PEAT-CO2

Assessment of CO2 emissions from drained peatlands in SE Asia

Report R&D projects Q3943 / Q3684 / Q4142

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Summary

Forested tropical peatlands in SE Asia store at least 42,000 Megatonnes of soil carbon. This carbon is increasingly released to the atmosphere due to drainage and fires associated with plantation development and logging. Peatlands make up 12% of the SE Asian land area but account for 25% of current deforestation. Out of 27 million hectares of peatland, 12 million hectares (45%) are currently deforested and mostly drained. One important crop in drained peatlands is palm oil, which is increasingly used as a biofuel in Europe.

In the PEAT-CO2 project, present and future emissions from drained peatlands were quantified using the latest data on peat extent and depth, present and projected land use and water management practice, decomposition rates and fire emissions. It was found that current likely CO_2 emissions caused by decomposition of drained peatlands amounts to 632 Mt/y (between 355 and 874 Mt/y). This emission will increase in coming decades unless land management practices and peatland development plans are changed, and will continue well beyond the 21st century. In addition, over 1997-2006 an estimated average of 1400 Mt/y in CO2 emissions was caused by peatland fires that are also associated with drainage and degradation. The current total peatland CO_2 emission of 2000 Mt/y equals almost 8% of global emissions from fossil fuel burning. These emissions have been rapidly increasing since 1985 and will further increase unless action is taken. Over 90% of this emission originates from Indonesia, which puts the country in 3rd place (after the USA and China) in the global CO2 emission ranking.

It is concluded that deforested and drained peatlands in SE Asia are a globally significant source of CO_2 emissions and a major obstacle to meeting the aim of stabilizing greenhouse gas emissions, as expressed by the international community. It is therefore recommended that international action is taken to help SE Asian countries, especially Indonesia, to better conserve their peat resources through forest conservation and through water management improvements aiming to restore high water tables.

Contents

1 Introduction

1.1 Background

Peatlands cover 3% (some 4 million km^2) of the Earth's land area (Global Peatlands Initiative, 2002) and store a large fraction of the Worlds terrestrial carbon resources: up to 528,000 Megatonnes (Gorham 1991, Immirzi and Maltby 1992), equivalent to one-third of global soil carbon and to 70 times the current annual global emissions from fossil fuel burning (approximately 7,000 Mt/y in 2006 in carbon equivalents or 26,000 Mt/y in CO_2 equivalents).

This carbon store is now being released to the Earth's atmosphere through two mechanisms:

- Drainage of peatlands leads to aeration of the peat material and hence to oxidation (also called aerobic decomposition). This oxidation of peat material (which consists of some 10% plant remains and 90% water) results in CO_2 gas emissions. Much of the dry peat matter is carbon (50% to 60% in SE Asia, depending on peat type).
- Fires in degraded peatlands result in further CO_2 gas emissions; fires are extremely rare in non-degraded and non-drained peatlands.

Most rapid peatland degradation presently occurs in SE Asia where the peatlands are being deforested, drained and burnt for development of oil palm and timber plantations, agriculture and logging. Apart from CO_2 emissions, these developments are also a threat to the remaining biodiversity in SE Asia as the peatlands are an important habitat for many endangered species, including Orang Utan in Borneo and Sumatran Tiger in Sumatra. Furthermore, the peat fires cause regional haze (smog) problems that affect public health and economies in the SE Asian region.

The data used in PEAT-CO2 show that peatlands covers 27.1 Million hectares in SE Asia (defined here as Indonesia, Malaysia, Brunei and Papua New Guinea), or 10% of the total land area. Over 22.5 Million hectares (83%) of this are in Indonesia, with a further 2 Million hectares in Malaysia and 2.6 Million hectares in Papua New Guinea. Peat thicknesses range from less than 1 to over 12 metres; a significant fraction of peatlands are over 4 metres thick (at least 17% in Indonesia). According to PEAT-CO2 calculations the total carbon store in SE Asian peatlands is at least 42,000 Mt (assuming a carbon content of 60 kg/m^3); this estimate is likely to increase when peat thicknesses and peat characteristics are better known.

Scientists have been aware of the link between peatland development and CO_2 emissions for some time, but policy makers and peatland managers are still insufficiently aware of the global implications of local and national peatland management strategies and actions. As a result, CO_2 emissions from SE Asia's drained and burning peatlands are not yet recognized in the global climate change debate, and the major coordinated international action required to help these countries to better manage their peatlands has yet to start.

1.2 This Study and Report

The PEAT-CO2 project was started in 2005 by Delft Hydraulics in collaboration with Wetlands International and Alterra, to:

A) Demonstrate the causal links between drainage and CO_2 emissions (i.e. awareness raising);

B) Quantify the actual emissions caused by peatland drainage (i.e. research), and

C) Develop peatland management support tools with a focus on water management.

In 2005, the PEAT-CO2 project determined global CO_2 emissions from drained peatland on a regional basis, and developed a prototype of a PEAT-CO2 tool for rapid peatland management strategy assessments.

In 2006 the PEAT-CO2 project determined CO_2 emissions from SE Asia alone, using more accurate data and improved assessment methods. The results of the latter activity are presented here.

This document is a consultancy report. A scientific paper on approach and results of the study will be published in a special issue of Ecology, in 2007.

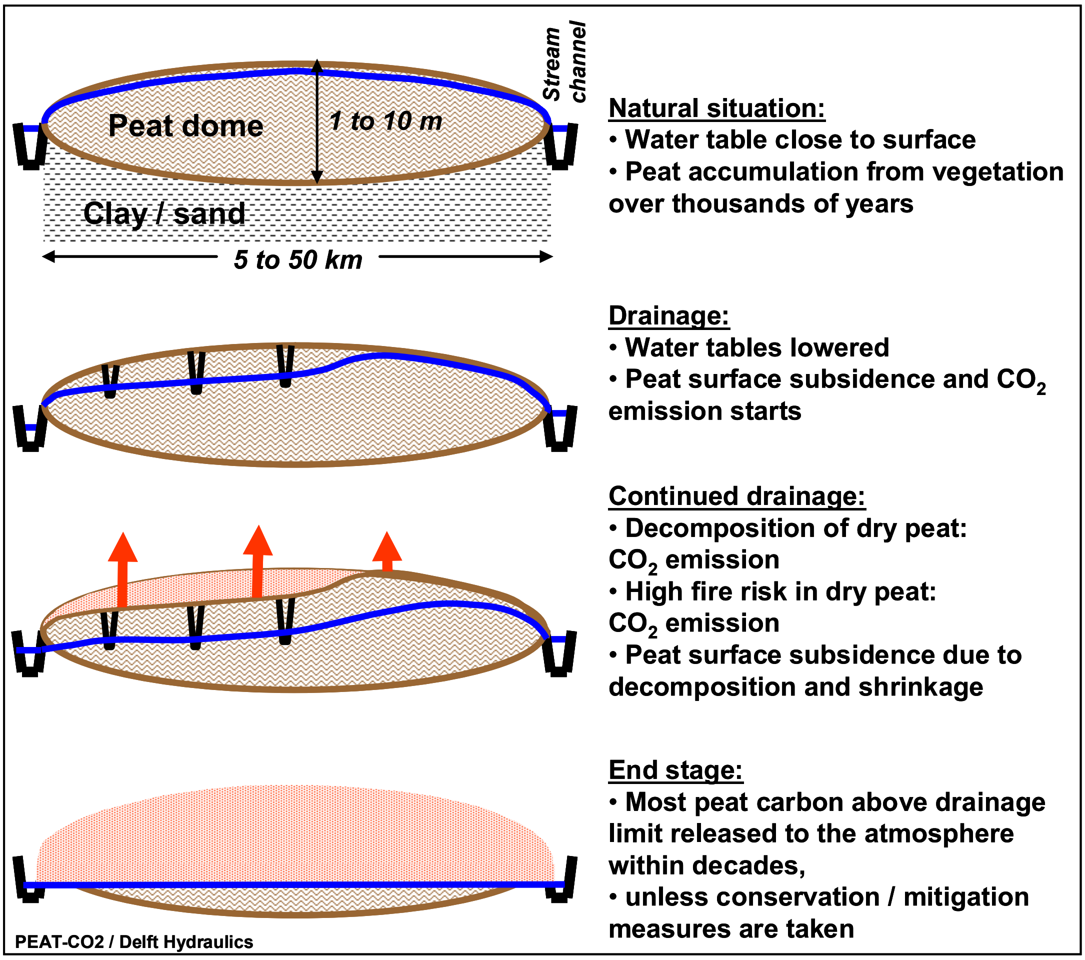

Figure 1 Schematic illustration of CO_2 emission from drained peatlands.

1.3 Acknowledgements

Within Delft Hydraulics the following persons contributed to the study and to this report:
Jaap Kwadijk, Rinus Vis, Marcel Ververs, Rolf van Buren, Marjolijn Haasnoot and others.

The following other organizations and persons were actively involved in the study presented here:

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- Alterra (Henk Wösten).
- University of Leicester (Susan Page).
- SarVision (Niels Wielaard).

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- Global Environment Centre (Faizal Parish).
- Global Forest Watch (Fred Stolle).
- Remote Sensing Solutions (Florian Siegert).
- University of Helsinki (Jyrki Jauhiainen).

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2 Analysis approach

2.1 Analysis area

The current analysis pertains to lowland peatlands in SE Asia:

- For the purpose of this study, 4 countries in SE Asia are included which have major peat resources: Indonesia, Malaysia, Papua New Guinea and Brunei. Smaller peatland areas are found in Thailand, Vietnam, Cambodia and the Philippines. However, these are less well studied and equivalent in area and carbon volume to only a few percent of the region included. They are therefore excluded from the analysis.
- The study includes only lowland peatlands, defined as peatlands under 300m above Sea level. Some peatland areas exist in higher areas in SE Asia, however the area of these peatlands was found to be less than 3% of the peatland area, mostly in Papua (formerly Irian Jaya, in Indonesia) and Papua New Guinea, and probably represents less than 1% of the peatland carbon store as the peat deposits typically have only limited thickness.

2.2 Analysis steps

The present and future CO_2 emissions from drained peatlands in SE Asia were determined in a number of steps:

A) Develop a peatland distribution map (Figure 2).
B) Develop a peatland land use map for the year 2000 (Figure 4, Figure 5).
C) Calculate peatland areas under different land uses, by Province, State and Country, in 2000 (Table 1).
D) Determine trends in land use in peatlands, by Province (Indonesia), State (Malaysia) and Country (Brunei, PNG) (Figure 11, Table 2, Table 3, Figure 6).
E) Determine drainage depths for land use types and determine the relation between drainage depth and CO_2 emission (Table 5, Figure 12).
F) Determine CO_2 emissions from oxidation in drained peatlands by Province, State and Country, in 2000 and in the future (Figure 13, Figure 14).
G) Estimate additional CO_2 emissions from degraded and drained peatlands (Figure 16).

The basic method of analysis enabled determination of the presence of relevant parameters (presence of peat, thickness of peat, presence of drainage, depth of drainage, rate of change in drainage, etc) in GIS maps with a resolution of 1km. The Arc-GIS package was used for this. The results were than summarized in Tables by geographic analysis units, and further calculations were performed using these Tables.

2.3 Data sources

Data were obtained from several sources, including preliminary results of studies that have yet to be published.

2.3.1 Peat extent and thickness

- Peat extent and peat thickness data for Kalimantan and Sumatra, collected in field surveys over 1990-2002, were provided by Wetlands International. These data are an improvement over the FAO soil data used in earlier analyses, which has lower accuracy and detail and no thickness information. However, numbers can still be improved especially for peat thickness.
- For the remaining areas, the FAO Digital Soil Map of the World was used to determine peat percentage in soil classes, using decision rules supplied by the International Soil Reference and Information Centre (ISRIC). Peat thickness data for Papua / Irian Jaya were provided by Wetlands International. Peat thickness in other areas was estimated as described later.

2.3.2 Land use

- SE Asia land use data for the year 2000 were obtained from the GLC 2000 global land cover classification, an EU-JRC product derived from SPOT VEGETATION satellite data at a 1km resolution.
- Indonesian forest cover data for the years 1985 and 1997, and plantation concession data, were provided by the World Resources Institute (Global Forest Watch).
- Analysis results for land cover datasets (based on satellite data) over the years 2000-2005 were provided by SarVision.

2.3.3 Drainage and CO_2 emission

- Numbers for typical drainage intensity and drainage depth for different land use classes ('cropland', 'mosaic cropland + shrubland', 'shrubland') were estimated in consultation with the experts involved in the study presented here, all of whom have considerable field experience in peatlands in SE Asia.
- The relation between average drainage depth and CO_2 emission was provided by Dr Henk Wösten of Alterra, and is supported by a literature review (the review received additional inputs from Dr Jyrki Jauhiainen of the University of Helsinki). The relation is a simplification and needs to be further developed, but is considered applicable for a drainage depth range between 0.5m and 1m, which is the most common drainage depth range in the analysis area.

2.3.4 Emissions from peatland fires

- Data on 1997-2006 hotspot counts in Borneo were provided by Dr Florian Siegert of Remote Sensing Solutions; these data will be published separately.
- Analysis of CO_2 emissions during the 1997 peatland fires in Indonesia, published by Dr Susan Page (NATURE, 2002), is the basis for defining average CO_2 emissions over 1997-2006.
- Preliminary results on the relation between land use and fire frequency were provided by Dr Allan Spessa of the Max Planck Institute.

3 Analyses and results

3.1 Peatland distribution, thickness and carbon storage

Peatland distribution in SE Asia is shown in Figure 2. The total peatland area in SE Asia is calculated at 27.1 million hectares, or 271,000 km^2 (Table 2). To put this in perspective: this is 10% of the SE Asian land area and approximately equal to the land area of the British Isles. Indonesia alone has 22.5 million hectares, which is 12 percent of its land area and 83% of the SE Asian peatland area.

Peat thickness in Indonesia (Sumatra, Kalimantan and Papua) ranges from less than 1 metre to over 12 metres, as shown in Figure 3. While 42% of the peatland area in Indonesia is over two metres thick, these thicker peat deposits store 77% of the total peat (and carbon, approximately) deposits. It is expected similar distributions apply for the remaining peatlands of SE Asia. Peat thicknesses outside Indonesia were estimated conservatively: an average thickness of 3m was assumed for Malaysia and Brunei (assumed similar to neighbouring Kalimantan), a thickness of 1.5 metres was assumed for Papua New Guinea (assumed similar to neighbouring Papua).

Carbon storage in peatlands depends on the type of peat deposits. In SE Asia, almost all lowland peat is derived from forest vegetation and has a high wood content, however the degree of decomposition varies from peatland to peatland and within peatlands. Most studies (e.g. Page et al, 2002) consider a value in the order of 60 kgC/m^3 to be representative for SE Asian peatlands in general. Using this figure, the peat extent- and thickness data used in the current study yield a total approximate carbon storage in SE Asian peatlands of 42,000 Megatons.

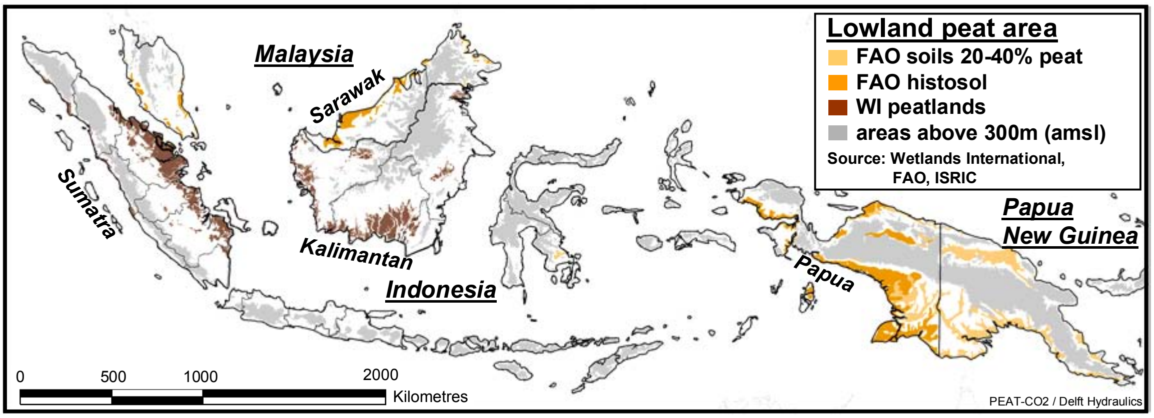


Figure 2 Lowland peat extent in SE Asia. The Wetlands International data have higher detail and accuracy than the FAO data.

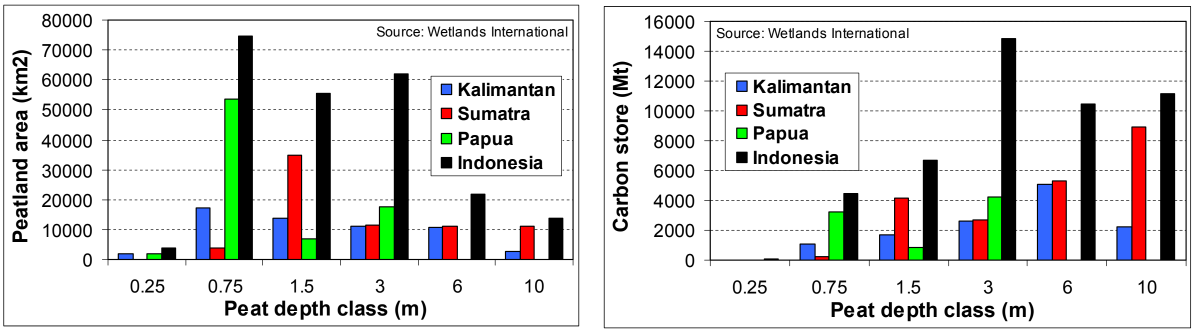


Figure 3 Peat depth/thickness classes by area. Large areas of peatland are in excess of 3 metres deep (Data: Wetlands International 2003, 2004).

3.2 Current (year 2000) and projected land use on peatlands

3.2.1 Distribution of forest cover and land use types on peatlands

Land use in the base year 2000 was derived from the GLC 2000 global land use / land cover spatial dataset. This dataset consists of (approximately) 1km cells which have been assigned specific land use classes; cells within geographic analysis units (Provinces, States and Countries) were added up by class to derive total areas for each class within each unit. This was done separately for the entire area and for lowland peatlands (under 300m elevation), by 'masking' the land use data with the peat area dataset described earlier. The results of this analysis are shown in Table 1.

In 2000, 61% of peatlands in SE Asia (that is, the countries included in the analysis: Indonesia, Malaysia, Papua New Guinea and Brunei) were covered in forest according to the GLC 2000 classification (Table 1). The same figure of 61% forest cover in 2000 applies to Indonesia. Within Indonesia, Papua had the highest remaining forest cover on peatlands (72%), Sumatra the lowest (52%).

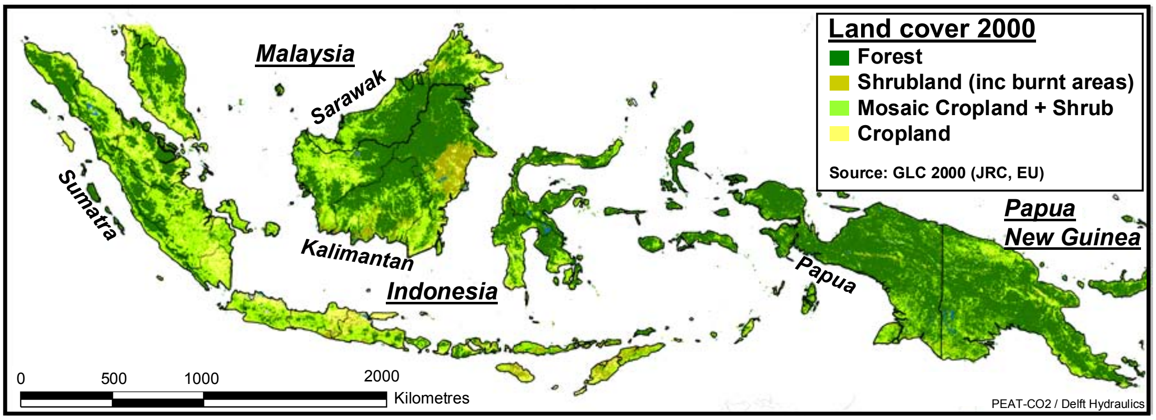


Figure 4 Land use in SE Asia as determined from GLC 2000 dataset.

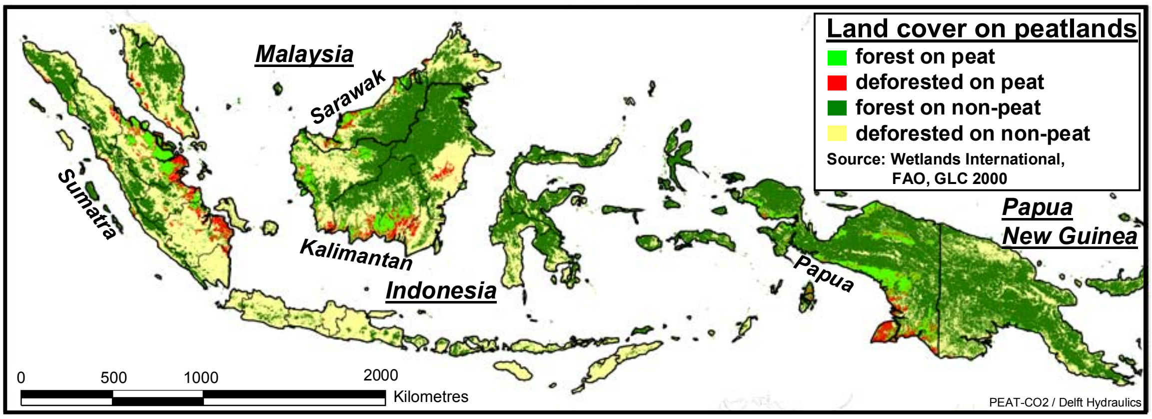


Figure 5 Forest status on peatland and non-peatland, in the year 2000.

Table 1 Peatland land use in the year 2000, as determined from the GLC 2000 global land use dataset.

	Forest				Shrubland + burnt			Mosaic: crop+shrub			Cropland
GLC 2000 class:	1	4	5	1,4,5	6	8	6,8	2	9	2,9	12
	Tree cover, broadleaved, evergreen, closed and closed to open	Tree cover, regularly flooded, Mangrove	Tree cover, regularly flooded, Swamp	**Total forest (including logged)**	Mosaics & Shrub Cover, shrub component dominant, mainly evergreen	Shrub cover, mainly deciduous, (Dry or burnt)	**Total shrubland + burnt**	Mosaic: Tree cover / Other nat. vegetation or Cropland (incl.very degraded and open tree cover)	Mosaic sof Cropland / Other natural vegetation (Shifting cultivation in maountains)	**Total mix cropland + shrub (small-scale agr.)**	Cultivated and managed, non irrigated (mixed)
	% area	% area	% area	% area	% area	% area	%area	% area	% area	%area	% area
Total Indonesia	**27**	**4**	**30**	**61**	**4**	**2**	**7**	**3**	**24**	**27**	**5**
Kalimantan	**30**	**2**	**27**	**58**	**15**	**4**	**20**	**2**	**17**	**19**	**3**
Central Kalimantan	33	1	24	57	19	2	22	2	15	18	3
East Kalimantan	29	4	11	44	22	19	42	0	9	9	5
West Kalimantan	28	3	43	74	5	1	7	2	17	19	1
South Kalimantan	14	0	4	18	15	3	18	6	45	51	14
Sumatra	**14**	**2**	**35**	**52**	**0**	**1**	**1**	**3**	**34**	**37**	**10**
D.I. Aceh	37	0	22	59	0	0	0	4	28	32	8
North Sumatera	20	1	16	36	0	2	2	3	39	42	20
Riau	14	3	49	66	0	1	1	2	24	26	7
Jambi	9	0	33	42	0	1	1	3	38	40	17
South Sumatera	11	1	14	26	0	1	2	4	57	61	12
West Sumatera	24	0	13	38	0	5	5	4	42	46	11
Papua	**36**	**9**	**27**	**72**	**0**	**1**	**2**	**4**	**20**	**25**	**1**
Malaysia	**36**	**4**	**15**	**53**	**2**	**1**	**1**	**7**	**32**	**38**	**7**
Peninsular Malaysia	37	0	0	37	0	1	1	4	47	50	13
Sabah	21	21	2	**43**	8	2	**10**	3	28	**31**	17
Sarawak	38	3	23	**59**	2	1	**2**	9	26	**35**	4
Brunei	**39**	**6**	**39**	**84**	**3**	**1**	**4**	**1**	**9**	**10**	**2**
Papua N. Guinea	**38**	**5**	**19**	**61**	**0**	**1**	**1**	**4**	**32**	**35**	**3**
SE ASIA	**29**	**4**	**28**	**61**	**4**	**2**	**5**	**4**	**26**	**29**	**5**

Source: GLC 2000

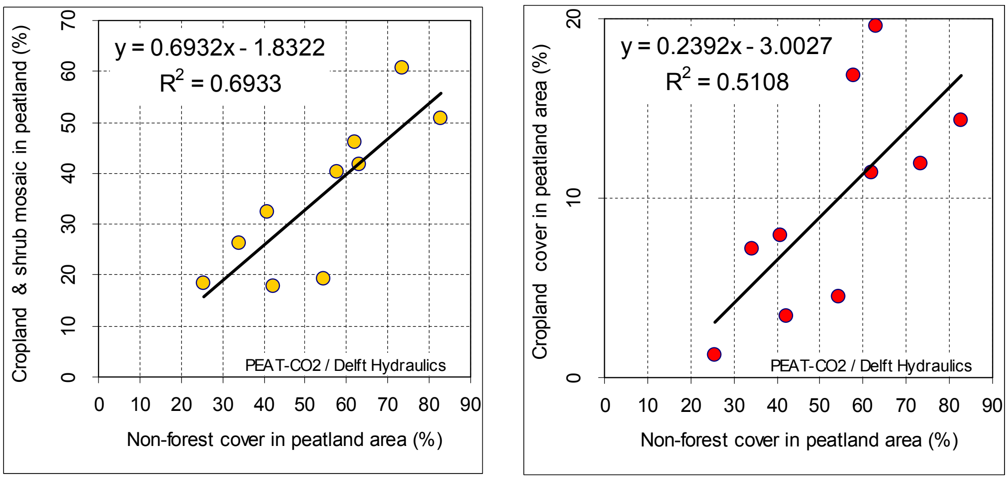


Figure 6 Comparison of peatland land use in Indonesian Provinces yields insight in land use development trends. Areas are expressed as a percentage of total peat area by Province, as in Table 1.

Left: the area of 'cropland & shrubland mosaic' (i.e. small-scale agriculture, more or less) increases proportionally with the total deforested area.
Right: the area of 'cropland' (i.e. large-scale agriculture, more or less) also increases with the total deforested area, but the fraction cropland increases faster than other land uses.

3.2.2 Trends and projections in land use changes on peatlands

Deforestation rate on peatlands

The tropical peat swamp forests are under tremendous pressure from agriculture/silviculture development and logging. Trends in forest cover in SE Asia were derived from changes between 1985 (World Resources Institute data) and 2000 (GLC 2000 data), as shown in Table 2. Over this period, peatlands were deforested at rate of 1.3% per year on average; the highest value is found in East Kalimantan (2.8%/y), the lowest in Papua (0.5%/y). As the 1985 data were only available for Indonesia, trend analysis for the other countries is based on comparison with Indonesia and results are less accurate. Trends for SE Asia were also verified for 2000-2005 using tentative SarVision data (Table 3); it appears the average deforestation rate in peatlands in SE Asia over 2000-2005 is 1.5%/y (of forest cover in 2000). Allowing for the difference in reference years (1985 and 2000), these percentages are very similar and suggest that deforestation on peatlands has continued at a high rate over the past 20 years.

According to Table 2, 10.6 million hectares (39%) of peatland in SE Asia was deforested in 2000. Accounting for continued deforestation at a rate of 1.5%/y, the deforested peatland area in 2006 is around 45% of total peatland area, or 12.1 million hectares.

Table 2 Basic data for PEAT-CO2 calculations, including the rate of deforestation in lowland peatlands.

Note that the Global Forest Watch forest cover data for 1997 (not shown) indicate lower forest cover than the GLC 2000 data used in the analysis. The rate of deforestation used in PEAT-CO2 analyses is therefore considered conservative.

Basic data for PEAT-CO2 SE Asia calculations	Total Area	Lowland peat area	Peatland % of total area	Total forest cover 1985	2000	Forest loss 1985-2000	Lowland peatland forest cover 1985	2000	Forest loss 1985-2000
	ESRI km2	WI+FAO km²	%	GFW %	GLC2000 %	%/y	GFW %	GLC2000 %	%/y
Indonesia	**1919317**	**225234**	**12**	**67**	**59**	**-0.7**	**81**	**61**	**-1.3**
Kalimantan	**531506**	**58379**	**11**	**72**	**57**	**-1.2**	**87**	**58**	**-1.9**
Central Kalimantan	154829	30951	20	69	63	-0.6	90	57	-2.2
East Kalimantan	193351	6655	3	88	65	-1.9	85	44	-2.8
West Kalimantan	147527	17569	12	61	50	-0.9	92	74	-1.2
South Kalimantan	35799	3204	9	45	26	-1.5	41	17	-1.6
Sumatra	**464301**	**69317**	**15**	**52**	**40**	**-1.0**	**78**	**52**	**-1.8**
D.I. Aceh	56515	2613	5	71	62	-0.8	87	59	-1.8
North Sumatra	71316	3467	5	40	36	-0.4	76	36	-2.6
Riau	92141	38365	42	69	48	-1.7	87	66	-1.4
Jambi	48518	7076	15	56	44	-1.0	67	42	-1.7
South Sumatra	84198	14015	17	38	20	-1.5	66	26	-2.6
West Sumatra	41585	2096	5	68	62	-0.5	69	38	-2.1
Papua	**411649**	**75543**	**18**	**84**	**80**	**-0.3**	**80**	**72**	**-0.5**
Other Indonesia	**511,860**	**21995**	**4**					**61**	
Malaysia	**327291**	**20431**	**6**				**78***	**53**	**-1.8***
Peninsular M.	131205	5990	5				78*	37	-2.8*
Sabah	72767	1718	2				86*	43	-2.9*
Sarawak	123320	12723	10				76*	59	-1.1*
Brunei	**5772**	**646**	**11**				**85***	**84**	**-0.2***
Papua New Guinea	**399989**	**25680**	**6**				**80***	**61**	**-1.3***
SE Asia	**2652370**	**271991**	**10**					**61**	

* Estimated

Comparison of forest cover and trends on peatlands and non-peatlands

The year 2000 forest cover on peatlands in SE Asia is similar to that in non-peatlands (according to the GLC 2000 dataset): 61% vs 59% in Indonesia, 51% vs 56% in Malaysia, 82 vs 80% in Papua New Guinea (Table 1). However, the deforestation rate in peatlands over 1985-2000 was almost double that in non-peatlands: 1.3%/y vs 0.7%/y in Indonesia (Table 2). Tentative findings by SarVision suggest that the deforestation rate in peatlands is stable since 2000 to 1.5%/y (Table 3, Figure 7), while that in non-peatlands is lower (0.85%/y) and has decreased in recent years. As a result, deforestation of peatlands amounted to 25% of all deforestation in SE Asia in the year 2005 (Table 3).

In relative terms, a greater oil palm and timber plantation area is planned on peatlands than on non-peatlands: 27% of concessions are planned on the 12% land surface that is peatland in Indonesia. No concession data were available for Malaysia at the time of this study, but the percentage of oil palm plantations on peatlands in Sarawak may be even greater (Figure 8).

Land use developments within deforested areas

Projections of land use change within deforested areas were based on the analysis of the relative areas of GLC 2000 classes (‘cropland’, ‘cropland + shrubland’ and ‘shrubland’) within the deforested areas of Indonesian Provinces (Figure 6). Linear relations derived as shown in Figure 6 were applied to the deforested area in the projections, at 5-year time steps. The advantage of this approach is transparency, the drawback is that once 100% of the peatland within a Province or Country is deforested, its land use is fixed. The area of ‘cropland’, interpreted as large-scale agriculture which has the highest drainage density and the deepest drainage, will not exceed 21% of the total area. The maximum area of ‘mosaic cropland + shrubland’, interpreted as small-scale agriculture with lower drainage density and depth, is 68% of the total deforested area. In actual fact the very large-scale and intensively drained palm oil and timber plantations concessions alone already cover 27% of the peatland area in Indonesia; a similar percentage may apply in Malaysia). The approach is therefore considered conservative: the future drainage intensity in deforested areas is probably underestimated.

No projections were developed for the degree of degradation within forest areas, due to logging (legal and illegal) and due to regional drainage impacts of plantations, for lack of data on this issue. This degradation is known to be rapidly increasing and to be accompanied by drainage and fires, and hence by CO_2 emissions. Not including forest degradation in the PEAT-CO2 assessment inherently leads to a further underestimation of drained area in peatlands in this study.

Table 3 Recent deforestation rates on peatland and non-peatland, for SE Asia, as determined by SarVision. These are tentative results, for Insular South East Asia, of a systematic forest cover monitoring system for tropical forest regions developed by SarVision. The system uses SPOT Vegetation satellite images (work on integration of MODIS and MERIS is ongoing) and provides forest cover updates on a 3-monthly basis since 1999. Results have been overlain on the peat extent maps used in the PEAT-CO2 SE Asia study, to identify trends after the year 2000 (the PEAT-CO2 trend analysis covers the years 1985 and 2000).
Note that the forest determined by SarVision are somewhat different from the ones used in the current study, because SarVision has included part of Thailand and the Philippines in the analysis. This hardly affects the forest cover on peatlands, but it does affect the total forest area. Also, the definition of ‘forest cover’ used by SarVision appears to be somewhat different from the GLC 2000 definition.

Deforestation rate (2000 - 2005) for Total Forest and Peat Swamp Forest in Insular SE Asia							
Year	**Total Forest**	**Total Forest Loss**		**Peat Swamp Forest**	**Peat Swamp Forest Loss**		
	km^2	km^2/y	% of total forest	km^2	km^2/y	% of peat forest	% of total forest loss
2000	1869762	22430	1.20	165839	2201	1.33	9.81
2001	1855477	14285	0.76	164036	1803	1.09	12.62
2002	1830239	25237	1.35	160685	3351	2.02	13.28
2003	1819106	11133	0.60	158846	1838	1.11	16.51
2004	1806412	12693	0.68	155863	2983	1.80	23.50
2005	1796804	9609	0.51	153471	2392	1.44	24.90
Average:		15898	0.85		2428	1.46	16.77
Source: SarVision							

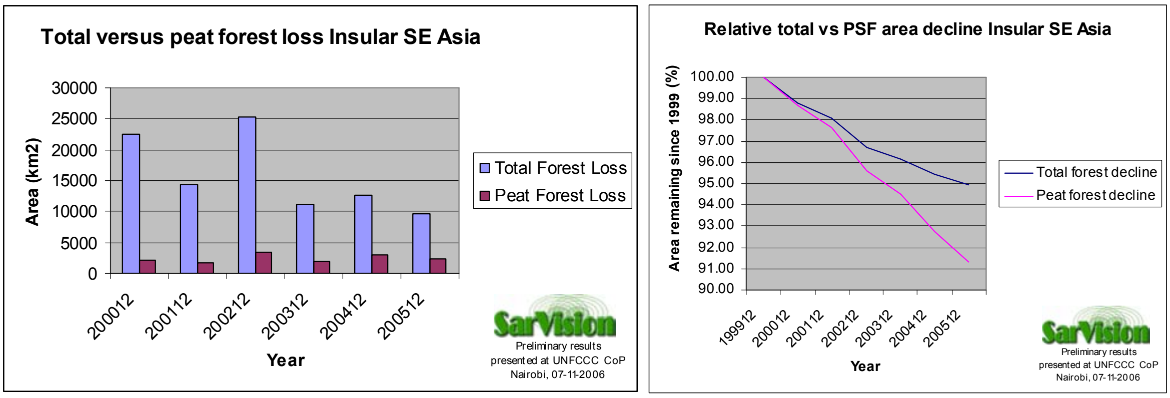


Figure 7 Graphic representation of figures shown in the table above.

Figure 8 Deforestation data for Sarawak (provided by SarVision) show that around 50% of forest lands cleared from 1999 to June 2006 (red areas) are located on peat lands (brown areas). Field observations and rapid assessment of satellite data suggest that many of these areas are cleared for large scale oil palm plantations.

3.2.3 Timber and oil palm plantation concessions on peatlands

Knowing the area of concessions on peatlands is important for quantification of potential future CO_2 emissions from peatlands.

There are three main types of concessions in SE Asian peatlands: logging concessions (HPH in Indonesia), timber plantation concessions much of which is acacia pulp wood plantations for paper production (HTI in Indonesia), and oil palm plantation concessions (BHP in Indonesia). Of these, especially the timber and oil palm plantation concessions on peatlands require intensive drainage.

Logging in peatlands (legally in HPH concessions, and illegally) is often accompanied by construction of transport canals, which also drain the peatlands. This drainage is often less deep than in plantation areas, causing less CO_2 emission unless accompanied by fires by unit area, but total emissions may still be significant as the areas involved are vary large.

No concession data were available for Malaysia and Papua New Guinea. Concession data for the main peatland areas in Indonesia (Sumatra, Kalimantan and Papua), provided by the World Resources Institute, were available to determine the planned or potential areas of various land uses on peatlands (Table 4). These data cover both existing and planned developments.

According to the concession data available, 27% of both timber and oil palm concession areas in Indonesia are on peatlands. The total oil palm concession area on peatlands is 28,009 km^2 (2.8 million hectares), the total timber concession area 19,923 km^2 (2 million hectares). Both concession types are concentrated in Sumatra and Kalimantan, with only a small oil palm concession area in Papua. Oil palm plantation concessions cover 14% of the total peatland area, oil palm + timber plantation concessions 23% (Table 2). This is not including state-owned and co-operative plantations, other (not BHP or HTI) agricultural developments (e.g. the Mega Rice Project in Central Kalimantan) and drainage schemes for logging purposes (legal and illegal). In addition to the plantation concessions, 12% of peatlands is earmarked as logging concession (HPH).

There are indications that the concession data are not very accurate: overlays between 2 or even 3 concession types are found in some areas. Also, it should be noted that these concession data represent only part of the total current + planned oil palm and timber plantations; co-operative plantations and state plantations appear not to be included. It is concluded that the concession data provide a useful estimate of the planned area of timber and oil palm plantations on peatlands, but better data are needed.

With the concession data available it is not possible to precisely determine the current areas of these land uses. However until better data are available we can only assume that the percentage of oil palm and timber plantations currently on peatlands is similar to the planned percentages. We therefore assume that some 25% of current oil palm and timber plantations are on peatlands. The current percentage in Indonesia may be higher: tentative inspection of satellite images of the Province of Riau indicates that at least 50%, and probably more than 75% of the 800,000 ha of oil palm concession in that Province Figure 10) is already developed. Assuming 75% is developed, these 600,000 hectares of existing oil palm plantations alone represent 15-20% of the present total palm plantation area in the country (3.5 to 4 million hectares according to most estimates).

An interesting assessment of the expected rate of development of oil palm plantations is provided in a report by the Indonesian Ministry of Forestry in co-operation with the European Union (Sargeant, 2001): *"The world demand for palm oil is forecast to increase from its present 20.2 million tonnes a year to 40 million tonnes in 2020. If this demand is to be met, 300 000 ha of new estates will need to be planted in each of the next 20 years. We predict that by far the largest slice of this new land will come from within Indonesia where labour and land remain plentiful. And we expect that Sumatra,* *with its relatively well-developed infrastructure and nucleus of skilled labour, will absorb 1.6 million hectares of this expansion. It is inevitable that most new oil palm will be in the wetlands, as the more 'desirable' dry lands of the island are now occupied. We expect that of the new areas, half will be developed by estates and half by smallholders."* There are two important aspects to this assessment:

1. It suggests that over 50% of oil palm plantations, at least in Sumatra (but similar considerations apply in parts of Kalimantan), will be developed on peatlands. This is more than is suggested by concession data available to the study.
2. It suggests that half of the plantations will be developed by smallholders, which may not be represented in the concession data.

As projections for global oil palm demand have been rising in recent years, with biofuel as an increasingly important use, the assessment above should probably be considered conservative at present (5 years later). It is concluded that a figure of 25% oil palm plantations may be a realistic estimate for current conditions, but is a conservative estimate for future conditions.

Table 4 Concessions on peatland in Indonesia.

Concessions in Indonesia									
		Logging		**Timber plantation**		**Oil Palm plantation**			
	Lowland peat area	HPH total~	HPH on lowland peat~	HTI total~	HTI on lowland peat~	BHP total~	BHP on lowland peat~	HTI+ BHP total~	HTI+ BHP on lowland peat~
	km²	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*	*km²*
Kalimantan		**124217**	**4451**	**27274**	**3104**	**50255**	**14725**		
Sumatra		**23601**	**6295**	**33544**	**11827**	**49513**	**12494**		
Papua		**95902**	**13686**	**14036**	**4992**	**3610**	**790**		
Total Kal + Sum + Pap		**243720**	**24432**	**74854**	**19923**	**103378**	**28009**	**178232**	**47932**
				as a percentage of total plantation area					
Kalimantan			**4**		**11**		**29**		
Sumatra			**27**		**35**		**25**		
Papua			**14**		**36**		**22**		
Total Kal + Sum + Pap			**10**		**27**		**27**		**27**
	km²	*% total area*	*% peat area*	*% total area*	*% peat area*	*% total area*	*% peat area*	*%peat area*	*%peat area*
Kalimantan	**58379**	**23**	**8**	**5**	**5**	**9**	**25**	**15**	**31**
C. Kalimantan	30951	28	5	2	2	18	41		
E. Kalimantan	6655	31	13	6	9	6	16		
W. Kalimantan	17569	11	12	7	11	6	5		
S. Kalimantan	3204	16	0	6	0	7	3		
Sumatra	**69317**	**5**	**9**	**7**	**17**	**11**	**18**	**18**	**35**
D.I. Aceh	2613	11	5	6	0	6	40		
N. Sumatera	3467	3	1	5	0	3	18		
Riau	38365	8	13	16	20	22	23		
Jambi	7076	8	9	5	2	17	8		
S. Sumatera	14015	1	1	10	29	5	6		
W. Sumatera	2096	8	11	1	2	22	23		
Papua	**75543**	**23**	**18**	**3**	**7**	**1**	**1**	**4**	**8**
Total Kal + Sum + Pap	**204156**	**16**	**12**	**5**	**10**	**7**	**14**	**11**	**23**
Data sources:	*World Resources Institute / Global Forest Watch (concession areas)*								
	Wetlands International (peatland Kalimantan, Sumatra)								
	FAO / ISRIC (peatland Irian Jaya)								
~'total' area is total area of Province (or Region/Country); 'lowland peat' area is peat area under 300m within that Province									

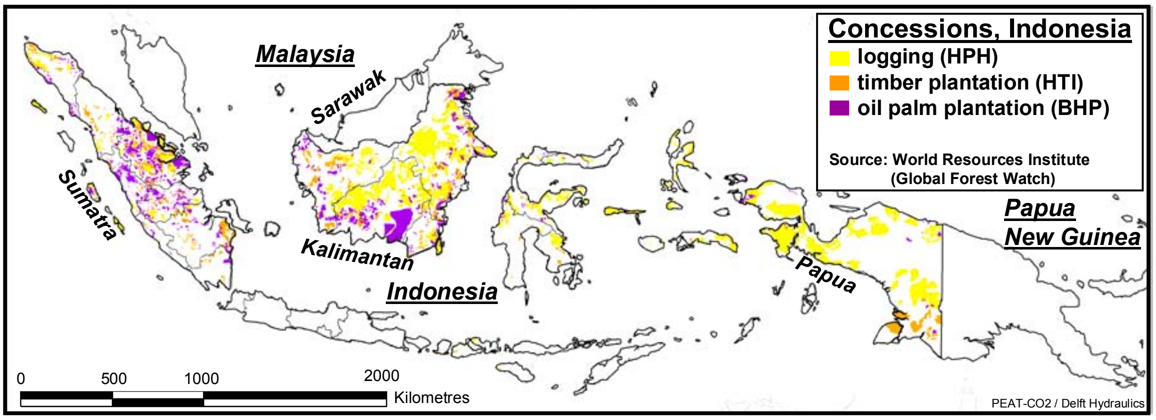


Figure 9 Concessions in Indonesia (Source: World Resources Institute / Global Forest Watch).

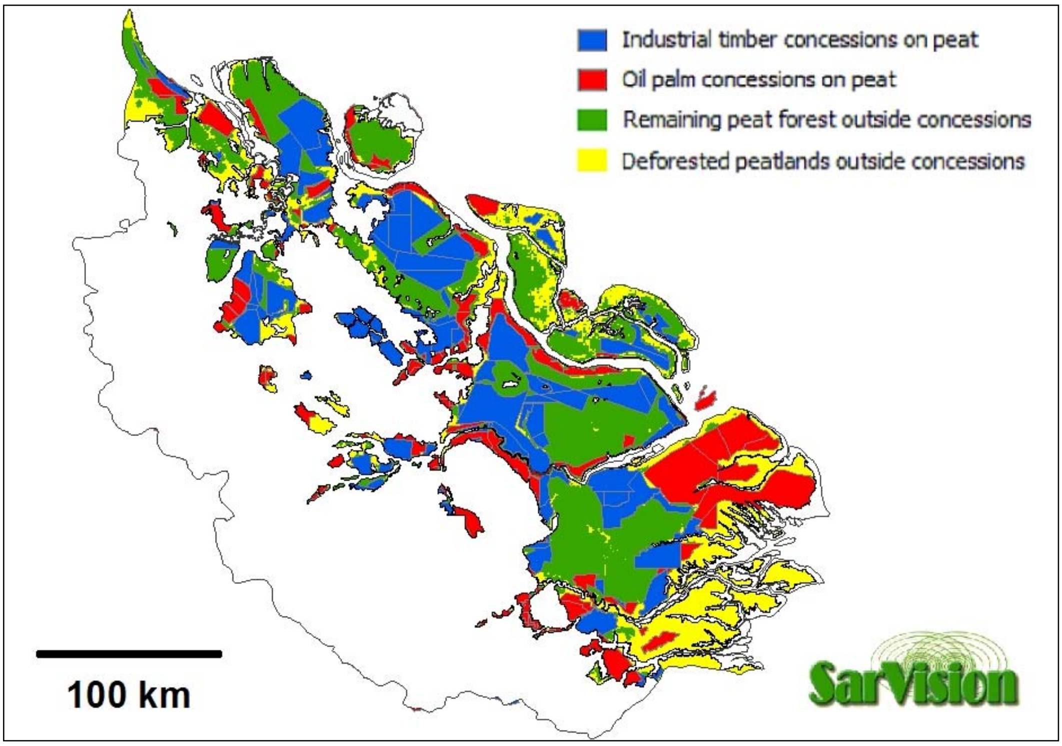


Figure 10 Plantation concessions (i.e. planned and existing plantations) on peatlands in the Province of Riau (Sumatra). Based on concession data provided by the Riau Plantation Service (2004). According to these data, 37.7% (801,555 ha) of existing plus planned oil palm plantations in Riau are located on peat lands. Logging concessions (HPHs) are not shown but cover much of the area marked as 'remaining forest outside concessions). It should be noted that the data provided by the Riau Plantation Service are approximate.

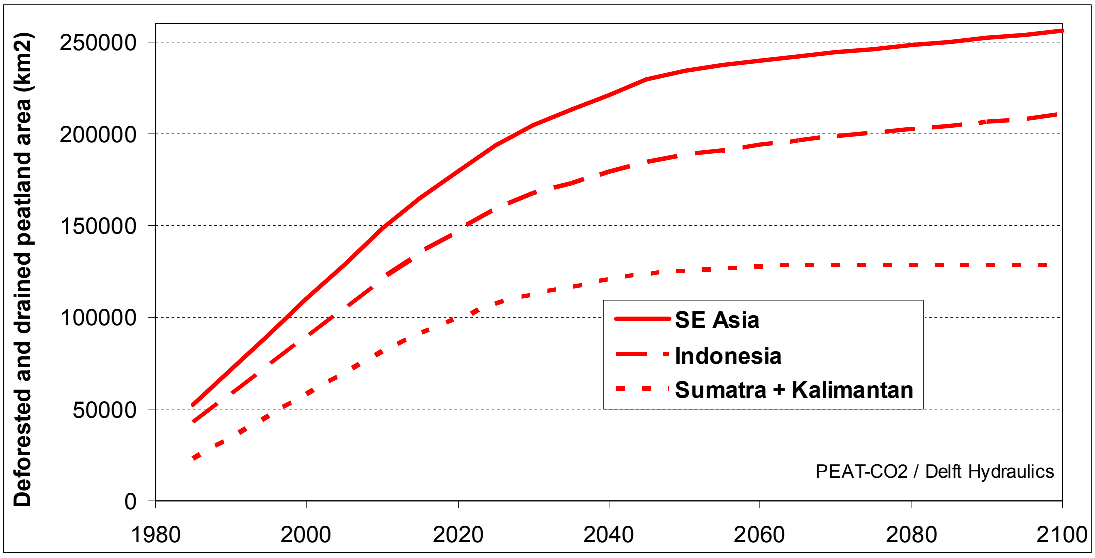
3.2.4 Result: land use projections for SE Asian peatlands

Projections of deforestation rate were developed by simply continuing the rate of forest loss between 1985 and 2000 into the future, until all peatland is fully deforested, per Province (Indonesia) or country. The numbers were then added up to derive overall deforestation projections for larger geographic units, as shown in Figure 11.

Predicting future land use developments by projecting past trends is a crude simplification of actual developments of course, but it can be argued in this case that it is realistic, even conservative in some respects, to assume current rates of deforestation and drainage to continue:

- Deforestation rates have continued at a constant rate (on average) for 20 years, as indicated by comparison between deforestation rates over 1985-2000 and over 2000-2005.
- The rate of deforestation in peatlands was shown to be almost twice that in non-peatlands. With non-peatland lowland areas being largely deforested in most of Indonesia, the remaining forested peatlands and mountain ranges are increasingly important sources of timber. Of these, peatlands are the more attractive as they are more easily accessible and are seen to allow agricultural development.
- No policy has been implemented to specifically conserve and protect peatlands forests. The Indonesian Presidential Decree No. 32/1990, stipulates that peat areas deeper than 3 meters should not be developed, but this decree has generally not been enforced. Moreover, this policy warrants review as it would allow reclamation and drainage of the outer zone of a peat dome with a depth of less than 3 meters. This would lead to subsidence of the deeper parts of the dome, a process that could continue until the entire dome would be lower than 3 meters and thus “eligible” for reclamation (Silvius & Suryadiputra, 2005).
- The area of gazetted conservation reserves in peatlands is unclear but is estimated at less than 10 or even 5% of the total peatland area. Moreover, all peatland conservation areas in western Indonesia are being subject to degradation from logging, drainage and fires (e.g. Berbak and Sembilang National Parks in Sumatra, Tanjung Putting and Sebangau National Parks in Central Kalimantan). Almost all remaining peat swamp forests in Malaysia have been subject to degradation from logging and often also drainage.

As noted earlier (Section 3.2.2), the current baseline and projection method limit the area of large intensively drained croplands (including plantations) to 21% of the peatland area after deforestation is completed. We also found that the concession area of timber and oil palm plantations alone covers 23% of peatlands in Indonesia, and that additional plantations outside these concessions exist and more are planned. The projected cropland area should thus be considered conservative.



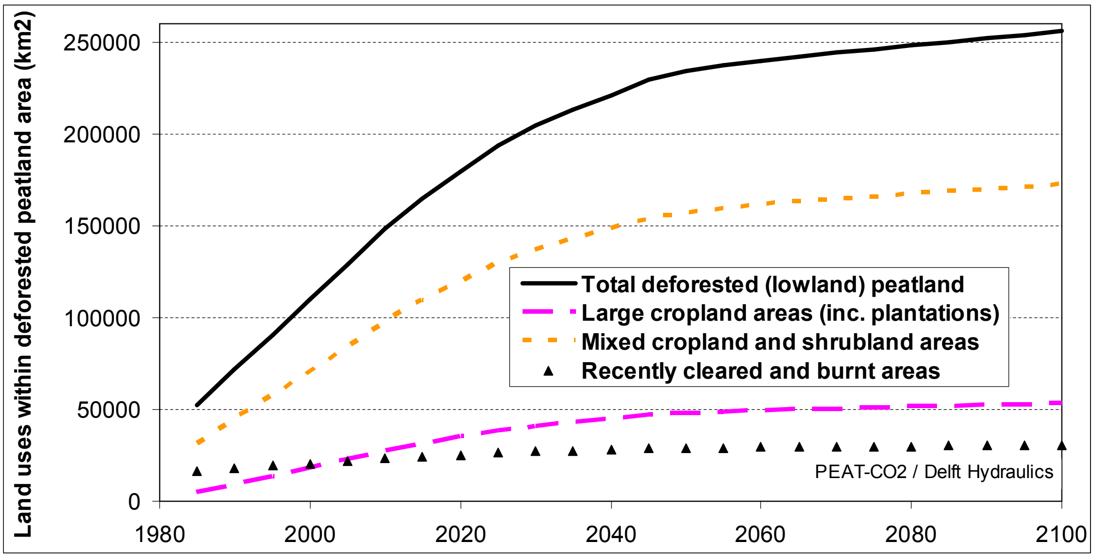


Figure 11 Current trends and future projections of deforestation in lowland peatlands in SE Asia.

Land use classes are derived from the GLC 2000 classification, see Table 1.

3.3 Current and projected CO_2 emissions from oxidation in drained peatlands

Emissions from drained peatlands were determined in the following steps:

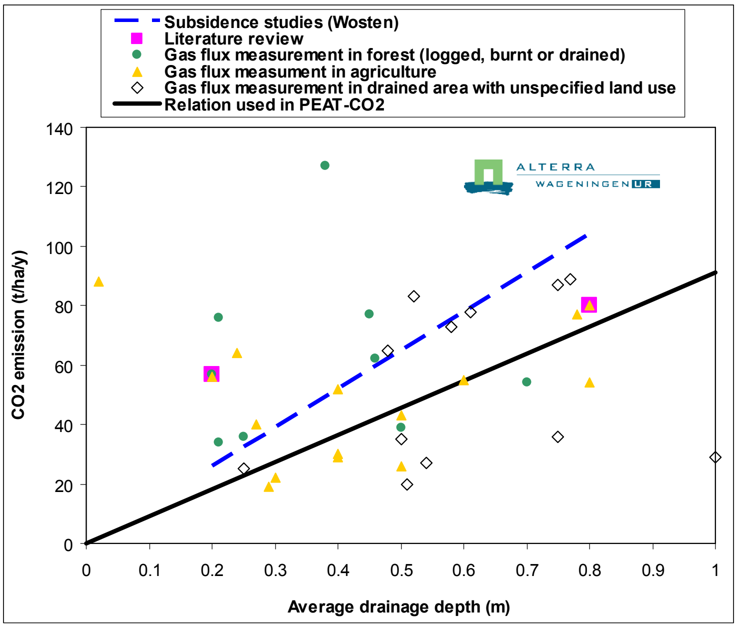
1. Drained areas within land use classes, and drainage depths, were estimated in consultation with peatland experts (Table 5). Estimates of minimum and maximum values were averaged to determine a 'likely' value. Estimates are considered conservative: e.g. average drainage depths well over 1 metres (up to 3 metres in some cases) are reported for many oil palm and pulp wood (acacia) plantations as well as degraded non-used areas (e.g. the Ex-Mega Rice area in Central Kalimantan) whilst a likely value of 0.95m was used. Some observers report that nearly 100% of the area within the 'mixed cropland / shrubland' and 'shrubland' land use classes should be considered drained whilst values of 88% and 50% were applied.
2. Drainage depths were linked to CO_2 emissions (in tonnes/ha/year) using a relation provided by Henk Wösten (Alterra), shown in Figure 12. This relation was derived primarily from the most reliable source of information: long term monitoring of peat subsidence in drained peatlands, combined with peat carbon content and bulk density analysis to filter the contribution of compaction from the total subsidence rate - the remainder is attributed to CO_2 emission (Wösten et al, 1997; Wösten and Ritzema, 2001). This assessment method is accurate but yields only few measurement points; for lack of a large enough population of observations a linear relation between drainage depth and CO_2 emission was fitted through the data whereas the actual relation is known to be non-linear. In the drainage depth range most common in SE Asian peatlands, between 0.5 and 1 metre, the relation is supported by results from numerous gas emission monitoring studies in peatlands (Figure 12, Table 6).
3. The resulting typical emissions for land use classes were applied to that the total area of each class in each Province/State/Country, for the drained area assumed (Table 5).

Total emissions per Province/State/Country were calculated for past, current and projected land uses, as shown in Figure 13. Emissions in 2005 were calculated to be between 355 and 874 Mt/y, with a likely value of 632 Mt/y. Applying the land use projections proposed earlier (Section 3.2.4), emissions increase every year for the first decades after 2000. However, as shallow peat deposits become depleted, and the drained peatland area therefore diminishes, emissions are predicted to peak sometime between 2015 and 2035, between 557 and 981 Mt/y (likely value 823 Mt/y), and are predicted to then steadily decline. As the deeper peat deposits will take much longer to be depleted, significant CO_2 emission would continue beyond 2100.

It should be noted that 'forest' is considered non-drained for the purpose of this assessment, while it is known that many remaining forests are affected by drainage: by neighbouring plantations and agricultural areas, by roads, by canals constructed for transport of illegal logs, and by forest fires that create depressions that act as drains within the peatland hydrological system. Those forests are likely to have become net sources of carbon emissions to the atmosphere, instead of the carbon sinks and stores they are in their natural state. This is another reason to consider the calculated CO_2 emission from peatlands conservative. A further reason is that above-ground biomass losses during deforestation are not included in the analysis.

Table 5 Parameters used in CO_2 emission calculations.

			minimum	likely	maximum
Step A: Drained area (within land use class)	Large croplands, including plantations	%	100	100	100
	Mixed cropland / shrubland: small-scale agriculture	%	75	88	100
	Shrubland; recently cleared & burnt areas	%	25	50	75
Step B: Drainage depth (within land use class)	Large croplands, including plantations	m	0.80	0.95	1.10
	Mixed cropland / shrubland; small-scale agriculture	m	0.40	0.60	0.80
	Shrubland; recently cleared & burnt areas	m	0.25	0.33	0.40
Step C: A relation of 0.91 t/ha/y CO_2 emission per cm drainage depth in peatland was used in calculations.					
Step D: CO2 emissions (calculated from A, B, C)	Large croplands, including plantations	t/ha/y	73	86	100
	Mixed cropland / shrubland: small-scale agriculture	t/ha/y	27	48	73
	Shrubland; recently cleared & burnt areas	t/ha/y	6	15	27



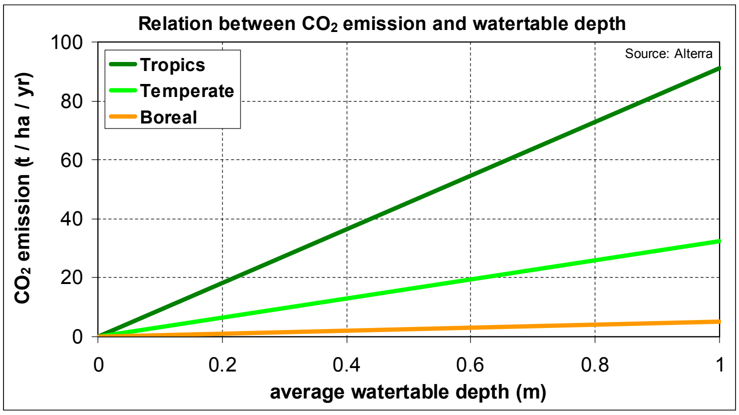


Figure 12 Relation between drainage depth and CO_2 emission from decomposition (fires excluded) in tropical peatlands, as used in PEAT-CO2. Note that the average water table depth in a natural peatland is near the soil surface (by definition, as vegetation matter only accumulates to form peat under waterlogged conditions).
Top: The relation for tropical areas, including SE Asia, is based both on long-term subsidence studies and shorter-term gas flux emission studies applying the 'closed chamber method' (see Table 6). Results of different methods were combined to derive a linear relation. This relation needs to be further developed, as it should be non-linear: in reality CO_2 emissions are known to be limited with drainage depths up to 0.2m-0.3m. Also, CO_2 emissions for a given drainage depth will change over time. However, use of a constant and linear relation is deemed acceptable for long-term assessments and for drainage depths between 0.25m and 1.1m as applied in this study.
Bottom: Tropical drained peatlands have far higher CO_2 emissions than temperate and boreal drained peatlands at the same drainage depth, because of higher decomposition rates in permanently hot and humid climates. Moreover, peatlands in SE Asia are generally drained to much greater depths than is common in temperate and boreal peatlands.

Table 6 Literature review of CO_2 emissions related to drainage depth for different land use types.

Provided by Dr Henk Wösten of Alterra.

Author	Measurement method	Country / region	land use	drainage depth	drainage duration	CO_2-em. (tonnes /ha/year)
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Logged forest	25	variable	36
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Recently burned and cleared forest	46	variable	62
Ali et al. 2006	gas flux measurement with closed chamber method	Jambi, Indonesia	Settled agriculture	78	variable	77
Armentano and Menges 1986	from literature: Tate (1980); Stephens & Stewart (1976); Rigg & Gessel (1956); Broadbent (1960)	Florida, Pacific coast	Pasture/Forestry	20		57
Armentano and Menges 1986	from literature: Tate (1980); Stephens & Stewart (1976); Rigg & Gessel (1956); Broadbent (1960)	Florida, Pacific coast	Crops	80		80
Barchia and Sabiham 2002	gas flux measurement with closed chamber method	Central Kalimantan	Rice fields at 3 locations	10		4
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	drained forest	18 cm	constant	86
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	cassava field	24 cm	constant	64
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	upland paddy field	13 cm	constant	73
Furukawa et al. 2005	gas flux measurement with closed chamber method	Jambi, Indonesia	lowland paddy field	5 above ground surface		10
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	0	constant	45
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Paddy field	2	constant	88
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	38		127
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Paddy field	0		51
Hadi et al. 2001	gas flux measurement with closed chamber method	South Kalimantan	Rice-soybean rotation field	18		74
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Abandoned upland crops field	0		36
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Abandoned paddy fields	20		56
Inubushi et al. 2003 + Inubushi et al. 2005	gas flux measurement with closed chamber method	South Kalimantan	Secondary forest	18		44
Jauhiainen et al. 2005	gas flux measurement with closed chamber method	Sebangau river catchment, Kalimantan, Indonesia	peat swamp forest	Ave -17 cm, Max. 24 cm, Min. -75 cm, Median -10 cm	variable	35
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Sebangau river catchment, Kalimantan, Indonesia	selectively logged forest (near tree)	Ave -21 cm, Max. 10 cm, Min. -67 cm, Median -15 cm	variable	76
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	cleared burned area (high surface)	-19	variable	23
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	cleared burned area (depression)	Ave 1 cm, Max. 46 cm, Min. -49 cm, Median -6 cm	variable	28
Jauhiainen et al. 2004	gas flux measurement with closed chamber method	Kalimantan, Indonesia	Clear felled but recovering forest	Ave -21 cm, Max. 10 cm, Min. -67 cm, Median -15 cm	variable	34

Author	Measurement method	Country / region	land use	drainage depth	drainage duration	CO_2-em. (tonnes /ha/year)
Jauhiainen et al. 2004	gas flux measurement with closed chamber me.	Kalimantan, Indonesia	farm field	Ave -29 cm, Min. -72 cm, Max. – 5 cm, Median -24 cm	Median -24 cm	19
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan,	Drained peat and Hollow	0		17
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Drained peat	50		26
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Hummock	50		43
Jauhiainen et al. 2001	gas flux measurement with closed chamber me.	Central Kalimantan	Hollow	40		52
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		25		25
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		50		35
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		75		36
Jauhiainen 2006	gas flux measurement with closed chamber me.	Central Kalimantan		100		29
Melling et al. 2005	gas flux measurement with closed chamber m.	Sarawak, Malaysia	forest	45 cm	variable	77
Melling et al. 2005	gas flux measurement with closed chamber method	Sarawak, Malaysia	oil palm	60 cm	variable	55
Melling et al. 2005	gas flux measurement with closed chamber method	Sarawak, Malaysia	sago	27 cm	variable	40
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	forest	50		39
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	oil palm plantation	80		54
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Western Johore, Malaysia	pineapple field	40		30
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Central Selangor, Malaysia	maize field	40		29
Murayama and Bakar 1996 a+b	gas flux measurement with closed chamber method	Central Selangor, Malaysia	fallow peat	30		22
Vijarnsorn et al. and Ueda et al.	gas flux measurement with closed chamber method	Thailand	forest	70		54
Wösten et al. 1997 and Wösten and Ritzema 2001	Measurements of subsidence and soil characteristics	Western Johore and Sarawak	agriculture	An average water level drawdown (by drainage) of 10 cm results in 1cm/year of subsidence and yields 13t/y of CO_2 emission.		

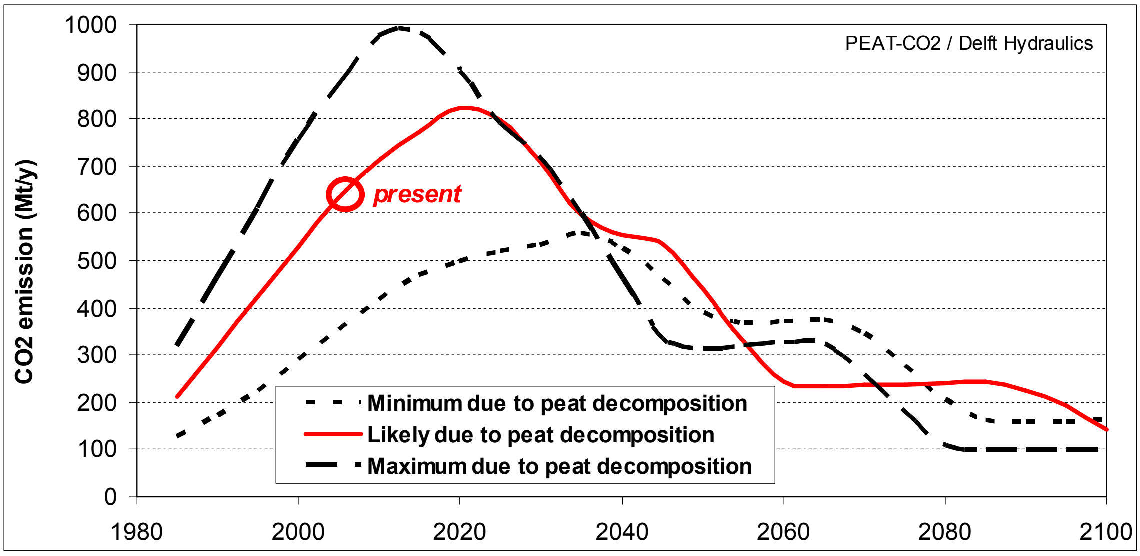


Figure 13 Historical, current and projected CO_2 emissions from peatlands, as a result of drainage (fires excluded). The increase in emissions is caused by progressive deforestation and drainage of peatlands. The decrease after 2020 ('likely' scenario) is caused by shallower peat deposits being depleted, which represent the largest peat extent (see Figure 3). The stepwise pattern of this decrease is explained by the discrete peat thickness data available (0.25m, 0.75m, 1.5m, 3m, 6m, 10m).

Note that peat extent and -thickness data for 1990 (Sumatra) and 2000 (Kalimantan) have been assumed at the starting year of the analysis, in 1985. Considering the uncertainty margin around these data, and the likely systematic underestimation of peat thicknesses, this does not introduce a large additional error in the analysis.

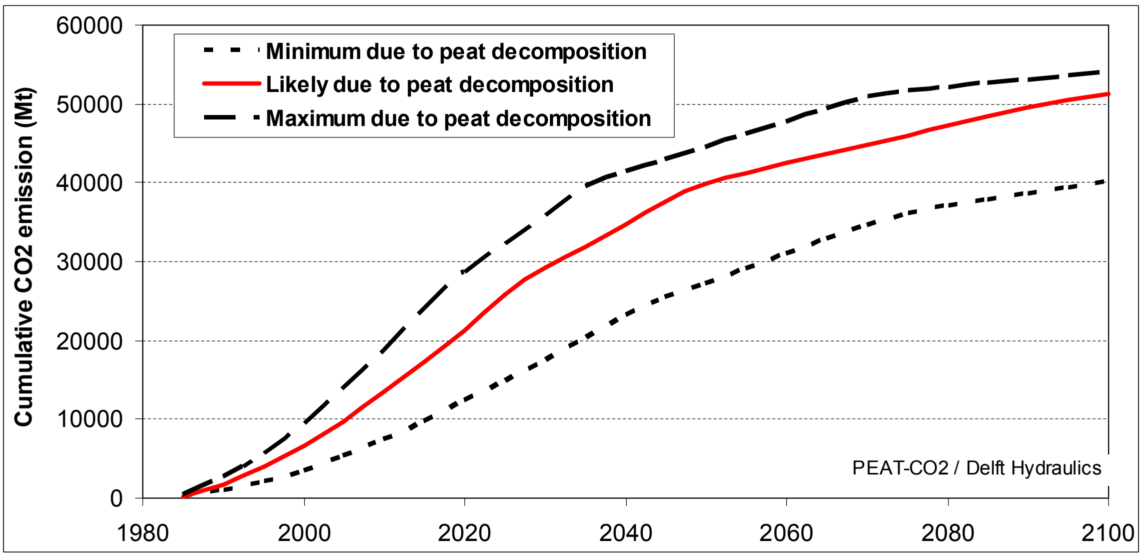


Figure 14 Cumulative CO_2 emissions from SE Asia. Note that total storage is at least 155,000 Mt CO_2 (42,000 Mt carbon). This means that A) CO_2 emission through drainage alone can continue for centuries, and B) even if fire emissions are included in the projections, i.e. not stopped in the near future, the resulting higher emissions will continue for many centuries.

3.4 CO_2 emissions from peatland fires

The PEAT-CO2 research focuses on the little known issue of emissions caused by peat decomposition in drained peatlands, not on the better-known issue of emissions caused by peat fires. However, a rapid assessment of emissions due to fire is included in this report for two reasons:

1. Fires, like decomposition, are the direct result of peatland deforestation and drainage (Figure 17). In common with CO_2 emissions from decomposition emissions caused by fires, which combust both above-ground vegetation and the surface peat, provide a powerful argument for conservation and rehabilitation (in remaining forest areas) and management improvements (in plantations and agricultural areas).
2. Studies are underway which will allow calculation of fire risk- and frequency as a function of water depth and land management, similar to the way we now calculate decomposition emissions. Inclusion of fire emissions is likely to be part of further refinements of the PEAT-CO2 calculations in 2007.

The assessment presented here is based on two main information elements:

1. A study of CO_2 emissions due to peat fires in Indonesia in 1997 (Page et al, NATURE, 2002) puts this figure between 810 and 2470 Million tonnes carbon loss (i.e. 3000 to 9000 Mt CO_2 emission) for that single event, or 15 to 40% of fossil fuel emissions in that year. This number is supported, amongst others, by the fact that 1997 has had the largest annual jump in global atmospheric CO_2 on record.
2. An annual fire hotspot count over 1997-2006 (Figure 15) for Borneo, using satellite data. This data is yet to be published and was kindly provided by Dr Florian Siegert of Remote Sensing Solutions. The data show that over 60,000 fires were counted in three out of 10 years: 1997, 1998 and 2002. The 2006 data in Figure 15 are incomplete (they include fire counts up until mid-October whilst fires continued for a further month) and are likely to be near those of the other major fire years. Publications by Siegert et al (NATURE, 2001) and Page et al (NATURE, 2002) confirm that the 1997 fires occurred mainly in degraded areas (peatland and non-peatland), associated with logging and development projects.

It should be noted that while there were major fire years in 1997, 1998, 2002 and 2006, when millions of hectares were burnt and regional haze problems became a political issue between Indonesia, Malaysia and Singapore, large peat areas are burnt every year and haze problems in areas of Sumatra and Kalimantan are now considered normal in the dry season.

The rapid assessment approach was to relate the 1997 hotspot count for Kalimantan (which is 90% of the Borneo count, Siegert pers. comm.) to the emission range provided by Page et al (NATURE, 2002), and then to apply it to other years proportional to the hotspot count. This results in the annual minimum and maximum emissions shown in Figure 16. These numbers result in a minimum average CO_2 emission (over 1997-2006) of 1418 Mt/y, and a maximum of 4324 Mt/y.

The rapid assessment method applied yields tentative results, and publications on more thorough analyses of CO_2 emissions from peatland fires in SE Asia are expected in the near future. For one thing, the annual hotspot count applies to both peatlands and non-peatlands. While the 1997 hotspot count is almost equal to that of 1998, fires in the latter year are known to have affected peatlands to a lesser extent than in the first year. Another point is that single fires in dry years affect greater areas, and burn away deeper layers of peat, than fires in wet years which are unlikely to affect peatlands to the same extent. This implies the hotspot count in peatlands is not fully proportional to CO_2 emissions from peatlands; a doubling of the number of fires more than doubles CO_2 emissions. Yet another point is that emissions from fires outside of Indonesia are not included, while Malaysia and Papua New Guinea are known to have peatland fires as well.

The net effect of these limitations of the rapid assessment method will be an overestimation of CO_2 emissions. We therefore consider the lower number more realistic than the higher number. We accept an annual CO_2 emission from peatlands fires in Indonesia of 1400 Mt/y as a tentative estimate; the emission from peatlands in other SE Asian countries is unknown.

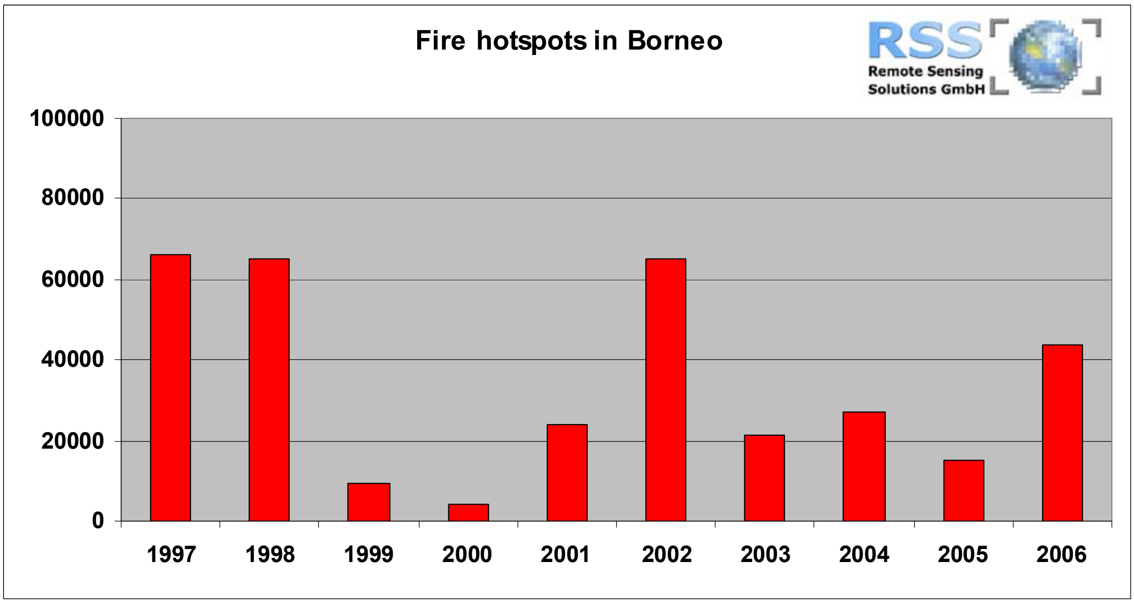


Figure 15 Fire hotspot data (number of fires counted, per year) for Borneo as detected by satellites(NOAA, ATSR and MODIS) from 1997 to 2006. These tentative data are yet to be published but were provided by Dr Florian Siegert (Remote sensing Solutions GmbH, Germany) to allow this study to derive a tentative estimate of annual CO_2 emissions from fires.

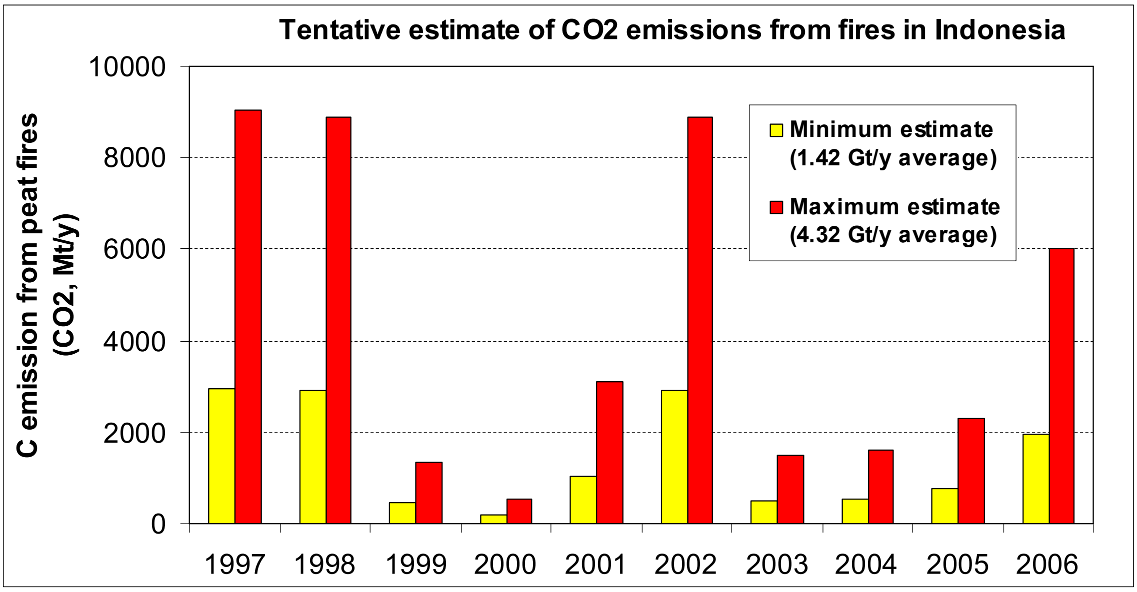


Figure 16 Tentative estimate of annual and average annual carbon emissions due to peatland fires, determined on the basis of hotspot counts for Borneo (see figure above) and the carbon emissions calculated by Page et al for 1997 (NATURE, 2002). Better estimates are being prepared for publication by Page, Siegert and others.

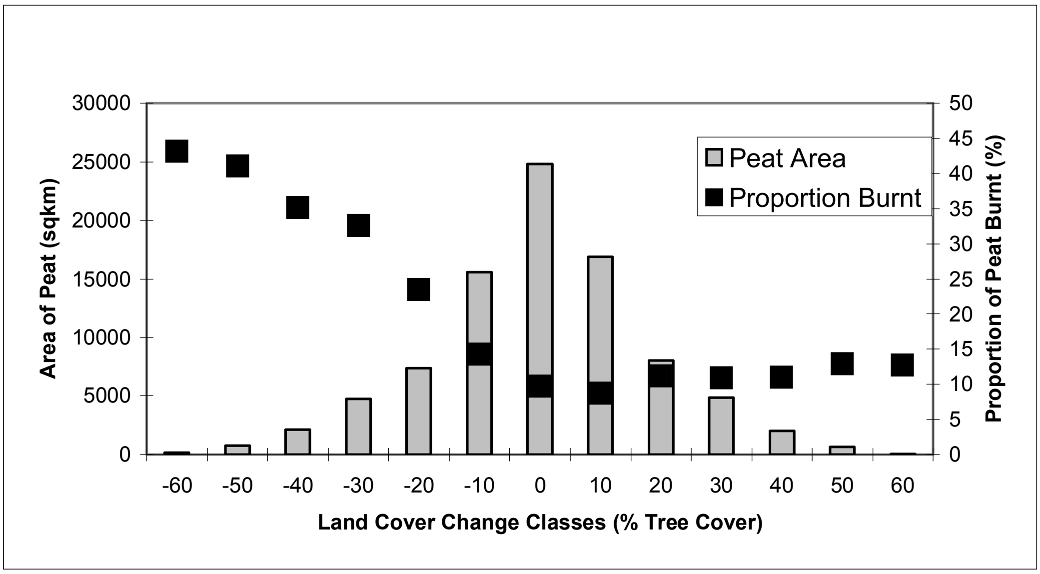


Figure 17 Relationship between Land Cover Change, Total Peat Area and Proportion of Peat Area Burnt for Kalimantan, 1997 to 2003.

This graph was provided by Allan Spessa, Ulrich Weber (Max Planck Institute for Biogeochemistry, Jena, Germany) and Florian Siegert (Remote Sensing Solutions GmbH), and is based on research that will be published separately in the near future. The graph clearly illustrates the close link between deforestation, land management and elevated peat burning. The proportion of peat burnt between 1997-2003 was several orders of magnitude higher in areas experiencing deforestation, that is, negative land cover change, than in other areas. In peatlands experiencing a net loss in land cover between 1997 and 2003, there is a very strong positive correlation between the magnitude of area burnt and the magnitude of land cover change ($R^2 = 0.96$, $N = 7$ classes including the no-change class).

4 Discussion of uncertainties

The current report is the result of an assessment using the latest available data. The subject matter is complex and not well-studied, as the importance of CO_2 emissions from SE Asian peatlands and the role of water management is only now starting to be widely recognized. Therefore, there are several uncertainties in the assessment.

The uncertainties will be discussed here briefly to A) indicate the level of confidence we have in specific results and B) identify areas where better data would allow reduced uncertainty, i.e. identify targets for follow-up research. The discussion shows that we have aimed to use conservative numbers and assumptions at every step of the analysis. As a result, we consider the chance CO_2 emissions are underestimated to be greater than the chance they are overestimated.

4.1 Uncertainty sources

4.1.1 Input data

Peat thickness. There are three main sources of uncertainty:

1. The thickness of the more remote and less well-mapped peatlands in Indonesia is not very well known. As peat thicknesses tend to be greatest in the central parts of these highly inaccessible and often vast (tens of kilometres across) peatlands, this is likely to result in an underestimation of peat thickness and therefore in an underestimate of long-term CO_2 emission.
2. Data on the thickness of peatlands in Malaysia and Papua New Guinea were not available at the time of this study. Conservative assumptions were made, which will likely result in an underestimate of long-term CO_2 emission.
3. Data on recent loss of peat in areas with limited peat thickness. Peat thickness data used are based on field surveys between 1990 and 2002. These data were then used as the starting point of the CO2 emission simulation, in 1985. As some areas were already drained during the field surveys, and therefore reduced in thickness, the peat thickness in 1985 is underestimated for these areas. This means that the simulated rate of depletion of shallow peat deposits is greater than the actual rate, i.e. simulated CO_2 emissions peak earlier and decline slightly faster than actual emissions.

It is concluded that the uncertainties in peat thickness all lead to an underestimate of CO_2 emissions, in the longer (1, 2) or shorter (3) term. The impact on long-term emission simulations is probably greater than on the short-term emission simulations.

Extent and distribution of peat lands. The data on peat extent available to the project can be improved especially for areas outside of Kalimantan and Sumatra, where FAO data from the Digital Soil Map of the World were used. However, comparison of these data for Kalimantan and Sumatra with the more recent and detailed Wetlands International data showed greater differences in distribution than in total extent.

Carbon content of SE Asian peat. Carbon content depends on A) bulk density of the peat material (i.e. percentage solid matter vs water) and B) carbon content of the solid matter, which both vary with source material and degree of decomposition. Carbon contents between 90 kgC/m^3 and 45 kgC/m^3 have been published for various peat deposits in SE Asia. The relation between subsidence rate and CO_2 emission applied in this assessment (Wösten and Ritzema, 2002) assumes a carbon content of 60 kg/m^3 which is fairly conservative and does not introduce a great uncertainty to the result.

Carbon store. The carbon store in SE Asian peatlands is not input data but a function of A) peat thickness, B) peatland extent and C) peat carbon content. As described above, peat thickness is considered to have the greatest uncertainty and is likely to be underestimated. This means the total carbon store may also be underestimated. This will have an impact especially on the CO_2 emission projections in the long term, less in the short term.

Land use / land cover. The GLC 2000 global land cover classification was used to determine land use for SE Asia in the year 2000. The decision rule that 'mosaic cropland + shrubland' on peatland is always accompanied by drainage introduces some uncertainty especially in the case of Papua (in Indonesia). Here, areas are classified as 'mosaic cropland + shrubland' that are known to be a savannah-like landscape created by traditional land management techniques requiring regular burning of the Melaleuca and herbaceous peat swamp vegetation (Silvius & Taufik, 1990). These areas are generally non-drained, agriculture often takes place on elevated islands of dug up mud (from the submerged swamp soil), which probably causes less peat oxidation. It is therefore likely that the emissions (per unit area) from these areas are relatively minor compared to the emissions in Sumatra and Kalimantan. This may have lead to an overestimate of CO_2 emissions from SE Asian peatlands, with a maximum of 16% in the unlikely case that emissions from Papua would actually be negligible.

Percentage of peatland drained. Drainage intensity was estimated as a function of land use / land cover (Table 5), in consultation with the experts involved in the study. The estimate is considered conservative but does introduce some uncertainty. Additional uncertainty is introduced by the fact that an unknown but probably significant drained peatland area is not included in the analysis: forested areas affected by legal and illegal logging (canals are often used in log transport), plantation drainage (which may bring down peatland water levels over several kilometres in the longer term) and fires (which create depressions in the peat surface). In the early 1990s already, over 90% of peat swamp forests in Sumatra were affected by human interventions such as forestry, agriculture and related drainage (Silvius & Giesen, 1992); the present extent and degree of these impacts in remaining forests in SE Asia is very significant but not well-documented. The overall effect of this uncertainty is probably an underestimate of the overall drained peatland area.

Drainage depth. Drainage depth was estimated in consultation with the experts involved in the study. Estimates are considered conservative especially for heavily drained areas (plantations and abandoned plantations like the ex-Mega Rice Project), where drainage depths well over 1 metres are often observed while a 'likely' drainage depth of 0.95m was assumed in the assessment (Table 5). Similarly, a drainage depth approaching 1 metre may be more realistic in many small-scale agricultural areas than the depth of 0.6m used as 'likely' value in the analysis. The overall effect of uncertainties is therefore probably an underestimate of the overall drainage depth.

Percentage of oil palm plantations on peat lands. For precise assessment of the CO_2 emissions caused by palm oil production on peatlands alone, accurate data on the present extent of oil palm plantations on peatlands are needed that are now lacking. Currently our estimate is that some 25% of palm oil plantations is on peatlands, following from the fact that 27% of oil palm plantation concessions (i.e. existing and planned plantations) are on peatlands. This uncertainty does not affect the assessment of CO_2 emissions from peatlands, but does affect our knowledge of how much of this emission is caused by palm oil production.

4.1.2 Emission relations

Relation between drainage depth and CO_2 emissions. There is significant uncertainty in the CO_2 emission resulting from a specific drainage depth. Few long-term studies of subsidence rates in drained peatlands in SE Asia have been published. Short-term studies of CO_2 emissions are difficult to interpret because A) CO_2 emissions from root respiration must be separated from emissions caused by decomposition, B) short-term effects (shortly after drainage) must be separated from long-term effects, and C) water table and soil moisture regime are often insufficiently monitored. Because of this potential uncertainty, a thorough literature review was compiled (see Table 6). The relation used in the assessment, derived on the basis of this review, is considered conservative.

CH_4 emission. The only form of carbon emission to the atmosphere considered in this assessment is CO_2 (carbon dioxide) emission. CH_4 (methane) emissions from drained peatlands are considered by most experts to be limited in comparison, but may still be significant because CH_4 is a far stronger greenhouse gas (23 times stronger in 'carbon dioxide equivalents'). CH_4 emissions in peatlands may originate especially where peat areas are flooded for prolonged periods after fires or after subsidence due to drainage, and reduced conditions are created in the peat soil. The uncertainty in this emission, is considered low, as research so far indicates that CH_4 emissions from tropical peatlands are negligible (Jauhiainen et al, 2005), so it has been excluded from the assessment. This may result in an underestimate of the total emission of greenhouse gases (in carbon dioxide equivalents) from drained and burnt peatlands.

Peat fires
The CO_2 emission due to peatland fires is highly uncertain. Separate publications on this issue are expected in the near future. Ideally, fire risk is quantified as a function of land use (drainage depth and land management), so future CO_2 emissions caused by fires can be simulated as was done for CO_2 emissions caused by oxidation. Until that is possible, emissions caused by fires remain the relatively largest uncertainty in emission projections. As explained in the text, the current assumption of 1400 Mt/y of CO_2 emissions from fires is at the lower end of the estimated range (1400 to 4300 Mt/y). The likelihood of this number being an underestimate is therefore considered greater than of it being an overestimate.

4.1.3 Trends and projections

Deforestation trend assessment. The main trend assessment performed was of deforestation between 1985 and 2000, with a verification for 2000-2005. Overall uncertainty in this assessment is fairly limited as well-researched sources were used. There is a greater likelihood that forest area in 2000 is overestimated than underestimated, due to inclusion in the 'forest' area of severely degraded forests and of timber plantations. The rate of deforestation assumed in the assessment is therefore considered conservative.

Drainage trend assessment. Drainage trend was established as a function of derived trends in development of cropland and 'cropland/shrubland mosaics'. These derived trends are highly conservative, e.g. the area of large-scale croplands can not exceed 21% of the peatland area even if all peatland is deforested, while the concession areas for palm oil and timber plantations alone already cover 23% of the peatlands in Indonesia.

Land use projections. As projections are a simple continuation of past trends, there are two uncertainties: those in the past trends and those in continuation of these trends into the future. The uncertainty in the latter is very significant, of course. The projections may turn out to be too pessimistic if SE Asian countries, supported by the international community, decide to drastically improve peatland conservation and management strategies. If such improvements do not materialize however, the projections may be too optimistic as the remaining peatland resources (forests, but also converted peatlands still suitable for agriculture) dwindle while demands (for timber and for agricultural land) increase.

4.2 Assessment of overall uncertainty

From the discussion of uncertainties presented above it is clear that A) there are significant uncertainties in most data and parameters used, and B) the assessment has consistently aimed to be conservative. Therefore, the resulting range in emissions (355 to 874 in 2006, with a most likely value of 632 Mt/y) is also considered conservative. This range accounts for uncertainties in drainage intensity and drainage depth. Uncertainties that are not included are those in peat thickness, carbon content of peat, relation between drainage depth and CO_2 emission, CH_4 emission and trends and projections in land use, especially in drainage. There is no obvious way to quantify the effect of these uncertainties, but it should be noted that most of them are higher to the upside than to the downside, i.e. emissions are more likely to be underestimated than to be overestimated.

An important point to note regarding these uncertainties is that most of them affect annual release of carbon to the atmosphere over the coming 10 to 50 years. Climate scientists are often interested in emissions in the long term (100 years or longer) and the precise annual emission in the short term is less relevant from that perspective. Halving the emission rate through marginal improvements in for instance fire fighting methods, but without fundamental changes in forest conservation and water management practices, would simply mean it takes twice as long to increase the global atmospheric CO_2 emission by the same amount. The implication is that most uncertainties discussed above may not be very important from a climate change perspective: more important is the fact that it can now be proved that most carbon stored in SE Asian peatlands is likely to be released to the atmosphere in the short or long term if current developments and practices are allowed to continue.

4.3 Proposed research activities to reduce uncertainties

A number of actions can be identified that will significantly reduce the uncertainty in the assessment of CO_2 emissions in the short term and the longer term. In 2007, it may be possible to improve the assessment using data that are expected to become available in the coming months:

1. Use of GLOBCOVER data for land use / land cover assessment. These data will apply to 2005 (data for 2000 were used in the current assessment), will have higher resolution (300m vs the 1000m used in the current assessment) and is expected to have higher accuracy.
2. Use of improved data on the present and planned distribution of oil palm and timber plantations and other intensively drained areas in peatlands.
3. Linked to the availability of more detailed and accurate land cover data and plantation data, is the option to develop land use scenarios for individual peatlands, rather than a single projection for all of SE Asia. This will also provide a basis for improved forest conservation and water management plans for these individual areas.
4. Use of improved data on peat extent and peat depth outside of Sumatra and Kalimantan. Such data are now being finalized by Wetlands International for Papua. Similar data are understood to be available in various databases for Malaysia (especially Sarawak) as well.
5. Inclusion of lateral processes in the peatland subsidence and emission calculations. These impacts do not stop at the boundary of a drained area, but affect a progressively larger peripheral zone. The width of that zone depends on drainage depth and peat characteristics (hydraulic conductivity, thickness, slope); it may extend for kilometres in years or decades. Inclusion of lateral processes will yield insight in the area affected by a drainage system.
6. Feedback effects from climate change. It is understood that most climate change models predict that the SE Asian peatland region, notably southern regions in Borneo and Sumatra, will become dryer in the future (Dr Pep Canadell, Director of Global Carbon Project, pers. comm.). This means that the need for improved conservation and water management will be even greater. Climate change projections can be used to quantify this effect.

Parallel to this, but possibly only yielding major uncertainty reductions in 2 years or more, the following activities are proposed:

7. Development of a physically-based relation between drainage depth, subsidence rate and CO_2 emission. This relation will likely be non-linear and may take into account water depth regime instead of average water depth. Separate relations may need to be defined in different land use types, to account for the effects of vegetation cover and land management (mechanized, fertilized etc).
8. Development of a stochastic relation (supported by physical considerations) between fire risk and land and water management practice, allowing prediction of fire frequency under different management strategies.

5 Conclusions and recommendations

The total amount of carbon in peatlands in SE Asia is at least 42,000 Megatonnes (depending on assumptions of peat thickness and carbon content), equalling at least 155,000 Megatonnes in potential CO_2 emissions. Present likely CO_2 emissions (fires excluded) from drained peatlands are calculated to be between 355 and 874 Mt/y, with a most likely value of 632 Mt/y. If current rates and practices of peatland development and degradation continue, this may increase to 823 Mt/y (most likely value) in 10 to 30 years, followed by a steady decline over centuries when increasingly thicker peat deposits become depleted.

Current emissions from Indonesia alone are 516 Mt/y. To put this in perspective, this equals:

- 82% of peatland emissions in SE Asia (fires excluded).
- 58% of global peatland emissions (Figure 18; fires excluded).
- Almost 2 times the emissions from fossil fuel burning in Indonesia.

If emissions from peatland fires (which are also caused by deforestation and drainage) are included, the total CO_2 emission number is significantly higher. Over 1997-2006, CO_2 emissions from peatland fires in Indonesia were several times those due to peat decomposition in drained peatland areas: 1400 Mt/y to possibly as much as 4300 Mt/y. The lower (and more likely) figure, added to current likely emissions from peat decomposition, yields a total CO_2 emission figure for SE Asian peatlands of 2000 Mt/y (over 90% of which are from Indonesia), equivalent to almost 8% of global emissions from fossil fuel burning. This is probably the most concentrated (produced on only 0.2% of the global land area) land-use related CO_2 emission in the world. If emissions from peatland drainage and degradation (including fires) are included, Indonesia takes third place in global CO_2 emissions, behind the USA and China. Without peatland emissions, Indonesia takes 21st place.

Interestingly, the annual CO_2 emission of 2000 Mt/y found for 2005 is supported by an independent study: Wetlands International has estimated an average annual emission of 1480 Mt/y between 1990 and 2002, based on mapping of lost peat areas and measurement of reductions in peat thickness in remaining peatlands. They found an area of 3.7 million hectares of historically mapped peatland to be fully lost by 2002, i.e. all peat was removed and the soil should now be classified as 'mineral' (Wetlands International 2003, 2004).

It should be noted that, while peat fire emissions currently exceed those from slower peat decomposition, this does not mean that the problem can be solved by fire fighting:

- First of all, peatland fires are promoted by deforestation and by forest degradation and peat drying linked to peatland drainage, and can be stopped in the longer term only if these root causes are dealt with.
- Secondly, only stopping the fires but not the drainage merely means it will take a longer time for the carbon resources to be released to the atmosphere. Climate scientists look at total emissions over long time intervals, e.g. 100 years, and may consider the timing of peatland emissions (with or without fires) less relevant.

It is concluded that, while fire fighting and emergency measures may be helpful in the short term, a fundamental change in the management of peatlands in SE Asia, especially Indonesia, is required if the carbon is to remain stored in peatlands. The most effective measure to achieve this is conservation of remaining peatland forests, alongside rehabilitation of degraded peatlands and improved management of plantations and agricultural areas. In all cases – conservation, rehabilitation and plantation management – the natural water table regime should be restored (or approached as much as possible) through improved water management, i.e. through less severe or no drainage.

Current developments give little reason for optimism: while deforestation rates on non-peatlands in SE Asia have decreased somewhat (at least in part due to depletion of forest resources), those in peatlands have been stable (on average) for up to 20 years. Current (2000-2005) average deforestation rate is 1.5%/y; lower values apply in Papua (and probably Papua New Guinea), higher values apply elsewhere. In 2005, 25% of all deforestation in SE Asia was on peatlands. Apart from logging for wood production, an important driver behind peatland deforestation is development of palm oil and timber plantations, which require intensive drainage and cause the highest CO_2 emissions of all possible land uses.

A particular point regarding CO2 emissions from SE Asia peatlands, which requires attention from the international community, is that of the relation between palm oil production and peatland drainage. A large fraction (27%) of palm oil concessions (i.e. existing and planned plantations) in Indonesia is on peatlands; a similar percentage is expected to apply in Malaysia. These plantations are expanding at a rapid rate, driven in part by the increasing demand for palm oil as a biofuel on Western markets. Production of 1 tonne of palm oil causes a CO_2 emission between 10 and 30 tonnes through peat oxidation (assuming production of 3 to 6 tonnes of palm oil per hectare, under fully drained conditions, and excluding fire emissions). The demand for biofuel, aiming to reduce global CO_2 emissions, may thus be causing an increase in global CO_2 emissions.

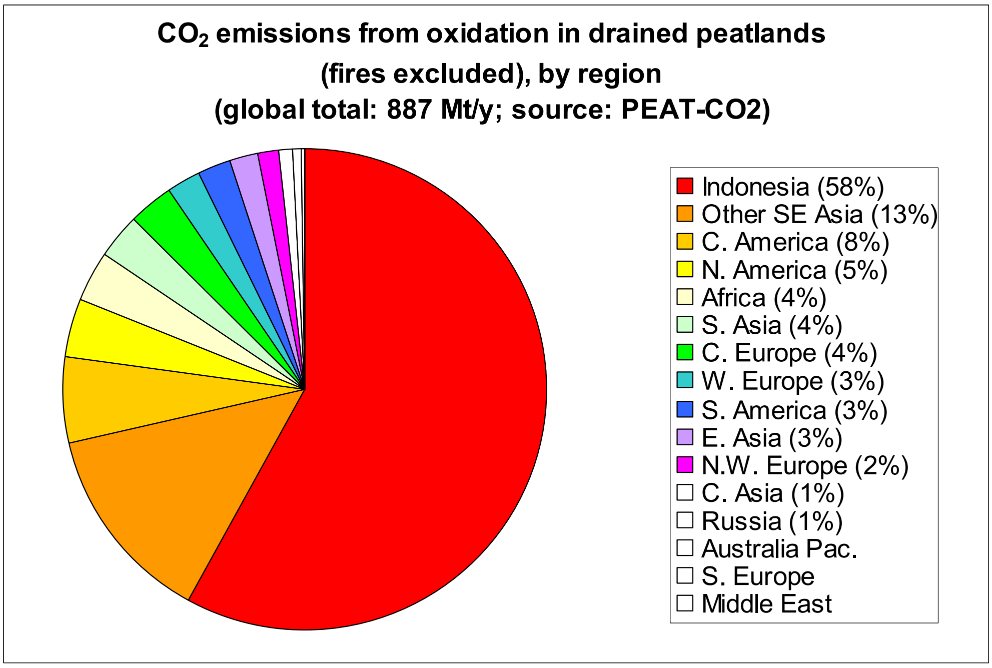


Figure 18 CO_2 emissions from peatlands in Indonesia and the rest of SE Asia as compared to emissions from other peatland regions in the World. This is a tentative calculation for areas outside of SE Asia, using FAO soil data and GLC 2000 land cover data. Note that emissions owing to fire are not included; nor are emissions from peat burning for energy and due to drainage other than for agriculture.

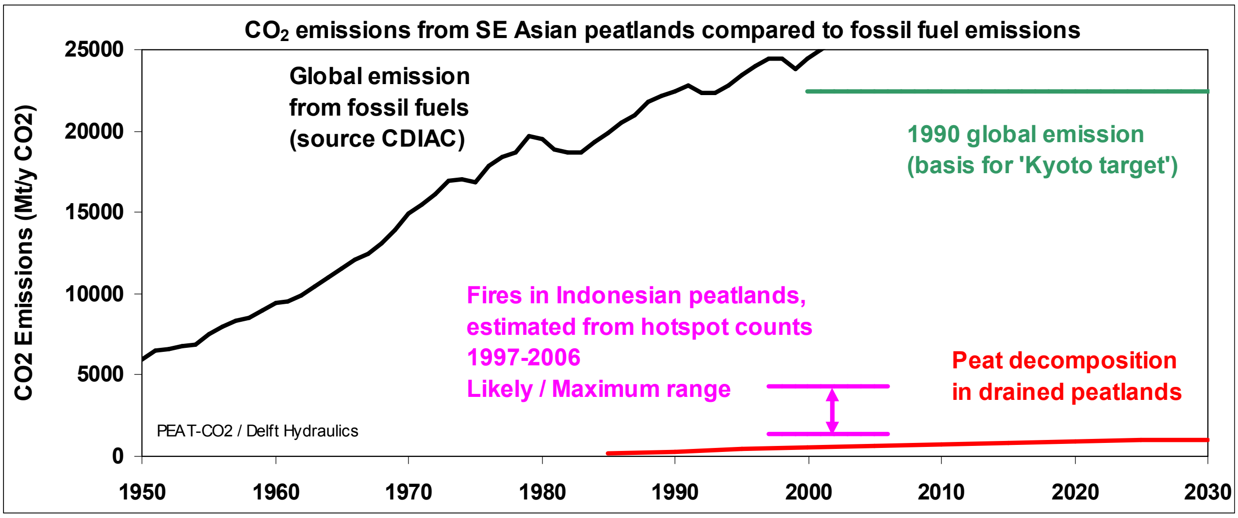


Figure 19 Comparison of emissions from drained and burning peatlands in SE Asia with global emissions from fossil fuel burning.

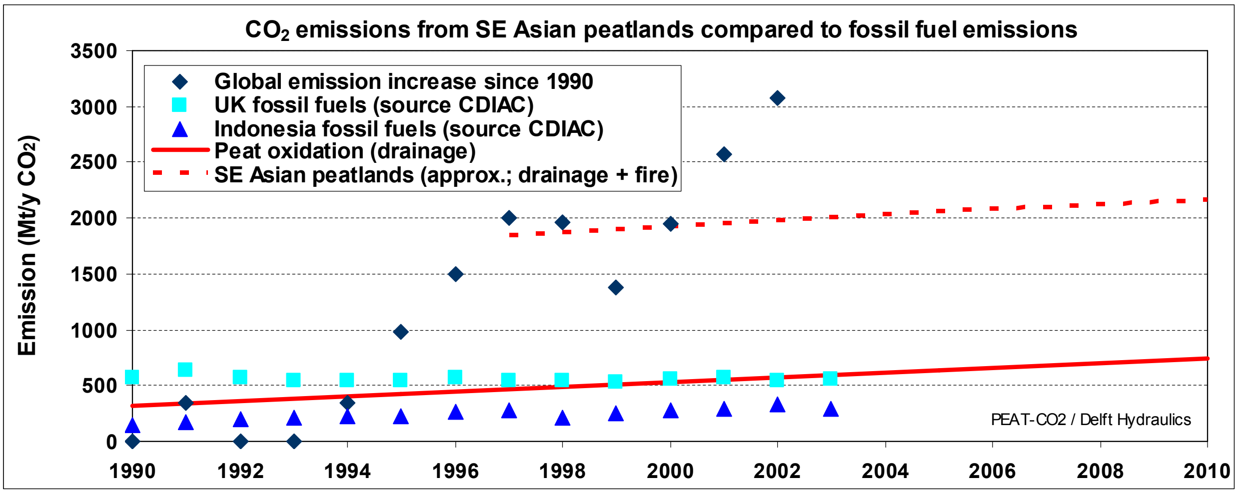


Figure 20 Comparison of emissions from drained and burning peatlands in SE Asia with global emission increases since 1990 (the benchmark year for the Kyoto Protocol) and with national fossil fuel emissions in Indonesia (the source of 90% of peatland emissions) and the UK (as an example of emissions from a large industrialized nation).

5.1 Recommendations for improved peatland carbon conservation

To reduce CO_2 emissions from SE Asian peatlands, a drastic change in land and water conservation and management practices is required. The measures needed to reduce CO_2 emissions would also reduce other negative effects of current peatland management practices:

- Haze problems caused by peat fires, which affect public health and economy (impact on natural resource base, tourism and transport sectors) in the entire region;
- Productivity loss in plantations on deep peat, which often become undrainable within decades because of peat subsidence;
- Loss of natural timber production in the longer term owing to degradation of remaining forests;
- Loss of biodiversity;
- Flooding problems downstream of drained and degraded peatlands;
- Salt water intrusion and development of acid sulphate soils in coastal areas.

Policy

Emissions and other negative effects of unsustainable peatland management can only be reduced if a land development policy based on the following three principles is adopted:

1. Forest **conservation** and drainage avoidance in remaining peat swamp forests.
2. Where possible **restoration** of degraded peatland hydrological systems and peat swamp forests or other sustainable vegetation cover.
3. **Improved water management** in peatland plantations, embedded in water management master plans for peatland areas.

In addition, peatland development planning should be based on the following three approaches:

- **Precautionary approach.** In planning of land-use in peatlands, it is advisable to use the precautionary approach. Large scale developments in peatlands should be pursued only after considerable research and after successful completion of pilot projects.
- **Hydrological system approach**. Land-use planning in peatlands should follow the ecosystem approach, taking special account of the hydrological vulnerability of peat domes and the ecological relationships with the surrounding habitats and land-uses. Particular regard should be given to the place of the area within the water catchments/ water shed, and the potential impacts of and on upstream and down stream habitats and land-uses (including potential land-uses). In peat swamp forests it may be necessary to consider multi-river basin complexes, as multiple watersheds may be dependent on shared peat domes, and impacts on one river basin may affect the shared hydrological basis.
- **Integrated approach**. Wise management of peatland ecosystems requires a change of approach from single sector priorities to integrated planning strategies, involving all stakeholders to ensure that consideration is given to potential impacts on the ecosystem as a whole. Land-use planning in peatlands should involve all relevant sectors and major stakeholder groups, including local people, from the outset of development planning. A precondition for successful integrated planning is the (enhancement of) awareness of the various groups regarding peatland ecology and hydrology, and the full scale of values that peatlands may have:
    a. The use of a peatland for a specific purpose may have considerable side effects and all other functions must be taken into account in the full assessment of the suitability of a particular use.

b. With respect to side effects, a use could be considered permissible when:
   - negative side effects will not occur, or
   - the resources and services affected will remain sufficiently abundant, or
   - the resources and services affected can be readily substituted, or
   - the impact is easily reversible, or
   - an integrated cost benefit analysis involving thorough consideration of all aspects of the proposed use yield a positive advise.

Water management measures

In practice, implementation of a CO_2-reduction policy will require a strategy that includes the following measures:

- **Conservation of peat swamp forest.** In a natural system, peat domes gradually release water into adjoining depressional peat swamps, which slowly release it to streams and rivers. High water tables are thus maintained during the dry season in peat domes, peat swamps and river corridors. The simplest and most effective measure to prevent a further increase in fires and CO_2 emissions is thus by conservation of remaining peats swamp forests and rehabilitation of degraded peatswamp forests.
- **Maintenance of water stores in rehabilitated peat swamps.** The peatland hydrological system is degraded through any drainage, even limited drainage for (illegal or legal) log transport. The result is A) dry peat forest soils and increased fire risk, B) enhanced peak flows in the wet season contributing to downstream flooding, C) reduced low flows in the dry season, causing lower water tables ant enhanced fire risk in downstream areas. For example, it is thought that drainage in the Air Hitam Laut watershed has contributed to extensive fires in the downstream Berbak National Park (Wösten et al, 2006). Restoration of water storage in swamps, through water management measures aiming to elevate water levels over large areas and restoration of the natural peatland hydrological system (which will take many years), would contribute to reduced fire risk and CO_2 emissions both locally and in downstream areas. This measure is best linked to rehabilitation of peat swamp forest vegetation, which requires careful water level control to allow forest regeneration.
- **Implementation of operational water management systems in plantations.** Current water management systems in peatlands are mostly unsuitable for peatland conditions: the main objective now is generally to prevent flooding in the wet season, whereas an equally important target should be to prevent falling water levels and increased subsidence and fire risk in the dry season. Operational water management systems are needed that can be adjusted to meet different targets throughout the year and thus optimize productivity while minimizing fire risk and CO_2 emissions.
- **Water management master planning.** Water levels in peatlands can be optimized, and fire risk and CO_2 emissions minimized, if water management is planned and co-ordinated for entire peat bodies (i.e. entire hydrological units). When using this integrated landscape-based approach the current distinction made between of areas deeper or shallower than 3 meters becomes should be revised. This distinction, first developed in the Indonesian Presidential Decree 32/1990 does not provide guidance for sustainable peatland management. The master planning process requires involvement of all major stakeholder groups: Government, communities, concession holders and NGOs.
- **Land and water management capacity building.** Management requirements in peatlands are very different from those in other areas, and require an understanding of the hydrological system that is usually lacking in present peatland water management in SE Asia. Also, it is sometimes thought that fire fighting is the solution to the recurrent peatland fires; this is true only to a small extent because A) peatland fires are nearly impossible to extinguish once they are established over large areas and B) the root cause of fires is the drying of peat through drainage. Furthermore,

peatland CO_2 emissions are not only caused by fires but also by slow decomposition. Development of water management capacity in peatland areas is crucial for reduction of CO_2 emission from those areas.

Other measures:

- **International Assistance:** A strategy for improved peatland conservation and management would benefit from official recognition of the SE Asian peatlands as globally important carbon stores that require carbon conservation management if CO_2 emissions are not to continue at current levels or even increase. On this basis, alongside the arguments of sustainable development, haze reduction and biodiversity conservation, international funding could be made available for conservation of peatland forest, rehabilitation of degraded areas, and improvement of water management in agricultural/plantation areas. This should involve multi donor cooperation, long-term commitments from the global community, development of social and financial security for local stakeholders, good governance, and development of alternative financial mechanisms enabling rapid capacity building and implementation of conservation, rehabilitation and sustainable development programmes.
- **Poverty reduction.** Many of the problems in SE Asian peatlands impact negatively on the local communities and their development opportunities. Poverty rates in Indonesian peatlands are up to four times higher than in other areas in Indonesia and respiratory and related diseases caused by peat smog are a significant public health issue in the degraded peatland areas. Without alternative sustainable development options local communities will increasingly be forced to over-exploit the remaining natural resources in peatlands, further worsening the problems of deforestation, overdrainage and fires and thereby increasing CO2 emissions. It is therefore crucial that development, rehabilitation and conservation measures in peatlands will have a pro-poor approach. This should incorporate strategies to:
    - develop alternative jobs and income,
    - develop alternative – sustainable - ways of using peatlands for agriculture, fisheries, forestry and plantations that require no drainage,
    - monetarize the international value of peatlands (e.g. carbon and biodiversity values).
- **Monitoring** of land and water management. CO_2 emissions from peatlands should be recognized as a major contribution to greenhouse gas emissions that should be curbed. The international community is likely to require monitoring programmes for forest conservation and water management in SE Asian peatlands.

6 References

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