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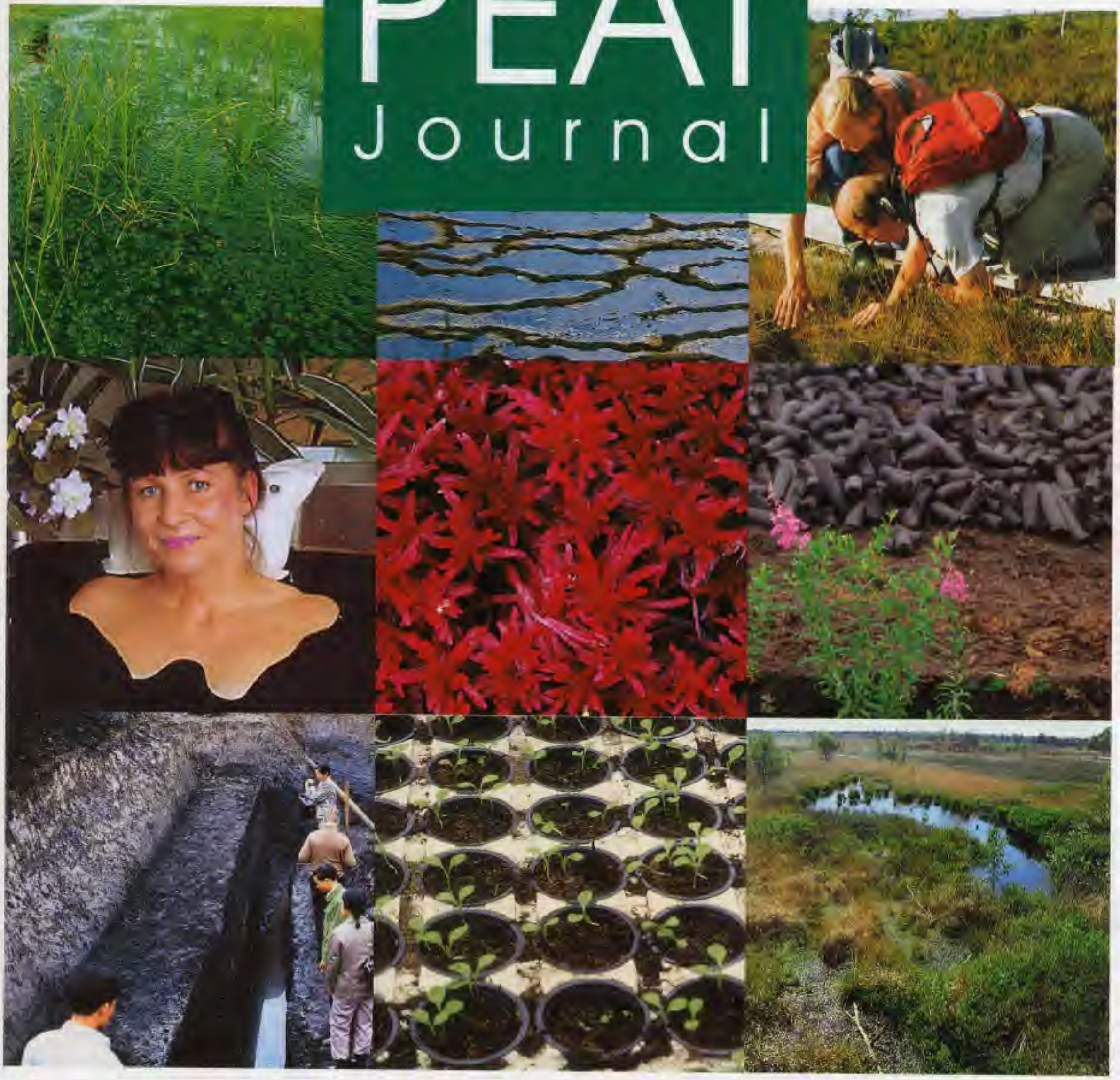

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# THE IMPACT OF LOGGING ON LAND USE CHANGE IN CENTRAL KALIMANTAN, INDONESIA

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## SUMMARY

The province of Central Kalimantan contains about three million hectares of peatland, which is one of the largest contiguous areas of tropical peatland in the world. Peat Swamp Forests (PSF) are among the earth's most endangered and least known ecosystems. They have a huge carbon storage capacity but are extremely fragile and liable to disturbance. Local communities have used them extensively for centuries without significant impact on the environment. This changed in 1995 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, in Central Kalimantan, Indonesia, into rice fields. Between 1996 and 1998 more than 4000 km of drainage and irrigation channels were constructed in the designated area. Boosted by the El Nino Southern Oscillation (ENSO) episode in 1997, many fires initiated for land clearance purposes spread into pristine forest areas where they continued to burn with great intensity. The newly established drainage and irrigation system aggravated fire impacts, fostering this disaster. The multi-temporal analysis of six LANDSAT TM images acquired between 1991 and 2000 shows extremely high rates of deforestation during this time. Between 1991 and 2000 the area of forest was reduced at the rate of 3.2% per year. If the situation continues 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 local people. Unless land use policies are changed to control logging and the drainage of the peatland is stopped recurrent fires will lead to an irrecoverable loss of this unique rainforest ecosystem and release of huge amounts of carbon to the atmosphere.

*Keywords:* logging, remote sensing, GIS, land use, deforestation, tropical rainforest, peat swamp forest, Kalimantan, Borneo

## INTRODUCTION

Approximately half of the study site (2 million hectares) around Palangkaraya, the provincial capital of Central Kalimantan, is covered by peatland that supports a natural vegetation of peat swamp forest (Rieley *et A*, 1996). The forest consists of secondary, logged and clear-cut areas (Sieffermann *et al.,* 1988). In recent decades the size of this peat area has been shrinking because of land-use conversion, mainly to agriculture and exploitation of the forest timber resources. If these forests are removed completely, either by large-scale cutting or by uncontrolled forest fires, as happened in 1982/83, 1987, 1994, and 1997, it will take centuries for new forest with similar species diversity to re-establish (Anderson, 1983; Barber & Schweithelm, 2000; Boehm *et al.,* 1997; Boehm & Siegert, 2000). In 1996 the Indonesian Government commenced the One Million Hectare Mega Rice Project (MRP) for rice cultivation, linked to transmigration (Notohadiprawiro, 1998). In order to open this area and make it suitable for growth of crops, large drainage and irrigation channels were excavated through the peat-covered landscapes between the Sebangau and Barito Rivers. Over 4000 km of parent, main, secondary, third and quarter level channels were constructed between January 1996 and July 1998, when the project was halted. The total area affected by this project was actually 1.5 million hectares that, for operational purposes, was divided into five landscape units known as Blocks A, B, C, D and E. The MRP became a major location of fire "hot spots" because of burning of vegetation for land clearance, especially in the dry season (Jaya *et al.,* 2000; Page *et al.,* 2000). In June 1997, months before fires and smog had become a serious health hazard to millions of people in Southeast Asia, areas upstream of the land development project were already suffering serious food shortages (Barber & Schweithelm, 2000; Boehm & Siegert, 2000). A marked drop in the water level of major rivers, combined with poor visibility owing 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 results. In many areas uncontrolled illegal logging preceded the exploitation and conversion of tropical rain forest. This study was carried out in order to document the extent of official logging and illegal logging in the peatland areas of south-east Central Kalimantan and analyze how this affected land use in this area, and susceptibility to future fire damage.

## METHODS

LANDSAT TM images Path 118 Row 61 and Path 118 Row 62 from three acquisitions, June 30, 1991, May 29, 1997 and July 16, 2000, were analysed. The geographic location covers an area of 60,000 km2 (Upper left corner: Latitude -0.57°, Longitude 113.73°, lower right corner: Latitude -3.57° Longitude 114.62°). Basic image processing included geo-referencing, mosaicking of Row 61/62 and image to image registration using a Global Positioning Sensor (GPS) to determine the exact location of ground control points (GCP). For visual image interpretation bands 3, 4 and 5 were selected to produce a colour RGB image, Band assignment was 5, 4, 3 = RGB. This band combination proved to be the best in this region and allowed for the separation of more than 20 vegetation and land use classes (Fig. 1A). Each channel was interactively contrast enhanced in a reference LANDSAT TM5 image (1991) in order to maximise overall image contrast. The six Landsat TM scenes were spectrally adjusted to the reference image by histogram matching.

The basic land cover legend was adapted from the TREES classification scheme (Stiebig *et al.,* 2000). Interpretation of Landsat TM images was carried out by visual on-screen digitising at a scale of 1:100,000 (minimal mapping unit 50 ha) (Fig. 1B). The interpretation key for land cover was established from GPS measured ground observations. The LANDSAT TM image mosaic Path 118 Row 61-62 was used as reference for the land cover map. In the subsequent image mosaics of 1997 and 2000 only areas in which changes in land cover occurred have been mapped. Clouds, haze and non-overlapping areas were masked out. A change assessment was done by comparison of historical and more recent satellite images within the overlapping area (change 1991-1997, 1997-2000) and a change matrix was produced which included all land cover classes and the percentages of changes between these classes. Logging roads and logging railways were clearly visible in band combination 5, 4, 3 images. Even logging roads/railways established before 1991 were visible in the year 2000 Landsat ETM image. Logging roads/railways were delineated on-screen as line features. All area and length calculations were done using a Geographical Information System (GIS).

Extensive ground surveys on foot and by boat, car and small aeroplane were carried out in 1998, 1999 and 2000 in order to check image classification of land use and vegetation within the study area. More than 2000 GPS measurements were collected using the continuous track mode of the GPS instrument acquiring measurements every 10 to 30 seconds (aerial surveys) or 20 to 60 seconds (ground surveys). The accuracy of the vegetation and land use interpretation was determined using 258 GPS recorded ground observations. In addition four hours of GPS synchronized digital video material acquired during two aerial surveys were used to check areas that could not be accessed on foot (peat swamp forest is flooded for up to 10 months of the year, the ground surface is very uneven, the vegetation is almost impenetrable). For the accuracy assessment in these areas we used 148 randomly selected digital video images. Overall classification accuracy for vegetation types was >95%.

## RESULTS AND DISCUSSION

An overview of the vegetation changes and classes of land use, which occurred within a 9-year period between 1991, 1997 and 2000, is presented in Table la. Table 1 b gives the TREES (Tropical Ecosystem Environment Observation by Satellite, an initiative funded by the European Commission and headed by the Joint Research Center in Ispra, Italy) classification legend. The total area analyzed was 5.18 Mha. 8.6% was covered in accumulated cloud over all three of the LANDSAT image mosaics.

To assess peat swamp forest conversion processes in detail, it is essential to have knowledge of the type of conversion. Our analysis shows that the highest

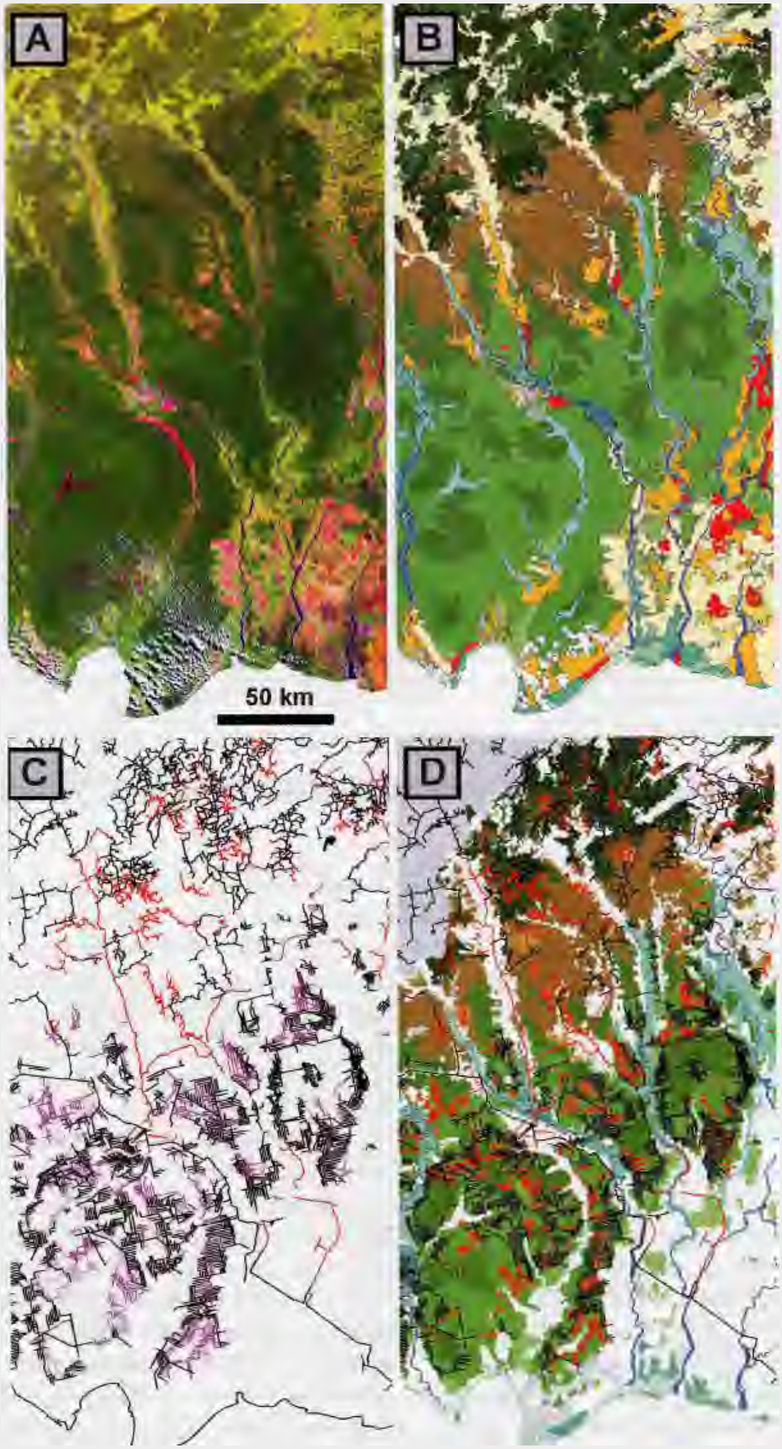


*Fig. 1. A. Landsat TM mosaic (1991, RGB=5,4,3). B. Land cover classification of A. C. Logging roads (curved lines) are visible in the upper half of the study area (black: 1991, red: 1997). Logging railways (straight lines) are visible in the lower part of the study area (black: 1991, purple: 1997; bright purple: 2000). D. Logging roads and logging railways superimposed on forest classification: dark green colours: lowland Dipterocarp forest, blue green colours: peat swamp forest (low pole: dark blue green, medium: medium blue green, tall: bright blue green), brown colours: heath forest, bright blue-green: mangrove forests.*

*Table 1: Vegetation and land cover changes in the study area of Central Kalimantan from 1991 to 2000*

| TREES legend | TREES land cover classification | TM 5 June 1991 | | TM 5 May 1997 | | ETM 7 July 2000 | |
|---|---|---|---|---|---|---|---|
| | | ha | % | ha | % | ha | ck |
| Illa | Closed, high density, evergreen lowland forest | 286,773 | 5.5% | 96,679 | 1.9% | 90,032 | 1.7% |
| Illb | Closed, medium density, evergr, lowland forest | 373,007 | 7.2% | 351,591 | 6.8% | 334,077 | 6.5% |
| Ilic | Open evergreen lowland forest | 73,425 | 1.4% | 21,027 | 0.4% | 30,258 | 0.6% |
| llld | Fragmented evergreen lowland forest | 0 | 0.0% | 9,482 | 0.2% | 15,743 | 0.3% |
| 1 14a | Closed, high density, heath forest | 528,332 | 10.2% | 477,873 | 9.2% | 443,117 | 8.6% |
| ı 14b | Closed, medium density, heath forest | 41,651 | 0.8% | 39,042 | 0.8% | 43,975 | 0.8% |
| 1I 4d | Open heath forest | 10,051 | 0.2% | 14,770 | 0.3% | 15,082 | 0.3% |
| 131 a | Closed, high density, periodically inundated fo, | 81,405 | 1.6% | 27,215 | 0.5% | 22,631 | 0.4% |
| 13Id | Fragmented, periodically inundated forest | 199,188 | 3.8% | 230,134 | 4.4% | 228.245 | 4.4% |
| I 34a | Closed, high density peat swamp forest | 540,669 | 10.4% | 362,073 | 7.0% | 317,705 | 6. I % |
| I34b | Closed, medium density peat swamp forest | 1,231,738 | 23.8% | 1,217,075 | 23.5% | 845,405 | 16.3% |
| I 34c | Open peat swamp forest | 29,680 | 0.6% | 44,906 | 0.9% | 35,827 | 0.7% |
| 134d | Fragmented peat swamp forest | 87,789 | 1.7% | 89,015 | 1.7% | 85,606 | 1.7% |
| 160 | Forest Regrowth | 55,324 | 1.1% | 38,307 | 0.7% | 34,059 | 0.7% |
| 170a | Closed, high density mangrove forest | 47,747 | 0.9% | 30,504 | 0.6% | 30,504 | 0.6% |
| I 70c | Open mangrove forest | 28,600 | 0.6% | 15,519 | 0.3% | 15,518 | 0.3% |
| 170d | Fragmented mangrove forest | 16,572 | 0.3% | 42,369 | 0.8% | 43,431 | 0.8% |
| 210 | Shifting cultivation mosaic | 572,988 | 11.1% | 493,043 | 9.5% | 503,030 | 9.7% |
| 23 | Forest Mosaics, other vegetation & forest | 348,582 | 6.7% | 362,939 | 7.0% | 608,406 | 11.7% |
| 321 | Dry grassland | 6,465 | 0.1% | 7,330 | 0.1% | 7,330 | 0.1% |
| 322 | Swamp grassland | 84,486 | 1.6% | 87,617 | 1.7% | 85,466 | 1.6%, |
| 412 | Rain-fed arable land | 293,266 | 5.7% | 306,358 | 5.9% | 314.781 | 6.1% |
| 420 | Plantations | 28,815 | 0.6% | 47,684 | 0.9% | 47,135 | 0.9%, |
| 51 | Urban | 1I ,666 | 0.2% | 12,038 | 0.2% | 12,038 | 0.2% |
| 59 | Bushland (Non-vegetated) | 87,043 | 1.7% | 252,368 | 4.9% | 467,722 | 9.0% |
| 62 | Rivers | 57,462 | 1.1 % | 57,135 | 1.1 % | 57,133 | 1.1 % |
| 81 | Clouds | 59,888 | 1.2% | 446,279 | 8.6% | 446,124 | 8.6% |
| | Total | , 5,182,614 | 100% | 5,180,374 | 100% | 5,180,380 | 100% |

deforestation rate observed was for closed, medium density peat swamp forest, which decteased by 7.5% (23.8%-16.3%, 134b) over a period of 9 years. The second highest rate was 4.3% obtained for closed, high-density peat swamp forest (10.4%-6.1%, 134a) followed by 3.8% (5.5%-1.7%, 111a) for closed, high density, evergreen lowland forest. The land occupied by deforested bushland and forest mosaics together with other vegetation and forest types increased by 7.3% (1.7%-9.0%, 59) and 5.0% (6.7%-11.7%, 23), respectively, over the time period of 9 years.

Blocks A, B, C and D of the MRP were subject to the most intensive changes in the last 36 months by clear cutting and forest fires. The overall forest conversion rate for the 5 MRP Blocks A-E is shown in Table 2 where comparison can be made with the relatively pristine PSF of the Sg. Katingan - Sg. Sebangau area. It is evident that both authorized concession logging and illegal logging increased between the Barito and Kahayan Rivers and, more recently, between the Kahayan and Sebangau Rivers as a direct result of the MRP.

The rate of reduction of the forest area between 1991 and 1997 was approximately 2.0% per year. Between 1997 and 2000 the rate of deforestation increased to about 6.5 % per year, as a result of the land clearance associated with the MRP activities that peaked in 1997 and the peatland fires that occurred in the same year. The average rate of forest disappearance between 1991 and 2000 was about 3.2 % per year in the 6 regions selected in this study. The major causes of deforestation between 1991 and 1997 were legal logging operations, land clearing for small-scale farming and land clearing for plantations. This changed in the period between 1997 and 2000 when large-scale land clearing by fire for the MRP accelerated in 1997 and illegal logging operations intensified throughout the whole region after the end of the Suharto regime and collapse of law and order in the hinterland of provinces such as Central Kalimantan. The extent and impact of logging activities between 1991 and 2000 are shown in Figure 1c. The length of logging roads increased between 1991 and 1997 from 4419 km to 6621 km (34% increase), the length of logging railways and extraction tracks increased from 7136 km to 9406 km (25% increase). By the year 2000 the length of the logging railways and extraction tracks increased by another 1920 km making a total of more than 11,000 km.

*Table 2: Change detection of forest areas between 1991, 1997 and 2000 for 5 MRP regions (A, B, C, D, E) and between rivers Katingan and Sebangau.*

| 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 (relatively pristine 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 (57.2%) (88.3% in 6y) (100%) | 1,110,151 (46.1%) (71.1% in 9y) (80.6% in 3y) |

*Table 3: Increase of the logged-over area between 1997 and 2000 in different types of peat swamp forest.*

| Logged over forest type | 1997 | 2000 | % increase |
|---|---|---|---|
| | *ha* | *ha* | |
| Low pole peat swamp forest | 3,056 | 3,649 | 19.4 % |
| Medium peat swamp forest | 26,371 | 43,293 | 64.2 % |
| Tall peat swamp forest | 7,575 | 9,799 | 29.4 % |
| Total logged area | 39,566 | 56,891 | 43.8 % |

The 1997 superimposition of logging roads and railways (including extraction tracks) on the different forest types (Figure 1D) shows that the extraction network is especially intensive in Dipterocarp forests (dark green to the North) where almost all forests containing merchantable timber have been opened up and logged. Roads and railways are absent only from forests of minor commercial value, such as low pole peat swamp forest (dark blue-green) and heath forest (brown colours).

Illegal logging can be discriminated from legal logging operations in Landsat ETM images by differences in their spatial pattern. Legal logging operated by concessionaires involves investment in infrastructure such as substantial logging roads and railways along which the logs are transported after tree felling (Fig. 2A). Roads and railways are clearly visible in Landsat TM images even 9 years after construction, i.e. railway routes visible in 1991 are still visible in the year 2000 image. They appear in bright green colours due to growth of secondary vegetation. Previously logged areas appear as a mixture of bright green and dark green pixels representing secondary vegetation and remaining primary vegetation (Fig. 2A). A recent removal of trees by logging appears as a change in signature in the Landsat TM image because some of the reflectance comes from soil (appearing as orange in Fig. 2B). Illegal loggers do not have the money and equipment to establish regular roads and railways and their access tracks into the forest appear as irregular patterns that

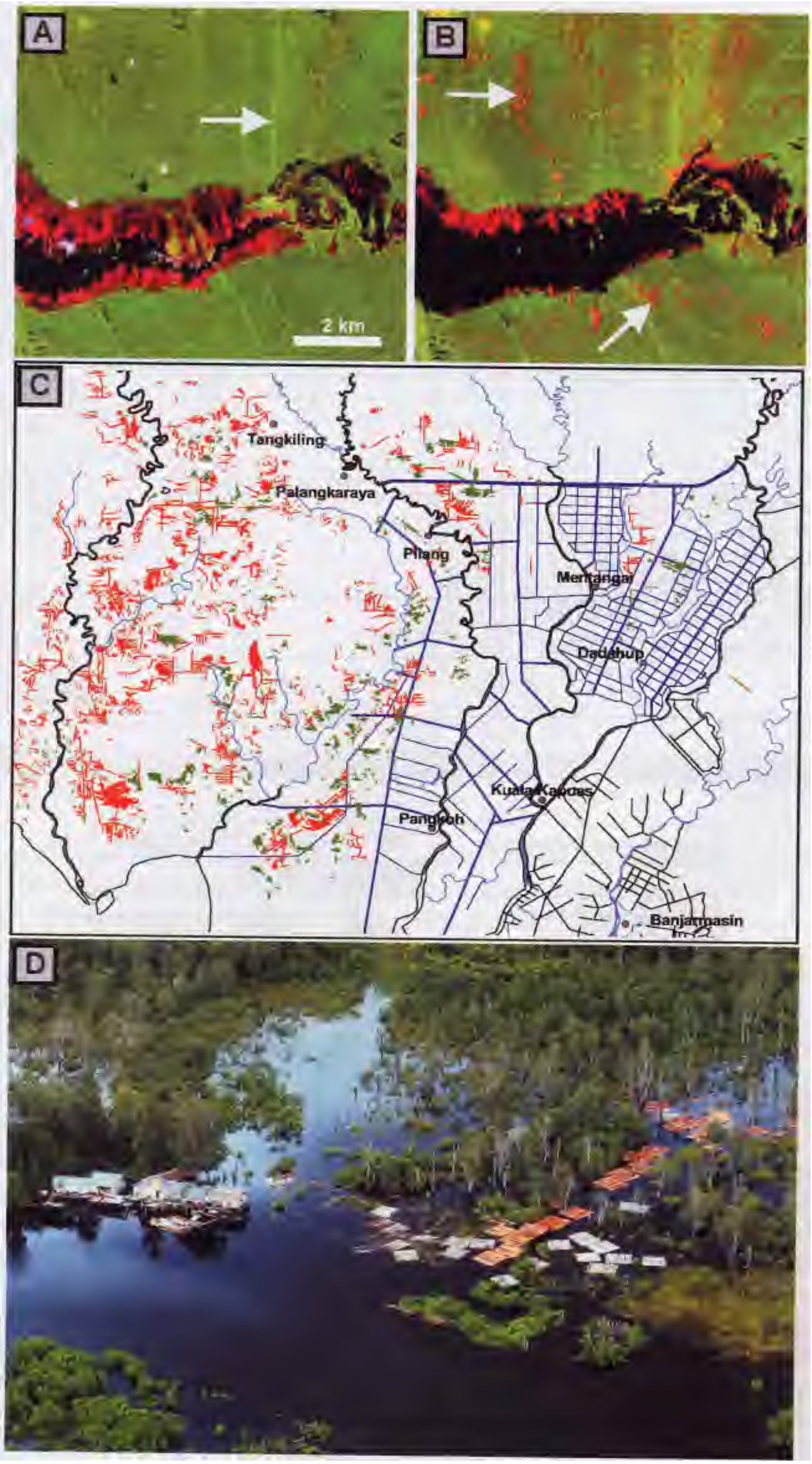


*Fig. 2. The detection of logging operations. A. Logging railways appear bright green in the 1997 image • (arrow) B. Logging activity in the 2000 image (arrows, orange colours indicate opened canopy). C. Logged over area in 1997 (green) and 2000 (red) and MRP irrigation system (right part of figure in blue and older channel system in black) D. Aerial photograph of an illegal logging camp.*

follow natural features such as small streams or abandoned logging railways (Fig. 2B).

Another difference between legal and illegal logging is evident from the pattern of harvesting. In official concessions all commercial size trees are harvested along strips of forest approximately 500 m wide on both sides of the access roads and railways creating a herringbone appearance on a satellite image. In contrast, illegal loggers take only those trees that are easily accessible from their tracks this shows as an irregular pattern on the Landsat ETM image as a result of their discovery of trees in the forest. (Fig. 2B).

Examination of the logged over area within the upper Sungai Sebangau catchment shows that the area logged increased by 43.8% (Table 3) between 1997 (green) and 2000 (red) (Figure 2C), especially within medium pole peat swamp forest (64.2 %). There was much less illegal logging activity in low pole forest, which contains only small numbers of merchantable trees. The large increase can be attributed mostly to illegal logging, a fact that was confirmed for 23 sites by field checks and aerial reconnaissance (Fig. 2D). Another alarming feature emerged that in 2000 most logging activity occurred between the Sebangau and Katingan river (left in Fig. 2C) and hardly any in the former MRP area (right in Figure 2C) because almost all valuable forest trees in the latter had been either felled in the land clearance operations that commenced in 1996 or destroyed by the 1997 fires. The area between the Sebangau and Katingan rivers is the last remaining large, contiguous block of peat swamp forest in Kalimantan. As logging opens the canopy and huge amounts of logging waste are deposited on the ground (illegal logging even more than legal operation) there is an extreme danger of another fire disaster happening in the near future.

## CONCLUSION

The major causes of forest conversion between 1991 and 1997 were legal logging operations and land clearing for small-scale farming and plantations. Legal logging concessions prepared the ground for further degradation of the forests by fire, illegal logging and farming (Siegert *et al.*, 2001). In 1997 large-scale land clearing by fire for the MRP and, in 2000, illegal logging became the major causes of deforestation. Between 1997 and 2000 the logged-over area increased by 43.8 %. If the deforestation rate remains as high as it has for the years 1991 to 2000 (3.2 % per year) 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 & Rieley, 1998, Boehm & Siegert, 2000). NOAA/AVHRR hotspot data indicate that land clearing is continuing although the Indonesian Government formally abandoned the MRP in 1999. Satellite images show a rapid conversion of peat swamp forest mostly into unused fallow land. Roads and the drainage channels of the MRP allow loggers and farmers unprecedented access into previously highly inaccessible forests. 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 all over Central Kalimantan. Huge areas of ecologically damaged peat landscape are visible from the air and satellite imagery. Logging and the drainage of the peat swamps by the channels have greatly increased 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 do not allow forests to recover and ferns and grasses invade that in turn produce much combustible debris. Unless land use policies are changed to control logging and the drainage of the peatland is reversed recurrent fires will lead to an irrecoverable loss of this unique rainforest ecosystem.

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