

# Decline of Sumatran Peat Swamp Forests since 1990

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**Abstract – In this paper we highlight the dramatic decline of Sumatran peat swamp forests since 1990. Comparison of three recently produced land cover maps (1990-2000-2010) revealed that the proportion of forested peatland in Sumatra plunged from 75% to 28% between 1990 and 2010, corresponding to over 30 000 km<sup>2</sup> of deforested peatland. These areas were primarily converted to plantations or taken over by secondary regrowth, with some areas reduced to extremely degraded open fernland. More detailed provincial level analysis on the three primary peat provinces in Sumatra revealed that South Sumatra province lost majority of its peat swamp forests already by the year 2000, while the deforestation continued on a very high level in Riau and Jambi provinces between 2000 and 2010. This ongoing rapid deforestation of peatlands not only jeopardizes the existence of the entire peat swamp forest ecosystem in Sumatra, but may have direct global consequences through elevated levels of carbon emissions.**

**Keywords:** Tropical peatland, Deforestation, Carbon emissions, Southeast Asia, Plantation development

## 1. INTRODUCTION

The approximately 70 000 km<sup>2</sup> of peatlands in Sumatra Island have been estimated to contain 19 Gt of carbon (Wahyunto et al. 2003), making them a globally considerable surface carbon deposit. In addition, peatlands have valuable ecological and hydrological functions. Peatlands e.g. regulate water flow and thereby stabilize evaporation rates on local and regional level. Furthermore, the Sumatran peat swamp forest ecosystems support unique flora and fauna partially endemic to insular Southeast Asia (Rieley and Page 2005). Deforestation and land cover changes in peat swamp forest ecosystems directly affect the balance of the entire peatland area and thereby have consequences also on the communities surrounding the peatlands.

Large scale exploitation of peat swamp forests is a rather recent phenomenon in Sumatra. Due to development in land conversion technologies, diminishing forest areas on mineral soils and escalating demand for forest and agricultural products, exploitation and conversion of Sumatran peat swamp forests started to accelerate rapidly in the late 1980's (Silvius and Diemont 2007). Since then, logging, drainage, plantation development and conversion to small-holder agricultural areas have taken place at high rate. These activities not only disturb the ecosystem functions of peatland areas but invariably increase carbon emissions due to the reduction of living biomass, surge in peat decomposition and increase in fire activity.

Drainage connected to practically all peatland development lowers the water table level in peatland areas. Low water table level in turn induces fast decomposition of peat

releasing carbon into the atmosphere (Hooijer et al. 2010). Moreover, drained peatland areas with degraded vegetation become extremely vulnerable to yearly fire activity and increase the risk of periodical severe fire episodes that may in the worst case release immense quantities of carbon into the atmosphere (Page et al. 2002).

In this paper we highlight the dramatic decline of Sumatran peat swamp forests since 1990. We use data from two recent mapping projects (Miettinen and Liew 2010, Miettinen et al. in press) to derive peat swamp forest extent in Sumatra for the years 1990, 2000 and 2010. In addition to the total area statistics, we analyse the spatio-temporal distribution of peatland deforestation over the past two decades between the three main peatland provinces in Sumatra: Riau, Jambi and South Sumatra.

## 2. MATERIALS AND METHODS

### 2.1 Land cover maps

The 1990 land cover map was based on visual image interpretation of high resolution (30m) Landsat 5 Thematic Mapper (TM) satellite data (Miettinen and Liew 2010). The 2000 and 2010 land cover information was obtained from two recently produced regional land cover maps (Miettinen et al. in press). These two maps were based on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor data. The classification was performed on a cloud free 250 m resolution composite image using a semi automatic classification method (Miettinen et al. in press).

The land cover classes of the original land cover maps used in this study (1990, 2000 and 2010) were simplified to enable comparative analysis of the status of land cover in 1990, 2000 and 2010. The 1990 map was first converted from vector to raster format in 250 m spatial resolution corresponding to the spatial resolution of the 2000 and 2010 maps. Subsequently, the classification structure of the original maps was simplified into six classes (Water, Forest, Plantation/regrowth, Mosaic, Open and Urban).

All degradation levels of the remaining peat swamp forests were assigned into the Forest-class. The Plantation/regrowth-class included all natural and planted secondary vegetation from shrubland and secondary forest to industrial plantations. The Mosaic-class included areas with a mixture of woody vegetation and open areas. Typically this land cover class occurred in either sparsely vegetated newly cleared areas or small-holder farming areas. And finally, the Open-class included agricultural fields and areas that were either bare or covered by ferns typically less than 2 m in height. All invalid areas in any of the maps were masked out from all the maps, thus creating the three maps used in the analysis in this study, each covering the same valid areas and including the same six land cover classes.

Table 1. Development of land cover distribution from 1990 to 2010 in Sumatran peatlands.

	1990		1990-2000		2000		2000-2010		2010	
	km <sup>2</sup>	%	km <sup>2</sup>	%/year	km <sup>2</sup>	%	km <sup>2</sup>	%/year	km <sup>2</sup>	%
Water	146	0.2	-1	-0.1	145	0.2	18	1.2	163	0.3
Peat swamp forest	49216	75.8	-18431	-4.6	30785	47.4	-12716	-5.2	18069	27.8
Plantation/regrowth	2953	4.5	18803	22.1	21756	33.5	7654	3.1	29411	45.3
Mosaic	7258	11.2	442	0.6	7700	11.9	123	0.2	7823	12.1
Open	5327	8.2	-813	-1.6	4514	7.0	4917	7.6	9432	14.5
Urban	4	0.0	0	-0.9	4	0.0	4	7.4	8	0.0
Total	64905				64905				64905	

The overlapping valid area of the 1990, 2000 and 2010 maps totalled in 65 000 km<sup>2</sup>, providing 90% coverage of Sumatran peatlands. Due to the strong simplification of the 1990 classification which had been based on visual interpretation of high resolution satellite images and the over 90% accuracy of the 2000 and 2010 maps in forest/non-forest level, the simplified land cover maps used in this study were expected to provide reliable data for the analysis of deforestation rates 1990-2010 and for the analysis of spatial distribution of deforestation between the three main peatland provinces in Sumatra Island: Riau, Jambi and South Sumatra. It is important to remember, however, that the areas considered as forest in these maps include a range of degradation levels. Thus, the results presented in this can be considered to give an overly optimistic impression on the status peat swamp forests in Sumatra Island.

## 2.2 Fire data

Two active fire (i.e. hotspot) datasets were used to visualize the connection between fire and deforestation in Sumatra during the past two decades. For the 1990's, Along Track Scanning Radiometer (ATSR) active fire detections were used. The data was produced by European Space Agency (ESA) and downloaded from the ATSR World Fire Atlas (ATSR 2010). This fire dataset was used from its commencement (July 1996) to the end of 1999. Most importantly, this dataset covered the exceptionally strong fire episode in 1997-1998 (Page et al. 2002, Field et al. 2009) induced by extraordinarily strong El Niño conditions.

Moderate Resolution Imaging Spectroradiometer (MODIS) hotspot data detected by the sensor on board Terra satellite was used from November 2000 onwards. The data were produced and provided by the MODIS Rapid Response System (Davies et al. 2009). Altogether the ATSR and MODIS active fire datasets were expected to deliver a good

general impression of fire situation in Sumatra, including both spatial and temporal distribution.

## 3. RESULTS AND DISCUSSION

The peat swamp forest cover in Sumatran peatlands dropped from 75% to 28% between 1990 and 2010 (Table 1). This corresponds to deforestation of over 31 000 km<sup>2</sup> or more than 60% of the peat swamp forest cover in 1990. Regardless of the decrease in absolute deforested area from the 1990's to the 2000's, the average yearly rate of deforestation in fact increased from 4.6%/a to 5.2%/a due to the rapidly diminishing area of remaining forest cover.

Table 1 also reveals that an overwhelming proportion (85%) of all deforested peatland turned into plantations and secondary regrowth by 2010. While these areas covered less than 5% of peatlands in 1990, they had reached 45% coverage by 2010. Another significant change in the land cover distribution in peatland areas was the increase of the proportion of open land from 8% to nearly 15% over the past two decades. These areas may be new clearances for land development (e.g. large scale industrial plantations or small-holder farming). However, in many cases they are extremely degraded areas that have been reduced to open fern land.

Comparison between the three main peatland provinces - Riau, Jambi and South Sumatra - revealed significant variation in temporal distribution of peatland deforestation within Sumatra. South Sumatra experienced clearly the strongest deforestation during the 1990's. It had lost 74% of its year 1990 peat swamp forest cover by the year 2000. This large scale destruction is expected to have happened largely through fires that raged in degraded forests during the last three years of the decade, most notably during the 1997-1998 fire episode (Figure 1b).

Table 2. Development of peat swamp forest cover from 1990 to 2010 in the three main peat provinces of Sumatra.

	1990		1990-2000		2000		2000-2010		2010	
	km <sup>2</sup>	%	km <sup>2</sup>	%/year	km <sup>2</sup>	%	km <sup>2</sup>	%/year	km <sup>2</sup>	%
Riau	30962	80.8	-7726	-2.8	23236	60.7	-9357	-5.0	13879	36.2
Jambi	4368	78.0	-1757	-5.0	2612	46.6	-994	-4.7	1618	28.9
South Sumatra	8404	61.9	-6189	-12.5	2215	16.3	-1015	-5.9	1200	8.8
Other provinces	5481	73.7	-2759	-6.8	2721	36.6	-1350	-6.6	1371	18.4
Total	49216	75.8	-18431	-4.6	30785	47.4	-12716	-5.2	18069	27.8

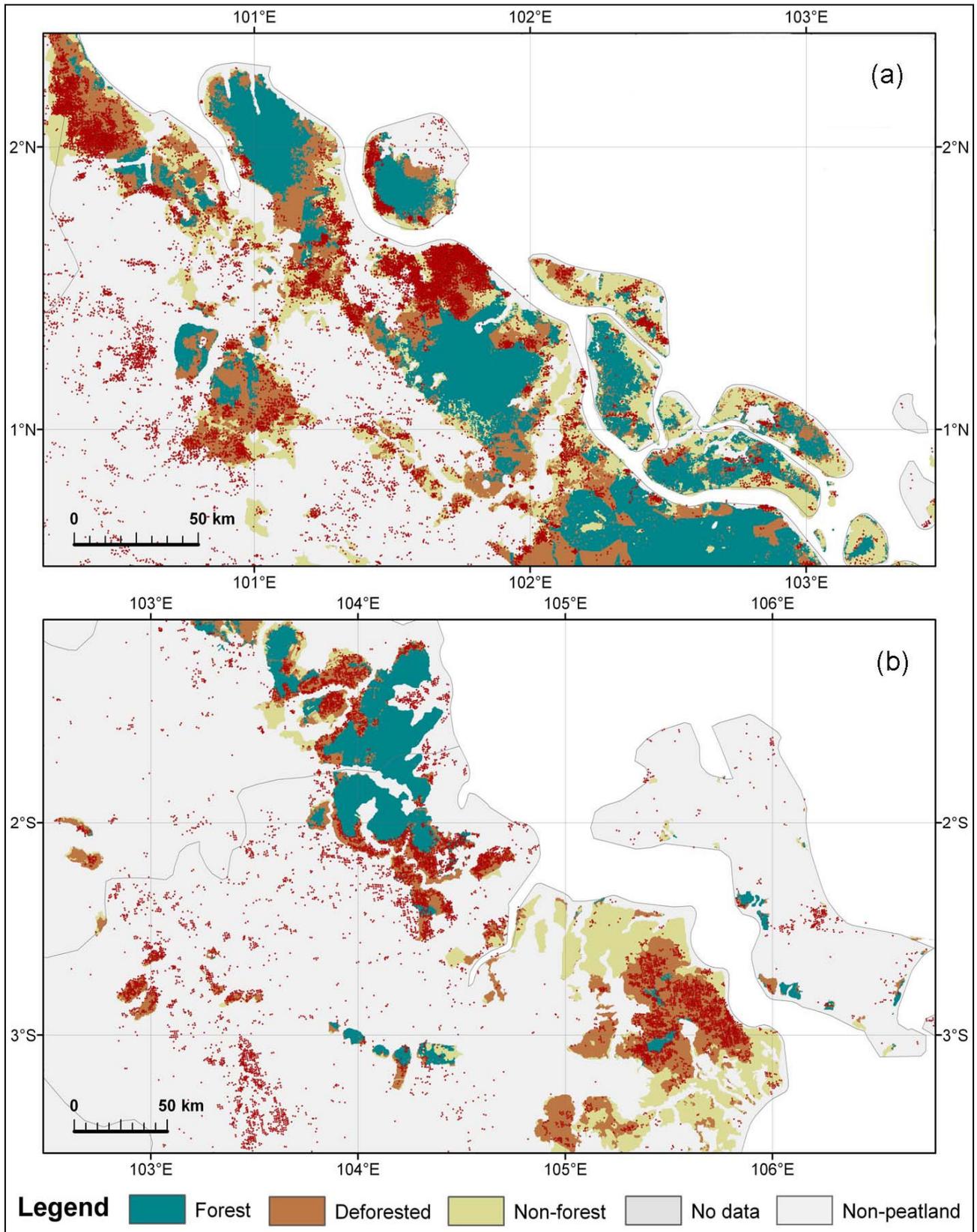


Figure 1. Deforestation on the peatlands of (a) northern Riau between 2000 and 2010 and (b) South Sumatra and Jambi between 1990 and 2000. Note the concentration of active fire detections (marked as red dots) on deforested peatland areas. The land cover types refer to decadal changes: e.g. Forest-class refers to areas that remained forest over the entire decade and Deforested-class refers to areas that were deforested during the decade etc.

Since the year 2000, fire has continued to be tightly connected to peatland deforestation in Sumatra (Figure 1a). However, it is believed that large proportion of the fire activity that occurred during the past decade was deliberate land clearance burning. No region wide episode of wild fires comparable to the one that took place under the extraordinarily strong El Niño conditions in 1997-1998 took place during the past decade.

Over the first decade of the new millennium, especially Riau province experienced dramatic increase in peatland deforestation (Table 2). This increase is expected to be largely driven by plantation development (based on further analysis of the deforested areas in high resolution satellite datasets) and fire is believed to have been widely used as a tool in land clearance and preparation (Figure 1). Apart from Riau, both the absolute areas deforested and the yearly deforestation rates decreased from the 1990's to the 2000's in Sumatra.

#### 4. CONCLUSION

The figures reported in this paper powerfully highlight the dramatic destruction of Sumatran peat swamp forests over the past two decades. As a result of all the deforestation revealed in this paper, Sumatran peatlands are now constantly emitting high amounts of carbon into the atmosphere due to peat decomposition (Hooijer et al. 2010), they are extremely vulnerable to repeated annual fire occurrence further degrading the area and releasing carbon dioxide into the atmosphere (Langner and Siegert 2009) and they are susceptible to catastrophic fire events comparable or worse to the 1997-1998 fires (Page et al. 2002, Field et al. 2009) when exceptionally strong El Niño conditions arise.

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#### ACKNOWLEDGEMENTS

The authors would like to thank the MODIS Rapid Response Project at the University of Maryland for providing the MODIS active fire data and the European Space Agency for providing the ATSR active fire data. The authors also acknowledge financial support from the Agency for Science, Technology and Research (A\*STAR) of Singapore for the Centre for Remote Imaging, Sensing and Processing (CRISP) where this study was conducted.