Distribution, Properties, and Carbon Stock of Indonesian Peatland

Wahyunto[1)], Ai Dariah [2)] and Fahmuddin Agus[2)]

[1)] Indonesian Center for Agricultural land Research and Development, Ministry of Agriculture, Jalan Ir H.Juanda No.98 Bogor. 16123. West Java, Indonesia. Email: wahyunto_wt@yahoo.co.id, wahyunto2010@gmail.com

[2)] Indonesian Soil Research Institute, Ministry of Agriculture, Jalan Ir.H.Juanda No.98 Bogor.16123. West Java, Indonesia. Email: aidariah@yahoo.com (Ai Dariah), fahmuddin_agus@yahoo.com (Fahmuddin Agus).

Abstract: From the 188 million ha Indonesia land area, peatland occupies about 20.9 million ha, mainly distributed in Sumatra, Kalimantan, and Papua, storing between 33,000 to 55,000 Mt carbon. This paper describes the properties and carbon stock (C_{org}) of peatland areas of Indonesia based on surveys during the period of 2000 – 2009. Most of the peat soils are distributed in lowland areas, especially in stagnant coastal plains and in swale or lagoons that are separated from the sea by beach ridges. This paper emphasizes the properties and carbon stock (C_{org}) of peatland areas of Indonesia based on surveys during the period of 2000 - 2009. Results show that Indonesian peat soil has a wide range of carbon stock due to the variation in bulk density (BD) and peat depth. Peat maturity and C_{org} seem to influence the carbon stock less dominantly. Mean BD in selected sites in Kalimantan and Sumatra are 0.12 to 0.17 gram cm^{-3} respectively, with the more mature peat tends to have a higher BD. Drained peat, used for agriculture, tend to be more mature in the surface layer. Mean C_{org} (by weight) in East Kalimantan, West Kalimantan and Sumatra (Aceh and West Sumatra) for fibrists, hemists and sapric peat soil maturity were 41%, 45% and 53% for East Kalimantan site and 39%, 50% and 66% for West Kalimantan site, respectively. Sumatran fibric, hemic and sapric peat had C_{org} of 38%, 45% and 52%, respectively. Peat thickness varies widely and related with peat formation and processes of compaction and decomposition. Saprist and Saprist/ Hemists peat maturity stock soil carbon ranges from 293 to 699 ton ha^{-1} m^{-1}; Hemists - Hemists/ Fibrists peat maturity stock around 362 to 606 Mg ha^{-1} m^{-1}, while Fibrists – Saprists/Fibrists peat stock about 366 to 612 Mg ha^{-1} m^{-1}. With peat thickness ranging from 0.5 to 12 m, peat soil carbon stock may range from about 293 to 699 Mg ha^{-1} m^{-1}, reflecting peatland importance as a carbon pool.

Key words: peatland properties, C- organic content, BD, peat maturity, carbon stock

1. Introduction

Peat lands have great potential for carbon storage. From 188 million ha Indonesia land, peatland occupied about 20.9 million ha, mainly distributed in Sumatra (7.2 million ha), Kalimantan (5.8 million ha) and Papua (7.9 million ha) has a various peat depth, storing about 33,000 to 55,000 Mt carbon (Wahyunto et al., 2004 and 2005). Most of the peat soils are distributed in low land areas, e.g. in stagnant coastal plains and in swale or lagoons that are separated from the sea by beach ridges (Sabiham, 2008). Peatland forests are under tremendous pressure from agriculture/silviculture development and logging. Under natural forest condition, peatland is a net carbon sink, but deforestation which mostly involves fire and followed by drainage, drastically increase CO_2 emissions.

In general rule, peatland is a generic term of any wetland that accumulates soil organic from partially decayed plant matter (Lyon and Carthy, 1995; Mitch and Gosseling, 1986). The term of peat soil is classified as organic soil or a Histosols. Refers to " Key to Soil Taxonomy", Histosols is soil if more than half of the upper part 80 cm (32 in) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials (United States Department of Agriculture, 2010). It's indicates a wide range of below ground carbon stock in peatland. Peat depth and the influence of mineral layers determine dominantly the carbon content. Peat maturity and carbon content seem to influence the carbon stock less dominantly.

Peatland forested area in Indonesia is about 12.31 million ha, including of: (i) conservation forest area of 2.34 million ha, (ii) protected forest area of 1.02 million ha, and (iii) production forest area of 8.95 million ha. Peat land area used for plantation is about 1.42 million ha, used as an agricultural area of 1.23 million ha, and used for other activities is about 4.66 million ha (Bappenas, 2010). Action plan concerning on the reduction of GHG emissions in peatlands area as an integral part of the reduction of GHG emissions from the forestry sector.

This paper describes the properties and carbon stock (C_{org}) of peatland areas of Indonesia especiall for Sumatra and Kalimantan islands based on surveys during the period of 2000 - 2009. This information will be very useful in developing the baseline data of peat soil properties and its carbon stock. From this baseline data, changes in carbon stock can be determined relatively easier, however, high quality carbon stock databases, over a set a land cover that commonly found in Indonesia landscape is urgently needed. There is opportunity of compensation, especially through the Reducing Emissions from Deforestation and Degradation + (REDD+) if the carbon in the peatland such as peat forest could be conserved. Therefore planning the wise use of peatland with low carbon emissions will be a challenge in the future regional development.

2. Source of Peat Soil Data Used

Satellite images supported with available peatland maps were used to detect spatial distribution of landuse/ land cover over peatland areas, and estimated spatial distribution of peat depth possibilities. A number transects were drawn for field observation. The transects in general were perpendicular to streams or canal drainage toward the center of peat dome, and a number observation points were selected along each transect. Observations were included determination of the peat depth using peat measuring stick designed to reach the depth of 10m, the expected extreme peat depth. Peat samples were collected based on various types of land use/ land cover by using Eijkelkamp type of peat auger, for the determination of peat density and carbon content. Assessment of peat maturity was determined manually during field observation.

Each layer (with the 20 cm or 50 cm depth increment) of the selected peat samples were analyzed for bulk density (graphimetric technique), ash content (loss on ignition technique). Carbon organic content were calculated based on ash content (Agus, 2009a). Descriptions of peat soil characteristics such as: peat thickness, maturity, drainage depth, the type of substratum material, and agricultural potential land were developed based on the field observation, and secondary data from previous research (Balai Penelitian Tanah, 2004) as well as on the sample analysis for the current study.

Laboratory peat soil samples analysis were conducted to determine C-organic content, Bulk Density and ash content of: (1) 174 soil samples from 46 site for Nunukan District, East Kalimantan Province; (2) 245 soil samples from 31 site for Kubu raya and Pontianak District, West Kalimantan Province; (3) 39 soil samples from 9 site for Pesisir Selatan district, West Sumatra province; and (4) 94 soil samples from 15 sites for Krueng Tripa South West Aceh, Nanggroe Aceh Darussalam Province, are grouped based on peat maturity. The results of Soil samples laboratory analysis, field data observation related maps and reports are used as data base for this paper.

3.General Characteristic of Peatland

Peat in Kalimantan and Sumatra are belongs to the suborders of fibrists (least decomposed peat), Hemists (about half decomposed peat) and Saprists (highly/most decomposed peat). At the lower category, the most commonly found great groups are Haplofibrists, Haplohemists, Sulfihemists and Haplosaprists (CSARD 2004 and 2005; Centre for Soil and Agroclimate Research, 1999). The centre of virgin peat soils are always saturated by stagnant water. The fringe areas have less monotonous water regime, with drier areas near depressions due to gravity drainage of the immediate surroundings.

Indonesian low land peats started to accumulate on the flat coastal “clay blankets” (Verstappen, 1975), not more than 4000 to 4500 years ago when the rise of sea level that followed the last glacial period slowed down. Under the natural forest peat sequesters carbon and grows between 0.5 and 1.0 mm year^{-1}, while drained peat emits carbon and subsides at the rate of 1.5-3.0 cm year^{-1}. Since the subsidence rate is 15-30 times the rate of growth under the drained, deforested peat, the peat can not be defined as a renewable resources (Andriesse 1988). Peat stores carbon between 30 to 70 kg C m^{-3} or equivalent to 300 to 700 t C ha^{-1} per one meter depth (Agus et al. 2010). Peatland area of Sumatra is 7.2 million ha and its below ground carbon stock about 22,283 Mt or about 3,093 MgC/ha. Peatland area in Kalimantan is about 5.77 million ha and contains about 11,274 Mt below ground carbon or about 1,954 Mg/ha (Wahyunto *et al*., 2004 and 2005).

Important physical properties of the peat soils are bulk density, porosity, water holding capacity, subsidence, and irreversible shrinkage. Under saturated condition, the peat mass has a low bearing capacity, that create difficulty in tillage practices using machinery and/or animals drawn tools. Peat has a poor anchorage for tall perennial trees, causing trees to lean. This also creates problems with tree crops susceptible to lodging.

The rate of bulk density (BD) of fibrist, hemists and saprists peat soil maturity for Kalimantan are 0.01 to 0.26, 0.01 to 0.33 and 0.08 to 0.38 g cm^{-3} respectively. The rate of Bulk density of Fibrists, hemists and saprists peat soil maturity for Sumatra are 0.06 to 0.10, 0.02 to 0.16 and 0.05 to 0.36 gram cm^{-3} respectively (Table 1). Normally, higher degree of peat maturity will be followed by the high degree of Bulk Density. The value of C organic content based on soil samples laboratory analysis showed that the rate of C- organic content of fibrists, hemists and saprists peat soil maturity for Kalimantan are 25 to 61%, 18 to 63% and 25 to 72 % respectively. The rate value C- organic content of fibrists, hemists and saprists peat soil maturity for Sumatra are 23 to 60%, 43 to 68% and 25 to 60% respectively (Table 1). There is a tendency, higher in peat maturity will be followed by the high degree of C organic content. Further more, it is indicated increase in Bulk density value of peat soil will be followed by increasing the degree of peat soil maturity.

Carbon content and bulk density by degree of peat decomposition (maturity) levels is presented in Table 1. It shows that more decomposed peat tend to also have higher C-organic contents and higher bulk density.

Table 1. Peat soil carbon content and its bulk density by degree of decomposition

No.	Degree of Peat Decomposition	Bulk Density (g cm^{-3})		C Organic Content (%)	
		Range	Average	Range	Average
A.	Sumatra -*)				
1.	Fibric	0.06 – 0.10	0.08	23 – 60	38.5
2.	Hemic	0.02 – 0.16	0.09	43 – 68	45.5
3.	Sapric	0.05 – 0.36	0.18	25 – 60	52.5
B.	Kalimantan -1-*)				
1.	Fibric	0.01 – 0.14	0.07	37 – 61	41.0
2.	Hemic	0.01 – 0.32	0.17	18 – 63	45.5
3.	Sapric	0.08 – 0.32	0.20	25 – 58	53.5
C.	Kalimantan-2-**)				
1.	Fibric	0.09 – 0.26	0.18	25 – 54	39.50
2.	Hemic	0.15 – 0.33	0.22	37 – 63	50.0
3.	Sapric	0.26 – 0.38	0.32	60 – 72	66.0

Source: *) Wahyunto et al., 2007, Pusat Penelitian Tanah dan Agroklimat, 1989 and Reconnaissance Soil Survey of West Kalimantan (CSARD, 2004 and 2005)
**) Agus et al., 2009 and Dariah et al., 2009.

Most of peat are acid (pH 3 to 4.5), and contain less than 5 percent inorganic constituents (CSARD, 2004; Pusat Penelitian Tanah dan Agroklimat, 1999). Deep lowland forest peat in Indonesia appeared to consist for two-thirds of lignin with cellulose and hemi-cellulose accounting for only 1-10 percent of the dry sample weight (Istomo, 2005).

Type of land use/ land cover and its environments could be influenced the degree of Bulk density (BD) and C- organic content. The rate of BD of peatland under secondary forest, shurbs and bushes, sawah and oilpalm plantation, are ranges from 0.10 – 0.17; 0.14 to 0.16; 0.08 to 0.13 and 0.12 to 0.25 g cm^{-3} respectively. C organic content may ranges: from 37 to 41%, 45 to 72%, 38-45% and 35 to 49% respectively. With peat thickness ranging from 40 to 590 cm leading to peat carbon density are ranges : 446 to 753 t ha^{-1} , 451 to 724 t ha^{-1} , 227 to 633 t ha^{-1} and 496 to 975 t ha^{-1} respectively (table 2). Based on peat soil data laboratory analyzed (Table 2), showed that peatland under secondary forest, tend to have higher Bulk density and Carbon density compared to peatland under shurbs/bushes and sawah/ annual crops. However peatland under oilpalm plantation tend having higher BD and carbon density. This is indicated that intensive management on peat land and environmental drainage could significantly influenced on BD and carbon density of peat.

Table 2. Bulk Density and C organic content by various land use and peat thickness

No.	Land use/ land cover	Number of Transect	Peat Thick-ness (cm)	Bulk Density (g cm^{-3})	C Org Content (%)	C Density (kg m^{-3})	C Density (t ha^{-1} m^{-1})	Total carbon stock (t ha^{-1})
1.	Sec. forest	26	90 – 330	0.10 – 0.17	37 – 41	44 – 75	446 – 753	657.7 – 1150.4
3.	Shurbs & Bushes	7	40 - 580	0.14 – 0.16	26 – 42	45 – 72	451 – 724	219.8 – 279.2
2.	Sawah/ dry field	19	90 - 320	0.08 – 0.13	36 – 45	38 – 63	227 – 633	403.9 – 1117.8
4.	Oilpalm	12	80 - 590	0.12 – 0.25	35 - 49	49 – 92	496 – 975	738.6 -3633.4

Virgin peat can retain considerable quantities of water. However, if dried to the extent that adsorptive water is lost, irreversible changes occur in the colloidal components of the peat resulting in a marked and permanent reduction of the water retention capacity. Woody peat, generally nearly very permeable to water, compacted (reclaimed/ drained) peat have much lower for the degree of its permeability. Overheated peat becomes hydrophobic and shrinks to granules with undesirable physical and agricultural properties and a high sensitivity to erosion.

Natural peat need to be drained to permit the cultivation of dry land crops. Peat land in Indonesia are more commonly opened by individual farmers although some medium sized government sponsored projects have been carried out as well. Despite small capital inputs, farmers are sometimes more successful than government-inspired reclamation projects because they are more flexible in the selection of their locations and use less advanced but time-tested techniques. Farmers prefer shallow hand-dug drainage ditches than can be deepened as needed (Subagjo and Adimihardja, 2003; Departemen Pekerjaan Umum, 1997). In the first few years, after the removal of the natural vegetation, suitable annual crops may produce fair yields, thanks to the nutrients that are still contained in the surface of soil (and in the ashes of burnt plant material). After a few years, when subsidence of the land surface has slowed, tree crops and vegetables can be planted. They may grow satisfactory for some time but yields will eventually decrease if the land is not fertilized.

The types of mineral materials underlying the peat dictate inherent fertility of peats. They may consist of non-sulfidic clay, sulfidic (marine) clay or sandy substratum. Non sulfidic clay mineral materials underlying the peat are commonly found in inland peats, and considered as the better substratum. If the underlying substratum is quartz sand, then the peat soils have low to very low inherent fertility. When the mineral substratum in shallow peats is sulfidic and exposed to aerobic condition there is a possibility of formation of acid sulfate soils; a very poor peat for crop cultivation.

4. Lowland peats of Indonesia

- **Extent and distribution of low land peats**

Peat soils occur both in lowlands and highlands, however, distribution of highland organic soils is very limited, and their extents are not extensive, so they are excluded from this study. The greater part of the Indonesian lowlands and coastal peats are found on the so called Sunda shield which was formed in Palaezoic times. Lowland peat soils almost enterily occurs in low lying poorly depressions and basins in the coastal areas. The swampy depressions between the vaguely defined river levees became successively covered with mangroves and a swamp forest vegetation which built up thick dome shaped formations of ombrogenous peat (Anderson, 1976). Despite general in-fertility of the habitat the peat swamps are usually covered in dense forest which contains some valuable timber trees, notably ramin (*Gony-stylus bancanus*).

Spatial analysis of Landsat Thematic Mapper Satellite Imagery-7 series data in 2000-2002 were conducted to deleniate spatial distribution of peat swamp environment, which were supported by available topographic, lithologic and soil maps, followed by limited ground truth for Sumatra and Kalimantan islands. However, peatland map of Papua was generated without ground truthing because they are situated in remote areas and lack of acessibility (Wahyunto et al., 2004; 2005 and 2006). Spatial data information resulted from previous research were used as references to generate peatland maps, namely : (a) Land Units and Land status map at scale 1:250,000 published by Regional Physical Planning for Transmigration –RePProT, 1989 (b) Land unit and soil Maps at scale 1:250.000 for Sumatra Publised by Centre for Soil and Agroclimate Research, 1990 (c) Various soil maps resulted from soil survey and mapping were conducted by the Bogor Institute of Agriculture and Centre for soil Research Bogor. From the above study found that the peatland of Sumatra, Kalimantan and Papua are found in tree maturity levels, these are:'Fibrists' (lest decomposed), 'Hemists' (half-decomposed), 'Saprists' (highly decomposed) and / or mixed with one of the three. In Soil taxonomy system, soils are classified as the suborder level Fibrists, Hemists, and Saprists, and at great group classified as Haplofibrists, Haplohemists, and Haplosaprists. Peat soils in the tidal marsh zone, classified as Sulfihemists, or Sulfisaprists. In general, each unit map is an association of Hemists/minerals, Hemists/Fibrists, Hemists/Saprists /minerals, Saprists/Hemists, Saprists/minerals. The thickness of peat vary from shallow (<100 cm) to very deep (more than 400 cm). Especially in Central Kalimantan are found very deep peat soil with thickness more than 8 meters. Papua peatland indicated shallower than both islands and less dome formed.

Area of peat lands in Indonesia is estimated to 20.9 million hectares or about 10.8% of Indonesia's land area, with peat thickness <2 m about 66% and peat thickness > 2 m about 34%. It is approximately 7.2 million hectares or 35% are located in Sumatra Island, 5.77 million ha or 27.8% was found in Kalimantan, and 7,9 million ha or 37.2% are located in Papua (Table 3.). Small-scale map could lead to over-estimate or under-estimate the peatland area. However, more detail scale of peatland maps based on spatial data compilation from various surveys that have been conducted in Indonesia by the various government/private sector (Ministry of forestry, Ministry of Environment, Board of assessment and Application Technology-BPPT, Ministry of Public Work, Bakosurtanal, Lapan, NGOs) needed to update and upgrade the data distribution of existing peatland. For areas not yet surveyed, needs to quickly be programmed for peatland mapping at suitable multi purpose scale, based on satellite image interpretation following by ground truthing.

Major distribution of lowland peat area found along the strecthes of eastern coastal area of Sumatra and part of western coast of Sumatra, along western and southern coastal plain of Kalimantan. In Irian Jaya/ Papua they are found along the south-southeastern coastal lands (northeast of Merauke town), swamps areas surroundings of the Bintuni and Arguni bays (east of Fak-fak), and flat low lying northern coastal areas (Northeast of Nabire).

As can be notice from Table 3, major extents of peatland in Sumatra occur in the coastal plains of the Riau and south Sumatra provinces. In a less expand is found in the provinces of Jambi, and North Sumatra respectively. In West coast of Sumatra the peatlands is mostly situated along the coast of the districts of Aceh jaya, West Aceh, Northwest Aceh, South Aceh, Aceh Singkil, Pesisir Selatan of West Sumatra province and Muko-muko of Bengkulu province. In Kalimantan, large expands of peat land occur in the southern coastal plains of Central and South Kalimantan and western flat lying coastal areas of West Kalimantan province. Spatial distribution of Sumatra, Kalimantan and Papua peatland are presented in figure 1, figure 2 and figure 3 respecitively (Appendix Fig.1, Fig.2 and Fig.3).

In addition to basin peats of the coastal areas, there are some significant areas of basin peats of the interior. These inland basin peatlands are found in the upper watershed of Kapuas river, surroundings the town of Putusibau, in West Kalimantan; around Semayang and Melintang lake, (west Samarinda), in the middle watershed of Mahakam river in East Kalimantan, and along the stretches of Mamberamo river in Papua. In Sumatra are found along upper watershed of Siak and Kampar river.

Table 3. Extent and distribution of peatlands in Indonesia

No.	Island/ Province	Peat thickness <200 cm (ha)	Peat thickness >200 cm (ha)	Total Area of Peatland (ha)
A	SUMATRA			
1	Riau	1,611,055	2,432,546	4,043,601
2	South Sumatra	1,454,383	29,279	1,483,662
3	Jambi	387,052	329,787	716,839
4	North Sumatra	302,908	22,387	325,295
5	Nanggroe Aceh D	202,794	71,247	274,041
6	West Sumatra	146,250	63,984	210,234
7	Lampung	87,567		87,567
8	Bengkulu	60,212	2,840	63,052
	Total of Peatland	4,252,221	2,952,070	7,204,291
	Percentage	59.0	41.0	100.0
B	KALIMANTAN			
1	West Kalimantan	1,211,956	518,024	1,729,980
2	Central Kalimantan	1,493,850	1,513,765	3,007,615
3	South Kalimantan	234,919	2,031,789	2,266,708
4	East Kalimantan	377,070	319,927	696,997
	Total of Peatland	3,317,795	2,448,426	5,766,221
	Percentage	57.5	42.5	100.0
C	PAPUA			
1	Papua	5,413,668	1,587,570	7,001,238
2	West Papua	844442	129,775	974,217
	Total	6,258,110	1,717,345	7,975,455
	Total of Peatland	78.5	21.5	100.0
	Grand Total of Indonesia peatland	13,828,126 66.0	7,117,841 34.0	20,945,967 100.0

Source: Wahyunto et al.,(2004, 2005 and 2006)

Analysis data on the extend peatlands during the last 30 years (from 1980) arrive at the conclusion, there has been recognized that a number of peat dome areas have been disappeared, and be replaced with tidal wetland rice field, upland farming, and transmigrant settlements. Some areas due to improper reclamation of sulfidic marine soils, give rise to developed of true acid sulphate soils, causing soil unproductive, and the land are presently covered by shurbs and bushes, some even developed into unproductive idle lands.

A good example is the disappearance of primary peat forest in Pulau Petak area, a deltaic island with the size of aproximately 20 by 70 km length, West of Banjarmasin, South Kalimantan. The area was mapped by Van Wijk in 1951, then remapped for tidal swamp rice program by Soil Reserach Institute in 1972 (SRI, 1973). in 1987 – 1992, the same location had been used as a study site for Acid Sulphate Soils Program of the Ducth LAWOO-AARD project (Jansen et al., 1992), where by landuse of the islands was again remapped. In the area, there were originally two basin peat domes of fresh water type in the central part of the island. Changes of the extend peat soils are presented in Table 4.

During the period 1951 – 1972, about a half of the valuable primary forest where peat soils occur, had lost because, after the construction of the Tamban and Talaran canals, local settles drained the land to cultivate wetland rice. A large decrease on peat soils, i.e. 63.6%, occurs during the period 1972 – 1992, when the flux of transmigrants arrived and settled along several large canals dug by goverment to enable establishment of tidal swamp rice areas. When area was visited again in 1999, in a reconnaissance soil survey of the whole province by CSARD team, no more significant peat soils are found in the Pulau Petak delta.

Table 4. Extent of peatland coverage in the Pulau Petak, South Kalimantan, over the period 1951 - 1999

Year	Extent of peat soils (1,000 ha)	% of the island	Increase/ decrease (%)	Source
1951	51.36	21.4		Wijk van (1951)
1972	26.4	11.0	-48.6	SRI (1973)
1992	9.6	4.0	-63.6	Jansen et al., (1992)
1999	0.0	0	-100.0	CSARD (2000)

Source : Muchrizal S (2003).

- **Below ground carbon stock of peatland**

To estimate below ground peatland carbon stock were used the following parameters: bulk density of peat soil, area distribution, peat thickness and C-org content. The equation used to calculate below ground carbon stock of peat soil is:

$$\text{Carbon content (KC)} = B \times A \times T \times C$$

Where KC, B, A, T and C are below ground carbon stock in tons, Bulk Density (BD) of peat soil in gram / cm^3, Area distribution of peat in m^2, Thickness of peat in meters and Carbon content (C-organic) in percent (%) respectively.

Based on the depth/ thickness of peatland could be split up into: peaty soil (peat thickness <50 cm), shallow peat (peat thickness 50-100 cm), moderate deep peat (peat thickness 101 – 200 cm), deep peat (peat thickness 201 – 400 cm) and very deep peat (peat thickness >400 cm). For further classification of peat thickness concerning to below ground carbon stock of peatsoil, are split up into two groups these are: (1) peat thickness < 2 meters and (2) peat thickness >2 meters. Resulted calculation of below ground carbon stock of peat soil for 3 major Indonesian islands i.e.Sumatra, Kalimantan and Papua is presented in Table 5.

Total below ground carbon stock of peat lands (referring to peatland spatial data in the year of 2002) for 3 major island of Indonesia is about 33,709 million tons or 33.7 Giga tons, these are distributed in Sumatra 18.8 Giga ton (55.8%), Kalimantan 11.27 Giga ton (33.4%) and Papua 3.6 Giga ton (10.7%). It is indicated belong to both peatland with < 2 meter thickness (22.4%) and > 2 meter thickness (77.6%) respectively.

Below ground carbon stock of peat lands in Sumatra, when ranked from highest carbon stock of province is located in Riau province (14, 605 million tons of carbon), followed by South Sumatra Province (1,470 million tons), Jambi (1,413 million tons), Aceh (458 million tons), West Sumatra (422 million tons), North Sumatra (377 million tons), Lampung (35 million tons) and and the lowest is Bengkulu (30 million tons of carbon). Differences in the below carbon stock of each province is determined by the extent (area distribution) and depth / thickness of peat from each province (Table 5).

Central Kalimantan has the highest below ground carbon stock, which amounted to 6,351 million tons (56.34%) of the total island of Borneo. Then with a lower carbon content followed by the West Kalimantan province amounted to 3,625 million tons (32.15%), East Kalimantan, 1,211 million tons (10.75%), and South Kalimantan 85 million tons (0.76%).

Below ground carbon stock found in Papua and West Papua Provinces are: 2,530 million tons or (69.9% of the total of Papua) and 1,092 million tons (30.1%) respectively.

Table 5. Peatland below ground carbon stock for Sumatra, Kalimantan and Papua

No.	Island/ Province	Below ground carbon stock (million ton)		
		peat thickness <200 cm	Peat thickness >200 cm	Total carbon stock
A.	SUMATRA			
1	Riau	1,891.77	12,713.27	14,605.04
2	South Sumatra	1,389.06	81.23	1,470.29
3	Jambi	290.83	1,122.36	1,413.19
4	North Sumatra	298.26	79.02	377.28
5	Nanggroe Aceh D	233.57	225.29	458.86
6	West Sumatra	82.11	340.13	422.24
7	Lampung	35.94		35.94
8	Bengkulu	20.82	9.72	30.54
	Total of carbon stock	4,242.36	14,571.02	18,813.38
	Percentage (%)	22.55	77.45	100.00
B.	KALIMANTAN			
1	West Kalimantan	1,290.26	2,334.93	3,625.19
2	Central Kalimantan	472.47	5,879.06	6,351.53
3	South Kalimantan	25.14	59.89	85.03
4	East Kalimantan	112.92	1,098.99	1,211.91
	Total of carbon stock	1,900.79	9,372.87	11,273.66
	Percentage (%)	16.86	83.14	100.00
C.	PAPUA			
1	Papua	1,107.83	1,423.01	2,530.84
2	West Papua	306.27	785.74	1,092.01
3	Total of carbon stock	1,414.10	2,208.75	3,622.85
	Percentage (%)	39.03	60.97	100.00
	Grand Total Indonesia)	7,557.25	26,152.64	33,709.89
	Percentage (%)	22.42	77.58	100.00

Source : Wahyunto et al., 2004, 2005 and 2006

5. Bulk Density of Peat Soil in Various Landuse

The bulk density (BD) of peat soil is likely the most important parameter. The fact that the BD of peat is low when compared to that of a minral soil and the fact that it varies considerably for different peat types and even within one peat type. Fibric tropical forest peats have bulk density values of less than 0.1 gram cm^{-3}. The high decomposed sapric peats have values in excess of 0.2 gram cm^{-3}. Higher values are common in areas with topogenous clayey peats near the fringes of characteristics dome shaped peat formation on in areas with intensive agriculture management such as paddy field/sawah, oil palm plantation. The bulk density values of surface soils in the central dome areas under peat forest are generally lower than those peats under fringe dome of mixed swamp forest vegetation. In shallow fringe areas of peat dome where peat soils commonly contain admixture of clay, bulk density values are higher at some depth than in the surface soils (Driessen and L Rochimah, 1976).

Fiveteen site observations were selected randomly depending on the types of land use and land cover and peat depth. Each layer (with the 20 cm depth increment) of the selected peat samples were analyzed for bulk density (graphimetric technique), ash content (loss on ignition, LoI. technique). Organic C were calculated based on ash content (Agus, 2009a). Descriptions of peat soil characteristics such as: peat thickness, peat maturity, drainage depth, and the type of substratum material, were developed based on the field observation, and secondary data from previous research (Balai Penelitian Tanah, 2004).

Table 6 . Bulk Density and Carbon density of peat soil by peat soil depth increment and type of land use/ land cover

No	Observer Code	Peat Thickness (cm)	Soil Sample analysis	Land use/ Land cover	Peat Maturity	C Organic Content (%)	Bulk Density (gr cm^{-3})	Carbon Density (kg m^{-3})
1.	Nr. 9/I	330	0-20	Sec Forest	sapric	38.25	**0.25**	94.37
	Nr. 9/II		20-40		fibric	32.23	**0.20**	63.33
	Nr. 9/III		40-60		fibric	42.55	**0.12**	52.19
	Nr. 9/IV		60-80		fibric	35.64	**0.08**	27.06
	Nr.9 (average)	330		Sec Forest	sapric	37.17	**0.16**	59.24
2.	Nr. 21/I	155	0-20	Sec Forest	hemic	46.74	**0.14**	66.94
	Nr. 21/II		20-40		hemic	52.97	**0.10**	54.82
	Nr. 21/III		40-60		fibric	49.65	**0.08**	41.88
	Nr. 21/IV		60-80		fibric	46.12	**0.08**	37.39
	Nr. 21 (Average)	155		Sec Forest	hemic	48.80	0.10	50.26
3.	Hs. 5/I	175	0-20	Sec Forest	fibric	34.38	**0.12**	41.87
	Hs. 5/II		20-40		fibric	50.76	**0.12**	60.37
	Hs. 5/III		40-60		fibric	49.08	**0.09**	41.88
	Hs. 5/IV		60-80		fibric	38.13	**0.09**	34.33
	Hs. 5/I	175		Sec Forest	fibric	43.08	**0.10**	44.61
4.	Hs. 11/I	90	0-20	Sec forest	sapric	45.86	**0.15**	68.64
	Hs. 11/II		20-40	bush	sapric	38.67	**0.13**	51.32
	Hs. 11/III		40-60		fibric	49.99	**0.11**	53.76
	Hs. 11 (average)		60-80			12.28	**0.08**	10.36
5.	Nr. 24/I	90	0-20	Sec Forest	sapric	45.46	**0.27**	123.90
	Nr. 24/II		20-40	open,	sapric	44.70	**0.19**	84.61
	Nr. 24/III		40-60	slash & burn	hemic	40.99	**0.09**	37.54
	Nr. 24/IV		60-80		hemic	35.86	**0.15**	55.20
	Nr. 24 (average)	90		Sec Forest	sapric	41.75	**0.17**	75.31
6.	Nr. 12/I	320	0-20	Sawah	hemic	31.23	**0.14**	45.03
	Nr. 12/II		20-40		hemic	35.91	**0.13**	45.14
	Nr. 12/III		40-60		fibric	37.48	**0.10**	37.52
	Nr. 12/IV		60-80		fibric	41.76	**0.08**	33.17
	Nr. 12 (average)	320		Sawah	hemic	36.56	**0.11**	40.22
7.	Nr. 22/I	90	0-20	Sec Forest	sapric	43.16	**0.16**	67.76
	Nr. 22/II		20-40	sawah	sapric	54.61	**0.16**	85.08
	Nr. 22/III		40-60		fibric	46.97	**0.15**	70.20
	Nr. 22/IV		60-80		fibric	35.87	**0.08**	30.45
	Nr. 22 (average)	190		Sec Forest	sapric	45.15	**0.13**	63.37
8.	Hs. 6/I	170	0-20	Sec Forest	fibric	38.04	**0.11**	42.45
	Hs. 6/II		20-40	sawah	fibric	47.81	**0.08**	40.43
	Hs. 6/III		40-60		fibric	48.93	**0.09**	41.76
	Hs. 6/IV		60-80		fibric	48.14	**0.06**	29.13
	Hs. 6 (average)	170		Sec Forest	fibric	45.73	**0.08**	38.44
9.	Nr. 28/I	90	0-20	Sec Forest	sapric	44.63	**0.19**	86.23
	Nr. 28/II		20-40	Dry field/	hemic	40.17	**0.14**	56.08
	Nr. 28/III		40-60	palawija	hemic	42.93	**0.09**	40.77
	Nr. 28/IV		60-90			47.69	**0.09**	43.93
	Nr. 28 (average)	90		Sec Forest	sapric	43.86	**0.12**	56.75

Source: Wahyunto et al., 2007

Table 7 . Bulk Density and Carbon density of peat soil by peat soil depth increment and type of land use/ land cover

No	Observer Code	Peat Thickness (cm)	Soil Sample analysis	Land use/ Land cover	Peat Maturity	C Organic Content (%)	Bulk Density (g cm^{-3})	Carbon Density kg/m^3
10	Hs. 3/I	40	0-20	shurb& bush	fibric	40.78	**0.16**	63.27
	Hs. 3/II		20-40		fibric	32.28	**0.14**	46.62
	Hs. 3/III		40-60		fibric	19.55	**0.13**	25.54
	Hs. 3/IV		60-80			14.12		
	Hs.3 (average)	40		shurb& bush	fibric	26.68	*0.14*	45.14
11.	WT. 4/I	580	0-20	sec forest/	sapric	50.25	**0.24**	121.39
	WT. 4/II		20-40	shurb& bush	sapric	45.91	**0.15**	67.66
	WT. 4/III		40-60		hemic	39.49	**0.14**	56.43
	WT. 4/IV		60-80		hemic	32.73	**0.14**	44.26
	WT. 4/V		80-100			28.62	No data	
	WT. 4 (average)	580		sec forest/	sapric	42.10	*0.16*	72.43
12	WT. 7/I	80	0-20	oil palm	sapric	35.02	**0.33**	116.29
	WT. 7/II		20-40	10 years	sapric	43.80	**0.29**	126.61
	WT. 7/III		40-60		sapric	33.23	**0.23**	77.15
	WT. 7/IV		60-80		hemic	31.28	**0.16**	49.28
	WT. 7 (average)	80		oil palm	sapric	35.83	**0.25**	92.33
13	WT. 11/I	590	0-20	Oil palm	sapric	34.48	**0.36**	123.17
	WT. 11/II		20-40	6 year	sapric	38.40	**0.27**	104.15
	WT. 11/III		40-60		hemic	64.02	**0.17**	106.82
	WT. 11/IV		60-80		hemic	53.60	**0.10**	55.95
	WT. 11/V		80-100		hemic	58.15	No data	
	WT 11 (average)	590		Oil palm	sapric	49.73	*0.22*	97.52
14	WT. 1/I	410	0-20	Oil palm	sapric	28.57	**0.21**	59.48
	WT. 1/II		20-40	Pesisir slt	sapric	39.19	**0.12**	48.75
	WT. 1/III		40-60		sapric	44.58	**0.12**	51.90
	WT. 1/IV		60-80		hemic	59.80	**0.11**	67.78
	WT.1 (average)	410		Oil palm	sapric	43.04	**0.14**	56.98
15.	WT. 3/I	210	0-20	Oil palm	sapric	44.41	**0.14**	61.12
	WT. 3/II		20-40		sapric	36.46	**0.11**	38.57
	WT. 3/III		40-60		hemic	39.11	**0.11**	44.03
	WT. 3/IV		60-80		hemic	51.54	**0.11**	54.75
	WT.3 (average)	210		Oil palm	sapric	42.88	**0.12**	49.62

Source: Wahyunto et al., 2007

The rate of bulk density (BD) of peatland under secondary forest, shurbs and bush, annual crops (sawah and dry field), and oilpalm plantation are 0.08 to 0.27 kg m^{-3}, 0.13 to 0.24 kg m^{-3}, 0.06 to 0.16 kg m^{-3}, and 0.10 to 0.36 kg m^{-3} respectively. The rate of carbon density of peatland under secondary forest, shurbs and bush, annual crops (sawah and dry field), and oil palm plantation are 27.06 to 94.37 kg m^{-3}, 25.54 to 121.39 kg m^{-3}, 29.13 to 86.23 kg m^{-3} and 38.57 to 126.61 kg m^{-3} (table 6 and table 7). Type of land cover and its environments could be influenced the degree of peat maturity. Normally, higher degree of peat maturity will be followed by the high degree of Bulk Density. Especially in the upper part of the profiles, higher BDs are found, There is decrease of BD with depth almost for the whole data set. In the peat soils site, that contain admixture of clay, bulk density values are higher at some depth than in the surface soils. Peat BD of intensive agricultural crops which need deep drain such as oilpalm plantation, tend to have higher value on BD compared to other type of land use/land cover. It is indicated that drain peat and intensive management agricultural on peat may increase the rate of peat decomposition and influenced on physical properties of peat including BD.

6. Peat Decomposition in Various Land use

Three basic kinds of organic soils materials are distinguished, are : fibric, hemic and sapric, according to the degree of decomposition of the original plant material. Fibric lest decomposed contain of fragment of wood larger than 2 cm in cross section or in the smallest dimension, must be decomposed enough that they are can be crushed and shredded with fingers. Hemic soil material are intermediate in degree of decomposition, they partly altered both phycically and biochemically (USDA, 2010). Sapric soil materials are mostly decomposed of their organic materials. They normal have the highest bulk density than the other type of peat soil, and the lowest water content on a dry-weight basis at saturation. They are commonly very dark to black, and relatively stable.

Sumatra and Kalimantan peat land, in the natural vegetation cover such as secondary forest, bushes and shrubs, generally deeper peatland will be found higher peat maturity. Peat maturity in any different land use/ land cover are presented in Table 8, Table 9 and Table 10.

Table 8. **Saprist** peat soil maturity in any different land use/ land cover

Type of land use/ Land Cover	Peat depth (cm)	C-Org content (%)		Bulk Density (BD) ($g\ cm^{-3}$)		Carbon Density ($kg\ m^{-3}$)		Carbon stock $t\ ha^{-1}\ m^{-1}$	
		Range	Average	Range	Average	Range	Average	Range	Average
Sec forest-Kaltim	330-500	35-55	45	0.14-0.18	0.16	49-83	66	491-826	659
Sec forest-Tripa	130	11-43	27	0.08-0.19	0.14	23-34	29	293	293
Sec forest/slash-burn	90-225	36-52	44	0.12-0.17	0.15	44-77	61	460-753	607
oil palm-1(Nunukan)	75-590	30-55	43	0.14-0.25	0.2	42-94	68	422-975	699
oil palm-2 (Kubu)	165-287	25-53	39	0.17-0.32	0.25	48-72	60	475-722	599
Oilpalm-3 (Tripa)	180-237	15-60	38	0.05-0.3	0.18	31-67	49	451-494	473
Rubber – Kubu	218-260	42-58	50	0.08-0.14	0.11	60-76	68	597-758	678
Sec forest/ dry field	70-250	20-50	35	0.1-0.17	0.14	35-53	44	227-532	380
Sec forest/ sawah	100-250	28-47	38	0.09 - 0.14	0.12	35-66	51	234-680	457
Zea mays	484-700	55-57	56	0.08-0.11	0.1	40-50	45	426-530	478
pineapple	637	56-58	57	0.04-0.11	0.8	41	41	412	412

Source : Wahyunto et al., 2007, Agus et al., 2010 and Dariah et. al., 2009

Peatland under secondary forest with saprist, hemist and fibrist peat maturity, showed that the rate of bulk density are: 0.14 – 0.16; 0.06 – 0.12 dan 0.07 – 0.11 gram cm^{-3} respectively, C organic content may ranges: from 27 to 45%, 35 to 56% and 42 to 44% respectively. With peat thickness ranging from 70 to 700 cm leading to peat carbon density are ranges : 293 – 659 t ha^{-1} m^{-1}, 362 – 518 t ha^{-1} m^{-1} and 543 – 609 t ha^{-1} m^{-1} respectively. Based on peat soil data laboratory analyzed, showed that peatland under secondary forest, having higher decomposed (saprists peat maturity) tend to have higher Bulk density and Carbon density.

Saprists, Hemists and fibrist peat maturity under plantation crops (oil palm and Rubber) having rate values of Bulk Density (BD) are: from 0.05 to 0.32; from 0.04 to 0.32 and from 0.07 to 0.16 respectively, and having the rate value of C organic content are ranges: from 15 to 60%, from 31 to 62% and from 28 to 63% respectively. With peat thickness ranging from 75 – 590 cm, leading to peat carbon density are range: from 422 to 975 t ha^{-1} m^{-1} , from 376 to 694 t ha^{-1} $m^{-1}$and from 433 to 529 t ha^{-1} m^{-1} respectively. This ranges value for BD, C organic content dan carbon density tend to be higher than other types of agricultural crops, and some place often higher than secondary forest/ log over forest.

Table 9. **Hemist** peat soil maturity in any different landuse/ land cover

Type of landuse/ Land Cover	Peat depth (cm)	C-Org content (%)		Bulk Density (BD) (g cm^{-3})		Carbon Density (kg m^{-3})		Carbon stock t ha^{-1} m^{-1}	
		Range	Average	Range	Average	Range	Average	Range	Average
Sec forest	155-700	18-51	35	0.09-0.15	0.12	22-80	51	220-802	511
Sec forest-2 (Tripa)	220-500	43-68	56	0.02-0.10	0.6	15-59	37	311-413	362
Sec forest/slash-burn	150-360	38-45	42	0.08-0.15	0.12	31-68	50	327-709	518
Shurbs & bushes	240-460	27-63	45	0.01-0.11	0.06	30-68	49	408-430	419
oil palm-1(Tripa)	325	52-68	60	0.04-0.10	0.07	24-58	41	413	413
oil palm-2 (Kubu)	117-278	31-51	41	0.19-0.32	0.26	38-69	54	376-694	535
Rubber	216-283	54-58	56	0.10-0.13	0.12	60-61	61	600-612	606
Sec forest/ dry field									
Sec forest/ sawah	130-330	36-46	41	0.09-0.11	0.1	37-50	44	368-646	507
Zea mays	420-580	56-57	57	0.09-0.10	0.1	40-50	45	430-534	482
pineapple	617-700	56-57	57	0.07-0.09	0.08	35-41	38	354-408	381

Source : Wahyunto et al., 2007, Agus et al., 2010 and Dariah et. al., 2009

Table 10. **Fibrist** peat soil maturity in any different landuse/ land cover

Type of landuse/ Land Cover	Peat depth (cm)	C-Org content (%)		Bulk density (BD) (g cm^{-3})		Carbon Density (kg m^{-3})		Carbon stock t ha^{-1} m^{-1}	
		Range	Average	Range	Average	Range	Average	Range	Average
Sec forest-Kaltim	70-350	37-51	44	0.01-0.13	0.07	43-66	55	446-639	543
Sec Forest- Tripa	220-500	23-60	42	0.06-0.16	0.11	34-95	65	609	609
oil palm-1(sumatra	350-390	28-63	46	0.07-0.16	0.12	28-79	54	433-529	481
Sec forest/ dry field	40	26	26	0.14	0.14	45	45	451	451
Sec forest/ sawah	170	45	45	0.08	0.08	38	38	384	384
Zea mays	594	57	57	0.12	0.12	61	61	512	512
pineapple	637-670	55-57	56	0.07-0.08	0.08	34-39	37	344-388	366
Vegetables	715-726	56-57	56	0.08	0.08	36-39	38	361-386	374

Source : Wahyunto et al., 2007, Agus et al., 2010 and Dariah et. al., 2009

Peatland under annual crops agriculture tend to have lower carbon stock and lower bulk density when compared with other dataset under any different landuse. However its carbon density lower than the other peat land under any type of landuse/ land cover have been observed. Saprist, hemist and fibrist peat maturity under annual crops having rate values of Bulk Density are : from 0.04 to 0.17; from 0.07 to 0.11 and 0.07 to 0.12 resepectively. The C organik soil ranges from 20 to 58%, from 36 to 57% and from 26 to 57 % respectively. With peat thickness ranging from 227 to 680 t ha^{-1} m^{-1} , from 354 to 646 t ha^{-1} m^{-1}and from 344 to 512 t ha^{-1} m^{-1} respectively.

There were no clear pattern in the carbon content of the Sumatra and Kalimantan peat. However, bulk density of peatland under Oilpalm plantation tend to be higher than the other landuse/ land cover. Average carbon density, in general was/were higher for peat under oil palm that that under secondary forest (table 8 to 10.). Saprists/hemists peat soil maturity were found under oil palm plantation and sawah/ paddy field. This is indicated that intensive management on peat land could significant influence on bulk density and rate of decomposition process.

7. Peatland Utilized Problem

Peat depth or peat thickness in Sumatra and Kalimantan having a lot variations and correlated with peat maturity. In the region are dominantly covered by natural vegetation (forest, bushes), deeper peat soil (> 3 meters often more than 5 meter depth) generally having high degree of maturity peat soil. Saprists – saprists/ hemists peat soil generally having more than 200 cm depth. Fibrist, Saprists/ Fibrists, Hemists/ Fibrists are kindly disposed toward having more variation in peat depth (from shallow peat to moderately deep peat). However, recently there are certain area having shallow saprists peat soil (less than 100 cm depth), because of these area converted to agricultural areas as a paddy field. Type of land cover and its environments could be influenced the degree of C- organic content (Agus et al., 2010). Further more, increase in Bulk density value of peat soil will be followed by increasing the degree of peat soil maturity.

Shallow peats (thickness <3 m) marginally suitable for agricultural cultivation. Generally thicker peat, the lower the potential for agricultural cultivation. Highly decomposed peat (sapric) more fertile when compared with hemic and fibric peat (less decomposed). Low bearing capacity of peat which is characterized by low BD value and high water absorption capacity, affecting difficulty of ensuring normal growth, the thicker peat tree crops will always collapsed and lay down.

From the environmental aspect, peatlands play an important role in regulating water management in catchment areas, storage of carbon (C) and maintaining biodiversity. The function of this environment will decrease drastically if the peat forest converted to agricultural land. Peat with higher maturity level tend to have higher C content. Peat with a higher content of C will tend to emit more CO2 when burned. However, growing population (growth of 1.3% per year) and the decrease in potential for dry land agricultural development, hence the more peatlands used for agriculture (including plantations), particularly at provincial, district, mostly in the form of peat land area. Physical and fertility constraint of peatlands, required additional inputs/ a lot of capital for agricultural development and maintenance of infrastructure. The advantages (output) of this peatland agricultural development, is generally lower compared with agricultural development in upland (mineral soil). In an area of the province or district, because of the dominance of peat (ie: Riau Province, Kubu Raya District, West Kalimantan Province), the utilization of peatlands is not an option, but because of necessity, because only they possess peatlands. With tenacity and experience of farmers in the years managed to turn this marginal peatlands become productive enough land for vegetables (caisin, long beans, eggplant, tomatoes, cucumbers, and pariah), dragon fruit, watermelon , pineapple. Plantations are also still able to grow quite well in peat thickness> 3 meters, especially rubber, coffee, cocoa, and palm oil. Shallow peatland (1meter) with a maturity level saprik, widely used for rice paddies. Farmers in the Kubu Raya, could managed to obtain revenue from peatlands as rubber smallholder farmer amounted to USD 21.54 million / household / year (Herman et al., 2009). Peatlands in this region is the cornerstone of life expectancy, because the dominant peatlands. In various types of agricultural land use on peatlands, due to the practice of burning to enrich the soil farming systems may emit CO_2. Burning is not only increased CO_2 emissions but also cause air pollution Efforts to reduce emissions can be done through: peat fire control system of traditional agriculture into a permanent agricultural system, control of forest clearance, land rehabilitation shrubs, and agricultural expansion is only performed on shrub/fern land.

8. Strategy on Soil Management Techniques with Low Emission on Peatsoil Carbon

Agriculture development with low GHG emission on peatland could be achieved through various program including soil management techniques are as follows:

1. Reduce the pressure of the opening of new farmland through conversion of peat swamp forests. Intensification of agriculture should be applied to food crops farming system, small holder estate crops and livestock. This program may include the use of new varieties that have high productivity and short age period of harvesting, improved fertilizers, and other cultivation systems.

2. Rehabilitation of idle land or un utilized land (including peatland) covered by bushes and shurbs vegetation with others used area for agriculture-(APL) status. Idle land/ unutilized land rehabilitation also has a great potential to increase carbon stocks, and will be able to improve

people's lives. This rehabilitation could be stressed on smallholder tree crops farming systems, such as rubber, coffee, chocolate, pineapples, horticulture (fruit and vegetable), with regards to land suitabilities and institutional supporters.

3. Land swap at APL region on mineral soil, that having high carbon stock (> 100 Mg C ha^{-1}) to the region of land that having low carbon stok (<35 Mg C ha^{-1}).
4. Improving the management of peatlands.

Quite significant GHG emission reductions on peatland can be achieved through various programs:

a. The use of peatlands for oilpalm plantation expansion, should be refer to Agriculture Ministry Decree (Permentan) No. 14/2009. This Decree guiding the opening of plantation including for oilpalm on peatlands only in the region within the criteria: average of peat depth <3m (et least 70% of areas consesion), with hemis sapris peat maturity level, and avoid quartz sand and sulfuric/ acid sulphate soil subtratum.

b. Control of burning peat. Burning peat often occurred among the farming land during land preparation to cultivate crops (generally annual crops) in order to obtain nutrients from the ashes of the former combustion of peat. Estimated one cm of peat fires potentially causing the emission of about 5 Mg C ha^{-1} or 18 Mg CO_2-e ha^{-1}. In case farmers are given subsidies on fertilizer, peat lands, then the emissions from the fires will be abolished gradually.

c. Drainage arrangement. The depth of the drainage channel greatly affect CO_2 emissions through the decomposition of peat. For the depth of drainage channels should be minimized to a degree not lower production. Annual crops, lowland rice, rubber, oil palm, and sago palm usually require 20, 10, 20, 80, and 0 cm drainage depths (Agus et al., 2007). CO_2 emission increases with the depth of drainage. About 9.1 Mg CO_2 is emitted/ha/yr for every 10 cm drainage depth (Hooijer et al., 2006).

d. Use ameliorant. Various waste substances, such as continence steel, which contains high-potential Fe and Si binding (chelating) simple organic acids and organic acids that are not easily decompose. The use of these substances in addition to potentially reduce peatland emissions, can also solve the problem of slag disposal which today are classified as toxic waste and hazardous (B3).

9. References

Agus, F., Suyanto, Wahyunto and van Noordwijk M. 2007. Reducing Emission from Peatland Deforestration and Degradation: Carbon Emission and Opportunity Costs. Paper presented in " International Symposium and Workshop on Tropical Peatland" Carbon – Climate – Human Interaction – Carbon Pools, Fire, Mitigation, Restoration, and Wise Use, Yogyakarta Indonesia, 27 – 29 August 2007.

Agus, F. 2009. Panduan Metode Pengukuran Karbon Tersimpan di Lahan Gambut (*Guidelines for measuring carbon stock in peatland*). Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian Bogor and World Agroforestry Centre, SEA, Bogor, Indonesia. (*In Indonesian*)

Agus F., Wahyunto, A. Dariah, P. Setyanto, I. G.M. Subiksa, E. Runtunuwu, E. Susanti, W. Supriatna. 2010. Carbon budget and management strategies for conserving carbon in peatland: Case study in Kubu Raya and Pontianak Districts, West Kalimantan, Indonesia. Proceedings, International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries, 28 to 29 Sept., 2010, Bogor, Indonesia.

Agus, F., Runtunuwu, E., June, T., Susanti, E., Komara, H., Syahbuddin, H., Las, I. and van Noordwijk, M. 2009. Carbon budget in land use transitions to plantation. Indonesian Journal of Agricultural Research and Development 29(4): 119−126.

Anderson J.A.R. 1976. Observation of the ecology of five peat swamp forests in Sumatra and Kalimantan. Proceeding of : Peat and Podzolic Soils and their potential for agriculture in

Indonesia. ATA 106 Midterm Seminar, Tugu, October 13-14, 1976 page : 45-55. Soil Research Institute. Bogor.

Andriesse, J.P. 1988. Nature and Management of Tropical Peat Soils. FAO Soils Bulletin No.59, Rome.

Balai Penelitian Tanah (ISRI). 2004. Pedoman Pengamatan Tanah di Lapang. Balai Penelitian Tanah, Pusat Penelitian dan Pengembangan Tanah dan Agroklimat Bogor.

Bappenas.2010. Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca (GRK). Bappenas. Jalan Suropati, Jakarta.

Center for Soil and Agroclimate Research and Development – CSARD. 2004. Reconnaisance Soil Survey of West Kalimantan Part-I. Project Research Report. Center for Soil and Agroclimate Research and Development. Bogor *(Unpublished)*

Center for Soil and Agroclimate Research and Development – CSARD. 2005. Reconnaisance Soil Survey of West Kalimantan Part-II. Project Research Report. Center for Soil and Agroclimate Research and Development. Bogor *(Unpublished)*

Dariah, Fahmuddin Agus, Erni Susanti dan Elsa Surmaini. 2009. Cadangan karbon lahan gambut pada berbagai penggunaan lahan di Kabupaten Kubu Raya dan Pontianak, Kalimantan Barat. Country Report. Ministry of Research and Technology. Jakarta. (*Unpublised*).

Departemen Pekerjaan Umum. 1997. Environmental Profile of Wetlands in West Kalimantan Province. Jalan Pattimura 20. Jakrat Indonesia.

Driessen P.M and L. Rochimah. 1976. The physical Properties of Lowland Peats From Kalimantan. Proceeding of ATA 106 Midterm Seminar:.Peat and Podzolic Soils and Their Potensial for Agriculture in Indonesia. Tugu, October 14-14, 1976 page: 55-71. Soil Research Institute. Bogor- Indonesia.

Herman, Fahmuddin Agus, IGM Subiksa. E.Runtunuwu dan Irsal Las. 2009. Analisis pendapatan, kelayakan usaha dan emisi CO_2 pertanian lahan gambut Kabupaten Kubu raya, Kalimantan Barat. Country Report. Ministry of Research and Technology. Jakarta. (*Unpublised*)

Hooijer, A., M. Silvius, H. Wörsten, and S. Page. 2006. Peat CO2, Assessment of CO2 Emission from drained peatlands in SE Asia. Delft Hydraulics report Q3943 (2006).

Istomo. 2005. Keseimbangan hara dan karbon dalam pemanfaatan lahan gambut berkelanjutan. Prosiding Lokakarya Pemanfaatan lahan Gambut secara bijaksana untuk manfaat berkelanjutan di Palangkaraya 10-11 Mei 2005 dan di Pekanbaru 31 Mei – 1 Juni 2005. Wetland International Indonesia Programme. Bogor. hal 133-147

Janssen, J.A.M., W.Andriesss, H. Prasetyo, and A.K.Bregt. 1992. Acid Sulphate Soils in the humid tropics. Guidelines for soil surveys: the main problem considered. LAWOO-AARD. Jakarta.

Lyon, J.G., and J.Mc Carthy. 1995. Wetland and Environmental Applications of GIS. CRC Lewwis Publishers. Boca Raton, New York, London, Tokyo.

Mitch and Gosselink. 1986. NC Division of Coasltal Management. http:/www.delineationsplus.com/ articles/cfm. Last retrieved, July 30, 2010.

Muchrizal S.2003. Policy on the use of degraded land in tidal swamp land (in bahasa Indonesia). A policy paper. 7 pp.

Radjagukguk, B. 1991. Utilization and management of peatlands in Indonesia for agriculture and forestry. Proceedings of the International Symposium on Tropical Peatland, 6-10 May 1991 Kucing, Serawak, Malaysia.

Sabiham S. 2008. Suitability and sustainability aspects of peatland utilization for agriculture. Prosiding Seminar Nasional dan Dialog Sumberdaya Lahan Pertanian, Bogor 10-20 November 2008 halaman: 33-46. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Bogor.

SRI (Soil Research Institute). 1973. Report on Soil investigations of the Delta Pulau Petak (South and Central Kalimantan). 124 pp

Subagjo, H. and Adimihardja. 2003. Agriculture in Peatland Areas. Halaman 303-405, Proceeding Workshop on Wise Use and Sustainable Peatlands Management Practices. Di Bogor tanggal 13-14 Oktober 2003.

Pusat Penelitian Tanah dan Agroklimat. 1999. Buku Keterangan Peta Satuan Lahan dan Tanah Lembar Painan, Tapak Tuan dan Meulaboh. Proyek Perencanaan dan Evaluasi Sumberdaya Lahan. Pusat Penelitian Tanah dan Agroklimat. Bogor-Indonesia. .

United States Departement of Agriculture. 2010. Key to Soil Taxonomy. Natural Resources Conservation Service. USDA, Washington DC.20250-9410.

Verstappen, H.Th., 1975. On Paleo-Climates and landform developments in Malesia. In: Mod. Quat.Res. Inst. S.E. Asia, Groningen University. The Netherlands

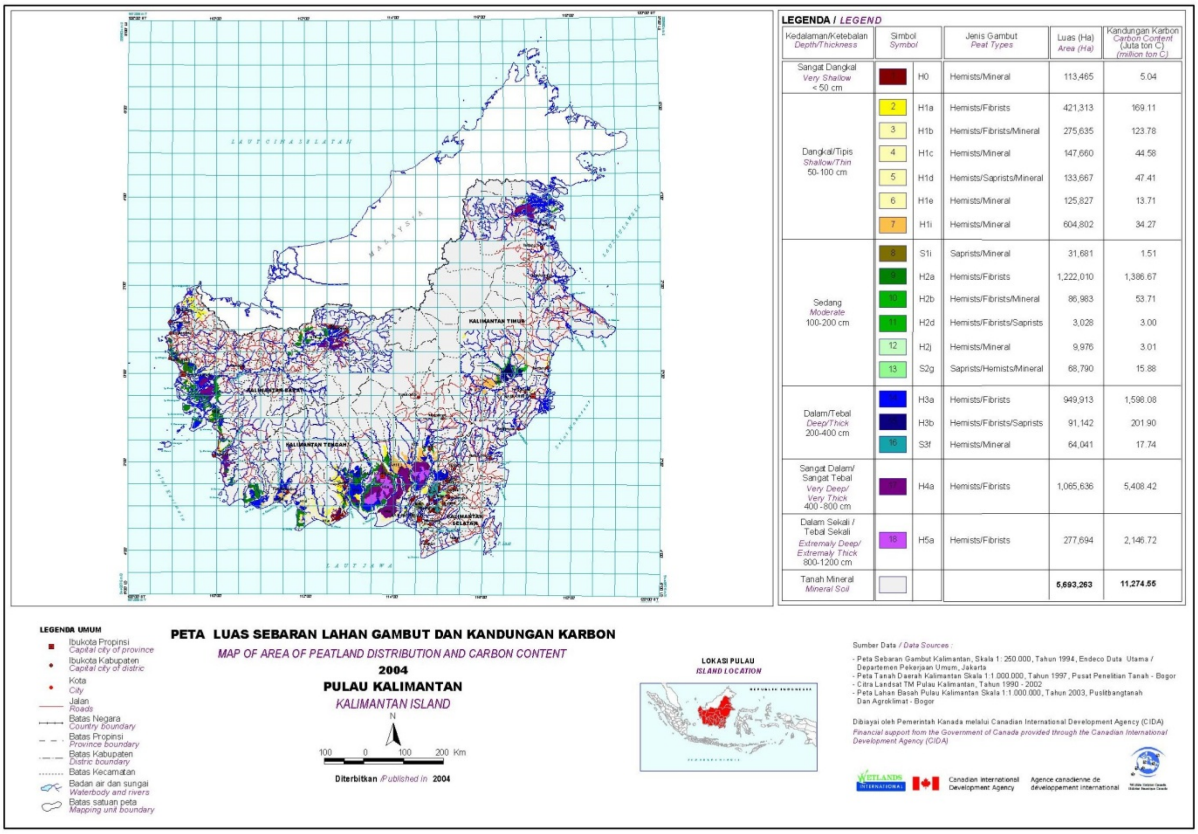
Wahyunto, Ritung S., Suparto and Subagjo H. 2004. Map of Peatland Distribution Area and Carbon Content in Kalimantan. Wetland International- Indonesia Program and Wildlife Habitat Canada (WHC). Bogor - Indonesia

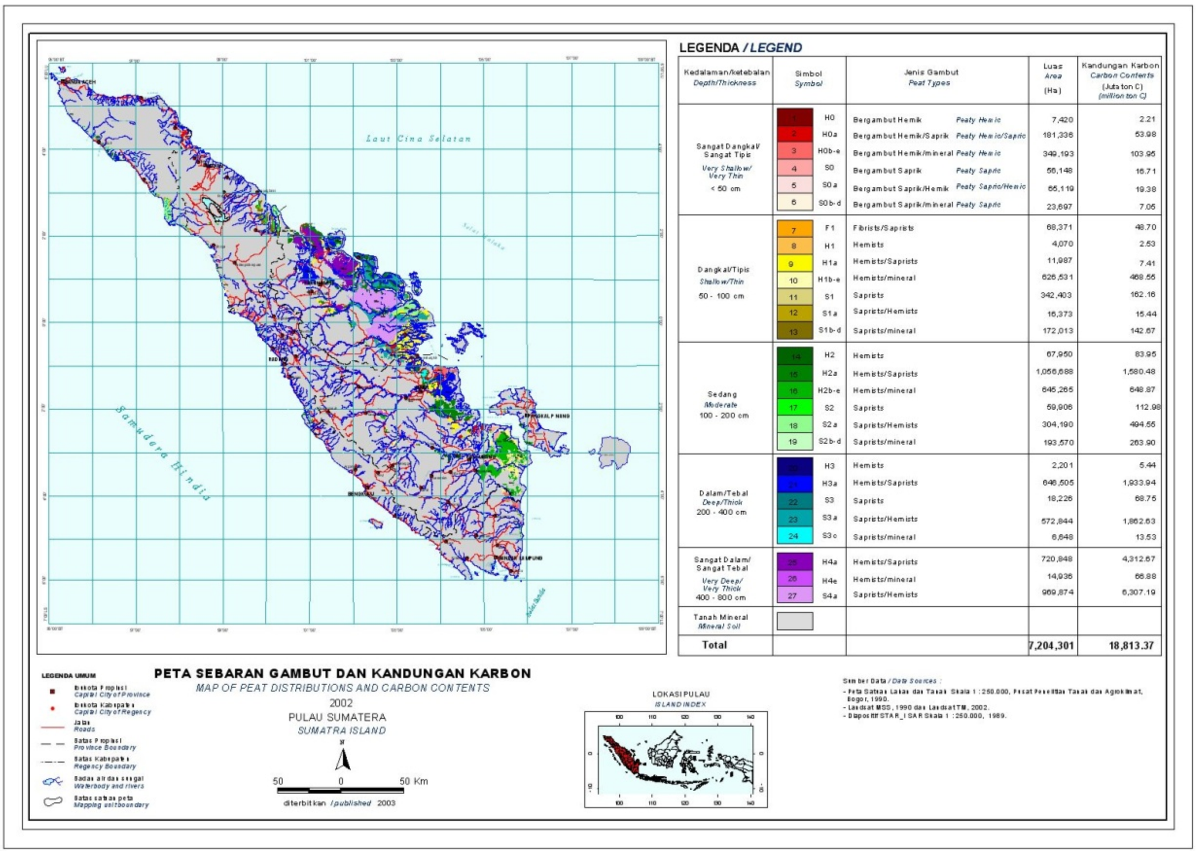
Wahyunto, Ritung S., Suparto and Subagjo H. 2005. Peat land Distribution and Carbon Content in Sumatra and Kalimantan. Wetland International- Indonesia Program and Wildlife Habitat Canada (WHC). Bogor – Indonesia

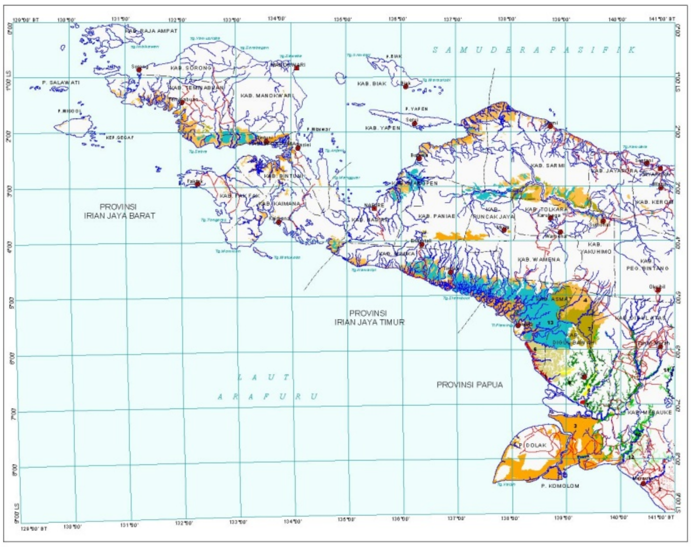
Wahyunto, Suparto, Bambang Heryanto and Hasyim Bekti. 2006. Sebaran Lahan Gambut, Luas dan Cadangan Karbon Bawah Permukaan di Papua. Wetland International Indonesia Programme. Bogor – Indonesia.

Wahyunto, Wahyu Wahdini, Hasyim Bekti and Sunaryo. 2007. Assessment of carbon stock and emission from peat land. Research Report, Indonesian Centre for Agricultural Land Resources Research and Development and World Agroforestry Centre (ICRAF). Bogor-Indonesia. 2007. *Unpublished* .

Wijk, C.L. van. 1951. Soil survey of the tidal swamps of south Borneo in connection with their agricultural possibilities. Cont. Gen. Agric. Res. Sta.No.123, Bogor, Indonesia.


LEGENDA / LEGEND
Kedalaman/Ketebalan Depth/Thickness | Simbol Symbol | Jenis Gambut Peat Types | Luas (Ha) Area (Ha) | Kandungan Karbon Carbon Content (Juta ton C) (million ton C)
Sangat Dangkal Very Shallow < 50 cm | 1 H0 | Hemists/Mineral | 113,465 | 5.04
Dangkal/Tipis Shallow/Thin 50-100 cm
2 H1a | Hemists/Fibrists | 421,313 | 169.11
3 H1b | Hemists/Fibrists/Mineral | 275,635 | 123.78
4 H1c | Hemists/Mineral | 147,660 | 44.58
5 H1d | Hemists/Saprists/Mineral | 133,667 | 47.41
6 H1e | Hemists/Mineral | 125,827 | 13.71
7 H1i | Hemists/Mineral | 604,802 | 34.27
Sedang Moderate 100-200 cm
8 S1i | Saprists/Mineral | 31,681 | 1.51
9 H2a | Hemists/Fibrists | 1,222,010 | 1,386.67
10 H2b | Hemists/Fibrists/Mineral | 86,983 | 53.71
11 H2d | Hemists/Fibrists/Saprists | 3,028 | 3.00
12 H2j | Hemists/Mineral | 9,976 | 3.01
13 S2g | Saprists/Hemists/Mineral | 68,790 | 15.88
Dalam/Tebal Deep/Thick 200-400 cm
14 H3a | Hemists/Fibrists | 949,913 | 1,598.08
15 H3b | Hemists/Fibrists/Saprists | 91,142 | 201.90
16 S3f | Hemists/Mineral | 64,041 | 17.74
Sangat Dalam/ Sangat Tebal Very Deep/ Very Thick 400 -800 cm | 17 H4a | Hemists/Fibrists | 1,065,636 | 5,408.42
Dalam Sekali / Tebal Sekali Extremaly Deep/ Extremaly Thick 800-1200 cm | 18 H5a | Hemists/Fibrists | 277,694 | 2,146.72
Tanah Mineral Mineral Soil | 5,693,263 | 11,274.55
LEGENDA UMUM
Ibukota Propinsi Capital city of province
Ibukota Kabupaten Capital city of distric
Kota City
Jalan Roads
Batas Negara Country boundary
Batas Propinsi Province boundary
Batas Kabupaten Distric boundary
Batas Kecamatan
Badan air dan sungai Waterbody and rivers
Batas satuan peta Mapping unit boundary
PETA LUAS SEBARAN LAHAN GAMBUT DAN KANDUNGAN KARBON
MAP OF AREA OF PEATLAND DISTRIBUTION AND CARBON CONTENT
2004
PULAU KALIMANTAN
KALIMANTAN ISLAND
N
100 0 100 200 Km
Diterbitkan /Published in 2004
LOKASI PULAU
ISLAND LOCATION
Sumber Data / Data Sources :
- Peta Sebaran Gambut Kalimantan, Skala 1: 250.000, Tahun 1994, Endeco Duta Utama / Departemen Pekerjaan Umum, Jakarta
- Peta Tanah Daerah Kalimantan Skala 1:1.000.000, Tahun 1997, Pusat Penelitian Tanah - Bogor
- Citra Landsat TM Pulau Kalimantan, Tahun 1990 - 2002
- Peta Lahan Basah Pulau Kalimantan Skala 1:1.000.000, Tahun 2003, Puslitbangtanah Dan Agroklimat - Bogor
Dibiayai oleh Pemerintah Kanada melalui Canadian International Development Agency (CIDA)
Financial support from the Government of Canada provided through the Canadian International Development Agency (CIDA)
WETLANDS INTERNATIONAL
Canadian International Development Agency
Agence canadienne de développement international


LEGENDA / LEGEND
Kedalaman/ketebalan Depth/Thickness | Simbol Symbol | Jenis Gambut Peat Types | Luas Area (Ha) | Kandungan Karbon Carbon Contents (Juta ton C) (million ton C)
Sangat Dangkal/ Sangat Tipis Very Shallow/ Very Thin < 50 cm
1 H0 | Bergambut Hemik Peaty Hemic | 7,420 | 2.21
2 H0a | Bergambut Hemik/Saprik Peaty Hemic/Sapric | 181,336 | 53.98
3 H0b-e | Bergambut Hemik/mineral Peaty Hemic | 349,193 | 103.95
4 S0 | Bergambut Saprik Peaty Sapric | 56,148 | 16.71
5 S0a | Bergambut Saprik/Hemik Peaty Sapric/Hemic | 65,119 | 19.38
6 S0b-d | Bergambut Saprik/mineral Peaty Sapric | 23,697 | 7.05
Dangkal/Tipis Shallow/Thin 50 - 100 cm
7 F1 | Fibrists/Saprists | 68,371 | 48.70
8 H1 | Hemists | 4,070 | 2.53
9 H1a | Hemists/Saprists | 11,987 | 7.41
10 H1b-e | Hemists/mineral | 626,531 | 468.55
11 S1 | Saprists | 342,403 | 162.16
12 S1a | Saprists/Hemists | 16,373 | 15.44
13 S1b-d | Saprists/mineral | 172,013 | 142.67
Sedang Moderate 100 - 200 cm
14 H2 | Hemists | 67,950 | 83.95
15 H2a | Hemists/Saprists | 1,056,688 | 1,580.48
16 H2b-e | Hemists/mineral | 645,265 | 648.87
17 S2 | Saprists | 59,906 | 112.98
18 S2a | Saprists/Hemists | 304,190 | 494.55
19 S2b-d | Saprists/mineral | 193,570 | 263.90
Dalam/Tebal Deep/Thick 200 - 400 cm
20 H3 | Hemists | 2,201 | 5.44
21 H3a | Hemists/Saprists | 646,505 | 1,933.94
22 S3 | Saprists | 18,226 | 68.75
23 S3a | Saprists/Hemists | 572,844 | 1,862.63
24 S3c | Saprists/mineral | 6,648 | 13.53
Sangat Dalam/ Sangat Tebal Very Deep/ Very Thick 400 - 800 cm
25 H4a | Hemists/Saprists | 720,848 | 4,312.67
26 H4e | Hemists/mineral | 14,936 | 66.88
27 S4a | Saprists/Hemists | 969,874 | 6,307.19
Tanah Mineral Mineral Soil
Total | 7,204,301 | 18,813.37
Laut Cina Selatan
Samudera Hindia
LEGENDA UMUM
Ibukota Propinsi Capital City of Province
Ibukota Kabupaten Capital City of Regency
Jalan Roads
Batas Propinsi Province Boundary
Batas Kabupaten Regency Boundary
Badan air dan sungai Waterbody and rivers
Batas satuan peta Mapping unit boundary
PETA SEBARAN GAMBUT DAN KANDUNGAN KARBON
MAP OF PEAT DISTRIBUTIONS AND CARBON CONTENTS
2002
PULAU SUMATERA
SUMATRA ISLAND
50 0 50 Km
diterbitkan /published 2003
LOKASI PULAU
ISLAND INDEX
Sumber Data / Data Sources :
- Peta Satuan Lahan dan Tanah Skala 1 : 250.000, Pusat Penelitian Tanah dan Agroklimat, Bogor, 1990.
- Landsat MSS, 1990 dan Landsat TM, 2002.
- Diapositif STAR_ISAR Skala 1 : 250.000, 1989.



LEGENDA / *LEGEND*

Kedalaman/Ketebalan *Depth/Thickness*	Simbol *Symbol*	Jenis Gambut *Peat Types*	Proporsi (%) *Proportion*	Luas (Ha) *Area (Ha)*	Kandungan Karbon *Carbon Content* (Juta ton C) *(million ton C)*
Sangat Dangkal/Tipis *Very Shallow/Thin* < 50 cm	1	Mineral/mineral bergambut	70/30	92,356	3.41
	2	Mineral bergambut	100	88,137	10.86
Dangkal/Tipis *Shallow/Thin* 50-100 cm	3	Mineral/Hemists	75/25	1,871,731	246.99
	4	Mineral/Hemists	60/40	2,362,555	497.67
	5	Mineral/Saprists/Hemists	60/20/20	47,991	10.55
	6	Saprists/mineral bergambut	60/40	316,072	108.56
	7	Hemists/mineral	75/25	778,031	307.30
Sedang *Moderate* 101-200 cm	8	Mineral/Hemists	80/20	287,929	60.65
	9	Mineral/Saprists	80/20	35,386	8.11
	10	Mineral/Fibrists	75/25	264,017	46.23
	11	Hemists/Fibrists/mineral	60/20/20	25,292	19.53
	12	Saprists/Hemists/mineral	75/20/5	88,613	94.76
Dalam/Tebal *Deep/Thick* 201-300 cm	13	Hemists/Fibrists/ Saprists/mineral	30/30/20/20	1,717,345	2.208.74
Tanah Mineral *Mineral Soil*				tidak dihitung	tidak dihitung
Total				**7,975,455**	**3,623.36**

LEGENDA UMUM

- Ibukota Provinsi / *Capital city of the province*
- Ibukota Kabupaten / *Capital city of the district*
- Jalan / *Roads*
- Batas Negara / *Country boundary*
- Batas Provinsi / *Province boundary*
- Batas Kabupaten / *District boundary*
- Batas Kecamatan / *Sub-district boundary*
- Badan air dan sungai / *Waterbody and rivers*
- Batas satuan peta / *Mapping unit boundary*

PETA SEBARAN LAHAN GAMBUT, LUAS DAN KANDUNGAN KARBON

MAP OF PEATLAND DISTRIBUTION, AREA AND CARBON CONTENT

PAPUA - INDONESIA

N

100 0 100 200 Km

1:6.000.000

Diterbitkan / *Published in* 2006

LOKASI PULAU
ISLAND INDEX

Sumber Data / *Data Sources* :

- Survei Tanah Tinjau Skala 1:250.000 Daerah Merauke-1, Provinsi Irian Jaya, Pusat Penelitian Tanah - Bogor, 1987
- Survei Tanah Tinjau Skala 1:250.000 Daerah Merauke-2, Provinsi Irian Jaya, Pusat Penelitian Tanah - Bogor, 1988
- Land System and Land Suitability Maps of Irian - Indonesia, Scale 1:250.000, Regional Physical Planning Program for Transmigration (RePPProT), 1986, Department of Transmigration and Bakosurtanal
- Atlas Sumberdaya Tanah Ekplorasi Indonesia, Skala 1:1.000.000, Pusat Penelitian Tanah - Bogor, 2000

Canadian International Development Agency
Agence canadienne de développement international

8