |
|---|---|---|---|---|---|---|---|---|
| **TREES 1991** | **ha** | **%** | **TREES 1997** | **Ha** | **%** | **TREES 2000** | **ha** | **%** |
| 111a | 286.773 | 5.5% | 111a | 96.679 | 1.9% | 111a | 90.032 | 1.7% |
| 111b | 373.007 | 7.2% | 111b | 351.591 | 6.8% | 111b | 334.077 | 6.4% |
| 111c | 73.425 | 1.4% | 111c | 21.027 | 0.4% | 111c | 30.258 | 0.6% |
| 111d | 0 | 0.0% | 111d | 9.482 | 0.2% | 111d | 15.743 | 0.3% |
| 114a | 528.332 | 10.2% | 114a | 477.873 | 9.2% | 114a | 443.117 | 8.6% |
| 114b | 41.651 | 0.8% | 114b | 39.042 | 0.8% | 114b | 43.975 | 0.8% |
| 114d | 10.051 | 0.2% | 114d | 14.770 | 0.3% | 114d | 15.082 | 0.3% |
| 131a | 81.405 | 1.6% | 131a | 27.215 | 0.5% | 131a | 22.631 | 0.4% |
| 131d | 199.188 | 3.8% | 131d | 230.134 | 4.4% | 131d | 228.245 | 4.4% |
| 134a | 540.669 | 10.4% | 134a | 362.073 | 7.0% | 134a | 317.705 | 6.1% |
| 134b | 1.231.738 | 23.8% | 134b | 1.217.075 | 23.5% | 134b | 845.405 | 16.3% |
| 134c | 29.680 | 0.6% | 134c | 44.906 | 0.9% | 134c | 35.827 | 0.7% |
| 134d | 87.789 | 1.7% | 134d | 89.015 | 1.7% | 134d | 85.606 | 1.7% |
| 160 | 55.324 | 1.1% | 160 | 38.307 | 0.7% | 160 | 34.059 | 0.7% |
| 170a | 47.747 | 0.9% | 170a | 30.504 | 0.6% | 170a | 30.504 | 0.6% |
| 170c | 28.600 | 0.6% | 170c | 15.519 | 0.3% | 170c | 15.518 | 0.3% |
| 170d | 16.572 | 0.3% | 170d | 42.369 | 0.8% | 170d | 43.431 | 0.8% |
| 210 | 572.988 | 11.1% | 210 | 493.043 | 9.5% | 210 | 503.030 | 9.7% |
| 23 | 348.582 | 6.7% | 23 | 362.939 | 7.0% | 23 | 608.406 | 11.7% |
| 321 | 6.465 | 0.1% | 321 | 7.330 | 0.1% | 321 | 7.330 | 0.1% |
| 322 | 84.486 | 1.6% | 322 | 87.617 | 1.7% | 322 | 85.466 | 1.6% |
| 412 | 293.266 | 5.7% | 412 | 306.358 | 5.9% | 412 | 314.781 | 6.1% |
| 420 | 28.815 | 0.6% | 420 | 47.684 | 0.9% | 420 | 47.135 | 0.9% |
| 51 | 11.666 | 0.2% | 51 | 12.038 | 0.2% | 51 | 12.038 | 0.2% |
| 59 | 87.043 | 1.7% | 59 | 252.368 | 4.9% | 59 | 467.722 | 9.0% |
| 62 | 57.462 | 1.1% | 62 | 57.135 | 1.1% | 62 | 57.133 | 1.1% |
| 81 | 59.888 | 1.2% | 81 | 446.279 | 8.6% | 81 | 446.124 | 8.6% |
| **Total** | **5.182.614** | **100%** | **Total** | **5.180.374** | **100%** | **Total** | **5.180.380** | **100%** |

**Table 4:** TREES classification of LANDSAT TM 118-61 and 118-62 for 1991, 1997 and 2000, see Fig. 6 and 7, (Boehm and Siegert, 2001)

| **Central Kalimantan Palangkaraya 43.65km x 96.0km** | **TREES-Classes** | **TM 30-06-1991** | **TM 29-05-1997** | **TM 16-07-2000** | **TM 20-08-2001** |
|---|---|---|---|---|---|
| | | ***ha*** | ***ha*** | ***ha*** | ***ha*** |
| **Urban** | **51** | 3,191.4 | 3,501.9 | 3,511.5 | 3,493.1 |
| **Transmigration** | **52** | 1,037.6 | 1,774.1 | 1,767.6 | 1,758.8 |
| **Bushlands-Clearcut** | **59** | 54,914.4 | 84,108.4 | 163,384.9 | 166,130.6 |
| **PSF closed,high density** | **134a** | 109,099.8 | 17,826.0 | 2,334.5 | 2,088.2 |
| **PSF closed, medium density** | **134b** | 146,046.8 | 217,214.6 | 87,557.1 | 87,075.1 |
| **PSF open** | **134c** | 40,935.3 | 64,815.0 | 126,163.2 | 126,371.1 |
| **PSF fragmented** | **134d** | 41,959.1 | 7,707.9 | 13,335.7 | 11,225.2 |
| **PSF Sum** | **134a-d** | (338,041.0) **100%** | (307,563.5) **90.98%** | (229,390.4) **67.86%** | (226,759.6) **67.08%** |
| **Rivers 62** | **62** | 5,192.0 | 5,357.9 | 5,342.0 | 5,315.4 |
| **Catchments-rivers** | **322** | 16,663.6 | 16,734.3 | 15,643.7 | 15,582.5 |
| **Sum 419,040 ha** | | **419,040** | **419,040** | **419,040** | **419,040** |

**Table 5:** Change detection of several TREES-classes in an area 43.65km x 96km south of Palangkaraya with Rivers Sebangau, Kahayan and Kapuas, see Fig. 8-10, between 1991, 1997, 2000 and 2001.
Deforestation in this area shows a value of 33% in 10 years from 1991-2001 (from 338,041 ha in 1991 reduced to 226,759.6 ha in 2001). This is a **3.3% deforestation/year** in this selected area partly inside in the former MRP with Blocks A+B+C. The closed, high density PSF has gone nearly completely. The opened area No.59 Bushland-Clearcuts has increased from 54,914.4 ha in 1991 to 166130.6 ha in 2001.

| **Central Kalimantan** | | **Landsat TM5 30-06-1991** | **Landsat TM5 29-05-1997** | **Landsat TM7 16-07-2000** |
|---|---|---|---|---|
| **MRP with 5 Blocks:** | Regions ha | PSF-Forest ha | PSF-Forest ha | PSF-Forest ha |
| **Block A** | 315.894 (100%) | 135.585 42.9% | 107.330 34.0% | 39.838 12.6% |
| **Block B** | 161.461 (100%) | 109.134 67.6% | 82.816 51.3% | 51.008 31.6% |
| **Block C** | 440.760 (100%) | 233.275 52.9% | 180.196 40.9% | 73.387 16.6% |
| **Block D** | 145.707 (100%) | 3.159 2.2% | 0 0% | 0 0% |
| **Block E** | 504.022 (100%) | 399.475 79.2% | 383.042 76.0% | 359.988 71.4% |
| **Rivers Katingan and Sebangau (PSF)** | 838.888 (100%) | 682.056 81.3% | 631.262 75.2% | 573.921 68.4% |
| **Sum for 6 regions** | **2.406.732 100%** | 1.560.377 64.8% (100%) | **1.377.442 57.5%** (88.3% in 6years) (100%) | **1.110.151 45.7%** (71.1% in 9years) (80.6% in 3years) |

**Table 6:** Change detection of forest areas between 1991, 1997 and 2000 for 5 MRP regions and between rivers Katingan and Sebangau. The reduction of the forest between 1991 and 1997 is approx. 1.9%/year and between 1991 and 2001. Between 1997 and 2000 logging is increased for this three years of approx. 6.5%/year, this includes the fires in 1997, the illegal logging and the MRP activities. In average the deforestation is approx. 3.2%/year between 1991 and 2000.

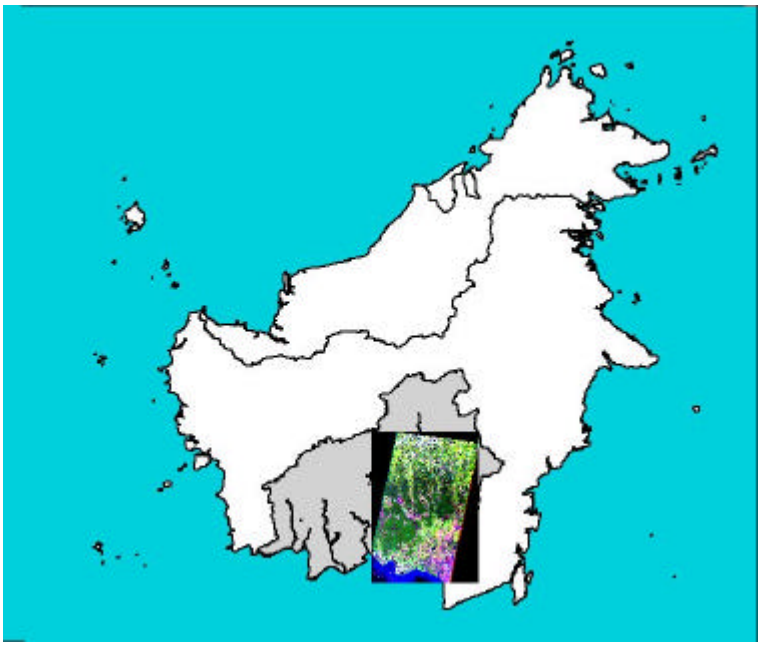


**Fig. 1:** Area of interest located on the island Borneo in Central Kalimantan (grey colour), Indonesia. Landsat images 118-61 and 118-62 taken from the time period 1991 to 2001.

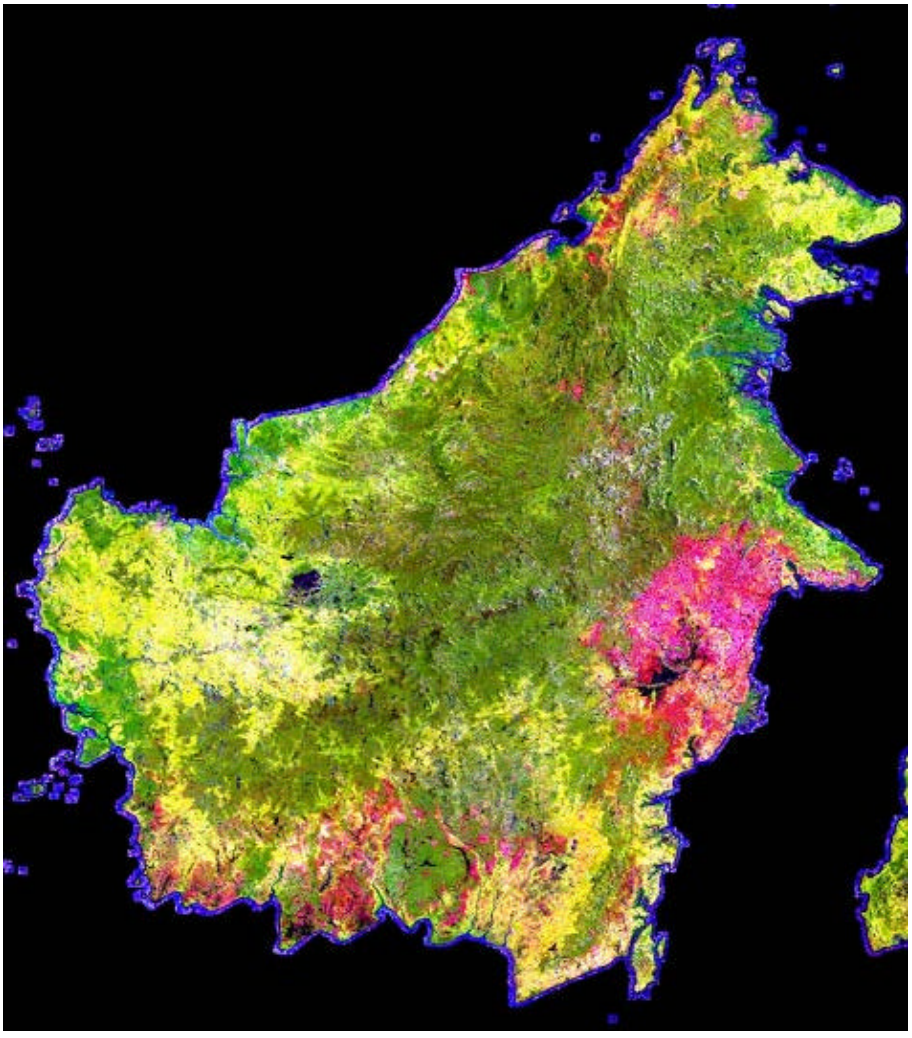
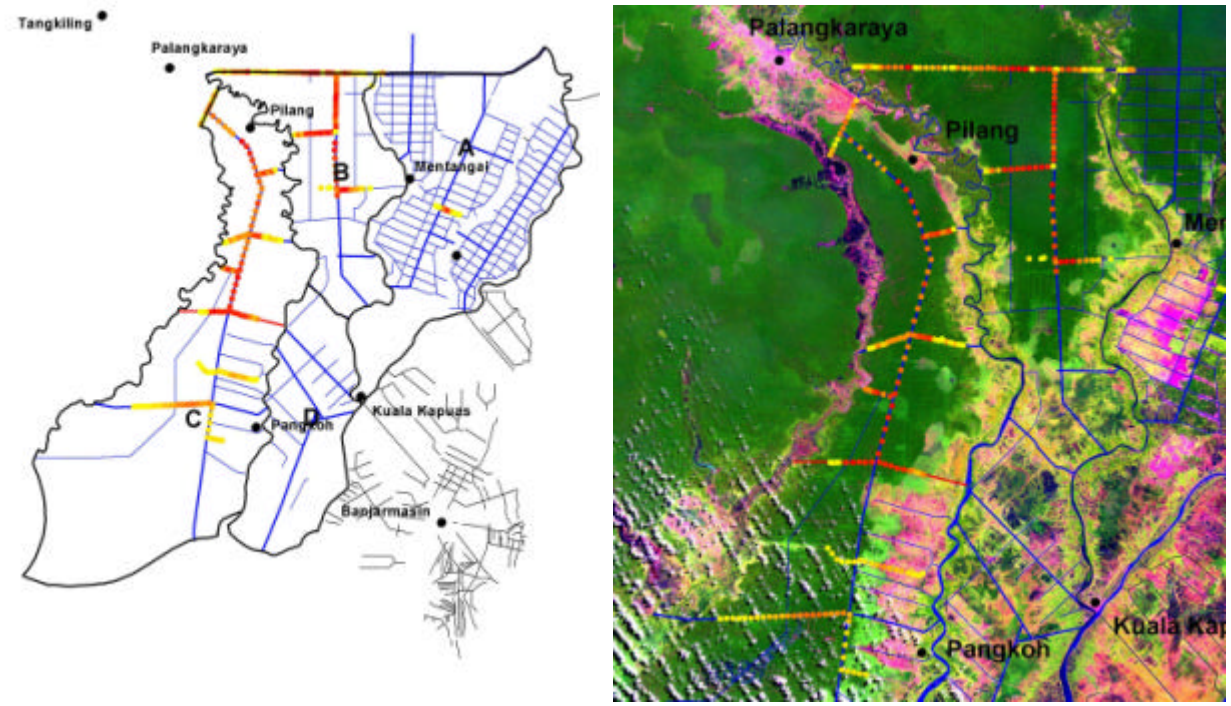
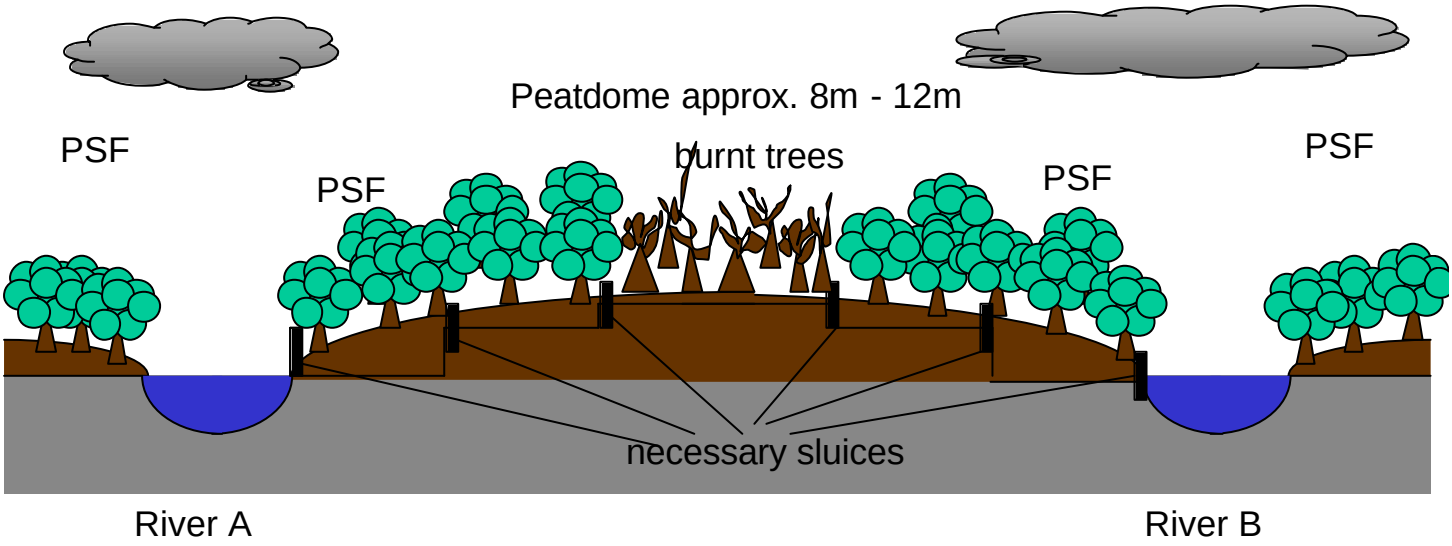


**Fig.2:** Spot-Image Vegetation of Borneo: yellow and red colours are opened areas, different types of green colour describes the remaining forest and black colour are water bodies. Courtesy of ESA

**Fig. 3: A** shows the MRP blocks A+B+C+D, the MRP channels and the location of peat drillings in Kalteng (Yellow and red points) and **B** is the Landsat TM 29.5.1997 (right) image superimposed with peat drillings (yellow and red points) done be staff of University of Palangkaraya.

**Fig. 4:** Cross-section between two rivers showing the hydrological conditions of the PSF and the peat dome in the MRP. Irrigation is impossible without proper sluices. Sluices are only built at the end of the main channels and secondary channels but not every 5 km.

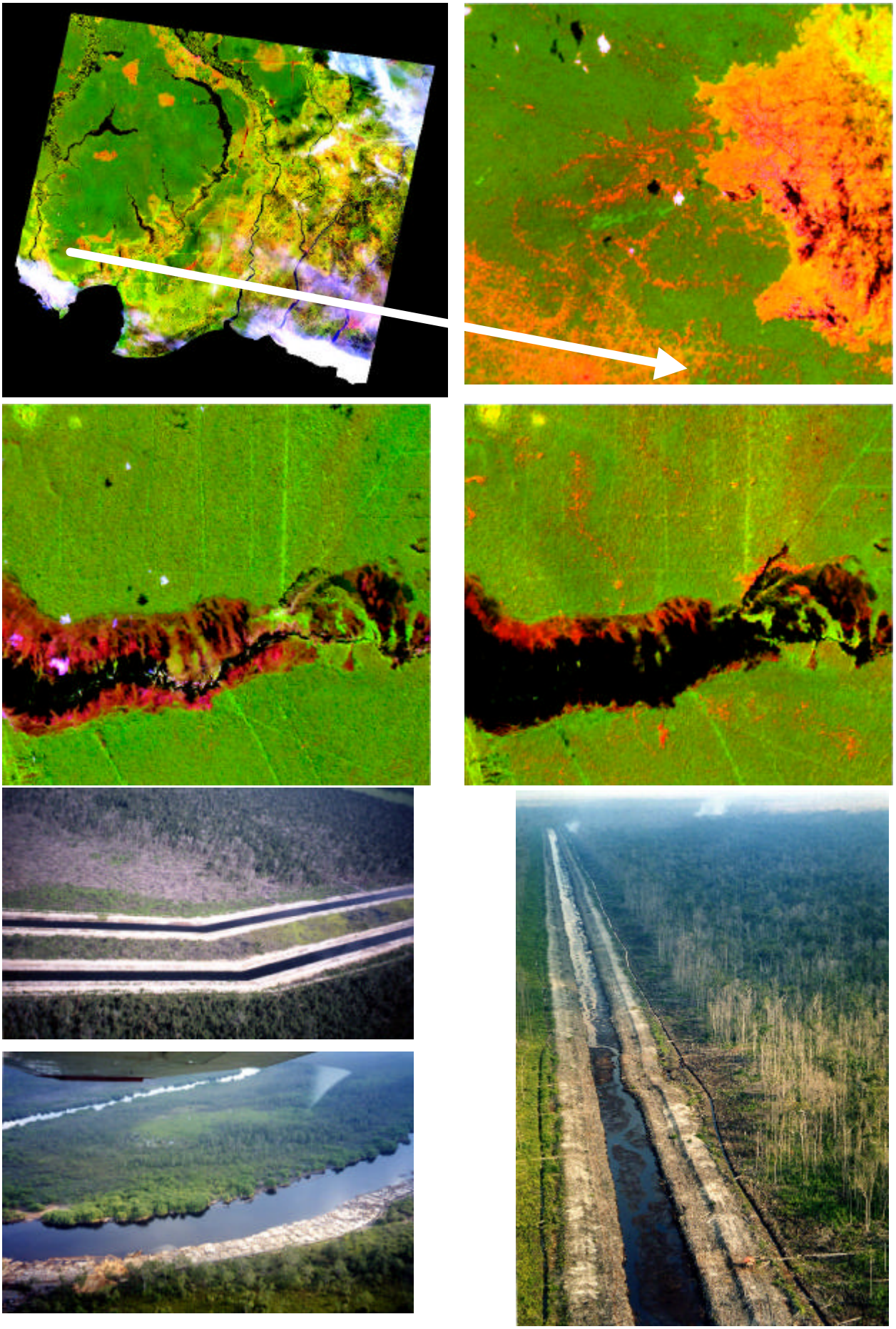



| BB10 | BB9A | BB8A | BB7A | BB6A | BB5A | BB4A | BB3A | BB2A | BB1A | BB0 | BB1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.93 | 2.92 | 5.05 | 2.53 | 1.29 | 3.92 | 3.10 | 3.14 | 3.17 | 6.40 | 9.34 | 5.67 |
| BB2 | BB3 | BB4 | BB5 | BB6 | BB7 | BB8 | BB9 | BB10 | BB11 | BB12 | BB13 |
| 5.40 | 5.53 | 6.13 | 4.02 | 2.10 | 0.82 | 2.67 | 4.75 | 3.34 | 1.14 | 0.81 | 0.41 |

**Table 1:** Peat depth (m) of Block B along the Main Parent Channel (46km) from Kahayan River to the middle of MPC at Kapuas River, see Figures 3, 4 and 5E.

**Fig. 5: A**: Landsat ETM7 acquired 7. Feb. 2000 (rainy season with high water table). **B**: Magnified image shows strong increase in (illegal) logging in 2000. **C**: Landsat from TM 29.5.1997 shows already logged over PSF, regular pattern of aisle are railways and meaning legal logging and **D:** nearly opened PSF in 2000, irregular pattern meaning illegal logging. **E:** Aerial photos from channels in the MRP partly without water and many timber trunks from illegal logging at Sebangau river.



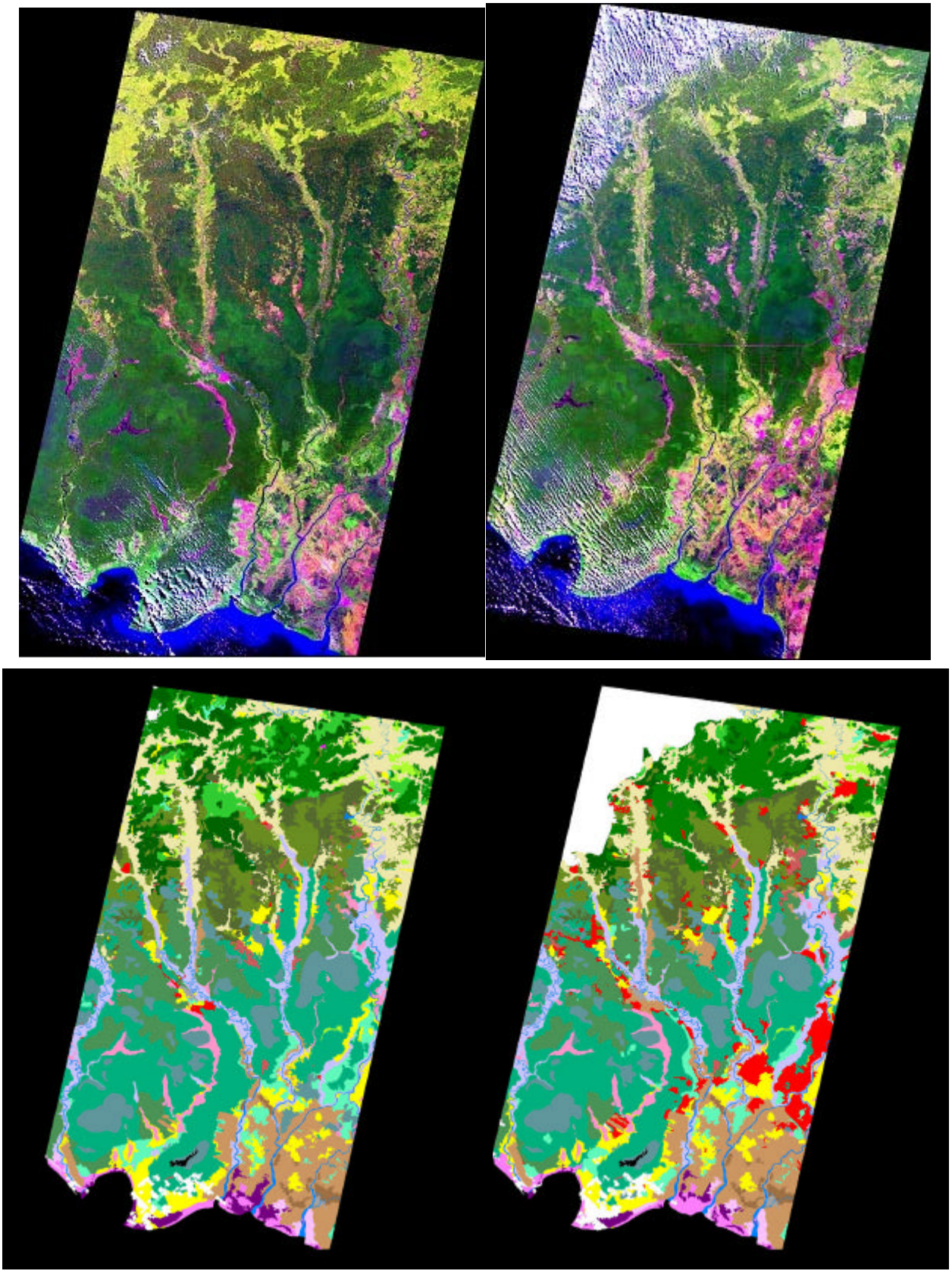


**Fig. 6:** Geocoded Landsat image 118-61 und 118-62 (RGB=543) acquired on 30.6.1991 and 29.5.1997. approx. 180km x 360km from Central Kalimantan, compare Fig.1. Different types of green indicates forest classes in the two upper false coloured TM satellite images, while yellow shows the shifting cultivation along the big rivers. Types of red is opened area, where the soil is visible from the sky. The lower two images are the classified TM images 1991 and 1997. The deforestation per year was 1.9% from 1991 – 1997 for the hole area.

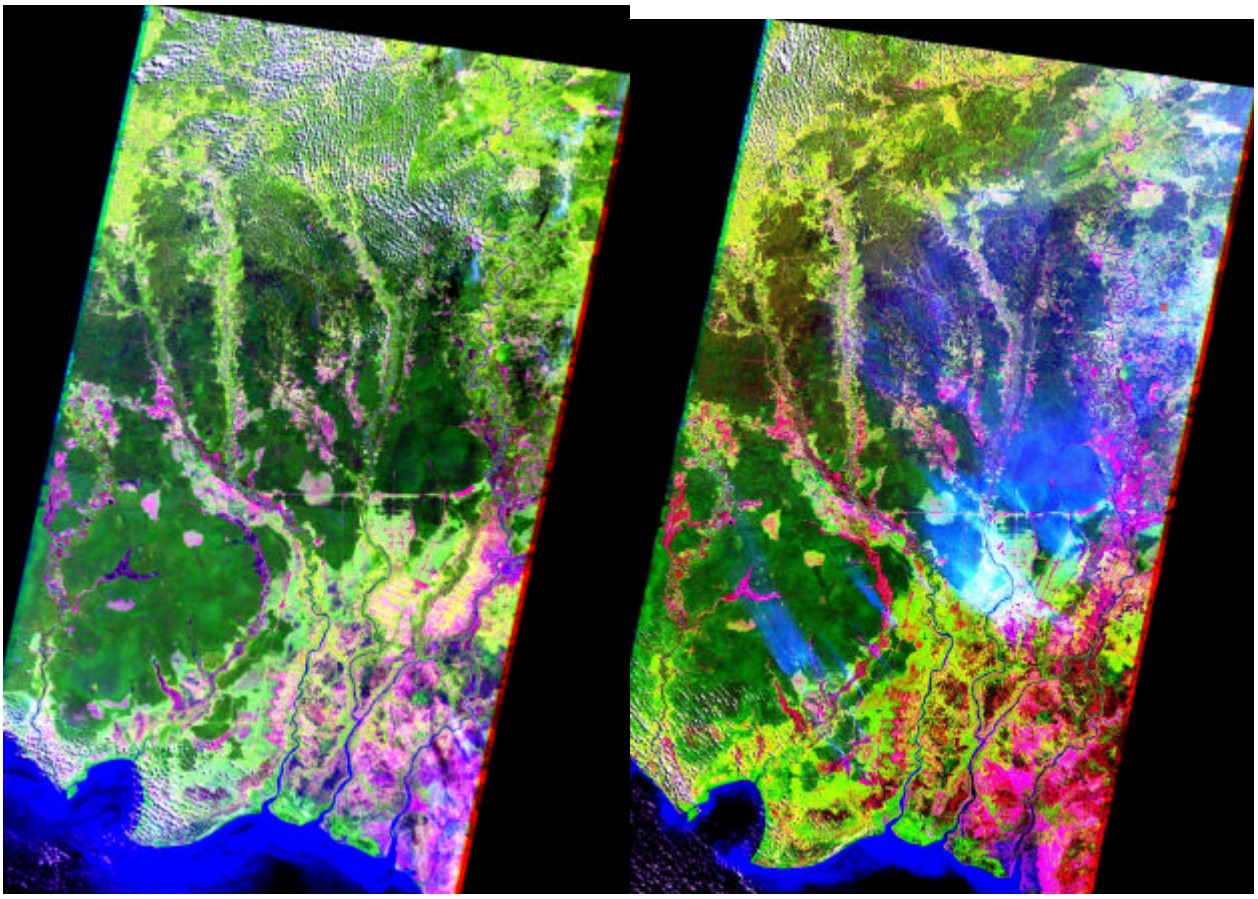
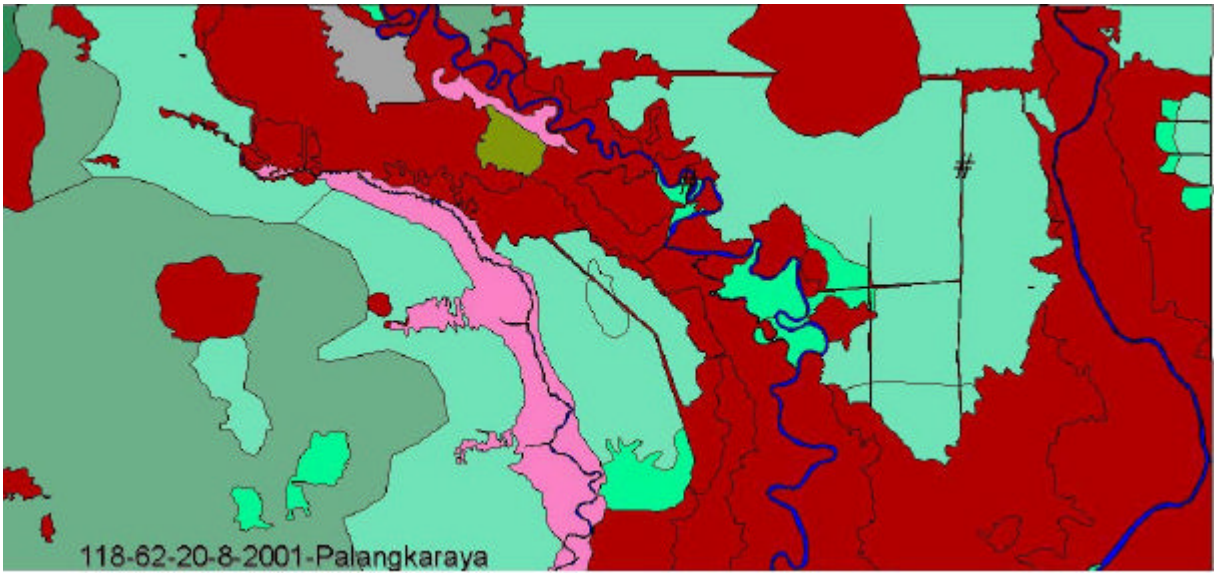


**Fig. 7:** Geocoded Landsat image 118-61 und 118-62 (RGB=543) acquired on 16.7.2000 and 20.8.2001 with approx. 180km x 360km from Central Kalimantan, compare Fig.1. Different types of green indicates forest classes in the two upper false coloured TM satellite images. In both images the influence of the MRP is strongly visible. Cleared PSF, huge burnt scars in the PSF and smoke from fires is in the 2001 image (right) detected. **Deforestation/year: 6.5% (1997-2000) and Deforestation/year: average3.2% (1991-2000)Fig. 8:** 2001-TREES-Classification of the area (43.65km x 96km) south of Palangkaraya on the based on the Landsat image 16.7.2000. Compare Table 5 and Fig. 9 and 10 (10C).



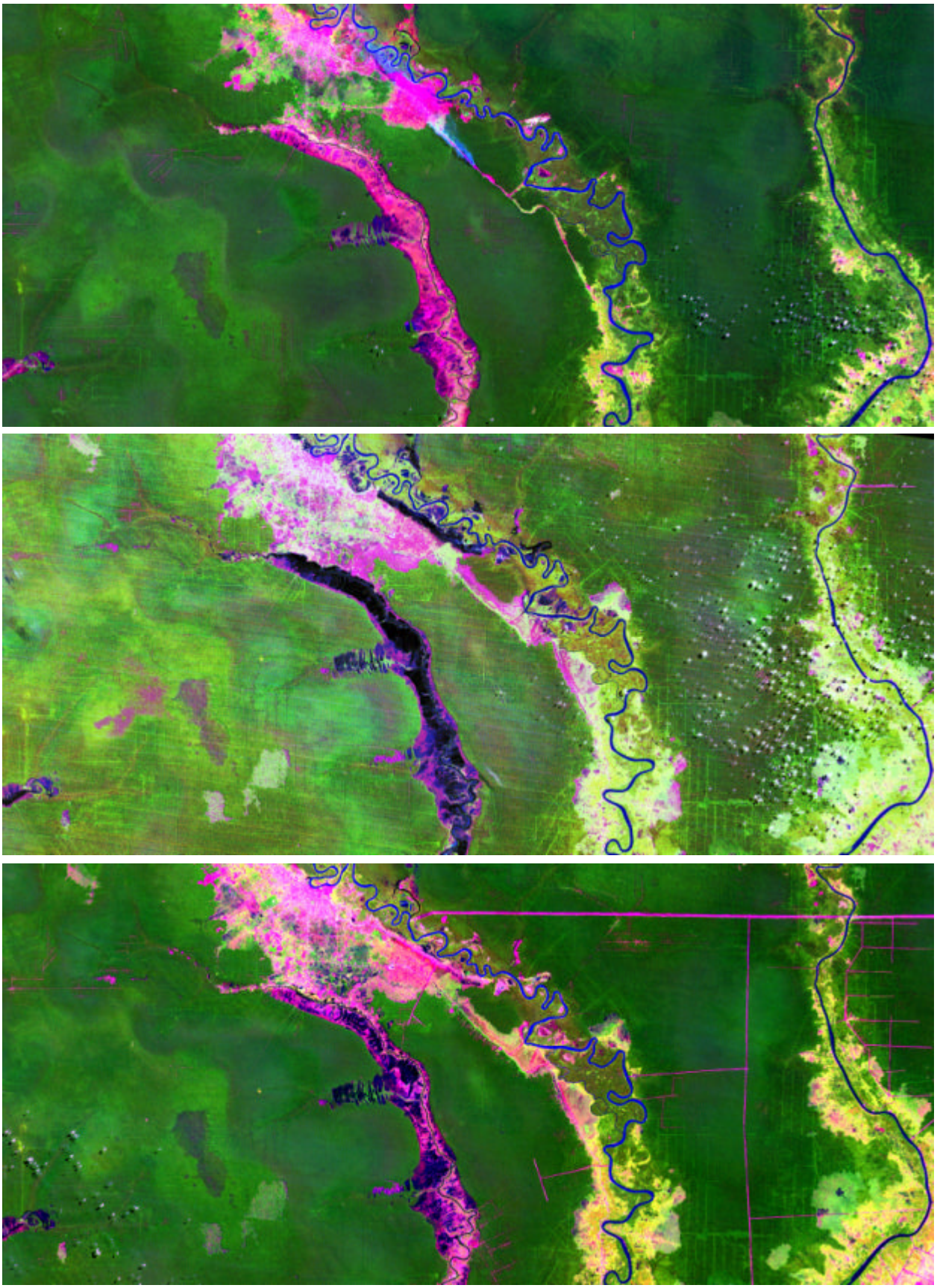


**Fig. 9:** Details from Landsat images see Fig. 6 with an area of 43.65km x 96km. It shows in each images the region of Palangkaraya and southern area with Sebangau Catchment, Kahayan, Kapuas (right). A: Landsat image from 30.6.1991, B: Landsat image from 10.5.1996; in 1996 the big channel on river Kapuas started to be built, C: Landsat image from 29.5.1997 with more opened forest for the channels in Block A, B and C.

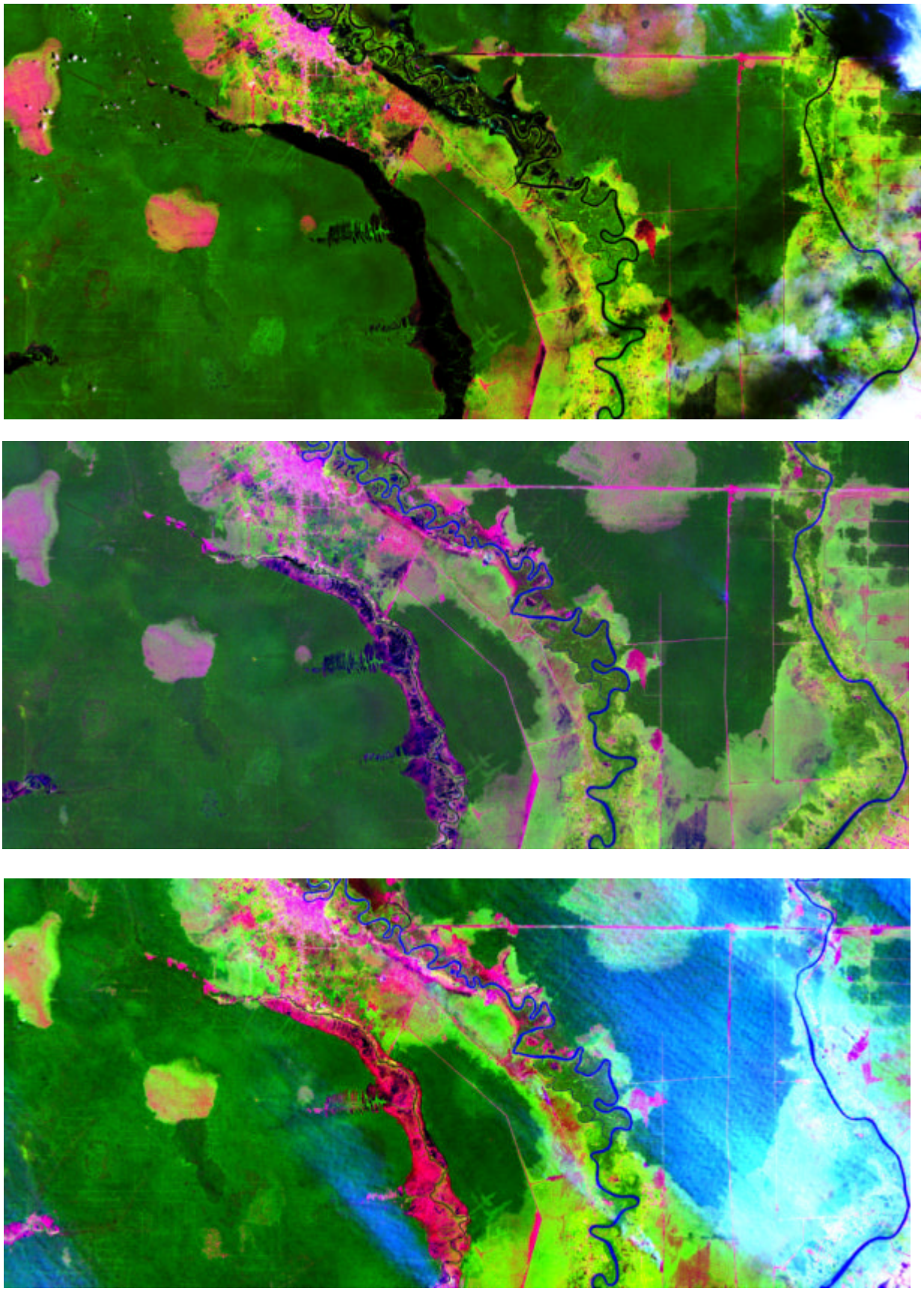


**Fig. 10:** Details from Landsat images see Fig. 7 with an area of 43.6km x 96km. It shows in each images the region of Palangkaraya and southern area with Sebangau Catchment, Kahayan, Kapuas (right). The influence of this area by the MRP and the fires from 1997 (Burned cares) are documented. **A:** Landsat image from 7.2.2000 (rainy season with much water in the catchment Sebangau, black colour), **B:** Landsat image from 16.7.2000, **C:** Landsat image from 20.8.2001 with smoke from the fires in 2001.

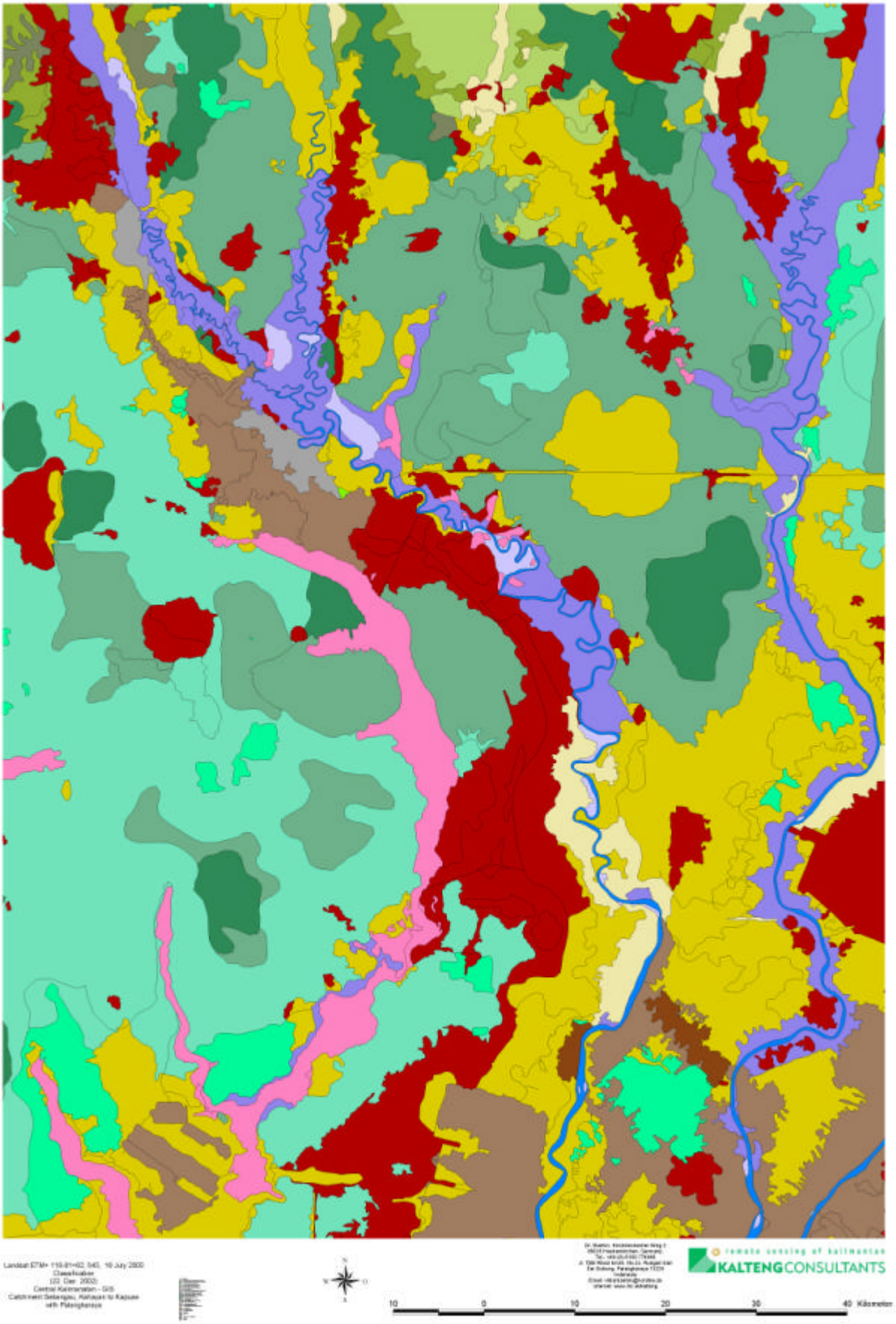



**Fig. 11:** TREES-Classification of the area around Palangkaraya from the Landsat ETM image acquired on 16.7.2000. TREES-classes 23, 51, 59, 131d, 134a, 134b, 134c, 134d, 322, 412, see Tab. 3, 4, 5 and 6.