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ECOLOGICAL IMPACT OF THE ONE MILLION HECTARE RICE PROJECT IN CENTRAL KALIMANTAN, INDONESIA, USING REMOTE SENSING AND GIS

Land Use Change and (Il)-legal Logging in Central Kalimantan, Indonesia

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Abstract

The province of Central Kalimantan contains about three million hectares of peatland, which is one of the largest unbroken tropical peatland areas in the world. Peat swamp forest (PSF) is among the earth's most endangered and least known ecosystem (12). They have a huge carbon storage capacity and are extremely fragile and liable to disturbance (10). Local communities have used them extensively for centuries with no significant effect on the environment. This changed in 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. Between January 1996 and July 1998 more than 4000km of drainage and irrigation channels were constructed in the area designated for the MRP (9). 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 August 1997 deforestation was initiated by means of fire clearance as the most economical method. Boosted by the El Niño Southern Oscillation (ENSO) episode in 1997, many of these fires set for land clearing spread into pristine forest areas where they continued to burn with greater intensity. The newly established drainage system aggravated fire impact, fostering this disaster. During five months of drought, the peat layer lost most of its water and the peat itself was ignited. A huge cloud of yellow, noxious smog covered 15 million km² of Southeast Asia for several weeks. After removal of the commercial timber, the remaining tree debris was removed by means of fire as the cheapest, most readily available land clearance method. Using optical and microwave satellite images and ground surveys, it was found that more than 20% of the PSF of the province was destroyed by fire in 1997. Since peat hydrology was disturbed by the drainage system, and the forest biomass was only partly combusted, the risk of fire is expected to be extremely high in the near future.

The multi-temporal analysis of six LANDSAT TM image acquired between 1991, 1997 (before the fires) and 2000 shows the quick changement of the sensitive peatland and high rates of deforestation. Two TM images, 118-61 and 118-62, with 5.4 million ha were compared. Additionally the MRP area 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 processed and the relative pristine PSF between catchment Sebangau and river Katingan with 2.4 million ha. The total area of MRP impact is 1.5 million hectares for the Blocks A, B, C, D and E. It was found that from the 6 descripted regions with 2.406.732ha 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 please.

Legal 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 legal 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. If the situation continues as for the years 1991 to 2000 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.

1. 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. The age of peat varies from several hundred years to 15,000 years (1,6,12,14).

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 10 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 (10,12).

The peatland area around Palangkaraya, the capital of the province, 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 (14). 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 (14). 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, and 1997 in Kalimantan (2,3,4), 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 (4,8). To analyse changing land use patterns to date mainly optical and radar satellite images and aerial photos have been evaluated.

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** (4,9). 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.

In 1997, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire (2,4). 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.

We have used LANDSAT TM (Thematic Mapper) –images (4,6,7,10). The project was funded partly by a European Union project with 8 international partners with the title: **Natural Resource Functions, Bio-diversity and Sustainable Management of Tropical Peatlands** and a TREES-project (Tropical Ecosystem Environment Observation by Satellite).

2. Material and Methods

LANDSAT TM images 118-61 and 118-62 were analysed for three time periods: 1991, 1997 and 2000. 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. 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 and TM7 scenes 16.7.2000.

The two adjacent scenes 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 Geographical Information System (GIS) database ARCVIEW 3.2. Accuracy was better than one pixel (30m) for the study area. The 1997 and 2000 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).

3. Results and Findings

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 Table 1a. Table 1b gives the TREES (Tropical Ecosystem Environment Observation by Satellite, an EC funded initiative) classification legend (15). The total analysed area is 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 and 16.7.2000. The clouds are subtracted from the GIS calculations. Classification of the three TMs from 1991, 1997 and 2000 are manually delineated in the ArcView-GIS.

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%**

TREES Classification			
111a	Closed, high density, evergreen lowland forest..	170a	Closed, high density mangrove forest
111b	Closed, medium density, evergr. 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 fo.	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 1a and 1b: TREES classification of LANDSAT TM 118-61 and 118-62 for 1991, 1997 and 2000

construction of a 10km long channel was started. A recommendation for protection and conservation as a refuge for animals, e.g. Orang Utan and forest products in this area has been forwarded to the Indonesian authorities. Parent, main, secondary, third and quarter level channels for irrigation and transport were built rapidly from the spring of 1996 to 1998. Over 4000km of channels were built in these two years (9), using US$225 million from the Indonesian Reforestation Fund.

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 & forest is 5.0% (6.7/-11.7%, 23) over the time period 9 years.

The overall forest conversion rate for the 5 MRP Blocks A-E is shown in Table 2 in comparison of relative pristine PSF of the Katingan – Sebangau area. In Fig 1a a visual view of the Table 2 is shown. Fig. 1b shows the vegitation classification for two Landsat images acquired in 7/2000. This Table 2 includes change detection of forest areas, mainly PSF which is selective and illegal logged for three time periods June 1991, May 1997 before the huge fires, and July 2000. It is visible that logging and illegal logging is increased between rivers Barito and Kahayan and now also between Kahayan and Sebangau in the MRP. The Palangkaraya region is excluded of the analysis.

The reduction of the forest between 1991 and 1997 is approx. 2.0%/year and between 1991 and 2000 in average approx. 3.2%/year in this 6 selected regions. Between 1997 and 2000 logging is increased for this three years of approx.

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 2: Change detection of forest areas between 1991. 1997 and 2000 for 5 MRP regions and between rivers Katingan and Sebangau

6.5%/year, this includes the fires in 1997 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 periode between 1997 and 2000 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. Figure 1a, shows visible the change of the forest in the 6 regions, compare Table 2.

The length of logging roads increased between **1991 and 1997 from 4419 km to 6621 km (34% increase), the length of logging railways increased from 7136 km to 9406 km (25% increase). By the year 2000 thelength of the logging railways increased by another 1920 km totally to more than 11,000 km.** The logging road network is especially dense in Dipterocarp forests. This representation makes clear that almost all valuable forests which contain merchantable timber are opened up and have been logged. O Roads and railnly forests of minor quality as low pole (bright green) or heath forest (blue-green colours) show no roads. Illegal logging could be often discriminated from legal logging operation in Landsat ETM images by it´s spatial pattern. Legal logging operation by concession holders involves investments in infrastructure like logging roads and railways along which the logs are harvested. Roads and railways were clearly visible in the Landsat TM images even after 9years (railways visible in 1991 were still visible in 2000). 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. Therefore the access pattern into the forest appears irregular and follows natural features like small streams or abandoned logging railways.

	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**	**160,775**	**44%**

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

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, illegaö loggers take only the most accessible trees. This results in an irregular pattern in the Landsat ETM image (Fig. 2B). Table 3 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,wgich 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 (Fig. 3). Another alarming information is that 2000 most logging activity occured 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 area have been destroyed by the 1997 fires. The area between the Sebangau and Katingan river is the last remaining large, continuous block of PSF in Kaltmantan. 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. 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 precipitation and other factors, further accelerating drainage. The project now faces hydrological problems on peat 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. Figures. 5A-E highlights the problem of the channels in the MRP.

Many small rivers, mainly black-water rivers, cross the irrigation channels - at least three cross the parent (main) channel: Sungai Jaya, Mentangai, and one other, between the River Kapuas and the River Kahayan.

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. 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.

4. Conclusion and discussion

If the situation continues as for the years 1991 to 2000 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.

NOAA AVHRR hotspot data (4) indicate that land clearing continues although the MRP has been stopped by the Government. The satellite images show a rapid conversion of PSF 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. 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. 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 and satellite imagery. Logging and the drainage of the peat swamp by channels highly increase the risk of fire. Draught and/or low water tables in peat areas cause trees to die and make the forests even more susceptible to fire. Recurrent fires give forests no time to recover, and the tropical climate causes rapid overgrowth by ferns and indigenous grass. Most of the Kalteng fires in 1997/1998 were manmade. Huge amounts of stored carbon were released into the atmosphere (5,6,7,11). Peatland destruction is an irreversible process. Unless land us 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.

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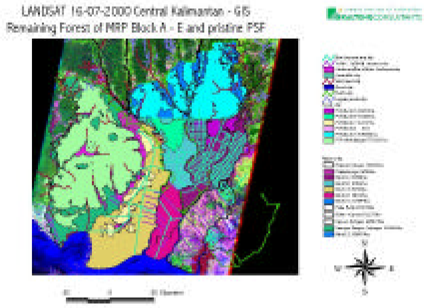


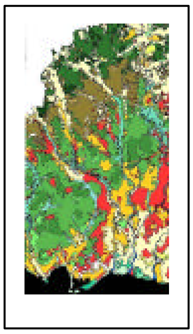
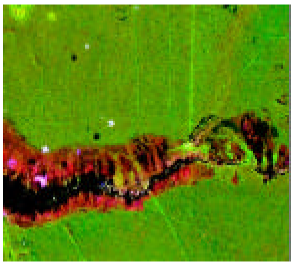


Figure 1a. Remaining Forest in 2000, comp. Table 2. **Fig.1b** Vegetation classification for two Landsat images 7/2000



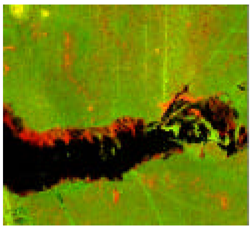


Figure 2. Detection of logging operation. **2A:** Logging railways appear bright green in the 1997 image (left).
2B: Logging activity in the 2000 image. **Figure 3.** Aerial photo of an illegal logging camp (right).

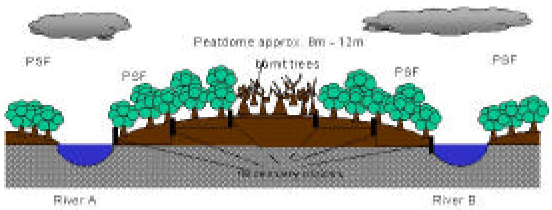


Figure 4: Hydrological Conditions of the MRP. Cross-section between two rivers showing the hydrological conditions of the PSF and the peatdome in the MRP. Irrigation is impossible without sluices.

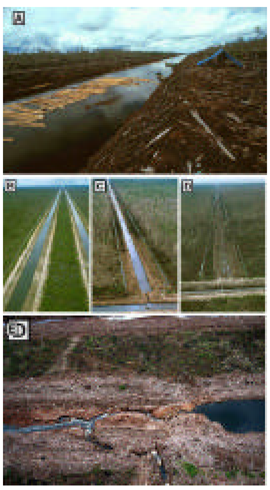


Figure 5. Aerial photos: **A:** Large peat layer of several metres is visible in the parent primary channel of the MRP area. Loggers use the channel for transporting timber. **B:** Parent primary channels (110km long). **C:** Secondary channel. **D:** Tertiary channel. **E:** Peat barrier, no sluices between one side of the PPC and the other (Fig. 4). Water flows out gradually. No sluices are available. Loggers transport the trunks.