Peatland Distribution in Sumatra and Kalimantan:

explanation of its data sets including source of information, data constraints and gaps

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Indonesia Programme

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Preface

This report describes the steps taken to produce Atlases of the distribution and stores of below-ground Carbon in the peatlands of Sumatra and Kalimantan. This report is intended to be read in conjunction with the Atlases produced and is incomplete without it. Readers are therefore strongly advised to read both documents. The titles of these atlases are :

- Wetlands International. 2003. Peta-peta sebaran lahan gambut, luas dan simpanan/kandungan karbon di Sumatra (Maps of peatland distribution and carbon content in Sumatra), 1990-2002.

- Wetlands International. 2004. Peta-peta sebaran lahan gambut, luas dan simpanan/ kandungan karbon di Kalimantan (Maps of peatland distribution and carbon content in Kalimantan), 2000-2002.

We are aware that in the production of these atlases we faced a number of constraints, all of which are discussed in this report. Nevertheless, we hope that the information contained within this report (and the atlases) will provide input for academics, researchers, policytakers and policymakers that will enable the peatlands of Sumatra and Kalimantan to be managed sustainably. By knowing the location and extent of peatlands in each kabupaten (district) of Sumatra and Kalimantan, it is hoped that managers will be more careful in deciding how they should be developed, considering that peatlands are highly vulnerable to fire but that their function, if well maintained, will provide many benefits to a wide variety of life both on and around them.

Finally, to all who have been involved directly or indirectly in the production of this book, we express our sincere thanks and hope that the time and effort that you have contributed will benefit us all in conserving Indonesia's wetlands in general, and in particular those in Sumatra and Kalimantan.

The authors

Wetlands International – Indonesia Programme

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Glossary of Terms and Abbreviations

Bakosurtanal.	:	National Mapping Coordination Board (*Badan Koordinasi dan Pemetaan Nasional*)
Balitbang	:	Research and Development Agency (*Badan Pelitian dan Pengembangan*)
BAPPEDA	:	Regional Development Planning Agency (*Badan Perencanaan Pembangunan Daerah*)
BAPPENAS	:	National Development Planning Agency (*Badan Perencanaan Pembangunan Nasional*)
BMG	:	Meteorology and Geophysics Office (*Badan Meteorogi dan Geofisika*)
BPPT	:	Agency for the Assessment and Application of Technology (*Badan Pengkajian dan Penerapan Teknologi*)
Bulk Density	:	The weight of a volume of undisturbed peat soil expressed in units of gr/cc or kg/m^3. Values range between 0.10-0.40 gr/cc, depending on the peat's level of maturity
CCFPI	:	Climate Change Forests and Peatlands in Indonesia, is a forestry project which is closely related to the issue of climate change, where the forest plays an important role in carbon sequestration. This project is implemented by WI-IP together with Wildlife Habitat Canada (WHC) and funded by grants from the Canadian Goverment (CIDA, Canadian International Development Agency) through the Canada Climate Change Development Fund for a period of four years (August 2001 – September 2005), then extended to December 2006. Activities under this Project involve the participation of community and government in the conservation and rehabilitation of peatlands and peat forests in Indonesia. This Project was specifically designed to support the United Nations Framework Convention on Climate Change (UNFCCC) for Canada and Indonesia.
CDM	:	Clean Development Mechanism
CIDA	:	Canadian International Development Agency
COP	:	Convention for the Parties

DAS	:	River catchment area (*Daerah Aliran Sungai*)
Decomposition	:	The breaking down of organic material by living creatures (mainly bacteria and moulds) in the environment, that produces inorganic compounds or simpler organic compounds.
Deptan	:	Ministry for Agriculture (*Departemen Pertanian*)
Ditjen. Bina Bangda	:	Directorate General for Regional Development, Ministry of Home Affairs (*Direktoral Jenderal Bina Pembangunan Daerah, Departemen Dalam Negeri*)
Ditjen PHKA	:	Directorate General for Forest Protection and Nature Conservation, under the Ministry for Forestry (*Direktorat Jenderal Perlindungan Hutan dan Konservasi Alam, Departemen Kehutanan*)
GEC	:	Global Environmental Center, a NGO based in Kuala Lumpur Malaysia
GHG	:	Green House Gases: certain gases in the atmosphere that can obstruct/prevent the escape of infrared radiation from the earth, with the result that the average temperature of the earth's surface is getting warmer. This resembles the trapping of infrared radiation inside a greenhouse, thus raising the temperature. The Kyoto Protocol lists six types of GHG whose emissions must be regulated/reduced: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulphur hexafluoride (SF_6), perfluorocarbon (PFC), and hydrofluorocarbon (HFC).
Giga	:	10^9 (1,000,000,000) E.g. 1 Giga ton = 1,000,000,000 ton
HPH	:	Forestry Licence (*Hak Pengusahaan Hutan*)
IPB	:	Bogor Agricultural University (*Institut Pertanian Bogor*)
Keppres	:	Presidential decree (*Keputusan Presiden*)
Kpts	:	Decree/decision (*Keputusan*)
LAPAN	:	National Institute for Aeronautics (*Lembaga Penerbangan dan Antariksa Nasional*)
LIPI	:	Indonesian Institute of Sciences (*Lembaga Ilmu Pengetahuan Indonesia*)
LREP	:	Land Resources Evaluation and Planning Project
LSM	:	Non-governmental organisation (*Lembaga Swadaya Masyarakat*)
Mendagri	:	Minister for Home Affairs (*Menteri Dalam Negeri*)

MenHut : Minister for Forestry (*Menteri Kehutanan*)

Men LH : Minister for the Environment (*Menteri Lingkungan Hidup*)

NGO : Non-governmental Organisation. A non-profit organisation managed outside the political structure with the purpose of achieving a particular social aim.

Organosol / histosol : Soil that contains enormous quantities of organic materials from partially decomposed plant matter. This soil is formed because the low oxygen content of inundated land slows down the decomposition of organic materials. The term 'histosol' derives from the word *Histos* meaning 'network'. 'Histosol' can therefore be taken to mean 'soil constructed from a network'. The term 'organosol' indicates soil with a very high content of organic materials. Organosol and Histosol are terms used in soil classification, usually to denote soil commonly known as peat.

Parit : Ditch, a small channel (width 0.5 – 3 m; depth 0.6 – 1.5 m length up to 13 km), made in peatland, usually dug by individuals or groups to transport logs and/or other forest products

Peat : (organosol or histosol) soil formed from the accumulation over a long period of time of organic matter such as the remains of plants. Peat soil is generally waterlogged or flooded all year long unless drained. Several experts have defined 'peat' in different ways:

- According to Driessen, 1978: peat is soil containing more than 65% organic material (dry weight) and having a peat depth greater than 0.5 m.
- According to "Soil Taxonomy": peat is soil comprised of organic materials with a thickness exceeding 40cm or 60cm, depending on the bulk density and level of decomposition of the organic matter

Peat dome : The central part of peatland, which rises like a dome. This part is usually less fertile because its nutrients come only from rainwater.

PEMDA : Regional Government (*Pemerintah Daerah*)

PERDA : Regional Regulation (*Peraturan Daerah*)

PERPRES : Presidential Regulation (*Peraturan Presiden*) – previously termed Presidential Decree (*Keppres= Keputusan Presiden*)

PLG	:	Proyek Lahan Gambut – the one million hectare peatland project developed in Central Kalimantan in 1995 during the era of President Suharto. The project was officially terminated in 1999 during the term of President Habibi because it was considered to be a failure.
PP	:	Government Regulation (*Peraturan Pemerintah*)
PU	:	Public Works (*Pekerjaan Umum*)
Puslitanak	:	Soil and Agroclimate Research Centre (*Pusat Penelitian Tanah dan Agroklimat*)
RePPProT	:	Regional Physical Planning Project for Transmigration
RTRWP	:	Provincial Spatial Planning (*Rencana Tata Ruang Wilayah Propinsi*)
SK	:	Decree/decision (*Surat Keputusan*)
Subsidence	:	In a geological, technical or mapping survey context, subsidence is defined as the downward movement or collapse of a surface (usually the earth's surface) relative to a certain datum – usually sealevel. The opposite of subsidence is uplift, which raises up the surface. In the context of peatlands, subsidence means the collapse of the peat's surface, usually as a result of over-drainage or damage to its hydrology and vegetation, oxidation of the peat.
UGM	:	Universitas Gajah Mada
UNEP	:	United Nations Environmental Programme
UNFCCC	:	United Nations Framework Convention on Climate Change
UU	:	Law (*Undang Undang*)
WHC	:	Wildlife Habitat Canada, a NGO in Canada
WI-IP	:	Wetlands International-Indonesia Programme, an international non-profit organisation active in the field of wetlands conservation
WWF-Indonesia	:	World Wide Fund for Nature Indonesia

1. Introduction

Peatland is a wetland ecosystem characterised by the accumulation of organic material over a long period of time. This accumulation occurs because organic materials pile up on the floor of wetland forests much more quickly than they decompose. The formation of peat almost always occurs in inundated conditions or in wet coastal basins where organic materials are produced in large quantities.

At the turn of the 21st century, the best known functions of peatlands were its role as a wetland habitat that supported characteristic flora and fauna (biodiversity), as a hydrological regulator (preventing floods during the wet season and preventing seawater intrusion during the dry), and as a source of livelihoods for the local community (e.g. timber for house construction, industry, foodstuffs, medicines, etc.). However, as we approach the end of the 2000s, the world's attention has begun to widen to see the global role that peat plays on the surface of this Earth, that is as a wetland habitat capable of sequestering and storing large amounts of carbon and thereby preventing the emission of green house gases (CO2 in particular), that impact on climate change, into the Earth's atmosphere.

The world's increasing attention to peat is not unrelated to the realization by many nations that global climate change is occurring and will have far reaching consequences for divers aspects of life on the surface of this Earth. One indication of their concern is the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) by a variety of countries, despite the inadequate support given by certain countries to its implementation on a practical level (as specified in the Kyoto Protocol).

Of the approximately 450 million hectares of peatlands throughout the whole world, about 12% (approx 54 million ha) are in the wet tropics, primarily in Asia, the Caribbean, Central America, and South Africa). Of these, Indonesia possesses the largest area of tropical peatlands, estimated at 13.5 to 26.5 million ha (50% of total tropical peatland area); these are found mainly in Sumatra, Kalimantan and Papua, along with a little in Halmahera and Sulawesi. Regrettably, however, information on their location and extent (let alone their carbon content) is still inadequate. To address this problem, Wetlands International-Indonesia Programme and its partners (with all their limitations) have attempted to put together an atlas of peat distribution (including below ground carbon content) in Sumatra and Kalimantan. The stages for this are described in this report.

2. Background to the compilation of the Peatland Distribution Atlas

To date, there is still uncertainty regarding some of the data and information on the extent (area), thickness and distribution of peatlands in Indonesia (including their physico-chemical characteristics). This is a serious constraint as precise, accurate data of this type is a necessary prerequisite to drawing up an appropriate peatland management strategy. The uncertainty is reflected in the wide variation in the figures obtained for the total extent of peatlands in Indonesia, ranging from 13.5 to 26.5 million ha, as submitted by different sources (Table 1). Meanwhile, other sources estimate the total to be around 20.6 million ha (22.5 million ha according to Hooijer et al, 2006) or about 10.8% of Indonesia's land area. Of this total, approximately 7.2 million ha is thought to lie on the island of Sumatra, 5.76 million ha in Kalimantan, and the remainder in Papua and other regions of Indonesia.

Table 1. Estimates of peatland area and distribution in Indonesia by various authors/ sources (taken from Najiyati et al 2005)

Author/Sources	Peatland distribution and area (million ha)				Total
	Sumatra	Kalimantan	Papua	Other	
Driessen (1978)	9.70	6.30	0.10	-	16.10
Puslittanah (1981)	8.90	6.50	10.90	0.20	26.50
Euroconsult (1984)	6.84	4.93	5.46	-	17.20
Soekardi & Hidayat (1988)	4.50	9.30	4.60	<0.10	18.40
Deptrans (1988)	8.20	6.80	4.60	0.40	20.10
Subagyo et al. (1990)	6.40	5.40	3.10	-	14.90
Deptrans (1990)	6.90	6.40	4.20	0.30	17.80
Nugroho *et al.* (1992)	4.80	6.10	2.50	0.10	13.50*
Radjagukguk (1993)	8.25	6.79	4.62	0.40	20.10
Dwiyono& Racman (1996)	7.16	4.34	8.40	0.10	20.00
Wetlands International (2002 – 2006)	7.20	5.80	8.00	-	21.00

* not including peatland associated with saline land and floodplain (2.46 million ha)

In view of the situation described above, from 2002 until 2006, funded by the Canada Climate Change Development Fund under the CCFPI Project (Climate Change, Forest and Peatlands in Indonesia), Wetlands International Indonesia Programme undertook to inventorise peatland conditions in Sumatra, Kalimantan and Papua. This mapping was not done from scratch, but started by inventorising existing survey data from a number of relevant institutions in Indonesia. This was followed by the identification of peatland sites by using

Remote Sensing / Satellite Imaging and Geographic Information System (Sistim Informasi Geografis, SIG). The data/information thus collected covered peat thickness, type/maturity, physico-chemical properties, extent and distribution, as well as an estimate of its below ground carbon content. Determination of the extent, distribution and carbon content of peatlands on the island of Sumatra was made based on information from 1990 and 2002, that for Kalimantan on data from 2000 and 2002. Data for Papua will not be discussed in this report.

To obtain the above information, WIIP worked together with (or at least used data from) a variety of sources, including Bogor Agricultural University (Institut Pertanian Bogor, IPB), the National Survey and Mapping Coordination Agency (Badan Koordinasi Survey dan Pemetaan Nasional, Bakosurtanal), the Soil and Agroclimate Research Centre (Pusat Penelitian dan Pengembangan Tanah dan Agroklimatology, Puslitanak).

From the above study two peatland atlases which represent Sumatra and Kalimantan were produced. Each atlas describes the area and distribution of peatlands at the district level of each province in the island as well as the amount of carbon stored therein. Table 2 below gives a summary of this data for each island and its provinces (note: WIIP has also recently finalized the atlas for Papua.)

Table 2. Peatland distribution and its carbon stores in each province

Island name	Province name	Area of peatland (ha)	Carbon stores (mill ton C)	(% area)
Sumatra (2002)				
1	Lampung	87,567	35.94	1.22
2	Sumsel	1,483,662	1,470.28	20.65
3	Jambi	716,839	1,413.19	9.83
4	Riau	4,043,601	14,605.04	56.19
5	Bengkulu	63,052	30.53	0.88
6	Sumbar	210,234	422.23	2.92
7	Sumut	325,295	377.28	4.52
8	Aceh	274,051	458.86	3.81
	Total Sumatera	**7,204,301**	**18,813.37**	**100**
Kalimantan				
	Kalbar	1,729,980.00	3,625.19	29.99
	Kalteng	3,010,640.00	6,351.52	52.18
	Kaltim	696,997.00	1,211.91	12.08
	Kalsel	331,629.00	85.94	5.75
	Total Kalimantan	**5,769,246.00**	**11,274.55**	**100**

3. Compilation of Peat Distribution Atlas for Sumatra and Kalimantan

Chapters III to V of this report describe the steps taken by WIIP in compiling peat distribution atlases for Sumatra and Kalimantan. The compilation of these atlases (also the one for Papua, which is not discussed in this report) was paid for by the CCFPI funded by CIDA. The atlas of Sumatra's peat swamps was published by WIIP in 2003 (containing the results from the identification of peatland area and distribution in 1990 and 2002), while the atlas for Kalimantan was published in 2004 (containing results from 2002) and that for Papua in 2006 (results from 2000/2001).

3.1. PRIMARY DATA USED TO COMPILE MAPS OF PEAT DISTRIBUTION AND CARBON CONTENT (SPATIAL DATA)

The peat distribution atlases for Sumatra and Kalimantan were compiled with reference to a number of maps published (mainly) by Puslitanak, in project reports (LREP and RePPProT) and their annexes, which form an integral part of the whole publication. The following is a list of the references used:

a. Atlas Peta Tanah Eksplorasi Indonesia skala 1:1.000.000 (Exploration soil map atlas of Indonesia) published by Puslitbang Tanah dan Agroklimat, 2000

b. Peta tanah eksplorasi Pulau Kalimantan skala 1:1000.000 (Exploration soil maps for Kalimantan) published by Puslit Tanah dan Agroklimat, 1997

c. Peta Lahan Rawa Pulau Kalimantan skala 1:1000,000 (Maps of swamp land in Kalimantan) published by Puslit. Tanah dan Agroklimat, 2000

d. Peta tanah tinjau mendalam wilayah pengembangan lahan gambut sejuta hektar (PLG), Kalimantan Tengah skala 1:100,000 (Detailed reconnaissance soil maps for million hectare peatland project in Central Kalimantan) published by Puslit Tanah dan Agroklimat, 1998

e. Peta dan buku Keterangan Satuan Lahan dan Tanah skala 1:250,000 (Map and explanatory booklet on soil and land mapping units) published by Land Resources Evaluation Project (LREP), Pusat Penelitian Tanah Bogor, 1990.

f. Land System and Land Suitability Map published by RePPProT, Department for Transmigration, 1986 for Sumatra and Kalimantan.

3.2. OTHER SUPPORTING MAPS

In addition to the primary materials listed above, reference was also made to a number of other documents, including maps, reports and remote sensing / satellite imagery data. The data/maps below were used as references for compiling spatial information, as point source data, and as peatland characteristics data.

For example: if at one site/point on the map or in the report it is stated that the site comprises shallow peat of hemist maturity level, this information can then be used as a reference, whereas for its spatial distribution reference is made to delineation and satellite imagery analysis, topographic maps, and geological maps.

3.2.1. Peta Rupabumi Indonesia (RBI) scale 1:250,000 published by Bakosurtanal, 1996 - 2000 as spatial data (for basic map)

The RBI map provides information on the distribution of : (a) road networks that include State roads at provincial and district level, as well as roads linking sub-districts and villages; (b) rivers flowing through the area, and the direction of their flow; (c) height contour lines and shorelines ; (d) cities and provincial, district (kabupaten) and sub-district (kecamatan) level settlements; (e) main types of land use: wet rice-fields, dry fields, forest, lakes, swamps; (f) administrative boundaries between provinces and kabupatens; (g) place names and types of land use (mountain, swamp, town, village, river, beach/coast).

Information on road networks, rivers, shoreline, distribution of settlements/ towns and lakes/swamps was all updated from satellite imagery analysis, while administrative area maps were revised from the administrative maps published by Bappenas (1986) and KPU (2003).

This digital RBI map data was used as a basic map on which to show the distribution and carbon content of peat in Sumatra and Kalimantan, each map on a scale of 1:250,000. The peat distribution maps for each province and island were generalized from the integration of several RBI maps (scale 1:250,000). A number of topographic maps (scale 1:250,000) were also used to calculate the area of peatland in each kabupaten district. These maps were processed using the Geographic Information System (Teknik Sistem Informasi Geografi) digital file data so that they could be printed in Ao format. For ease of use and portability, however, the final maps in the Peat Distribution ATLAS are also available as a handier A3 size hard copy.

The RBI maps of Sumatra and Kalimantan used for the basic map are presented in Table 3, Table 4 and Figure 1 and Figure 2.

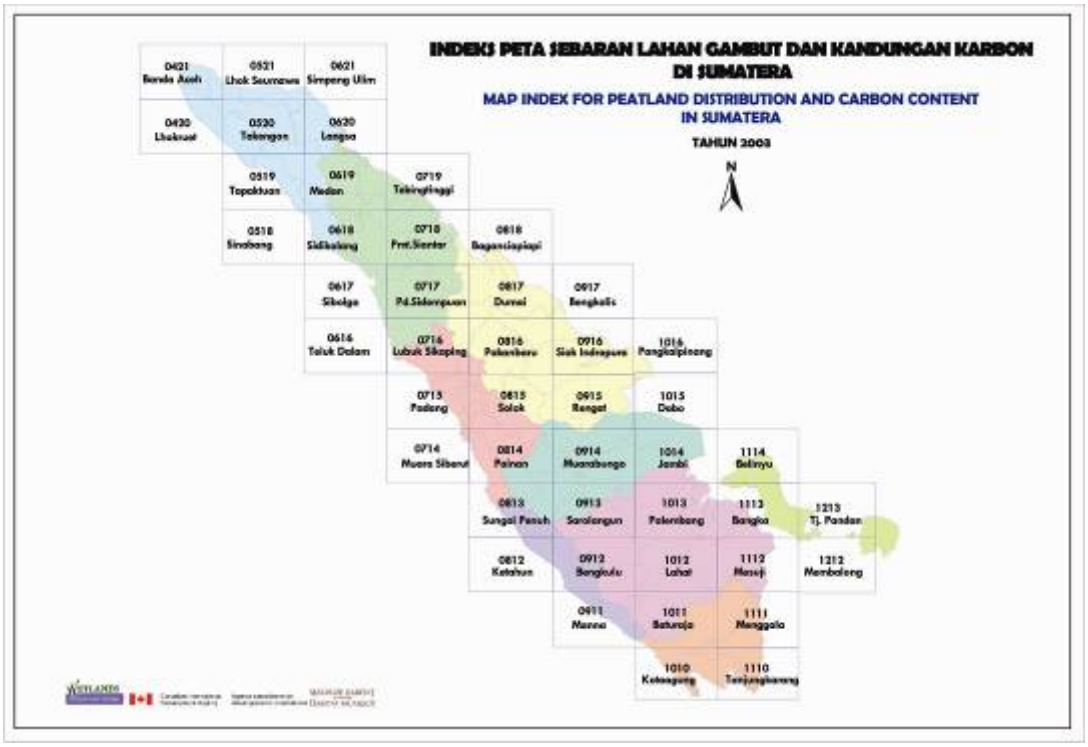

Figure 1. *The RBI map data was used as a basic map on which to show the distribution of peat in Sumatra*

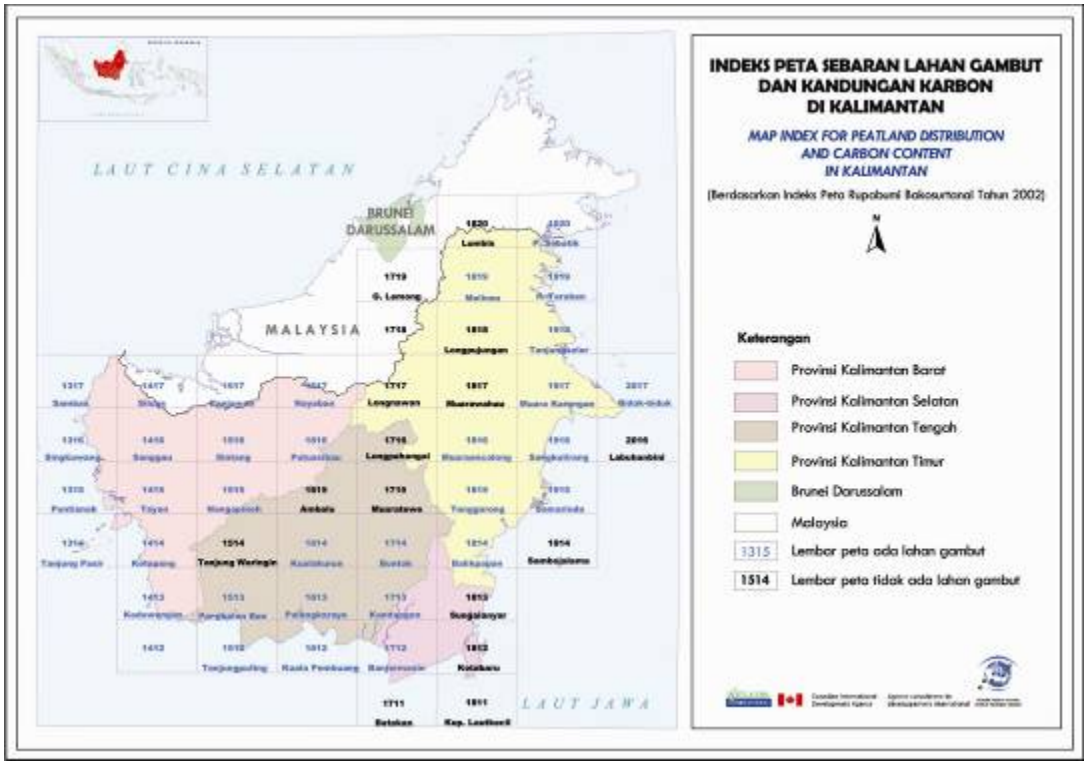

Figure 2. *The RBI map data was used as a basic map on which to show the distribution of peat in Kalimantan*

Table 3. RBI maps of Sumatra used as basic maps for the compilation of the peatland distribution Atlas for Sumatra

No.	Map No.	Map Name	No.	Map No.	Map Name
1	0421	Banda Aceh	22	0912	Bengkulu
2	0420	Lhok Kruet	23	0911	Manna
3	0521	Lhok Seumawe	24	1014	Jambi
4	0520	Takengon	25	1013	Palembang
5	0519	Tapak Tuan	26	1012	Lahat
6	0518	Sinabang	27	0714	Muara Siberut
7	0620	Langsa	28	1011	Baturaja
8	0621	Simpang Ulim	29	1016	Pangkal Pinang
9	0619	Medan	30	1010	Kotaagung
10	0618	Sidikalang	31	1113	Bangka
11	0617	Sibolga	32	1112	Toboali
12	0616	Teluk dalam	33	1015	Dado
13	0719	Tebing Tinggi	34	1111	Menggala
14	0718	Pematang Siantar	35	1110	Tanjung Karang
15	0717	Padang Sidempuan	36	0814	Painan
16	0716	Lubuk Sikaping	37	0812	Ketahun
17	0715	Padang	38	0813	Sungai Penuh
18	0714	Muara Siberut	39	0917	Bengkalis
19	0818	Bagan Siapi-api	40	0916	Siak Sri Inderapura
20	0817	Dumai	41	0915	Rengat
21	0816	Pakanbaru	42	0914	Muarabungo
22	0815	Solok	43	0913	Sarolangun

Table 4. RBI maps of Kalimantan used as basic maps for the compilation of the peatland distribution Atlas for Kalimantan

No.	Map No.	Map Name	No.	Map No.	Map Name
1	1317	Sambas	25	1717	Longnawan
2	1316	Singkawang	26	1716	Longpahangai
3	1315	Pontianak	27	1715	Muara tewe
4	1314	Tanjung Pasir	28	1714	Buntok
5	1417	Siluas	29	1713	Kandangan
6	1416	Sanggau	30	1712	Banjarmasin
7	1415	Tayan	31	1711	Batakan
8	1414	Ketapang	32	1820	Lumbis
9	1413+1412	Kedawangan	33	1819	Malinau
10	1517	Panjawan	34	1818	Longujungan

No.	Map No.	Map Name	No.	Map No.	Map Name
11	1516	Sintang	35	1817	Muarawahau
12	1515	Nanga Pinoh	36	1816	Muaraancalong
13	1514	Tanjung Waringin	37	1815	Tenggarong
14	1513	Pangkalan Bun	38	1814	Balikpapan
15	1512	Tanjung Putting	39	1813	Sungaianyar
16	1617	Nayaban	40	1812	Kotabaru
17	1616	Putusibau	41	1811	Kep. Laut kecil
18	1615	Ambalu	42	1920	P. Sebatik
19	1614	Kualakurun	43	1919	P.Tarakan
20	1613	Palangkaraya	44	1918	Tanjung Selor
21	1612	Kuala Pembuang	45	1917	Muara karangan
22	1718+1718	G. Lemong	46	1916	Sangkulirang
23	1915	Samarinda	47	2017	Biduk-biduk
24	1914	Sambojalama	48	1016	Labuhanbini

3.2.2. Soil and land mapping units scale 1:250,000 for the whole of Sumatra Island, published by Pusat Penelitian Tanah dan Agroklimat (Puslitanak), 1990

These maps were compiled by their publisher (Puslitanak) using remote sensing data (aerial photographs, radar images, Landsat MSS and Landsat TM satellite images) to determine mapping units from each land unit polygon. Using the results obtained from observation and field validation, these were then augmented with information on soil characteristics and other environments existing within the polygon. Soil/land unit distribution boundaries were delineated by analyzing remote sensing data. In these maps, peat swamps are included in the land unit / Physiographical Group "Peat Dome" which is dominated by peat soils (Histosol or Organosol).

In these maps, Peat Dome is classified at level I on the basis of its nutrient content: D.1. denotes eutrophic peat (relatively fertile as it is enriched by sediments) and D.2. oligotrophic peat (nutrient-poor). Level II differentiates by water quality (1: freshwater peat and 2: saltwater peat), and Level III distinguishes on the basis of peat depth (1: <0.5 m, 2: 0.5–2 m, and 3: >2 metres). For example, if the map legend ascribes the Symbol D.2.1.2 to a land unit containing peat, it means that this land is oligotrophic peat dome (D.2), freshwater (1), and that the peat is 0.5 to 2 m thick (2). This data was used as basic information in compiling the 1990 and 2002 peatland distribution maps for Sumatra.

The soil and land mapping units used as a source of main data for the 1990 peat distribution maps for Sumatra are listed in Table 5 and distribution is shown in Figure 3.

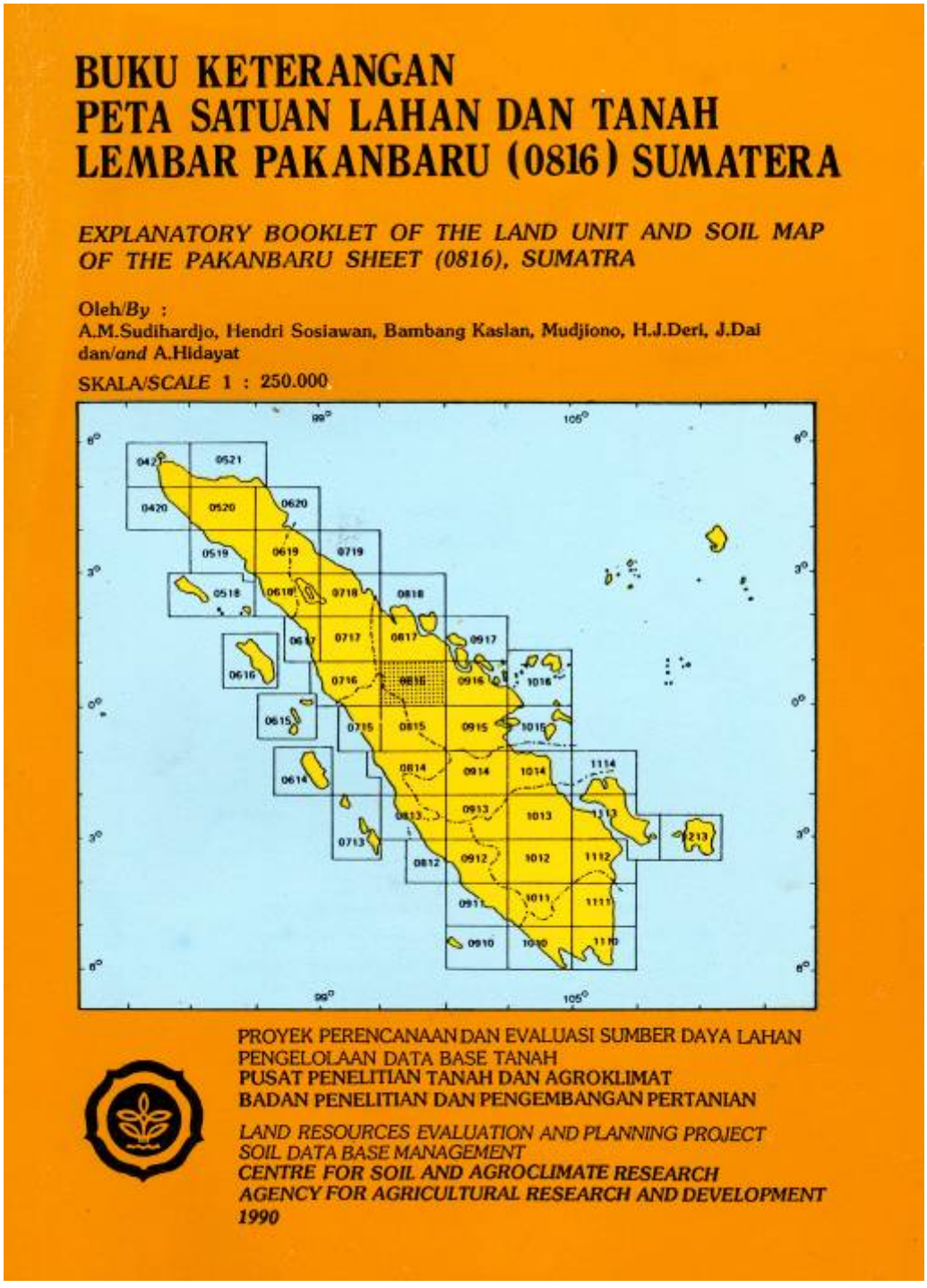

Figure 3. *The soil and land mapping units used as a source of main data for the Peat Distribution Map in Sumatra*

3.2.3. RePPProT Maps

The maps published by RePPProT (Regional Physical Planning Project for Transmigration) that were used included: Present Land Use and Land Status, and Land System and Land Suitability. The main ones used as reference for the peat distribution map of Sumatra (1990) and Kalimantan were the Land System and Land Suitability maps on a scale of 1:250,000. A desk study was made of these maps (80-90% took the form of analysis of remote sensing and other supporting data), supplemented by field verification data (10-20%). These maps, together with geological and soil maps/data, were used as input for the analysis of satellite images in order to identify the distribution of peatlands. However, if while analyzing the image of a particular site it was known for certain (from previous surveys to that area) that the site did in fact comprise peatland, even if this contradicted the RePPProT map, it was identified as peatland. The RePPProT maps used are presented in Table 5, Table 6, and Figure 4.

Figure 4. *Landsystem and Land Suitability Map published by RePPProT that were used for Peat Distribution Maps in Sumatra and Kalimantan*

Table 5. LAND SYSTEM AND LAND SUITABILITY MAPS
published by RePPProT, Departemen Transmigrasi, 1986 (Sumatra)

No.	Map No.	Map Name	No.	Map No.	Map Name
1	0421	Banda Aceh	27	0912	Bengkulu
2	0420	Lhok Kruet	28	0911	Manna
3	0521	Lhok Seumawe	29	1014	Jambi
4	0520	Takengon	30	1013	Palembang
5	0519	Tapak Tuan	31	1012	Lahat
6	0518	Sinabang	32	0714	Muara Siberut
7	0620	Langsa	33	1011	Baturaja
8	0619	Medan	34	1010	Kotaagung
9	0618	Sidikalang	35	1113	Pangkal Pinang
10	0617	Sibolga	36	1112	Tanjung Selapan
11	0719	Tebing Tinggi	37	1111	Menggala
12	0718	Pematang Siantar	38	1110	Tanjung Karang
13	0717	Padang Sidempuan			
14	0716	Lubuk Sikaping			
15	0715	Padang			
16	0818	Bagan Siapi-api			
17	0817	Dumai			
18	0816	Pakanbaru			
19	0815	Solok			
20	0814	Ketahun			
21	0813	Sungai Penuh			
22	0917	Bengkalis			
23	0916	Siak Sri Inderapura			
24	0915	Rengat			
25	0914	Muarabungo			
26	0913	Sarolangun			

Table 6. LAND SYSTEM AND LAND SUITABILITY MAP
published by RePPProT , Departemen Transmigrasi, 1986 (Kalimantan)

No.	Map No.	Map Name	No.	Map No.	Map Name
1	1317	Sambas	24	1717	LongNawan
2	1316	Singkawang	25	1716	Long Pahangai
3	1315	Pontianak	26	1715	Muara Teweh
4	1314	Tanjung Pasir	27	1714	Buntok
5	1417	Siluas	28	1713	Barabai
6	1416	Sanggau	29	1712	Banjarmasin
7	1415	Tayan	30	1820	Lumbis
8	1414	Ketapang	31	1819	Malinau
9	1413	Kendawangan	32	1818	Longbia
10	1517	Panjawan	33	1817	Muara Wahau
11	1516	Sintang	34	1816	Tabang
12	1515	Nangapinoh	35	1815	Longiram
13	1514	Tanjung Waringin	36	1814	Balikpapan
14	1513	Pangkalan Bun	37	1813	Sungai Anyar
15	1512	Muara Dua	38	1812	Kotabaru
16	1617	Nayaban	39	1920	Sibatik
17	1616	Putusibau	40	1919	Tarakan
18	1615	Ambalu	41	1918	Tanjung redeb
19	1614	Kuala Kurun	42	1917	Muara Lasa
20	1613	Palangka raya	43	1916	Bontang
21	1612	Kuala Pembuang	44	1915	Samarinda
22	1719	Apobayan	45	2017	Biduk-biduk
23	1718	Kanan	46	2016	Sabang

3.3. SATELLITE IMAGERY

3.3.1. Sumatra

In 1990, through the Land Resources Evaluation Project (LREP), the Soil and Agroclimate Research Centre (Puslitanak) published Soil and land mapping units (Peta Satuan Lahan dan Tanah) scale 1:250,000. These mapping units were compiled based on analysis of remote sensing data (satellite imagery, radar images, aerial photographs). Those for Sumatra show the distribution of peat <2 metres and >2 metres deep. In producing the peat atlas, WI-IP referred to these LREP maps, analysed satellite imagery recorded in the 1990s (Landsat TM-5 and MSS) and made modifications/revisions on the basis of results from field observations and laboratory analysis of peat soil samples. These modifications/ revisions included:

(1) more detailed information on peat depth: the Soil and land mapping units distinguish only between peat that is thicker or thinner than 2m. The atlas details four classes, i.e. shallow peat (50-100 cm), moderate depth (100-200 cm), deep (200–400 cm) and very deep (>400m),

(2) the maturity level for each class of depth: fibrists, hemists, saprists or a combination of these.

To determine the extent and severity of peatland shrinkage, data from two different years were compared. These were the 1990 peat distribution data described above, and data obtained from a survey by WI-IP in 2002, along with data from satellite images. This comparison showed changes in the distribution and depth of peatlands over a period of 12 years. Difficulty in obtaining cloud-free images for 2002 for the whole of Sumatra meant that the images used ranged from 2000 to 2002. The so-called "2002" comprehensive peat distribution for Sumatra therefore actually represents the period 2000-2002.

Satellite images used for the 1990s and 2002 peat distribution maps for Sumatra are listed in Table 7 and Figure 5.

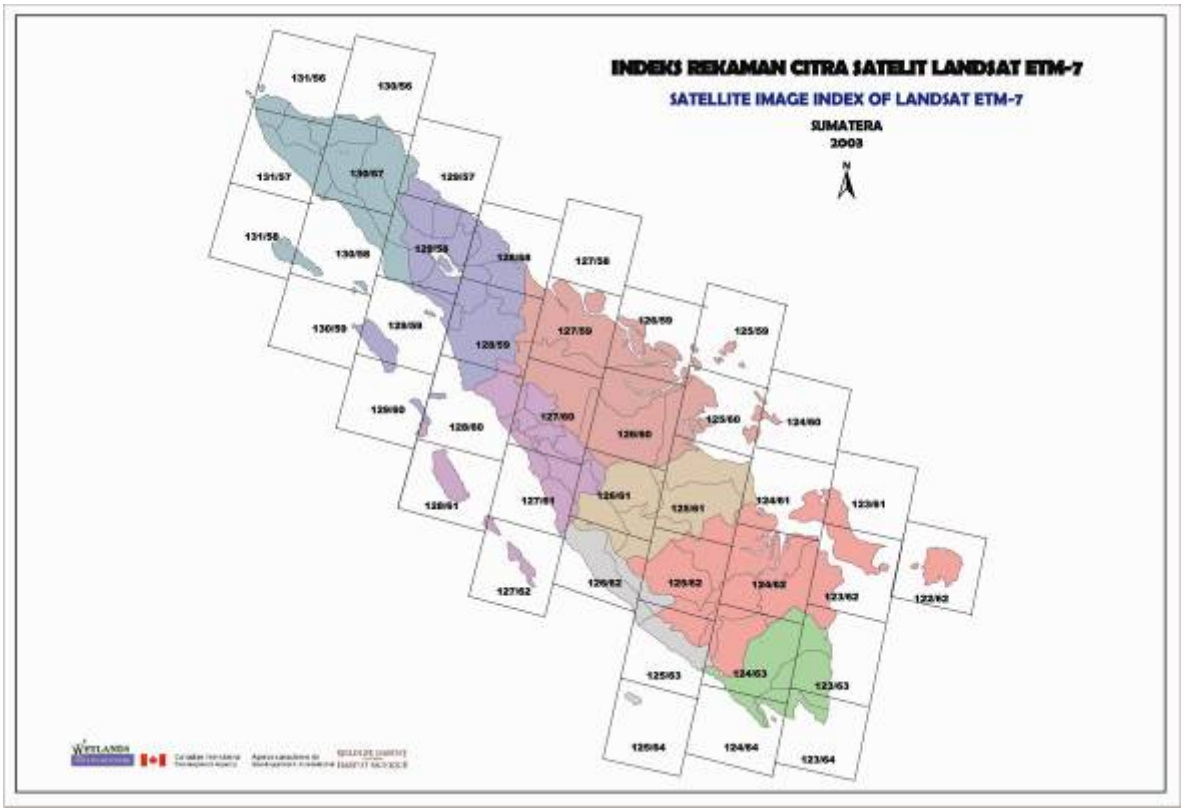

Figure 5. *Satellite image used for the peat distribution map in Sumatra*

Table 7. Satellite Images used to compile Atlas of peatland distribution in Sumatra

No.	Path-Row	Region recorded	No.	Path-Row	Region recorded
1	131/56	Nanggroe Aceh Darussalam	20	125/59	Riau
2	131/57	Nanggroe Aceh Darussalam	21	125/60	Riau
3	130/56	Nanggroe Aceh Darussalam	22	125/61	Jambi, Riau, Sumsel
4	130/57	Nanggroe Aceh Darussalam	23	125/62	Sumsel, Jambi, Bengkulu
5	130/58	Nanggroe Aceh Darussalam	24	125/63	Sumsel, Bengkulu, Lampung
6	129/57	Nanggroe Aceh Darussalam + Sumut	25	124/61	Sumsel, Jambi
7	129/58	Nanggroe Aceh Darussalam + Sumut	26	124/62	Sumsel, Lampung
8	129/59	Nanggroe Aceh Darussalam + Sumut	27	124/63	Sumsel, Lampung
9	128/58	Sumut, Riau	28	124/64	Lampung
10	128/59	Sumut, Riau, Sumbar	29	123/62	Sumsel
11	128/60	Sumut, Sumbar	30	123/63	Lampung, Sumsel
12	127/58	Riau	31	123/64	Lampung
13	127/59	Riau			
14	127/60	Riau, Sumbar			
15	127/61	Sumbar			
16	126/59	Riau			
17	126/60	Riau, Jambi			
18	126/61	Jambi, Sumbar, Riau			
19	126/62	Jambi, Sumsel, Bengkulu			

3.3.2. Kalimantan

To identify the whereabouts of peatland in 2002 in Kalimantan, satellite images ranging from 2001 to 2002 were used. However, several parts of Kalimantan are cloud-covered all year long, thus making it difficult to obtain completely cloud-free images of these areas. In this regard, data from survey and soil mapping as well as data/maps from RePPProt proved extremely useful in compiling the peat distribution map for Kalimantan. The satellite images used in the analysis of peat distribution in Kalimantan are presented in Table 8 and Figure 6.

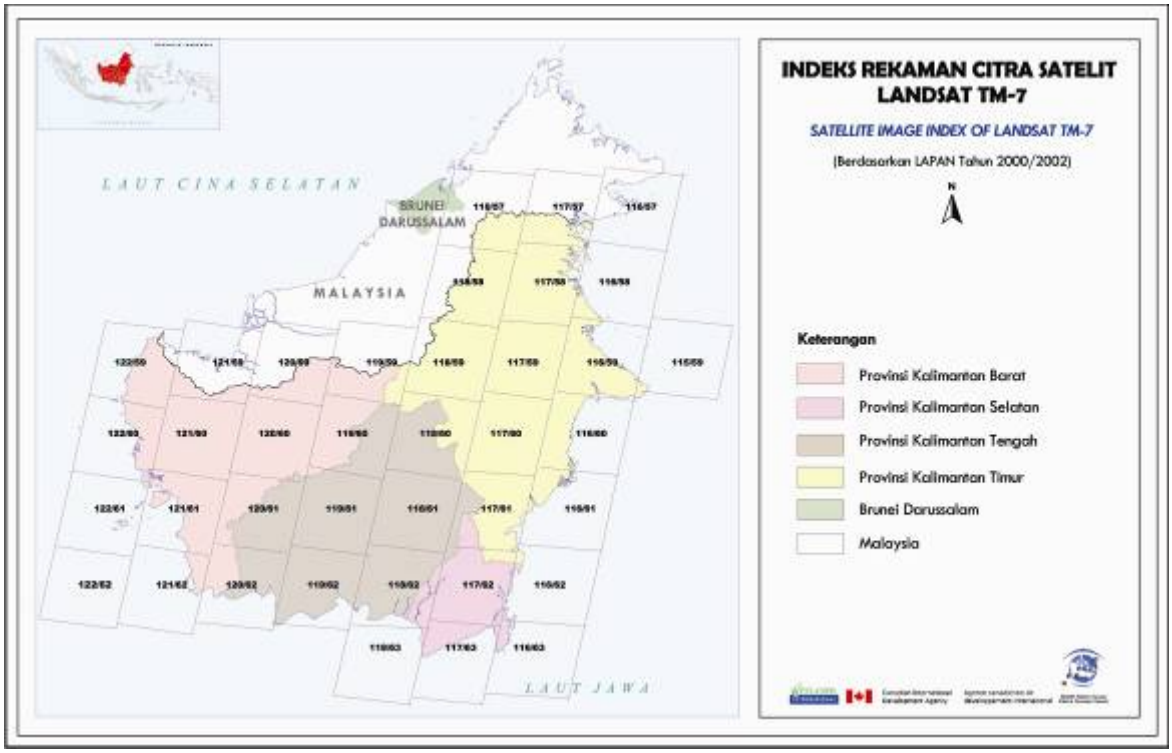

Figure 6. *Satellite image used for the peat distribution map in Kalimantan*

Table 8. Satellite images used to compile Atlas/maps of peatland distribution in Kalimantan

No.	Path-Row	Region recorded	No.	Path-Row	Region recorded
1	122/59	Kalbar	21	117/57	Kaltim
2	122/60	Kalbar	22	117/58	Kaltim
3	122/61	Kalbar	23	117/59	Kaltim
4	121/59	Kalbar	24	117/60	Kaltim
5	121/60	Kalabar	25	117/61	Kaltim, Kalteng, Kalsel
6	121/61	Kalbar	26	117/62	Kalsel, kalteng, Kaltim
7	121/62	Kalbar	27	117/63	Kalsel
8	120/59	Kalbar	28	118/62	Kalteng/ kalsel
9	120/60	Kalbar, Kalteng	29	118/63	Kalsel
10	120/61	Kalbar, Kalteng	30	116/58	Kaltim
11	120/62	Kalbar, Kalteng	31	116/59	Kaltim
12	119/59	Kalbar, Kaltim	32	116/60	Kaltim
13	119/60	Kalbar, Kaltim, Kalteng	33	116/61	Kaltim
14	119/61	Kalteng, Kalbar	34	116/62	Kalsel, Kaltim
15	119/62	Kalteng	35	116/63	Kalsel

No.	Path-Row	Region recorded	No.	Path-Row	Region recorded
16	118/57	Kaltim	36	115/59	Kaltim
17	118/58	Kaltim			
18	118/59	Kaltim			
19	118/60	Kaltim, Kalteng			
20	118/61	Kalteng			

3.4. SOIL MAPS AND REPORTS OF SURVEYS AND SOIL MAPPING IN SUMATRA AND KALIMANTAN

Soil maps at exploration level (scale 1:1000,000), reconnaissance soil maps (scale 1:250,000) and detailed reconnaissance soil maps (scale 1:100,000) covering Sumatra and Kalimantan published by Pusat Penelitian Tanah dan Agroklimat were used as reference sources for compiling the Atlases of peat distribution and carbon content in Sumatra and Kalimantan. In addition, information on the analysis of the physico-chemical parameters of soil samples was gleaned from various published reports; these parameters included the C-organic carbon content of the peat soil, and its Bulk Density value (BD). From these (and also peat volume) the size of the carbon store in the peat at each mapping site could be calculated (see analysis in 5.2). A list of the reports used as references for the Atlas of peat distribution and carbon store in Sumatra and Kalimantan is presented in Table 9.

Table 9. Maps and reports/information used as reference for compiling the Atlases of Peat Distribution and carbon store in Sumatra and Kalimantan.

EXPLORATION LEVEL LAND RESOURCE MAPS (Sumatra and Kalimantan)

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
1	Sumatra (Northern part)	1964	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
2	Sumatra (Southern part)	1964	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
3	P. Bangka	1955	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
4	P. Kalimantan	1993	-	1:1.000.000	Puslittanak	Exploration soil ma
5	Kalimantan Barat	1955	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
6	Kalimantan Barat	1971	-	1:1.000.000	Lembaga Penelitian Tanah	Exploration soil ma
7	Kalimantan Tengah	1960	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
8	Kalimantan Tengah	1970	-	1:1.000.000	Lembaga Penelitian Tanah	Exploration soil ma
9	Kalimantan Selatan	1958	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
10	Kalimantan Selatan	1971	-	1:1.000.000	Lembaga Penelitian Tanah	Exploration soil ma
11	Kalimantan Timur	1955	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma
12	Kalimantan Timur	1962	-	1:1.000.000	Lembaga Penelitian Tanah	Exploration soil ma
13	Kalimantan Timur (Southern part)	1967	-	1:1.000.000	Balai Penyelidikan Tanah	Exploration soil ma

RECONNAISSANCE LEVEL LAND RESOURCE MAPS (Sumatra)

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
NANGROE ACEH DARUSSALAM PROVINCE						
1	Kab. Aceh Utara, Timur, Besar dan Pidie	1987	1.600.000	1:250.000	Puslittan - P2DBT	Map & explanatory booklet
2	Lho'kruet (Lembar 0420)	1990	342.720	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
3	Banda Aceh (Lembar 0421)	1990	530.100	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
4	Simeulue (Lembar 0518)	1990	204.102	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
5	Tapaktuan (Lembar 0519)	1990	724.840	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
6	Lhok Seumawe (Lembar 0521)	1990	463.300	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
7	Langsa (Lembar 0620)	1990	742.246	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
8	Simpang Ulin (Lembar 0621)	1990	453.300	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
9	Takengon (Lembar 0520)	1991	1.796.535	1:250.000	Puslittanak – LREPP	Map & explanatory booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
PROVINSI SUMATRA UTARA / NORTH SUMATRA PROVINCE						
1	Sumatera Utara antara S.Wampu dan S.Asahan	1970	2.000.000	1:250.000	Lem Penelitian Tanah	Reconnaissance soil map
2	Kab.Tapanuli Utara & Tapanuli Selatan	1978	1.280.309	1:250.000	BPP (RISPA) Medan Subdit Tataguna Tanah Agraria	Map & explanatory booklet
3	Kab.Asahan & Kab. Labuhan Batu	1981	1.407.183	1:250.000	BPP (RISPA) Medan Subdit Tataguna Tanah Agraria	Map & explanatory booklet
4	Sidikalang (Lembar 0618)	1989	1.506.750	1:250.000	Puslittan – LREPP	Map & explanatory booklet
5	Pematangsiantar (Lembar 0718)	1989	1.524.750	1:250.000	Puslittan – LREPP	
6	Nias (Lembar 0616)	1990	402.297	1:250.000	Puslittanak – LREPP	
7	Padangsidempuan (Lembar 0617+0717)	1990	1.169.919	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
8	Medan (Lembar 0619)	1990	2.128.920	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
9	Tebing Tinggi (Lembar 0719)	1990	384.375	1:250.000	Puslittanak – LREPP	Map & explanatory booklet
PROVINSI RIAU / RIAU PROVINCE						
1	Pakanbaru	1957	-	1:250.000	Balai Penyelidikan Tanah	Reconnaissance soil map
2	Pulau Bintan	1971	-	1:250.000	Lembaga Penelitian Tanah	Reconnaissance soil map
3	Pakanbaru (Lembar 0816)	1990	1.860.320	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
4	Dumai & Bagansiapiapi (Lembar 0817+0818)	1990	1.882.885	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
5	Daerah Pasang Surut	1976	375.000	1:200.000	LPT – P4S	Reconnaissance soil map
6	Rengat (Lembar 0915)	1990	1.841.754	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
7	Siak Sri Indrapura (Lembar 0916)	1990	-	1:250.000	Puslittanak - LREPP	Map & explanatory booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
8	Bengkalis (Lembar 0917)	1990	366.156	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
9	Dabo (Lembar 1015)	1990	275.151	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
10	Tanjungpinang (Lembar 1012)	1990	417.857	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
JAMBI PROVINCE						
1	Sungai Penuh (Lembar 0813)	1990	1.112.684	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
2	Sarolangun (Lembar 0913)	1990	1.845.312	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
3	Muarabungo (Lembar 0914)	1990	1.835.734	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
4	Jambi (Lembar 1014)	1990	1.049.678	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
WEST SUMATERA PROVINCE						
1	Sumbar I (Kodya Padang, Kab. Solok dan Padang Pariaman	1984	942.180	1:250.000	Puslittan	Reconnaissance soil map
2	Sumbar II (Kab. Sawahlunto/ Sijunjung, Agam & Tanah Datar	1984	1.049.851	1:250.000	Puslittan	Reconnaissance soil map
3	Pagai (Lembar 0713)	1990	206.550	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
4	Painan dan Jambi (Lembar 0814+0714)	1990	1.715.073	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
5	Padang (Lembar 0715)	1990	579.080	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
6	Lubuk Sikaping (Lembar 0716)	1990	1.635.735	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
7	Solok (Lembar 0815)	1990	1.841.754	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
BENGKULU PROVINCE						
1	Bengkulu I (Kab.Bengkulu Utara, Kab.Rejang Lebong	1986	1.313.100	1:200.000	Puslittan - P3MT	Map & explanatory booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
2	Bengkulu II (Kab.Bengkulu Selatan)	1987	585.700	1:250.000	Puslittan - P2DBT	Map & explanatory booklet
3	Ketahun (Lembar 0815)	1990	202.383	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
4	Manna (Lembar 0910)	1990	685.829	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
5	Bengkulu (Lembar 0912)	1990	1.709.303	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
SOUTH SUMATERA PROVINCE						
1	Palembang Selatan	1953	250.000	1:250.000	Soepraptohardjo, M (BPT)	Reconnaissance soil map
2	Sumsel Bagian Selatan	1970	4.000.000	1:250.000	LPT	Reconnaissance soil map
3	P.Bangka	1971	-	1:250.000	LPT	Reconnaissance soil map
4	Toboali (Lembar 1112)	1989	1.121.650	1:250.000	Puslittan - LREPP	Map & explanatory booklet
5	Baturaja (Lembar 1011)	1990	1.821.400	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
6	Palembang (Lembar 1013)	1990	1.726.715	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
7	Belitung (Lembar 1213)	1990	483.262	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
8	Lahat (Lembar 1012)	1991	1.841.870	1:250.000	Puslittanak - LREPP	Map & explanatory booklet
LAMPUNG PROVINCE						
1	Lampung	1964	-	1:250.000	Lembaga Penelitian Tanah	Reconnaissance soil map
2	Jepara-Rawa Sragi-Sukadana	1964	250.000	1:250.000	Lembaga Penelitian Tanah	Reconnaissance soil map
3	Lampung	1968	987.900	1:250.000	Lembaga Penelitian Tanah	Reconnaissance soil map
4	Rajabasa	1972	-	1:250.000	Lembaga Penelitian Tanah	Reconnaissance soil map
5	Kotaagung (Lembar 1010)	1989	786.630	1:250.000	Puslittan - LREPP	Map & explanatory booklet
6	Tanjungkarang (Lembar 1110)	1989	717.600	1:250.000	Puslittan - LREPP	Map & explanatory booklet
7	Menggala	1989	1.071.300	1:250.000	Puslittan - LREPP	Map & explanatory booklet

RECONNAISSANCE LEVEL LAND RESOURCE MAPS (Kalimantan-Indonesia)

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
WEST KALIMANTAN PROVINCE						
1	Kalbar I (Kab.Sanggau dan Sintang)	1984	611.696	1:250.000	Puslittan - P3MT	Reconnaissance soil map & report booklet
2	Kalbar II (Kab.Sanggau dan Pontianak)	1986	762.350	1:250.000	Puslittan	Reconnaissance soil map & report booklet
3	Putussibau, Kab.Kapuashulu	1986	627.500	1:250.000	Puslittan - Sekjen Dep. Trans	Reconnaissance soil map & report booklet
4	Menjalin WPP V, Kab.Pontianak	1986	90.250	1:250.000	PT.Kern Teknik Indon - Ditjen Pankim, Dep.Trans	Reconnaissance soil map & report booklet
5	Sidas WPP Vc, Kab.Pontianak	1986	133.800	1:250.000	Gamidacon Inter.Con - Ditjen Pankim, Dep.Trans	Reconnaissance soil map & report booklet
CENTRAL KALIMANTAN PROVINCE						
1	Sei Barito & Sei Kapuas	1974	2.805.824	1:250.000	LPT - Pemda Tk.I Kalteng	Reconnaissance soil map & report booklet
2	Kalimantan Tengah	1981	2.000.000	1:250.000	Orstom Trans. Project (PTA - 44)	Reconnaissance soil map & report booklet
3	Kuala Jelai WPP IXc, Kab. Kobar	1986	125.000	1:250.000	PT.Karya Eka Sejahtera - Ditjen Pankim, Dep. Trans	Reconnaissance soil map & report booklet
4	S.Tuhup - S.Lahai, Kab.Barito Utara	1988	84.375	1:250.000	Puslittan - PT.Djayanti Djaya	Reconnaissance soil map & report booklet
SOUTH KALIMANTAN PROVINCE						
1	Gebied ten noorden van Pengaron	1938	38.000	1:250.000	Van Loenen, F.C (BI)	Reconnaissance soil map & report booklet
2	Gebied ten oosten van de Riam-Kiwa	1940	15.000	1:250.000	Razouk Schultz (BI)	Reconnaissance soil map & report booklet
EAST KALIMANTAN KALIMANTAN						
1	Enggalan Empayang WPP XVIIa, Kab.Kutai	1985	118.264	1:250.000	PT.Desa Contra Infra - Ditjen Pankim, Dep. Trans	Reconnaissance soil map & report booklet
2	Napaku/Paderongan, Kab.Bulungan	1986	500.000	1:250.000	Puslittan - Sekjen Dep.Trans	Reconnaissance soil map & report booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
3	Sasamba (Samarinda, Sanga-sanga, Muarajawo, Balikpapan)	1998	459.112	1:250.000	Puslittanak	Reconnaissance soil map & report booklet

DETAILED RECONNAISSANCE LEVEL LAND RESOURCE MAP (Sumatra)

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
NANGROE ACEH DARUSSALAM PROVINCE						
1	Cot Girek	1964	100.000	1:100.000	Badan Koordinasi Survei Bogor	Soil map & report booklet
NORTH SUMATERA PROVINCE						
1	Natal (Tapanuli)	1939	14.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
2	Dairi	1939	46.000	1:100.000	Dames, T.W.C (BI)	Soil map & report booklet
3	Medan	1959	-	1:100.000	Pangudijatno, G (BPT)	Soil map & report booklet
RIAU PROVINCE						
1	Middenstroom gebied vd S.Rokan Kanan	1941	600.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
2	Aek Natas	1952	70.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
3	Rumbai (Caltex)	1957	-	1:100.000	Soepraptohardjo - R.Dudal	Soil map & report booklet
4	Kep.Riau WPP IV (P.Batam dsk), Kab. Indragiri Hulu	1980	-	1:100.000	PT.Bima Seta Cipta Optima – Ditjen Pankim, Dep.Trans	Soil map & report booklet
5	Pasir Pangarayan WPP X, Kab.Kampar	1983	146.600	1:100.000	Faperta UNPAD - TKTD Cipta Karya PU	Soil map & report booklet
JAMBI PROVINCE						
1	Muara Tembesi	1937	2.650	1:100.000	Van Loenen, F.C (BI)	Soil map & report booklet
2	Tempino	1937	5.375	1:100.000	Van Loenen, F.C (BI)	Soil map & report booklet
3	Bukit Luncung	1937	7.075	1:100.000	Van Loenen, F.C (BI)	Soil map & report booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
4	Rantau Panjang	1937	3.125	1:100.000	Van Loenen, F.C (BI)	Soil map & report booklet
5	Batang Merangin	1939	132.400	1:100.000	Wentholt, F.A (BI)	Soil map & report booklet
6	Tabib - Air Hitam gebied	1940	100.000	1:100.000	Van Loenen, F.C (BI)	Soil map & report booklet
7	Tembesi Asai	1942	40.000	1:100.000	Hondius, P (D)	Soil map & report booklet
WEST SUMATERA PROVINCE						
1	Anai vlakte	1940	10.000	1:100.000	Van der Voort, M	Soil map & report booklet
2	Air Bangis, Kab. Pasamar	1940	22.000	1:100.000	Van der Voort, M	Soil map & report booklet
3	Siberut Utara, Kab.Padang Pariaman	1970	30.000	1:100.000	LPT	Soil map & report booklet
BENGKULU PROVINCE						
1	Perbo	1933	35.000	1:100.000	Idenburg, A.G.A (BI)	Soil map & report booklet
SOUTH SUMATERA PROVINCE						
1	Lubuk Linggau	1937	40.000	1:100.000	Te Ricle, H.J (BI)	Soil map & report booklet
2	Belitang nabij Martapura	1939	10.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
3	S.Dasar en S.Megang	1941	4.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
4	Kungku	1942	110.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
5	Komiba Baturaja	1956	20.000	1:100.000	Hardjono (BPT)	Soil map & report booklet
6	Baturaja	1957	-	1:100.000	Suhadi (BPT)	Soil map & report booklet
7	Tebing Tinggi	1963	-	1:100.000	Sukardi, M (LPT)	Soil map & report booklet
LAMPUNG PROVINCE						
1	Sukadana	1939	45.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
2	Way Tenong vlake on Omgeving	1940	10.000	1:100.000	Te Hiele, H.J (BI)	Soil map & report booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
3	Way Sekampung	1942	65.000	1:100.000	Van der Voort, M (BI)	Soil map & report booklet
4	DAS Sekampung	1971	200.000	1:100.000	LPT	Soil map & report booklet
5	DAS Sekampung Bawah	1972	-	1:100.000	LPT	Soil map & report booklet
6	Sekampung Watershed	1983	495.000	1:100.000	Puslittan - FAO	Soil map & report booklet

DETAILED RECONNAISSANCE LEVEL LAND RESOURCE MAP (Kalimantan Indonesia)

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
WEST KALIMANTAN PROVINCE						
1	Sanggau Ledo, Kab.Sambas	1949	23.000	1:100.000	Van Wijk, C.I (BI)	Soil map & report booklet
2	Singkawang	1969	4.000	1:100.000	LPT	Soil map & report booklet
3	Putussibau WPP XXIIc, Kab. Kapuas Hulu	1983	63.730	1:100.000	Faperta UNPAD - Ditjen Cipta Karya Dep. PU	Soil map & report booklet
4	Nanga Pinoh WPP XIXa, Kab.Sintang	1983	169.600	1:100.000	Faperta UNPAD - Ditjen Cipta Karya Dep. PU	Soil map & report booklet
5	Sosok WPP VIIb, Kab. Pontianak & Sanggau	1983	152.680	1:100.000	Faperta UNPAD - Ditjen Cipta Karya Dep. PU	Soil map & report booklet
6	Suhaid WPP XXIIb, Kab. Kapuas Hulu	1983	73.580	1:100.000	Faperta UNPAD - Ditjen Cipta Karya Dep. PU	Soil map & report booklet
CENTRAL KALIMANTAN PROVINCE						
1	Seruyan WPP XIIc, Kab. Kotim	1982	109.700	1:100.000	CV.Tunas Muda Usaha- Ditjen Pankim Dep Trans	Soil map & report booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
2	Riam Talawi WPP Xa, Kab.Kobar	1982	107.200	1:100.000	CV.Tunas Muda Usaha- Ditjen Pankim Dep. Trans	Soil map & report booklet
3	Mentangai WPP XVII, Kab.Kuala Kapuas & Barito Selatan	1983	215.640	1:100.000	Faperta UNPAD - Ditjen Cipta Karya Dep. PU	Soil map & report booklet
4	Sepangsimin WPP XX, Kab.Barito Utara	1985	112.712	1:100.000	PT.Mondeal - Ditjen Pankim Dep.Trans	Soil map & report booklet
5	Sungai Pinang WPP XXIb, Kab.Barito Utara	1985	214.468	1:100.000	Kampsax Int/Amythas - Phi Beta - Ditjen Pankim Dep.Trans	Soil map & report booklet
6	Sebagian Barito Utara & Kapuas	1994	1.000.000	1:100.000	Bappeda Tk.I Kalteng - Puslittanak	Soil map & report booklet
SOUTH KALIMANTAN PROVINCE						
1	Het Gebied ten Noordcosten van Pengaron	1930	15.000	1:100.000	Razoux Schultz, F.H.N (BI)	Soil map & report booklet
2	Samu gebied, het midden en het, boven Kendilo gebied en Pasir	1938	42.000	1:100.000	Indenburg, A.G.A (BI)	Soil map & report booklet
3	Delta Pulau Petak	1972	250.000	1:100.000	Soepraptohardjo, M	Soil map & report booklet
EAST KALIMANTAN PROVINCE						
1	Tanjung Plateau	1949	-	1:100.000	Van Soelen, W.J (BI)	Soil map & report booklet
2	Tenggarong, Kab.Kutai	1983	307.500	1:100.000	Transmigrations Area development	Soil map & report booklet
3	Mensalong WPP Ib, Kab.Bulungan	1983	182.980	1:100.000	Faperta UNPAD - Ditjen Cipta Karya PU	Soil map & report booklet
4	Ambau - Salimbatu WPP V, SKP A, Kab.Bulungan	1983	17.313	1:100.000	PT.Salti Eng - Ditjen Cipta Karya PU	Soil map & report booklet

No	Site	Year	Area (Ha)	Map Scale	Executor	Notes
5	Ambau - Salimbatu WPP V, SKP B, Kab.Bulungan	1983	13.650	1:100.000	PT.Salti Eng - Ditjen Cipta Karya PU	Soil map & report booklet
6	Ambau - Salimbatu WPP V, SKP C, Kab.Bulungan	1983	11.301	1:100.000	PT.Salti Eng - Ditjen Cipta Karya PU	Soil map & report booklet
7	Muara Biawu WPP XV, Kab.Pasir	1985	98.827	1:100.000	PT.Lenggogeni – Ditjen Pankim Dep.Trans	Soil map & report booklet
8	Sesayap WPP Ib, Kab.Bulungan	1985	131.320	1:100.000	Pedicinal - Ditjen Pankim Dep.Trans	Soil map & report booklet
9	Long Iban WPP IV, Kab.Bulungan	1985	121.180	1:100.000	Pedicinal - Ditjen Pankim Dep.Trans	Soil map & report booklet
10	Kuran Sumukut/Long Isan WPP VIIIb, Kab.Bulungan & Berau	1985	-	1:100.000	PT.Ninse Multi Dimensi - Ditjen Pankim, Dep Trans	Soil map & report booklet
11	Manubar WPP Xg, Kab.Kutai	1985	94.768	1:100.000	PT.Nusa Consultant - Ditjen Pankim, DepTrans	Soil map & report booklet

4. Methods and Steps to determine the presence of peat, its delineation and area

For Sumatra, the information to be presented in the Atlas comprises a collection of peat swamp distribution maps for 1990 and 2002.

In compiling the atlas of peat distribution in Sumatra, a variety of available supporting data (such as maps resulting from soil mapping surveys carried out by a number of state and private institutions, including universities) were used as reference. Particularly significant were the supporting data provided by the Soil and Agroclimate Research Centre in Bogor, which published "Peta Satuan Lahan dan Tanah skala 1:250.000" (Soil and Land Mapping Units, scale 1:250,000) together with their explanatory booklet for the whole of Sumatra in 1990. These maps and information were processed and analysed to form the primary source of data for presenting peat distribution maps showing conditions in 1990 (as the input maps had been published in 1990). By analysing this data for 1990 conditions (and also for 2002 conditions, as explained in 3.3.1 above) the dynamics/changes in peat distribution and characteristics over the 12 years from 1990 to 2002 could be determined. The dynamics of these changes covered the following parameters: changes/shrinkage in peatland area, changes in peat thickness (thickness decreased as a result of subsidence and/or fire), changes in land use, loss of the peat layer especially in areas of shallow and very shallow peat (<50 cm) as a result of agricultural use.

The methods and steps used to compile the peatland distribution maps were as described below :

4.1. COLLECT AND STUDY MAPS AND THEIR REPORT BOOKLETS CONTAINING INFORMATION ON PEAT SWAMP LANDS AND THEIR DISTRIBUTION

4.1.1. Peta Rupabumi Indonesia (Digital) maps scale 1:250,000 published by Bakosurtanal from 1986 to 1990 for the whole of Sumatra

For the entire mainland area of Sumatra 43 digital rupabumi/topographic maps were used (see Table 3), while those for the small islands off the east and west coasts of Sumatra were not used as the area of peatland there was too small to be mappable at a scale of 1:250,000. The digital RBI maps required further editing to accommodate landscape conditions existing at the

time of mapping (2002), in particular the network of main roads connecting provinces and districts (kabupaten), river networks, coastlines, and urban spread. Coastal plains near river estuaries flowing directly into the sea showed the most dynamic changes/growth as a result of erosion upstream and sedimentation downstream. The main source of data used for updating detailed information was satellite imagery (as explained in 3.3.1 above) and data/information obtained from field studies. Peatland distribution maps were prepared for each province (8 provinces) and for the whole of Sumatra Island by combining and generalising several 1:250,000 scale maps, the final maps being designed for presentation in Ao size format (Ansi E: 34 x 44 inch or 86.4 – 111.75 cm).

Information/sketches of the administrative divisions of each province and kabupaten district in Sumatra were obtained from the map of regional administrative divisions published by Bappenas in 1986. However, as some of these divisions had changed as a consequence of the decentralisation of government, maps bearing updated boundary information were obtained from the local Bappeda office during field visits, while also seeking confirmation and input/suggestions from Bappeda staff in order to complete and perfect the draft peatland distribution maps. A list of the RBI maps of Sumatra is presented in Table 3, and their distribution in Figure 1.

4.1.2. Peta Rupabumi Indonesia (Digital) maps scale 1:250,000 published by Bakosurtanal from 1990 to 2002 for the whole of Kalimantan

Peta Rupabumi Indonesia (Digital) maps on a scale of 1:250,000 were published by Bakosurtanal from 1990 to 2000. For the entire Kalimantan mainland 48 digital RBI/topographic maps were used (Table 2), while maps for islands Padang Tikar and Tanjung Pasir (West Kalimantan) and Pulau Laut were not used as the areas of peatland there were too small to be mappable at a scale of 1:250,000. The digital Rupabumi maps required further editing to accommodate landscape conditions existing at the time of mapping (2002), in particular the network of main roads connecting provinces and districts (kabupaten), river networks, coastlines, and urban spread. Coastal plains near river estuaries flowing directly into the sea showed the most dynamic changes/growth as a result of erosion upstream and sedimentation downstream, especially the Kapuas estuary at Pontianak and the Mahakam estuary at Samarinda, Kaltim. The main source of data used for updating detailed information was satellite imagery (ranging from 2001 to 2002, see explanation in 3.3.2 above) and data/information obtained from field studies. Peatland distribution maps were prepared for each province (4 provinces) and for the entire Indonesian part of Kalimantan Island by combining and generalising several 1:250,000 scale maps, the final maps being designed for presentation in Ao size format (Ansi E: 34 x 44 inch or 86.4 – 111.75 cm).

Information/sketches of the administrative divisions of each province and kabupaten district in Kalimantan were obtained from the map of regional administrative divisions published by

Bappenas in 1986. However, as some of these divisions had changed as a consequence of the decentralisation of government, maps bearing updated boundary information were obtained from the local Bappeda office during field visits, while also seeking confirmation and input/suggestions from Bappeda staff in order to complete and improve the draft peatland distribution maps. A list of the RBI maps of Kalimantan is presented in Table 2 and their distribution in Figure 2.

4.2. COMPILATION OF BASIC MAP FOR THE PRESENTATION OF PEAT DISTRIBUTION MAPS

To prepare basic maps that would then be used for the presentation of peat swamp land distribution, digital data was processed as follows.

The Peta Rupabumi Indonesia maps from Bakosurtanal are generally presented in mapsheet format (e.g. mapsheet 1713- Kandangan- Kalimantan). This mapsheet for Kandangan covers 2 provinces: Kalimantan Tengah (to the west of the map) and Kalimantan Selatan (to the east). To prepare maps of peat distribution per province, therefore, required the amalgamation of several RBI maps. When joining the edges of these, elements of the landscape, such as roads and rivers, did not match up and the toponomy was even different. In these cases independent data was needed to match and join up these elements, by analysing data from satellite imagery. The process of matching the map sheets and edges was done within the program packet Geographic Information System (GIS), using the 'editing' and 'edge adjustment' modules; any remaining gaps needed to be joined up through computerised digitation. Several mapsheets were combined into a single unit describing the distribution of peat in one province (generally, 7 to 20 mapsheets of 1:250,000 scale were combined for one province). For handy use, this map was formatted as one mapsheet and presented in hardcopy form size Ao (34 x 44 inches). This entailed generalisation and reformatting. To achieve this and to ensure that the information was understandable to the user, the font sizes, line sizes, geographic coordinates and map title had to be adjusted, which required map layouting.

4.3. COMPILATION OF PEAT MAPS/DATA, PROCESSING, ANALYSIS, EVALUATION, STANDARDISATION OF INFORMATION/SCALE, PRESENTATION IN MAP FORM (MATURITY LEVEL, DEPTH, BD, LAND USE AND DISTRIBUTION)

Data/information containing the spatial distribution of peat swamp lands, peat soil/land characteristics were generally taken from soil maps and surveys at several levels (detailed reconnaissance scale 1:100,000, reconnaissance scale 1:250,000 up to exploration scale 1:1,000,000). These maps were used as a primary source of data for presenting information on peat swamp land distribution and as a reference for the analysis of satellite imagery in

detecting the existing conditions of the peat swamp lands and their distribution (see Table 8 for a list of reports/maps used as reference).

These maps, together with their legend, explanatory booklet and/or report booklet, contain information on: peat distribution, maturity level, depth/thickness, general chemical properties and fertility. However, as the mapping level varies (depending on the purpose of mapping) the information presented also varies. For example, the information on peat thickness given in one source distinguishes only 2 classes: less than 2 metres and more than 2 metres, while another source classes peat thickness as: Very shallow (<0.5 m) or deep (> 4 m). Such data cannot be used directly as they stand, but nevertheless, peat thickness still needs to be classified. For the purposes of the atlas, this was done as follows. For Sumatra 5 classes of peat thickness are used: <50cm, 50-100cm, 100–200cm, 200–400cm, and >400cm. For Kalimantan, where the peat is deeper/thicker, the classification is into 6 classes: <50cm, 50–100cm, 100–200cm, 200–400cm, 400-800cm and 800-1200cm or over.

In seeking information on the location and characteristics of peatlands, reference was made to information within the particular site and spot (using geographic co-ordinates). Information, peatland characteristics and soil properties at each site/spot followed those given in the information booklet or legend being used as reference, except that the lines showing distribution boundaries were drawn on the basis of the results obtained from the analysis of satellite imagery.

In order to standardise the maturity levels and BD of the peat, the following approaches were taken.

Alternative 1: First priority was to obtain information on peat maturity level and BD accompanied by detailed results of their laboratory analysis.

Alternative 2: If the information was not accompanied by detailed laboratory results, further data was sought from the institution that had carried out the mapping (priority being given to agricultural institutions). The accuracy level of data will be higher where the data was obtained from field surveys carried out by the writer.

Alternative 3: If the information on peat characteristics differed from one reference to another, the information quoted was the one given in the majority of the sources.

4.4. SATELLITE IMAGERY ANALYSIS TO DETECT PEATLAND DISTRIBUTION

Before the satellite imagery could be analysed for information related to peatland and its distribution, certain characteristics of the satellite data/images needed to be corrected first in order to sharpen/clarify the scale (geometric measurements) and data quality, so that the

detailed information to be analysed would not contain significant deviations and would correspond closely to the actual conditions in the field. Geometric corrections were made (length, breadth and area) to rectify errors in measurements so that the geometry would match actual field conditions as closely as possible. The reference used was the topographic Rupabumi Indonesia maps ranging in scale from 1:50,000 to 1:250,000 published by Bakosurtanal. The corrections were made by matching up the geographic positions (co-ordinates) on the satellite image to those on the corresponding RBI map. Certain reference points, such as road junctions, river bends and other relatively permanent landmarks were also matched up by super-imposing them onto the same reference point on the RBI map, which was considered to be to correct scale (distance, breadth, area). In this way, once the geometry had been corrected with reference to the topographic maps, the accuracy of scale was then assumed to be the same as that of the reference maps used to correct them.

Image enhancement was carried out to ensure that the image appearance /performance would as far as possible match actual field conditions, thereby minimising deviations in the analysis and interpretation of information related to the characteristics and distribution of peat swamp lands. Image enhancement is the process of removing deviations that occurred at the time when the data was recorded by the satellite, as a result of weather disturbances, haze, effects due to the earth's rotation and satellite movements, and so on.

Analysis of the presence and distribution of peat swamp land was carried out as follows:

1. Using reference soil maps resulting from mapping surveys performed by trusted institutions (Puslitanak, IPB, UGM, PU and others).

   For a map to be used as reference, it was a prerequisite that it should be accompanied by a detailed laboratory analysis of soil samples, detailed information about the site/location where each soil sample was taken, and an analysis of its morphology. In compiling the peat distribution atlas, soil maps that lacked information on soil sample analysis results, sampling sites and morphology were not used as reference.

2. Analysis using 'Crop community' as a spectral signature.

   The presence of peat swamp land is characterised by several specific environmental conditions: it is permanently inundated and there is a piling up of organic material with the result that the vegetation growing on and tolerant to peat soil is also specific (e.g. jelutung, belangeran, etc.). In satellite images, peat swamp land shows a uniformly fine tone and texture reflecting the uniformity of the species of vegetation cover (crops cover types similarity) growing there. A dark tone indicates that the site comprises accumulated organic matter and is permanently wet. The darker the tone, the deeper the peat is thought to be (qualitative information). How deep it is (quantitative information) has to measured in the field (ground truthing). The closer together the field measurements of peat depth (also of the peat's physico-chemical properties), the more detailed the information obtained as to the peat's depth and characteristics.

3. Analysis of peat distribution and characteristics by extrapolation.

   Parameters that can be investigated from images as explained in 1 and 2 above include: tone, texture, performance and spectral signature that appear on the image of each site. The results thus obtained can then be used as a reference to identify the distribution of peat having the same characteristics and performance in other areas on the scene or satellite image sheet (extrapolation approach).

4.5. COMBINATION OF DATA ON PEATLAND BIO-PHYSICO-CHEMICAL CONDITION OBTAINED FROM THE LITERATURE STUDY WITH THOSE ON DISTRIBUTION, DEPTH AND LAND-USE TYPE OBTAINED FROM SATELLITE IMAGE ANALYSIS

This section will discuss the stages in the production of the draft basic 1:250,000 scale Map of peatland characteristics drawn by combining the results of the literature study and satellite image analysis. The stages were as follows:

1. The basic map (using UTM projection) is used to present spatial information resulting from satellite image analysis (satellite image projections were synchronized when geometric corrections were being made). This information comprises peatland distribution according to depth, classified over a range of 6 classes: 50cm, 50–100cm, 100–200cm, 200-400cm, 400–800cm, and >800cm).

2. After the results of the satellite image analysis had been entered onto the basic map (scale and projection having been synchronized and corrected), information from the literature study (such as: peat maturity level, carbon content and BD) was then entered onto each polygon or mapping unit, with reference to the site/geographic position on the basic map. Some polygons remained unfilled where the data was incomplete or no survey or mapping had yet been carried out.

4.6. GROUND TRUTHING

4.6.1. Aims

- To check the truth and accuracy of the satellite image analysis/interpretation of peat distribution and depth (to validate qualitative information so that it could be converted into quantitative information)

- To monitor and check the truth of information on peat maturity level in the literature as compared to the actual condition in the field. Where there was a discrepancy, the field observation data was taken as true.

4.6.2. Validation points & constraints encountered

In deciding on the sites and routes for ground-truthing and on the intensity of field monitoring, the following were taken into consideration:

- The number of teams and the effective number of ground-truthing days
- Ideally, each mapping unit should be visited and monitored in the field; if the polygon is considered large, monitoring should be performed at more than one site within it
- The monitoring route should represent several classes of peat depth and maturity
- The monitoring route should give priority to areas where data is limited, but should also include some transects representing areas that do have data in order to check the accuracy of the data collected.

4.6.3. Intensity of field monitoring (number of monitoring points and level of accuracy)

The intensity of field monitoring (number of monitoring points and level of accuracy) depends on the map scale required. Ideally, according to the principles of ground based mapping, peat swamp land distribution mapping should include a minimum size delineation of 0.4cm2 (Buurman and T.Balsem, 1990). This minimum is for all scales of mapping. Thus, on a peat distribution map scale 1:100,000 the minimum information size that can be presented is 40ha. Ideally, therefore, each monitoring site should represent detailed information for a minimum of 40ha. For a 1:250,000 scale map, the monitoring site should represent 250 ha., while for a 1: 1 million scale map each site should represent an area of 4,000 ha.

However, there are several constraints that make this impossible to do. Resolution using remote sensing technology assumes that each area having the same spectral signature also has the same peatland characteristics. With the remote sensing approach, each polygon (whatever its area) must possess at least one representative; if the area is very large, it is advisable to have more than one representative. The closer together and more intensive the field monitoring points, the more accurate the map will be. For the peat distribution maps of Sumatra and Kalimantan, generally 2-5 ground truth sites were established for each area of 10,000 ha and collection of field data on peatland characteristics, not including supporting data compiled from the various references and literature.

4.7. POST GROUND-TRUTHING ACTIVITIES

4.7.1. Re-analysis and map revision, compile and consolidate classification of peat swamp land characteristics

Not all mapping units resulting from satellite image analysis/interpretation and other relevant supporting data are consistent with the actual conditions in the field. Inconsistencies occur, for example, in the borders of peatland spread and in the peat thickness legend. Ground-truthing was carried out mainly in areas where doubts had arisen during analysis/interpretation, in order to avoid misinterpretations and resolve these doubts. After this had been done, the peatland maps resulting from satellite image analysis were reviewed and the data/information from field findings entered. In certain areas, the satellite images were re-analysed to correct the (provisional) desk study results with field data and laboratory soil sample analyses. Subsequently, the 1:250,000 scale map of peatland distribution was produced; and from this map (plus information on peat thickness, BD and C-organic content) the area and carbon content of each type/class of peat maturity and thickness were calculated.

4.7.2. Determination of area, delineation and distribution of peatland

Measurement to determine the land area covered by each class of peat (maturity and thickness) cannot be done by directly multiplying length by breadth, but must take into account the topography of the land; this is related to the projection used for the basic map, in this case the 1:250,000 scale Rupabumi Indonesia UTM projection map published by Bakosurtanal. With this projection, a tract of land is described as a flat area (where the site measured in the map has the same scale for length and breadth). The peatland areas for Sumatra and Kalimantan were calculated automatically by computer based on the area of each mapping unit presented in the basic RBI 1:250,000 maps.

Examples of the calculation of peatland distribution area for a range of depth and maturity classes for Sumatra and Kalimantan are presented in Table 10 and Table 11.

Table 10. Distribution and Area of Peatland in Sumatra, 1990

No.	Peat		Total Peat Area in each Province (hectares)								Total	
	Thickness	Peat Type	Riau	Sumsel	Jambi	Sumut	Aceh	Sumbar	Lampung	Bengkulu	Hektar	%
1	Shallow	Hemists/ Saprists	-	49.355	-	-	-	-	-	-	49.355	
2		Hemists/ mineral	59.333	16.846	92.250	47.212	2.219	89.353	-	3.588	311.071	
3		Saprists/ mineral	16.861	-	-	-	-	-	-	-	16.861	
		Subtotal :	76.194	66.201	92.250	47.212	2.219	89.353	-	3.588	377.287	5,23
		%	20,2	17,6	24,5	12,5	0,6	23,7	-	1,0	100,0	
4	Moderate	Fibrists/Saprists	4.070	-	-	-	-	-	-	-	4.070	
5		Hemists	-	86.411	-	-	-	-	-	946	87.357	
6		Hemists/ Saprists	1.090.577	311.258	198.966	-	-	22.735	-	10.820	1.634.357	
7		Hemists/ mineral	26.302	817.300*	5.562	30.622	27.853	-	87.567	9.556	1.004.762	
8		Saprists	26.652	64.370	-	17.847	-	-	-	-	108.869	
9		Saprists/ Hemists	81.603	-	-	22.185	141.104	20.082	-	-	264.974	
10		Saprists/ mineral	95.222	84.217	3.093	157.730	6.601	-	-	10.209	357.072	
		Subtotal :	1.324.426	1.363.556	207.621	228.384	175.558	42.817	87.567	31.531	3.461.461	48,06
		%	38,3	39,4	6,0	6,6	5,1	1,2	2,5	0,9	100,0	
11	Deep	Hemists	-	-	-	2.201	-	-	-	-	2.201	
12		Hemists/ Saprists	203.040	45.009	293.875	5.298	36.597	1.833	-	6.982	592.633	
13		Hemists/ mineral	-	-	-	-	-	-	-	5.786	5.786	
14		Saprists	1.314	-	-	40.470	-	-	-	-	41.784	
15		Saprists/ Hemists	370.989	-	22.430	1.731	59.677	20.366	-	-	475.194	
16		Saprists/ mineral	-	8.896	-	-	-	-	-	13.100	21.997	
		Subtotal :	575.343	53.905	316.305	49.699	96.274	22.199	-	25.867	1.139.595	15,81
		%	50,5	4,7	27,8	4,4	8,4	1,9	-	2,3	100,0	
17	Very deep	Hemists/ Saprists	827.419	-	70.212	-	-	55.865	-	2.066	955.562	
18		Hemists/ mineral	-	-	30.180	-	-	-	-	-	30.180	
19		Saprists/ Hemists	1.240.219	-	-	-	-	-	-	-	1.240.219	
		Subtotal :	2.067.639	-	100.392	-	-	55.865	-	2.066	2.225.961	30,90
		%	92,9	-	4,5	-	-	2,5	-	0,1	100,0	
Total			4.043.602	1.483.662	716.838	325.295	274.051	210.234	87.567	63.052	7.204.304	100.0
%			56,13	20,59	9,95	4,52	3,80	2,92	1,22	0,88	100,00	

Source : Peta Satuan Lahan dan Tanah seluruh Pulau Sumatra, (Soil and Land Mapping Units for the whole of Sumatra Island) 1986-1990 (42 sheet) (processed data)

Notes :

- Peat thickness: Shallow = 0.5 – 1 m; Moderate = 1.0 – 2 m; Deep = 2.0 – 4.0 m; Very deep > 4.0 m.
- In the Soil Taxonomy system (Soil Survey Staff, 1999), peat soils (Histosols) are based on the following degrees
  - decomposition of organic material classified into sub-order: Fibrists, Hemists, and Saprists.
  - Fibrists : raw/ not yet decomposed; Hemists : semi-decomposed; and Saprists : decomposed.
  - Sub-order Folists (organic litter on a layer of stones) not found.
- Peatland area for the whole of Sumatra Island was 7,204,304 ha including
  - peaty mineral (peat thickness <50cm): approximately 327,932 ha (classified as shallow peat
  - hemists/mineral + saprists mineral) and peatland deeper than 50cm: 6,876,372 ha.

* Including Bangka – Belitung: 31,778 ha.

Table 11. Distribution and Area of Peat Swamp Land in Central Kalimantan Province (Kalimantan Tengah)

No	Peat		Peatland Area in each ***Kabupaten*** District (in ha)									Total area	
	Thickness	Peat type	Barito Selatan	Barito Timur	Kahayan Hilir	Kotawr Barat	Kotawr Timur	Kapuas	Kating an	Seruyan	Suka-mara	Hectare	%
1	Very shallow	Hemists/mineral	---	---	---	---	19.385	19.268	---	37.337	---	75.990	
		Subtotal	---	---	---	---	19.385	19.268	---	37.337	---	75.990	2,52
		%	---	---	---	---	25,5	25,4	---	49,1	---	100,0	
2		Hemists/mineral	44.408	10.465	142.269	112.284	---	128.615	---	65.068	35.825	538.934	
3		Hemists/Sapists/min	---	---	---	17.400	---	---	---	103.543	3.931	124.874	
4	Shallow	Hemists/Fibrists/min	---	---	---	3.896	---	8.057	---	33.657	---	45.610	
5		Hemists/Fibrists	6.446	--	46.261	3.923	103.517	23.375	16.420	46.374	---	246.316	
6		Saprists/mineral	---	---	---	---	---	2.753	---	---	---	2.753	
		Subtotal	50.854	10.465	188.530	137.503	103.517	162.800	16.420	248.642	39.756	958.487	31,84
		%	5,3	1,1	19,7	14,3	10,8	17,0	1,7	25,9	4,1	100,0	
7	Moderate	Hemists/Fibrists	25.108	---	105.113	36.972	88.923	12.580	174.712	15.963	---	459.371	
8		Hemists/Fibrists/ Saprists	---	---	---	3.028	---	---	---	---	---	3.028	
		Subtotal	25.108	---	105.113	40.000	88.923	12.580	174.712	15.963	---	462.399	15,36
		%	5,4	---	22,7	8,7	19,2	2,7	37,8	3,5	---	100,0	
9	Deep	Hemists/Fibrists	63.882	14.351	11.227	89.596	129.799	65.413	122.736	21.611	56.363	574.978	
		Subtotal	63.882	14.351	11.227	89.596	129.799	65.413	122.736	21.611	56.363	574.978	19,10
		%	11,1	2,5	2,0	15,6	22,6	11,4	21,3	3,8	9,8	100,0	
10	Very deep	Hemists/Fibrists	11.226	---	394.776	---	20.211	136.483	88.794	9.603	---	661.093	
		Subtotal	11.226	---	394.776	---	20.211	136.483	88.794	9.603	---	661.093	21,96
		%	1,7	---	59,7	---	3,1	20,6	13,4	1,5	---	100,0	
11	Extremely deep	Hemists/Fibrists	18.445	---	96.114	---	---	52.208	110.927	---	---	277.694	
		Subtotal	18.445	---	96.114	---	---	52.208	110.927	---	---	277.694	9,22
		%	6,6	---	34,6	---	---	18,8	39,9	---	---	100,0	
Total			169.515	24.816	795.759	267.099	361.835	448.752	513.589	333.156	96.119	3.010.640	100,00
%			5,63	0,82	26,43	8,87	12,02	14,91	17,06	11,07	3,19	100,00	

Notes :

(1) Peat thickness : Very shallow = <0.5m; shallow = 0.5 - 1.0 m; moderate = 1.0 - 2.0 m; deep = 2.0 - 4.0 m; very deep = 4.0 - 8.0 m; extremely deep = >8.0 m;

(2) Peatland area for the whole of Kalimantan was 5,769,246 ha, including 189,448 ha of peaty mineral soil (depth <50 cm), and 5,579,798 ha of peat thicker than 50 cm.

(3) Peatland in Central Kalimantan province covered an area of 3,010,640 ha, or 52.18 % of the total peatland in Kalimantan.

4.7.3. Map formatting prior to printing, scale 1:250,000, for each province and the island

In each polygon of the peat distribution map, symbol(s) are assigned to describe the characteristics of the peatland at that site; these need to be explained in the legend. So that the user can read, use and understand the map, it must be produced in standard format with the addition of legend, lines of longitude and latitude, administrative boundaries, map title, map scale, compass directions, etc. Several 1:250,000 scale map sheets were combined to produce a single mapsheet per province and for the whole island. The digital data for these, if printed, is in Ao size format. Samples of provincial and island peatland distribution maps are presented in Figure 7, Figure 8, Figure 9 and Figure 10.

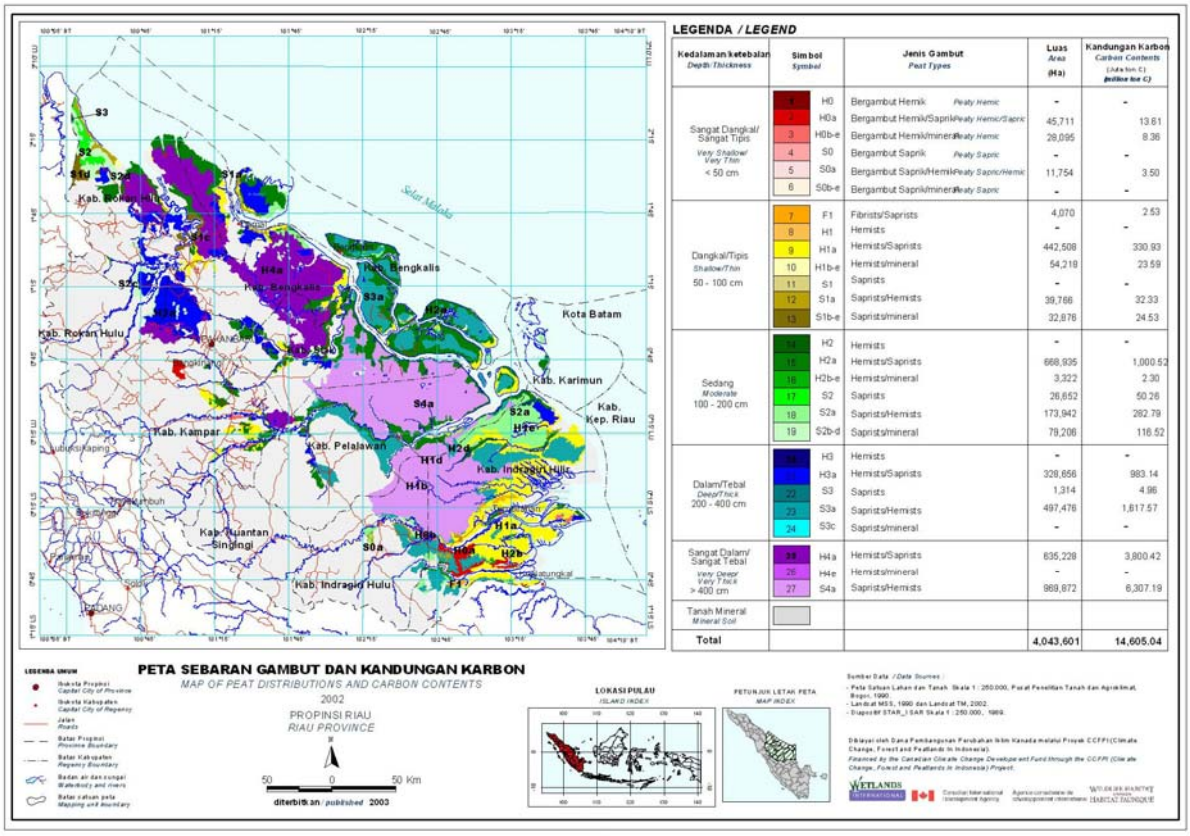

Figure 7. *Map of peat distribution and carbon content in Riau Province*

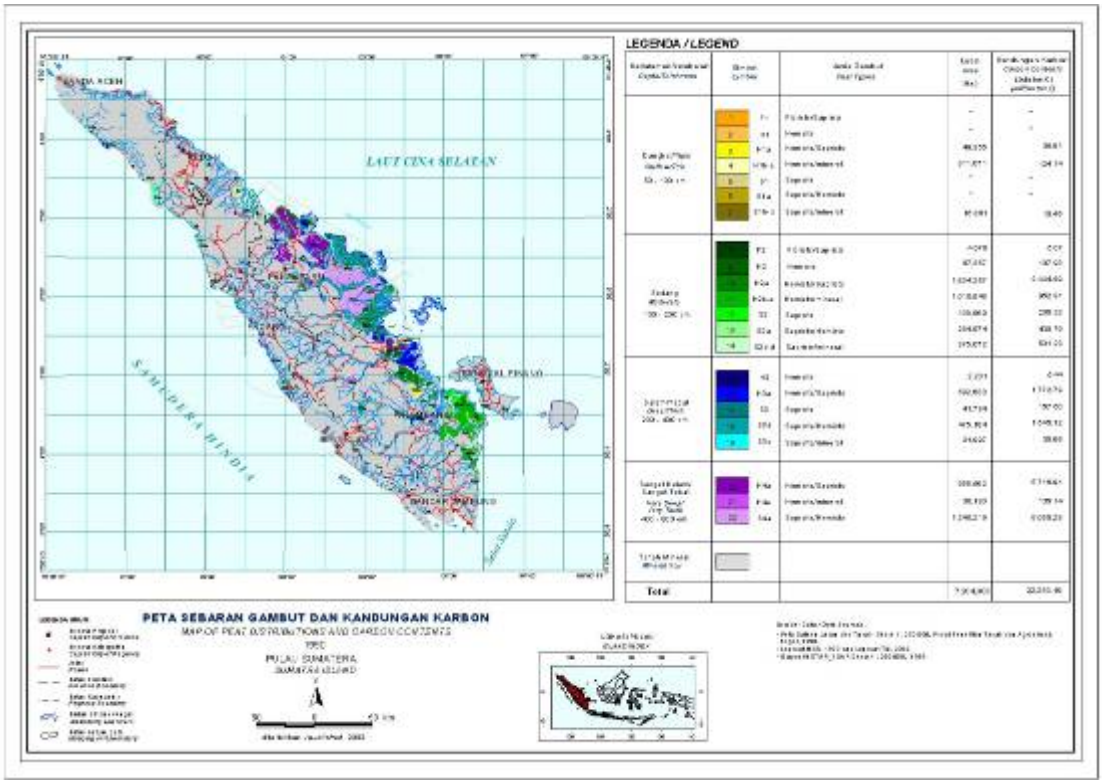

Figure 8a. *Map of peat distribution and carbon content in Sumatra, 1990*

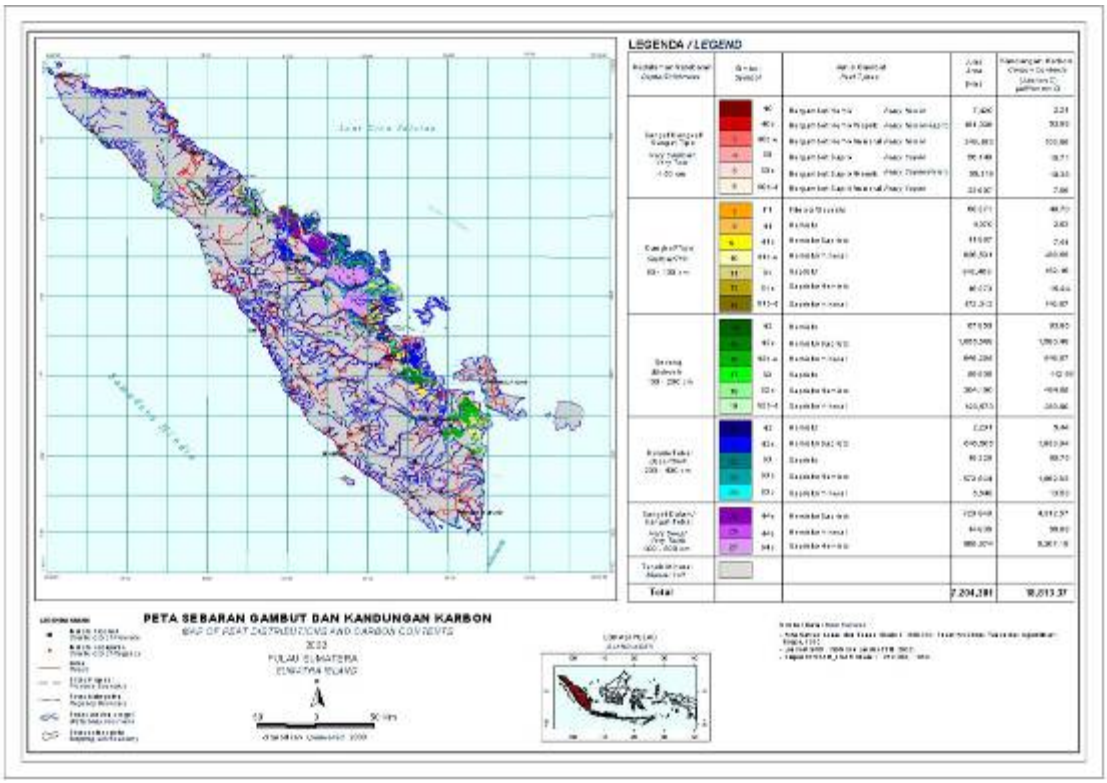

Figure 8b. *Map of peat distribution and carbon content in Sumatra, 2002*

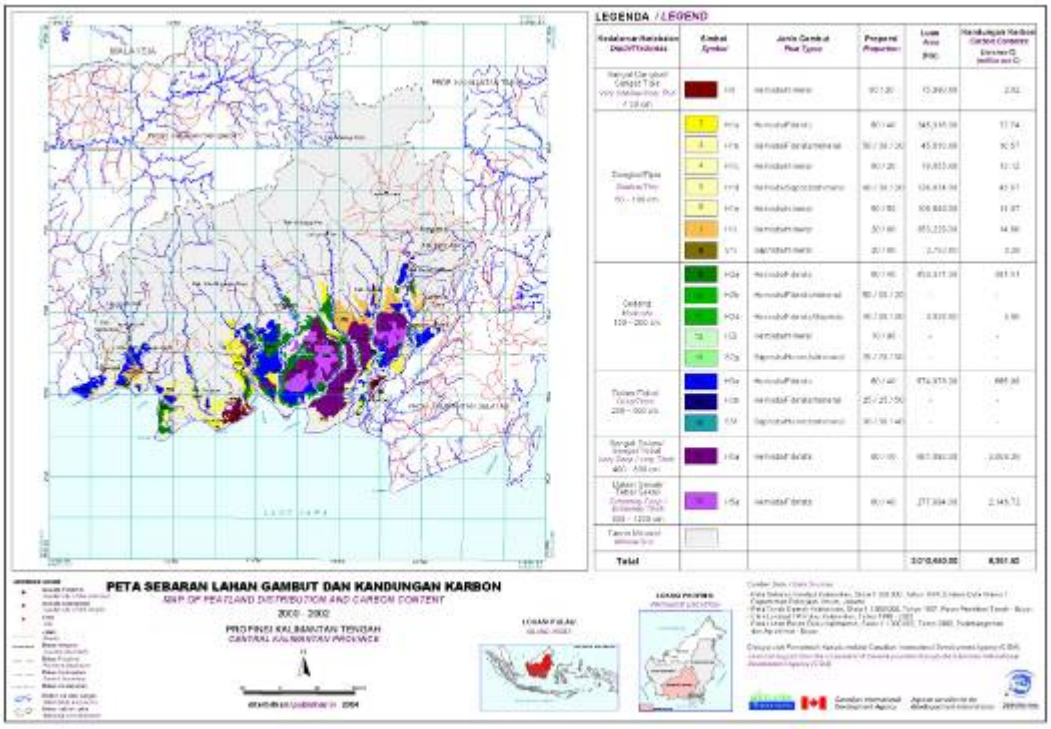

Figure 9. *Map of peat distribution and carbon content in Central Kalimantan Province*

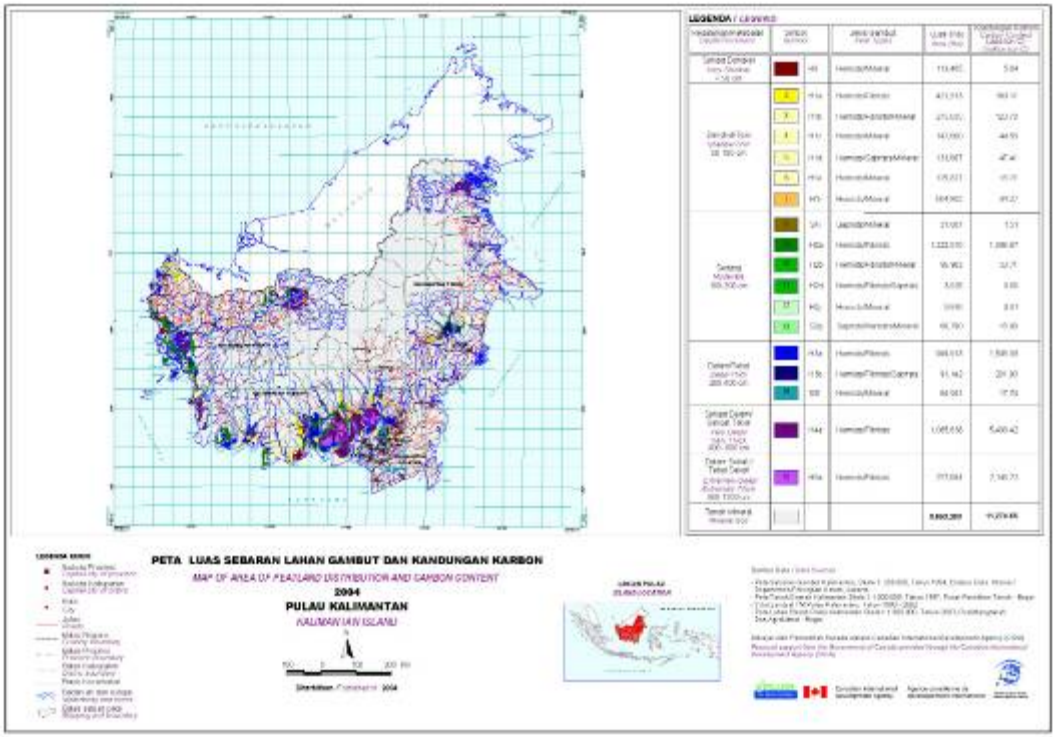

Figure 10*. Map of peat distribution and carbon content in Kalimantan*

4.8. CONSTRAINTS AFFECTING COMPILATION OF PEAT DISTRIBUTION MAPS/ATLAS

4.8.1. Landsat images (out of date, cloud cover, etc)

The satellite images used to seek information on peatland characteristics and distribution should ideally make use of images produced from the most recent recordings, so that the information presented is as up-to-date as possible, especially that on "current landuse". The current landuse conditions have a significant influence on the region's drainage which, in turn, affects subsidence and shrinkage in the thickness of the peat layer. The peat distribution maps presented here assume the condition of the peat swamp lands that were still covered by natural peat swamp forest at the time the satellite image was recorded.

In Sumatra and Kalimantan there are areas which are known to be covered in cloud throughout most of the year, so it is difficult to obtain satellite images that can describe the location of peatlands for the whole island within the same year. This was resolved by using a combination of satellite images taken over 2 or 3 consecutive years to produce the maps for 2002. Although these are labelled as the 2002 peat distribution maps for Sumatra and Kalimantan, in fact the satellite data used was that recorded during the period 2000- 2002.

4.8.2. Maps used

The maps and soil mapping reports used as reference for compiling the peatland distribution maps were the result of surveys accompanied by clear scale maps and the results of laboratory analysis of representative soil samples. A large number of soil mapping and survey reports, which lacked such maps and laboratory analysis, were therefore rejected.

4.8.3. Ground truthing limitations (area and intensity of observation)

Observations and current data collection in the field were done on a limited scale. On average, in a 10,000 ha area of peat swamp, 2-5 randomly selected sites were monitored and observed. The information for the peat distribution map for Sumatra Island is better than that for Kalimantan, because the supporting survey data and soil maps are more numerous than for Kalimantan.

4.8.4. Regional growth (changes to provincial and district boundaries)

The main data used to draw the kabupaten district and provincial boundaries were those published by Bappenas in 1986. To identify changes to these as a consequence of regional autonomy, efforts were made to obtain the latest updated administrative area map at the time of ground truthing. This was not always possible, however, so some of the new areas in provinces/districts that have grown could not be included in the peat distribution maps for both Sumatra and Kalimantan.

5. Estimate of Below Ground Carbon Store

Chapter IV gives a detailed analysis of the Methods and Steps to determine the presence, delineation and area of peat. Using the peat thickness data obtained from the 'desk study' as well as from direct measurements in the field (multiplied by data on area, see chapter IV) it was possible to determine the peat volume values. Subsequently, using other supporting data such as : maturity level, bulk density (BD) and organic carbon content, the below ground carbon stores could be calculated for the various districts and provinces of Sumatra and Kalimantan.

5.1. ACQUISITION OF DATA FOR KEY PARAMETERS

In calculating the below ground carbon store for peat in Sumatra and Kalimantan (see formula below), the values used for BD and C-organic content were derived from reports containing data from previous research (e.g. data from Institut Pertanian Bogor, Pusat Penelitian Tanah, WIIP etc). From these various sources of data, Wahyunto et al (2004) tabulated BD and C-organic values for a range of maturity/decomposition levels of peat soils in Sumatra (see Table 12) and Kalimantan (Table 13). These values can each be used to calculate carbon store for peatland areas in Sumatra and Kalimantan and perhaps also (if corrected by ground-truthing) for other parts of Indonesia.

Table 12. Values of BD and C-organic for different maturity levels of peat in Sumatra (Wahyunto *et al* -WIIP, 2004)*

No.	Peat maturity level	Bulk Density (BD) (gr/cc)		C-organic (%)	
		Range	Average	Range	Average
1.	Fibric	0.1012-0.12	0.1028	-	53.31
2.	Hemic	0.1325-0.29	0.1716	38.97-51.87	48.00
3.	Sapric	0.2492-0.37	0.2794	28.96-53.89	44.95
4.	Peaty mineral soil/ very shallow	0.2152-0.6878	0.3402	28.96-39.81	35.12

Table 13. Values of BD and C-organic for different maturity levels of peat in Kalimantan (Wahyunto et al -WIIP, 2004)*

PEAT MATURITY	BULK DENSITY (Gram/cc)		C-CONTENT (%)	
	Range	Average	Range	Average
Fibric	0.11-0.33	0.13	35.6 - 49.6	42.6
Hemic	0.13-0.38	0.23	17.5 - 54.9	36.2
Sapric	0.26-0.33	0.27	13.2 - 57.8	35.5
Peaty mineral soil/ very shallow	0,30 – 0,40	0,32	26,85 – 32,55	30,75

*) Data in these two tables were collected from a range of survey reports by other parties, as well as laboratory analysis reports on several peat samples taken by Puslitanak and WIIP during 2002 – 2004.

From the tables above it can be seen that the higher the level of peat decomposition/maturity the higher also the BD value, but the lower the C-organic content.

5.2. FORMULA FOR ESTIMATING BELOW GROUND CARBON STORE

The parameters used to calculate the size of the below ground carbon store in peatland are: peatland area, depth/thickness of the peat soil, bulk density (BD) and carbon store (C-organic) for each type of peat soil. The equation used is:

Below ground carbon store (KC) = B x A x D x C

where :

KC = carbon store, in tons
B = Bulk density (BD) of peat soil in gr/cc or ton/m3
A = Area of peat soil, in m2
D = Peat thickness, in m
C = Carbon content (C-organic) as percentage (%)

5.3. EXAMPLE OF CALCULATION

Table 14 below gives examples of the calculation of carbon store in East Kalimantan province for different peat maturity levels having different values of BD and C-organic.

From the table below it can be seen that in a peatland area of 49,534 ha, two different levels of peat maturity were found, i.e. Hemists/Fibrists (60/40) and shallow, meaning that 60% of this area of peatland is hemist and 40% fibrist. Hemist (denoted by 1 in the table) had a BD value of 0.14 ton/m3 and C-organic content 34.4%, while fibrist (denoted by 2) had BD 0.13 ton/m3 and C-organic content 43.8%.

Where a combination of peat and mineral soils was found, e.g. Hemists/Fibrists /Min (50/30/20), the mineral soil (non-peat) portion could be ignored in this context as it contains little or no C-organic. Therefore, only the hemist and fibrist portions were taken into account for calculating carbon store.

Table 14. Examples of calculation of carbon store for different peat maturity levels in East Kalimantan province

No.	Peat type, proportion and depth/thickness	Symbol	Area (ha)	Depth (Cm)		BD (ton/m3)		Proportion (%)		%C - org		Carbon store (ton C)		
				Interval	Average	1	2	1	2	1	2	1	2	Total
1	Hemists/Fibrists (60/40), shallow	H1a	49,534	50 -100	75	0.14	0.13	60	40	34.4	43.8	10,735,008	8,461,398	19,196,406
2	Hemists/Fibrists/ Min (50/30/20), shallow	H1b	4539	50 – 100	75	0.14	0.13	50	30	34.4	43.8	819,743	581,514	1,401,257
3	Hemists/Min (80/20), shallow	H1c	24121	50 – 100	75	0.14	0	80	0	34.4	0	6,970,004	-	6,970,004
4	Hemists/Saprists /Min (40/30/30), shallow	H1d	0									-	-	-
5	Hemists/Min (50/50), shallow	H1e	0									-	-	-
6	Hemists/Min (20/80), shallow	H1i	186335	50 -100	75	0.14	0	20	0	34.4	0	13,460,840	-	13,460,840
7	Hemists/Fibrists (60/40), moderate	H2a	25528	100 – 200	150	0.23	0	60	40	34.4	43.8	18,177,978	-	18,177,978
8	Hemists/Fibrists/ Min (50/30/20), shallow	H2b	0									-	-	-
9	Hemists/Fibrists/ Saprists (50/30/20), moderate	H2d	0									-	-	-

No.	Peat type, proportion and depth/thickness	Symbol	Area (ha)	Depth (Cm)		BD (ton/m3)		Proportion (%)		%C - org		Carbon store (ton C)		
				Interval	Average	1	2	1	2	1	2	1	2	Total
10	Hemists/Min (10/90), moderate	H2j	0									-	-	-
11	Hemists/Fibrists (60/40), deep	H3a	128561	200 -400	300	0.33	0.13	60	40	34.4	43.8	262,696,405	87,843,160	350,539,565
12	Hemists/Fibrists/ Min (50/30/20) deep	H3b	91142	200 – 400	300	0.33	0.13	50	30	34.4	43.8	155,196,598	46,706,629	201,903,227
13	Hemists/Fibrists (60/40), very deep	H4a	100224	400 – 800	600	0.33	0.13	60	40	34.4	43.8	409,587,425	136,962,109	546,549,535
14	Hemists/Fibrists (60/40), extremely deep	H5a	86981	800 – 12000	1000	0.13	0.13	60	40	34.4	0	233,387,419	-	233,387,419
Total			**696,965**	**Ha**								**1,111,031,422**	**280,554,811**	**1,391,586,232**

5.4. CONSTRAINTS AFFECTING CALCULATION OF CARBON STORE

As stated in the formula above, the results obtained from calculating carbon store (as given in the peat distribution Atlas for Sumatra and Kalimantan) are strongly influenced by the measurements obtained for the key parameters, i.e. volume, BD, C-content and peat maturity type, all of which are subject to both temporal and spatial variation.

With the increasing level of exploitation of Indonesia's peatlands from time to time and in different places, so the greater the level of change/variation in the values of these parameters. For example, if peat has been burned, drained, stripped of its trees, experienced a change in function, or been compacted thus becoming thinner (as peat volume reduced), its BD and C-content will change, as will its maturity level portion. With these temporal and spatial variations, the carbon store values calculated will also change (tending to fall) with time both at the same site and at different sites.

In view of the above, the level of accuracy for the carbon store values given in the Peat Distribution Atlas for Sumatra and Kalimantan is considered to be low, due to the following factors:

Peat thickness. Not all of the peat thickness values derive from systematic field measurements, while many were collected from research done by third parties at different times and measured in different ways. As a result, the information provided does not truly reflect the actual conditions.

Map Scale. As explained in chapter 4, the maps used were generally on a scale of 1:250,000. This is an extremely coarse measurement, as 625 ha is represented by just one observation, and during ground truthing (in Sumatra and Kalimantan) only 2 – 5 sites were visited to represent an area of 10,000 ha. In fact, in an area of 625 ha (and even more so 10,000 ha) there could be enormous variation in the depth and physico-chemical parameters of the peat.

In order to obtain carbon store estimates with a high level of credibility, the number of points/spots for measuring peat thickness and other parameters (C-content, BD and maturity) must be adequate. The presence of a peat dome and variable sub-surface level topography can also cause the number of observation spots and number of soil samples taken for analysis to vary. Below here follows a hypothesis regarding the accuracy level achieved if the total number of samples observed varies, and also the number of field workers needed.

From Tables 15 and 16 below, it can be seen that for a coarse map scale (1:250,000, exploration study) the potential for error in the data for estimating peat volume (and maybe other parameters too) is around 31.25% (because only 1 sample was taken per 625 Ha). However, such a coarse scale is also economical in terms of time, labour and cost, which can be extremely expensive when such a large area is being studied. How detailed a survey should be, therefore, depends on the purpose for which the data is to be used. If the intention is to calculate below ground carbon for the purposes of carbon trading (e.g. through the CDM mechanism), clearly a high level of accuracy in measurement is to be strongly recommended.

Table 15. Accuracy level as affected by number of observation points / samples

Map Scale	Category	Sampling Distance (m)	No of Samples	1 sample per Grid(m2)	Estimated subsurface topography variation (20 cm/100m)	Estimated max Accumulated Error (m) = sampling distance x tophography variation	Mean Accumulated Error	Estimated average Peat Depth in study area (m)	Error (%)
1:10,000	Super Detail	100	70,000	10,000	0.002	0.2	0.1	8	1.25
1:25,000	Detail	250	11,200	62,500	0.002	0.5	0.25	8	3.125
1:50,000	Semi Detail	500	2,800	250,000	0.002	1	0.5	8	6.25
1:100000	Reconnaissance	1000	700	1,000,000	0.002	2	1	8	12.5
1:250000	Exploration Study	2500	112	6,250,000	0.002	5	2.5	8	31.25

Table 16. Effect of accuracy level on the total size of the survey team (man-power) required

Map Scale	category/ degree of accuracy	measurement distance			1 measurement per grid (ha) area	Area surveyed Ha	Total No. of measurement	No. of work days available	No. of measurement per day	No. of measurement (team capacity/day)	No of team needed	No. of local labors needed
		M	m	M2								
1:10.000	Super Detail	100	100	10,000	1	70,000	70,000	20	3,500	7	500	2,500
1:25.000	Detail	250	250	62,500	6.25	70,000	11,200	20	560	7	80	400
1:50.000	Semi Detail	500	500	250,000	25	70,000	2,800	20	140	7	20	100
1:100.000	Reconnaissance	1000	1000	1,000,000	100	70,000	700	20	35	7	5	25
1:250,000	Exploration Study	2500	2500	6,250,000	625	70,000	112	20	6	7	1	4

BD values. There are at least 2 methods for determining BD, which are: the clod method (Golavanov A.J., 1967 Notohadiprawiro, 1983) where the measurements are made directly in situ in the field, or the ring core method conducted ex-situ in the laboratory at a temperature of 105oC for 12 hours and under a pressure of 33 – 1500 kPa, so that the soil becomes compact and stable. Of these, the clod method yields bigger BD readings (because the peat clod's moisture content is still high) than the ring core method. The peat distribution Atlas for Sumatra and Kalimantan does not clarify how the BD values obtained from research by other parties (secondary data) were measured, whether by clod or ring core method. This affects the accuracy of below ground carbon store calculations.

C-content values. The Atlas also uses peat %C-organic values resulting from laboratory investigations by several other parties (laboratories belonging to Indonesian universities, government & private research institutes, etc.). It is not known for certain whether or not these laboratories are accredited, so the accuracy of their measurements of %C-organic values is likely to differ from one to the other.

Peat maturity level. The Atlas only differentiates horizontal-polygonial variation in peat maturity level (dimension as seen from above) and this variation is expressed in terms of the percentages of the maturity levels which make up its composition, such as: Hemists/Fibrists/Min (50% / 30% / 20%). This assumes that the maturity level is the same vertically all the way down to the base of the peat layer. If in fact it is not the same, this will affect the BD and carbon store values.

6. Recommendations for Improvement

To obtain more accurate information at district (kabupaten) and even sub-district (kecamatan) level, a detailed scale (1:10,000 or 1:25,000) is needed. Such detailed mapping requires more intensive observation; for example, observations should be made and soil samples taken at intervals of 250m (1 sample per ha) to 500m (1 sample per 6.25 ha) so that the measurements of variations in thickness, peat maturity, BD values and carbon content can more closely reflect the actual conditions in the field. For this purpose, other supporting data are also required; these include satellite images and high resolution topographic maps. (Satellite images SPOT and ALOS respectively have a pixel size of 10 x 10 m and 5 x 5 m equivalent to topographic maps on a scale of 1:10,000 to 1:25,000). Nevertheless, this requires much longer time and an adequate number of mappers.

It is especially important to create a peat swamp land database that contains spatial and temporal data for key parameters resulting from field measurements (e.g. peat thickness, type of land cover, land use, presence and depth of drainage channels, peat maturity level, subsidence rate) and from laboratory analysis of peat soil samples (e.g. BD, carbon content). With such a database, it would be possible to trace changes in those parameters (both spatial and temporal) and subsequently in the carbon content values (both above and below ground). These parameters must of course be measured using standard methods and with a high level of accuracy.

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