



# Global and regional importance of the tropical peatland carbon pool

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## Global and regional importance of the tropical peatland carbon pool



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Abstract:	<p>Accurate inventory of tropical peatland is important in order to (a) determine the magnitude of the carbon pool; (b) estimate the scale of transfers of peat-derived greenhouse gases to the atmosphere resulting from land use change; and (c) support carbon emissions reduction policies. We review available information on tropical peatland area and peat thickness and calculate peat volume and carbon content in order to determine their best estimates and ranges of variation globally, regionally and nationally. Our best estimate of tropical peatland area is 439,238 km<sup>2</sup> (~11% of global peatland area) of which 247,778 km<sup>2</sup> (57%) is in Southeast Asia. We estimate the volume of tropical peat to be 1,756 Gm<sup>3</sup> (~22-33% of global peat volume) with the highest share in Southeast Asia (77%). This new assessment reveals a larger tropical peatland carbon pool than previous estimates, with a best estimate of 88.5 Gt (range 81.5-91.8 Gt) equal to 17-19% of the global peat carbon pool. Of this, 68.5 Gt (77%) is in Southeast Asia. A single country, Indonesia, holds the largest share (57.4 Gt, 65%), followed by Malaysia (9.1 Gt, 10%). These data are used to provide revised estimates for Indonesian and Malaysian forest soil carbon pools of 77 Gt and 15 Gt, respectively, and total forest carbon pools (biomass plus soil) of 97 Gt and 19 Gt. Peat carbon comprises 60% of the total soil carbon pool in Malaysia and 74% in Indonesia. These results emphasise the prominent global and regional role played by the Southeast Asian peat carbon pool and the importance of including peat carbon in national and regional assessments of terrestrial carbon stocks. This information is essential given current interest in greenhouse gas emissions from</p>

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	developed and degraded peatlands and the need to predict future trends under the influence of land use and climate change.



For Review Only

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3 1 **Global and regional importance of the tropical peatland carbon pool**  
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46 19 **Running title:** Tropical peatland carbon pool  
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## 1 Abstract

2 Accurate inventory of tropical peatland is important in order to (a) determine the  
3 magnitude of the carbon pool; (b) estimate the scale of transfers of peat-derived  
4 greenhouse gases to the atmosphere resulting from land use change; and (c) support  
5 carbon emissions reduction policies. We review available information on tropical  
6 peatland area and peat thickness and calculate peat volume and carbon content in  
7 order to determine their best estimates and ranges of variation globally, regionally and  
8 nationally. Our best estimate of tropical peatland area is 439,238 km<sup>2</sup> (~11% of global  
9 peatland area) of which 247,778 km<sup>2</sup> (57%) is in Southeast Asia. We estimate the  
10 volume of tropical peat to be 1,756 Gm<sup>3</sup> (~22-33% of global peat volume) with the  
11 highest share in Southeast Asia (77%). This new assessment reveals a larger tropical  
12 peatland carbon pool than previous estimates, with a best estimate of 88.5 Gt (range  
13 81.5-91.8 Gt) equal to 17-19% of the global peat carbon pool. Of this, 68.5 Gt (77%)  
14 is in Southeast Asia. A single country, Indonesia, holds the largest share (57.4 Gt,  
15 65%), followed by Malaysia (9.1 Gt, 10%). These data are used to provide revised  
16 estimates for Indonesian and Malaysian forest soil carbon pools of 77 Gt and 15 Gt,  
17 respectively, and total forest carbon pools (biomass plus soil) of 97 Gt and 19 Gt. Peat  
18 carbon comprises 60% of the total soil carbon pool in Malaysia and 74% in Indonesia.  
19 These results emphasise the prominent global and regional role played by the  
20 Southeast Asian peat carbon pool and the importance of including peat carbon in  
21 national and regional assessments of terrestrial carbon stocks. This information is  
22 essential given current interest in greenhouse gas emissions from developed and  
23 degraded peatlands and the need to predict future trends under the influence of land  
24 use and climate change.

## 1 Introduction

2 Peatlands are globally important terrestrial carbon pools and vital components of  
3 carbon soil-atmosphere exchange processes (Immirzi *et al.*, 1992; Strack, 2008). By  
4 area, peatlands have their greatest extent of 3,570,000 km<sup>2</sup> in boreal and temperate  
5 zones (Immirzi *et al.*, 1992) but tropical peatlands, which are located in Southeast  
6 Asia, Africa, the Caribbean, Central and South America, are also an important  
7 component of the global peatland resource, contributing to terrestrial carbon storage  
8 in both their above-ground biomass and underlying thick deposits of peat (Rieley *et*  
9 *al.*, 1996; Page *et al.*, 1999; Page *et al.*, 2004). Most tropical peatlands are located at  
10 low altitude, although a proportion occurs at high altitude in the mountains of Africa,  
11 South America and Papua New Guinea.

12  
13 There is growing recognition of the importance of carbon storage in, and carbon gas  
14 emissions from, tropical peatlands and their role in global environmental change  
15 processes. Degradation of tropical peatlands leads to release of carbon and a reduction  
16 in the size of their carbon stores (Page *et al.*, 2002; Jauhiainen *et al.*, 2005, 2008;  
17 Hooijer *et al.*, 2006, 2009; Rieley *et al.*, 2008). The most rapid degradation of tropical  
18 peatland is currently taking place in Southeast Asia where there are strong economic  
19 and social pressures for timber, land for agriculture and plantations of oil palm and  
20 pulp trees (Koh *et al.*, 2009). As a consequence, this region's peatlands have  
21 undergone rapid deforestation in the last two decades (Langner *et al.*, 2007, Langner  
22 & Siegert, 2009), widespread drainage (Hooijer *et al.*, 2006, 2009), and frequent and  
23 intensive fires (Page *et al.*, 2002, 2009a; Langner *et al.*, 2007; Langner & Siegert,  
24 2009). These have caused high levels of carbon gas emissions to the atmosphere

1 through loss of biomass, peat oxidation and combustion (Hooijer *et al.*, 2006, 2009;  
2 Page *et al.*, 2002; van der Werf *et al.*, 2004, 2008). Tropical peatlands are also  
3 sensitive to changes in temperature and precipitation and evidence shows that  
4 prolonged periods of drought can change them from carbon sinks to carbon sources  
5 (Suzuki *et al.*, 1999; Hirano *et al.*, 2007).

6

7 As a consequence of these impacts, tropical peatlands are areas of high carbon  
8 density, which play an important role in carbon-gas land-atmosphere interactions  
9 (Canadell *et al.*, 2004; Gruber *et al.*, 2004). This updated and improved inventory is  
10 important in order to determine the global area of tropical peatland and the magnitude  
11 of its carbon pool, estimate the likely scale of transfers of peat-derived greenhouse  
12 gases to the atmosphere resulting from changes in tropical peatland use both now and  
13 in coming decades, and predict what is likely to happen to the peatland carbon sink  
14 and store under the influence of future climate change. These data are also necessary  
15 for improving global climate-carbon models and supporting initiatives to improve  
16 peatland management planning and policy for climate change mitigation and carbon  
17 accounting. For example, new policy initiatives to reduce greenhouse gas emissions  
18 through avoided deforestation in developing countries (REDD and the voluntary  
19 carbon market) have emphasised the potential for conserving tropical peatlands by  
20 negotiating carbon offset and trading agreements (Murdiyarso *et al.*, 2008).

21

22 This paper augments other recent regional studies of carbon pools in peat  
23 accumulating ecosystems (e.g. North American wetlands (Bridgham *et al.*, 2006),  
24 west Siberian peatlands (Yefremov & Yefremova, 2001) and the northern permafrost

1 region (Tarnocai *et al.*, 2009)) by re-evaluating the status of tropical peatlands in  
2 regional and global peatland and soil carbon pools. Several previous peatland  
3 inventories (e.g. Immirzi *et al.*, 1992; Lappalainen, 1996) presented the area and  
4 volume of tropical peatland on a country by country basis, but were hampered by a  
5 lack of reliable data and knowledge of their accuracy and provenance. Our study  
6 builds upon these inventories and incorporates new published and unpublished  
7 information, assesses the reliability of the data and, where possible, provides an  
8 evaluation of their uncertainty by giving ranges of estimates.

9  
10 The specific objectives of this paper are to (1) present best estimates of the important  
11 attributes of tropical peatland (area, thickness, volume, bulk density and carbon  
12 content) by country and region in order to provide improved knowledge and certainty  
13 of the amount of peat in tropical countries and the magnitude of the carbon pools, and  
14 (2) assess the contribution of tropical peatland to national, regional and global  
15 peatland inventories and soil carbon stocks.

## 19 MATERIALS AND METHODS

20 In carrying out this assessment, we constrained the data in several ways: firstly, by  
21 including only those countries that lie between the Tropics of Cancer and Capricorn  
22 (23.5°N and 23.5°S, respectively), which excludes some peatland in the sub-tropics  
23 (e.g. Florida Everglades) but includes high altitude peatlands, some of which bear  
24 greater resemblance to temperate than lowland tropical peatland and, secondly, by



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3 1 defining peat as the surface layer of soil, consisting mostly of partially decomposed  
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5 2 vegetation, with an organic content of at least 65% in a minimum thickness of 30 cm  
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8 3 (Andriess, 1988; Rieley & Page, 2005). Not all tropical peatland inventories follow  
9  
10 4 this definition, or define the resource, and there are inconsistencies in the data  
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12 5 available for assessment.  
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17 7 We encountered anomalies and mistakes in some estimates of tropical country  
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19 8 peatland areas that had been incorporated into subsequent reports and publications.  
20  
21 9 For example, the highest published estimate of peatland area in Indonesia (270,000  
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23 10 km<sup>2</sup>) provided by Jansen *et al.* (1985) is cited by several other authors. This area is  
24  
25 11 based on a definition of peat as a cumulative layer of 40 cm or more containing  
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27 12 greater than 30% organic matter and therefore is for the total area of Histosols that  
28  
29 13 includes both non-peat organic soil and true peat according to our definition. The  
30  
31 14 lowest reported value for Indonesia of 160,000 km<sup>2</sup> is also given by Jansen *et al.*  
32  
33 15 (1985), although its origin is probably Polak (1952), who considered peat as soils with  
34  
35 16 more than 65% organic matter in a cumulative layer of at least 1 metre. The  
36  
37 17 definitions of peat used to obtain these area values are, therefore, different and  
38  
39 18 illustrate the importance of using a standardised approach. In addition, we believe that  
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41 19 this lower value of 160,000 km<sup>2</sup>, which is cited frequently, applies only to Kalimantan  
42  
43 20 and Sumatra since Indonesia did not acquire Irian Jaya (now West Papua) until 1963  
44  
45 21 and its peatland area was not included in earlier inventories.  
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## 58 24 **Data sources, assessment and components**

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## 1 *Data Sources*

2 The principal sources of information consulted were global (Kivinen & Pakarinen,  
3 1980, 1981; Bord na Mona, 1984; Immirzi *et al.*, 1992; Lappalainen, 1996; Joosten &  
4 Clarke, 2002; GPD, 2004; World Energy Council, 2004) and tropical peatland  
5 inventories (Shier, 1985; Andriesse, 1988; Rieley *et al.*, 1996; Rieley & Page, 2005).  
6 Where possible, primary reports and published papers, from which these inventories  
7 were derived, were consulted. Later inventories tend to quote data from earlier ones  
8 and the trail leads mostly to the same origins, namely Bord na Mona (1984) and  
9 Kivinen & Pakarinen (1980, 1981); the former obtained information from official  
10 government sources and both derived data from various proceedings of and surveys  
11 undertaken by members of the International Peat Society (e.g. IPS, 1985). A few  
12 sources of information for peatland area in Indonesia could not be checked owing to  
13 their unavailability in a consultancy report (Jansen *et al.*, 1985), symposium  
14 proceedings (Soeprahardjo & Driessen, 1976) and an old issue of a Dutch  
15 scientific journal (Polak, 1952).

16  
17 These inventory data were collected and collated for different purposes using a variety  
18 of criteria and methods and mostly provide ranges of values, the upper and lower  
19 limits of which might have been obtained from different sources. For example, the  
20 detailed report prepared by Bord na Mona (Bord na Mona, 1984) for the World Bank  
21 focuses on the potential of peat in developing countries for energy and focussed on  
22 peat with a minimum thickness of one metre. Detailed inventories and primary reports  
23 were available for Southeast Asia, especially Indonesia, where a major proportion of  
24 tropical peatland is located and whose peat resources are relatively well documented  
25 (e.g. RePPPProt, 1988-1990). For most other countries, however, only single inventory

1 values were available giving the impression of precision of survey and accuracy of the  
2 data when, in fact, the opposite was the case. We also found that many published  
3 estimates had been rounded to tens, hundreds and even thousands of hectares, whilst  
4 some inventories focused on the highest available estimates and ignored much lower  
5 minimum values (e.g. Joosten & Clarke, 2002).

6

7

## 8 *Data components*

### 9 *Peatland area*

10 The area of tropical peatland is usually included in national soil inventories but those  
11 for different countries may not be strictly comparable owing to different definitions of  
12 peat and inclusion of non-peat organic soils in the statistics. If, for example, the  
13 minimum thickness of the surface organic layer adopted is 50 cm this will provide a  
14 smaller estimate of peatland area than if it were 20 cm or less. Many country  
15 inventories provide the area of Histosols and organic soils, of which peat is one type,  
16 but which is not always separated, and therefore the area of non-peat Histosols (<30  
17 cm) may exceed that of true peat. As far as was possible, non-peat Histosols are  
18 included in the maximum estimates and dealt with separately.

19

20 The data that we acquired on peatland area revealed large variation, not only between  
21 countries and regions but also within countries (minimum compared to maximum). In  
22 determining best estimates it is important to treat the maximum estimates with caution  
23 since they may include large areas of shallow peat and non-peat Histosols and organic  
24 soils. In a few instances they also include other wetlands. In arriving at best estimates,  
25 however, it is inappropriate to simply determine the means of the minimum and

1 maximum values, the approach adopted by Immirzi *et al.* (1992) and others. Instead  
2 we used a discriminating approach in which we assessed every piece of data to  
3 determine its likely accuracy. In doing this we used our expert judgment to accept  
4 data (maximum or minimum) as best estimates if the accounts were recent (post 1990)  
5 and originated from official sources. This was possible for only a few countries, for  
6 example, Indonesia and Malaysia. In those cases for which maximum values exceeded  
7 minimum values greatly we subtracted them, calculated 25% of the difference and  
8 added this amount to the minimum value. This was done to prevent distortion of best  
9 estimates as a result of inflated maximum areas and to provide a conservative  
10 evaluation.

### 13 ***Peat thickness***

14 Knowledge of peat thickness, country by country and best estimates for all tropical  
15 countries are essential in order to determine as accurately as possible the total volume  
16 of tropical peat and hence its carbon content. Data on peat thickness are much fewer  
17 than for area because acquisition requires time-consuming direct measurement in the  
18 field and the difficulty of sampling peat with a thickness of up to 10 metres or more  
19 containing a large proportion of very hard tree remains. Even when values are  
20 available, there is usually no information on the sampling methods or means of data  
21 evaluation and interpolation. Peat thickness cannot be treated in the same way as  
22 peatland area because (a) the minimum is often the lowest value that can qualify as  
23 peat (0.3 m), (b) the maximum may relate to only one or a few high values in the  
24 literature, and (c) mean peat thicknesses and ranges are seldom available.

25

1 A few sources provide maximum peat thickness, others indicate ranges while some  
2 give a mean. Default values of 0.3 m and 2 m were applied as minimum and  
3 maximum thicknesses, respectively, to those countries for which peat thickness data  
4 could not be found. We used mean thicknesses as best estimates where these were  
5 available, otherwise we derived them conservatively from 25% of the maximum  
6 values in order to derive conservative estimates. We used only best estimate peat  
7 thickness values to calculate minimum, maximum and best estimates of peat volume  
8 and carbon pools.

#### 10 *Peat volume*

11 This is the product of peatland area and peat thickness.

$$12 \quad V_p = A_p \times T_p \quad (1)$$

14 Where  $V_p$  = peat volume ( $m^3$ );  $A_p$  = area of tropical peatland ( $m^2$ );  $T_p$  = mean peat  
15 thickness (m)

17 The minimum mean peat volume in a country is obtained by multiplying the  
18 minimum area by the minimum thickness. The best estimate mean volumes are  
19 derived in a similar manner. In the determination of maximum peat volumes the areas  
20 in excess of the best estimate area values were considered to have thin peat only, with  
21 a mean thickness 0.3 m, and these volumes were computed separately and added to  
22 the best estimates to provide maximum peat volume values. This was felt necessary in  
23 order to maintain the conservative approach used throughout this assessment.

#### 25 *Bulk density and carbon content of tropical peat*

1 Peat bulk density (BD) is the dry mass of a standard volume of field material (solids  
2 plus pore space and water) that has been dried to constant weight at 80°C and is  
3 usually expressed in grammes per cubic centimetre ( $\text{g cm}^{-3}$ ) or kilogrammes per cubic  
4 metre ( $\text{kg m}^{-3}$ ). Bulk density depends on the degree of peat compaction, water content,  
5 plants from which the peat has formed, degree of peat decomposition, mineral content  
6 of the peat and land use. The method used to measure bulk density and the way in  
7 which it is expressed (e.g. dry or wet BD) are important considerations when  
8 comparing data from different authorities and between countries.

9  
10 Carbon content of peat is usually expressed as fraction of the dry peat dry weight  
11 (50% = 0.5). Carbon contents published in the literature have been determined by  
12 different methods that have changed over time and have become more automated and  
13 sophisticated. Consequently, differences between carbon contents may be partly a  
14 result of these differences in analytical procedures, although the methods used are  
15 seldom specified.

16  
17 Unfortunately, there are few published data on either bulk density or percentage  
18 carbon for tropical peatlands and these vary spatially over the surface of tropical  
19 peatland and at different depths within peat profiles. Most bulk density values in the  
20 literature are for surface or subsurface tropical peats to a maximum depth of 100 cm,  
21 but mostly in the upper 50 cm or less. Bulk density is often higher at the surface  
22 compared to the rest of the peat profile although the highest values are usually  
23 obtained for bottom peat samples, close to the underlying mineral ground, in which  
24 the organic matter content is lowest and mineral content highest (Weiss *et al.*, 2002;  
25 Page *et al.*, 2004). It is probably true to say that low bulk densities are associated with

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3 1 high carbon contents (i.e. more organic samples) and *vice versa*; high bulk densities  
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5 2 are associated with high mineral and low carbon contents.  
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10 4 Carbon contents of tropical peats are less variable across their surface and down  
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12 5 profiles than bulk densities. Lowest values are for samples taken near to the  
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14 6 underlying mineral substrate or for very shallow peats in which there is a larger  
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16 7 proportion of inorganic material and these do not fit with our definition of peat. The  
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18 8 carbon content of surface tropical peat varies depending on vegetation cover and land  
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20 9 use and, as with bulk density, may not provide a true representation of entire peat  
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22 10 deposits.  
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29 12 As with peat thickness, the most detailed information on bulk density and carbon  
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31 13 content was available for Indonesian and Malaysian peat deposits and very few data  
32  
33 14 were found for peat in other tropical countries. In the absence of data, we applied best  
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35 15 estimate values for bulk density and carbon content that were derived from our  
36  
37 16 assessment of the literature on peats in these two countries and taking into account  
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39 17 values from other countries where available.  
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### 45 19 *Carbon pool*

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48 20 The magnitude of the tropical peatland carbon pool is obtained by multiplying peat  
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50 21 volume by bulk density and percentage carbon content (Equation 2).  
51  
52  
53 22

$$54  
55 23 C_p = V_p \times BD_{be} \times C_c / 10^9 \quad (2)$$

1 Where  $C_p$  is the peatland carbon pool in Gt<sup>1</sup>;  $V_p$  is the volume of tropical peat in  
 2 Gm<sup>32</sup>;  $BD_{be}$  is best estimate mean dry bulk density determined as explained in the text  
 3 and expressed in g m<sup>-3</sup>;  $C_c$  is percentage carbon content expressed as a fraction.

## 6 **Results**

### 7 *Peatland area*

8 Data on the area of peatland in tropical countries and geographical regions together  
 9 with their maximum, minimum, best estimates and areas of shallow Histosols and  
 10 organic soils are presented in Table 1.

11 <<INSERT TABLE 1 NEAR HERE>>

12  
 13 The total area of tropical peatland lies within the range 384,776- 656,430 km<sup>2</sup>, with a  
 14 best estimate of 439,238 km<sup>2</sup>. The Southeast Asia region contains the largest share of  
 15 this resource (247,778 km<sup>2</sup>, 57% of the best estimate value), followed by South  
 16 America (106,363 km<sup>2</sup>; 24%), Africa (55,616 km<sup>2</sup>; 13%), Central America and the  
 17 Caribbean (22,956 km<sup>2</sup>; 5%), Asia (other) (6,335 km<sup>2</sup>; 1%) and the Pacific region  
 18 (190 km<sup>2</sup>; <1%) (Table 1). Within Southeast Asia, Indonesia has the largest area  
 19 (206,950 km<sup>2</sup>, 47% of the total best estimate), followed by Malaysia (25,889 km<sup>2</sup>;  
 20 6%) and Papua New Guinea (10,986 km<sup>2</sup>; 3%) with other countries in this region  
 21 containing a much smaller amount (1% collectively in Brunei, Myanmar, the  
 22 Philippines, Thailand and Vietnam).

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1 <sup>1</sup> Gt = Gigatonnes = Billion tonnes = t x 10<sup>9</sup> = g x 10<sup>15</sup> = Petagrammes

2 <sup>2</sup> Gm – Giga cubic metres = m<sup>3</sup> x 10<sup>9</sup>



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3 1 In South America the largest peatland area is in Peru (50,000 km<sup>2</sup>; 11%) followed by  
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5 2 Brazil (23,875 km<sup>2</sup>; 5%), Venezuela (10,000 km<sup>2</sup>; 2%) and Guyana (8,139 km<sup>2</sup>; 2%).  
6  
7  
8 3 In Africa, Zambia contains 12,201 km<sup>2</sup> (3%) of the tropical peatland area, followed by  
9  
10 4 Sudan with 9,068 km<sup>2</sup> (2%) and Uganda 7,300 km<sup>2</sup> (2%). Panama in Central America  
11  
12 5 has a peatland area of 7,870 km<sup>2</sup> (2%). All other tropical countries have smaller areas  
13  
14  
15 6 of peatland equal to 1% or less of the total.  
16  
17  
18 7

### 8 *Peat thickness*

9 Those tropical countries for which peat thickness values were available are listed in  
10 Table 2 and the best estimates of the means are used in subsequent calculations of  
11 peat volumes and carbon pools. For countries without information on peat thickness,  
12 default values were applied (see above).  
13

14 The thickest peat deposits in this assessment are in Africa with best estimates of mean  
15 peat thickness of 11 m in Rwanda, 8 m in Burundi, 7.5 m in Congo, 5 m in Nigeria  
16 and 4 m in both Democratic Republic of Congo and Uganda. In Southeast Asia the  
17 thickest peat is in Malaysia (7 m) followed by Indonesia (5.5 m). In Central America  
18 and the Caribbean peat is thickest in Panama with a best estimate of 6 m, followed by  
19 Cuba (1.8 m) and Trinidad and Tobago (1.3 m). There is no information on peat  
20 thickness for most other countries in this region and the default best estimate of 0.5 m  
21 has been applied to them. South American peats are shallower with a mean thickness  
22 of 4 m in Venezuela, 2 m in Brazil and 1.75 m in Peru.  
23

24 << INSERT TABLE 2 NEAR HERE >>  
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3 1 ***Peat volume***  
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5 2 The maximum, minimum and best estimates of peatland volume by country and by  
6 3 region are given in Table 3. The total volume of tropical peat is in the range 1,618 to  
7 4 1,822 Gm<sup>3</sup> with a best estimate of 1,756 Gm<sup>3</sup>. Southeast Asia has the largest share of  
8 5 the tropical peatland resource by volume (1,359 Gm<sup>3</sup>; 77% of the best estimate),  
9 6 followed by South America (190 Gm<sup>3</sup>; 11%), Africa (136 x 10<sup>9</sup> m<sup>3</sup>; 8%), Central  
10 7 America and the Caribbean (62 x Gm<sup>3</sup>; 4%), with Asia (other) and the Pacific region  
11 8 together containing only 9 Gm<sup>3</sup> (1%) (Table 3).  
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20 10 <<INSERT TABLE 3 NEAR HERE>>  
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29 12 Within Southeast Asia, as with area, Indonesia has the largest share of the tropical  
30 13 peatland resource by volume (1,138 Gm<sup>3</sup>; equivalent to 65% of the best estimate  
31 14 global total), followed by Malaysia (181 Gm<sup>3</sup>; 10%) and Papua New Guinea (27 Gm<sup>3</sup>;  
32 15 2%) (Table 3). All other countries in this region have less than 1% and contribute very  
33 16 little to the overall global tropical peat resource. In South America, Peru has 88 G m<sup>3</sup>  
34 17 (5%), followed by Brazil (48 G m<sup>3</sup>; 3%) and Venezuela (40 x 10<sup>9</sup> Gm<sup>3</sup>; 2%). Congo  
35 18 has the largest volume in Africa with 47 Gm<sup>3</sup> (3%), followed by Uganda (29 Gm<sup>3</sup>;  
36 19 2%). In Central America and the Caribbean, Panama has a peat volume of 47 Gm<sup>3</sup>  
37 20 (3%). All other countries contain 1% or less of the tropical peat volume.  
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53 22 ***Peat bulk density***  
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55 23 Virtually all of the bulk density data available in the literature are for Southeast Asia,  
56 24 especially Sarawak, Malaysia and Kalimantan and Sumatra in Indonesia, although a  
57 25 few values were found for some other countries (Table 4). It is difficult to obtain  
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1 primary data for bulk density and most published information provides ranges only;  
2 there are few individual values, means or standard deviations. For surface peats the  
3 bulk density values represent the spatial variation while, for peat cores, the ranges  
4 indicate upper and lower extremes only and do not provide detail of the variation in  
5 bulk density throughout the peat profile. If surface values only are used the bulk  
6 density will be higher than if the lower values in the rest of the profile are taken into  
7 account. Similarly, in peatland converted to agriculture the high bulk densities in the  
8 upper one metre or so of the peat soil following compaction do not indicate the much  
9 lower values in the permanently waterlogged peat beneath. In the absence of sufficient  
10 information on peat bulk density across the tropics we used a single best estimate of  
11  $0.09 \text{ g cm}^{-3}$  that is a combination of the weighted means of  $0.08 \text{ g cm}^{-3}$  (Page *et al.*,  
12 2004) for peatland in Central Kalimantan, Indonesia and  $0.13 \text{ g cm}^{-3}$  for Central  
13 Kalimantan,  $0.08\text{-}0.13 \text{ g cm}^{-3}$  for Sumatra and  $0.09\text{-}0.13 \text{ g cm}^{-3}$  for West Kalimantan  
14 (Neuzil, 1997). The bulk densities obtained for a few other countries are in  
15 accordance with these.

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17 <<INSERT TABLE 4 ABOUT HERE>>

### 18 19 ***Peat carbon content***

20 Published values of carbon content of Southeast Asian peats range from 41.6%  
21 (Sajarwan *et al.*, 2002) to 62.0% in Central Kalimantan (Neuzil, 1997; Page *et al.*,  
22 2004) (Table 4). The much lower values that appear in some studies, e.g. 23.8% (Jaya,  
23 2007) and 26.0% (Sajarwan *et al.*, 2002), are for samples taken near to the underlying  
24 mineral substrate or for non-peat organic soils in which there is a large proportion of  
25 inorganic material and these do not fit with our definition of peat. For the purposes of

1 this assessment, the mean carbon content in peat from the Sabangau catchment,  
2 Central Kalimantan (Page *et al.*, 2004) of  $56\pm 3\%$  was adopted for calculation of  
3 tropical peat carbon content. This value is virtually the same as the value of  $57\pm 3\%$   
4 obtained by Neuzil (1997) for several cores from Central Kalimantan, West  
5 Kalimantan and Sumatra and is similar to the peat carbon content values that could be  
6 found for a few other countries.

7

### 8 ***Peat carbon pool***

9 The values for global, regional and national tropical peatland carbon pools follow a  
10 similar pattern to peat volume. The total tropical peatland carbon pool is in the range  
11 82-92 Gt with a best estimate of 89 Gt. The largest pool is in Southeast Asia (69 Gt,  
12 77% of the best estimate total), followed by South America (10 Gt; 11%), Africa (7  
13 Gt; 8%), Central America and the Caribbean (3 Gt; 4%) and Asia (other) and the  
14 Pacific region (<1 Gt; 1% combined) (Table 5). Within Southeast Asia, Indonesia has  
15 by far the largest share of the tropical peatland carbon pool (57 Gt, 65%), followed by  
16 Malaysia (9 Gt, 10%), with Brunei, Myanmar, Papua New Guinea, the Philippines,  
17 Thailand and Vietnam, collectively, containing a smaller proportion of the total (2%).

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### 23 ***Discussion***

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3 1 There have been several previous evaluations of the global area of peatlands and  
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5 2 estimates of their carbon store but these differ widely owing to a lack of detailed  
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8 3 information from many countries and differences in definitions of peat and estimates  
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10 4 of peat thickness (e.g. Moore & Bellamy, 1974; Bord na Mona, 1984; Armentano &  
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12 5 Menges, 1986; Andriessse, 1988; Gorham, 1991; Immirzi *et al.*, 1992). We used the  
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14 6 evaluation by Immirzi *et al.* (1992) as the most comprehensive estimate of the area of  
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16 7 boreal and temperate peatlands and added to this our updated tropical peatland area to  
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18 8 arrive at an improved global total (Table 6).  
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29 12 Tropical peatlands, with a best estimate area from this assessment of 439,238  
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31 13 (384,773 – 656,430) km<sup>2</sup>, make up 10 to 16% of the global peatland extent. The  
32  
33 14 peatlands of Southeast Asia, with a best estimate area of 247,778 km<sup>2</sup>, represent  
34  
35 15 between 6% and 8% of the global peatland area. South America has a peatland area of  
36  
37 16 106,363 (3% of the global peatland area), Africa has 55,616 km<sup>2</sup> (1%) and Central  
38  
39 17 America and the Caribbean have 22,956 km<sup>2</sup> (<1%).  
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46 19 According to Immirzi *et al.* (1992), the total global peat volume (mean=best estimate)  
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48 20 is 5,958 Gm<sup>3</sup>, based on an average peat thickness of 1.5 m. This underestimates the  
49  
50 21 greater thickness of tropical peat compared to boreal and temperate peat. By  
51  
52 22 combining the non-tropical peat volume of 5,335 Gm<sup>3</sup> (Immirzi *et al.*, 1992) with our  
53  
54 23 best estimate of 1,756 Gm<sup>3</sup> for the volume of tropical peat provides a larger global  
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56 24 estimate of 7,091 Gm<sup>3</sup> showing that tropical peatlands contain 25% of the global  
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58 25 peatland volume (Table 7), making a much larger contribution than their area  
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1 suggests. By using a higher mean peat thickness value of 2.3 m for boreal and  
2 temperate peat, as suggested by Gorham (1991), produces a peat volume of 8,180  
3 Gm<sup>3</sup> which, when combined by our assessment of the tropical peat volume, produces  
4 a global estimate of 9,936 Gm<sup>3</sup>, of which tropical peat comprises 17-18% and  
5 Southeast Asian peat 14%.

6

7 <<INSERT TABLE 7 AROUND HERE>>

8

9 Immirzi *et al.* (1992) conclude that the amount of carbon stored within peatlands  
10 globally is in the range 329 to 525 Gt with a mean value of 462 Gt, although other  
11 published values range from 234 to 679 Gt (Gorham, 1991; Eswaran *et al.*, 1993;  
12 Batjes, 1996; Lappalainen, 1996; Joosten & Clarke, 2002). Using the minimum,  
13 maximum and mean estimates of non-tropical peatland area from Immirzi *et al.*  
14 (1992), multiplying these by their peat carbon density (1099.5 t C ha<sup>-1</sup>) in a mean  
15 global peat thickness of 1.5 m, and adding the new tropical peat carbon store values  
16 obtained in this assessment, provides a new overall global estimate of 469 – 486 Gt  
17 with a best estimate of 480 Gt (Table 8). Using the greater mean thickness value of  
18 2.3 m for boreal and sub-arctic peat (Gorham, 1991) and thus a higher carbon density  
19 value of 1466 t C ha<sup>-1</sup>, results in a larger estimate of the global peat carbon store of  
20 between 598 to 618 Gt with a best estimate of 610 Gt (Table 8). On this basis of these  
21 assessments, the tropical peat carbon pool is between 11 and 14% of the global peat  
22 carbon pool.

23

24 The Southeast Asian region contains the largest proportion of the tropical peat carbon  
25 store with between 66.4-69.8 Gt C (best estimate 68.5 Gt C). We found that

1 Indonesian peatlands alone store 57.4 Gt compared to 42 Gt used by Hooijer *et al.*  
2 (2006, 2009) in their assessment of CO<sub>2</sub> emissions from drained peatlands in  
3 Southeast Asia but close to the value of 55 Gt C calculated for the Indonesian  
4 peatland carbon pool by Jaenicke *et al.* (2008) using a combination of 3D modelling  
5 and satellite imagery.

6  
7 The soil is the largest terrestrial pool of organic carbon, with global estimates ranging  
8 between 1395 Gt (Adams *et al.*, 1990), 1462-1548 Gt (Batjes, 1996) and 1600-1800  
9 Gt (Bouwman, 1990). Compared to a median value of 1500 Gt C in soils, tropical  
10 peatland represents between 5-6% of the global soil carbon pool. The size of the  
11 carbon pool in tropical soils generally is poorly known (Batjes, 1996), but in countries  
12 where peatland occupies a significant proportion of the land area, e.g. Indonesia  
13 (10.8%) and Malaysia (7.9%), this ecosystem holds a major proportion of the national  
14 soil carbon stock. Brown *et al.* (1993) estimated that the carbon pool in Indonesia's  
15 forest soils (to 100 cm depth) and vegetation was 40 Gt, of which soil carbon  
16 accounted for 50% (i.e. 20 Gt); values for Malaysia were 10 Gt C (6 Gt in soil plus 4  
17 Gt in biomass). Including our values for peat carbon pools could increase the  
18 Indonesian forest soil carbon pool to about 77 Gt (even allowing for the fact that  
19 Brown *et al.* (1993) included 100 cm thickness of peat swamp forest soil carbon in  
20 their estimate), producing a total forest carbon pool value of 97 Gt, of which the soil  
21 component is 79% and the peat 58%. Likewise the Malaysian forest soil carbon store  
22 increases to 15 Gt, with a total forest store of 19 Gt. Of this total value, soil carbon  
23 makes up 79% and the peat carbon proportion is 47%. Thus in these two countries,  
24 peat carbon comprises 60% of the total soil carbon pool in Malaysia and 74% in  
25 Indonesia. Forests across the entire tropical Asian region are estimated to have a total

1 soil carbon pool of 43 Gt with an additional 42 Gt in biomass (Brown *et al.*, 1993);  
2 including our best estimate of the tropical Asian peatland carbon pool (i.e. Southeast  
3 Asia plus Asia (other)) increases the value of this region's forest soil carbon pool to  
4 ~130 Gt, 68% of which is in peat. This new data assessment draws attention to the  
5 large contribution of Southeast Asian peatlands to both national and regional forest  
6 soil carbon and emphasises the importance of considering peat carbon stores in  
7 assessments of emissions from tropical land use change and fire.

8  
9 Our assessment highlights countries for which there is a lack of primary data on  
10 peatland area, thickness, bulk density and carbon content, leading to uncertainty in the  
11 calculation of peat volumes and carbon pools. Some inventories include organic soils  
12 and shallow non-peat Histosols in peatland inventories. This applies to peatland area  
13 but it is a much greater problem for peat thickness, bulk density and carbon content  
14 which have been inadequately determined in many countries. Further detailed field  
15 surveys would undoubtedly contribute to more precise and better constrained  
16 estimates of tropical peatland carbon pools, particularly in Africa, Central and South  
17 America where there is still relatively little spatial information on peat thickness.

18  
19 Even in Southeast Asia, where the peatlands of Indonesia and Malaysia have been  
20 relatively well studied, there is still a lack of knowledge of the aerial extent and  
21 volume of peatlands in some locations. In West Papua (Irian Jaya), for example, there  
22 are at least 70,000 km<sup>2</sup> of thick peat deposits that have received very little study. This  
23 is also the case in Papua New Guinea, where the difference between non-peat and  
24 peat-forming wetlands is ill defined. In this assessment we have used a best estimate  
25 peatland area of 16,971 km<sup>2</sup> for Papua New Guinea, whilst Joosten and Clarke (2002)



1 provide a higher value of 28,900 km<sup>2</sup>. Their original data source (Wayi and Freyne,  
2 1992) indicates that this is the extent of Histosols (i.e. organic soils associated with a  
3 wide range of wetlands, not all of which conform to our definition of peat), thus the  
4 best estimate value we have used could underestimate the true extent of the resource.  
5 This uncertainty regarding classification of wetlands and wetland soils is not confined  
6 to Southeast Asia. For example, our best estimates of peatland areas in Sudan and  
7 Zambia are 9,068 and 11,060 km<sup>2</sup>, whilst the extent of Histosols and non-peat organic  
8 soils (according to our definition of peat) is 33,270 and 15,645 km<sup>2</sup>, respectively  
9 (GPD, 2004); again, we may have underestimated the true extent of peatland in these  
10 and several other countries.

11  
12 In other cases, the lack of precise information is because of limited field survey in  
13 remote locations. Ruokalainen *et al.* (2001) have suggested that Amazonian peatlands  
14 could have a total area of 150,000 km<sup>2</sup>. They do not provide verifiable evidence for  
15 their assertions and these data should be treated with care until they are confirmed.  
16 Most of these are small, topogenous (as opposed to ombrogenous) wetlands  
17 associated with *Mauritia flexuosa* (aguaje palm) swamps that are predominantly  
18 riverine or flood plain wetlands interspersed amongst dryland forest types (Lähteenoja  
19 *et al.*, 2009; Phillips *et al.*, 1997). There is no general agreement that these are peat  
20 forming in all situations, although they may accumulate plant litter to a thickness in  
21 excess of 0.5 m that could be classified as peat. Undoubtedly, Amazonian peatlands  
22 warrant further more detailed investigation and assessment, although, owing to their  
23 shallow nature (average depth 1.75 m, according to data presented for 12 peat cores in  
24 Peru (Lähteenoja *et al.* (2009)) they will likely make only a small additional  
25 contribution to the tropical peatland carbon pool unless extensive thick, ombrogenous

1 deposits are described. Tropical mountain peatlands also warrant further  
2 investigation. These are mostly small in area, occurring primarily in basins and on  
3 slopes, but they can be numerous and, collectively, could make a substantial  
4 contribution to regional peat resources, particularly in Andean countries (Chimner &  
5 Karberg, 2008).

6  
7 African peatlands are also under investigated. Some peatlands have thick peat  
8 deposits with maximum recorded thickness in excess of 30 m (Table 2) in Burundi,  
9 Congo and Democratic Republic of Congo. At present it is difficult to carry out field  
10 investigations in these countries owing to their political situation, but if it were, our  
11 best estimates of peatland areas might be increased with implications for the size of  
12 their carbon pools.

13  
14 Improved knowledge and understanding of the tropical peatland resource is vital  
15 given the current rapid rate of peatland development occurring across the tropics and  
16 specifically in Southeast Asia where the vast majority of the resource is located.  
17 Consideration of the scale of carbon flux from deforestation or degradation of tropical  
18 peatland should take into account the high below-ground carbon storage, which will  
19 typically be an order of magnitude greater than that in the above-ground biomass. For  
20 example, our best estimate of carbon density in Indonesian peatland is  $2,772 \text{ t C ha}^{-1}$   
21 (based on a best estimate peat thickness of 5.5 m), which is much higher than typical  
22 values for above ground peat swamp forest biomass of 100 to  $150 \text{ t C ha}^{-1}$  (Page *et al.*,  
23 2006). Deforestation of Southeast Asian peatlands is proceeding at rates as high as  
24  $2.2\% \text{ yr}^{-1}$  across Borneo (2002 to 2005; Langner *et al.*, 2007) and  $9.0\% \text{ yr}^{-1}$  for some  
25 specific locations (former Mega Rice Project, Central Kalimantan, 1997 to 2005;

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3 1 Hoscilo *et al.*, submitted). Relatively few studies (e.g. Page *et al.*, 2002; van der Werf  
4  
5 2 *et al.*, 2004, 2008; Hooijer *et al.*, 2006, 2009; Fargione *et al.*, 2008) have explicitly  
6  
7 3 recognised the scale of carbon emissions arising from disturbance of tropical  
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9 4 peatlands where the flux from the below-ground carbon pool can be several orders of  
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11 5 magnitude greater than that from the above-ground pool and extend over a much  
12  
13 6 longer time period. For the year 2000, Hooijer *et al.* (2006) estimated that some  
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15 7 106,000 km<sup>2</sup> (43%) of the tropical peatland resource across Southeast Asia had been  
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17 8 deforested, drained and converted to some other form of land use. Based on our best  
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19 9 estimate of the regional peatland carbon pool, this renders ~29 Gt C vulnerable to  
20  
21 10 release to the atmosphere as a result of peat oxidation and fire over coming decades.  
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23 11 Even with improved land management, the magnitude of emissions from tropical  
24  
25 12 peatland is unlikely to be reduced, since climate modelling studies have shown that  
26  
27 13 peatland areas of equatorial Southeast Asia and Amazonia will experience reduced  
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29 14 rainfall and greater seasonality (IPCC, 2007; Li *et al.*, 2007; Mahli *et al.*, 2008),  
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31 15 which will lead to lower peatland water tables, enhanced peat decomposition and an  
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33 16 increased likelihood of fire.  
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44 18 New policy initiatives to reduce greenhouse gas emissions through avoided  
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46 19 deforestation in developing countries (REDD and the voluntary market) are likely to  
47  
48 20 become a dominant component of land-based carbon mitigation in the future (Agus,  
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50 21 2008; Murdiyarso *et al.*, 2008). This study emphasises that tropical peatlands have  
51  
52 22 one of the highest carbon densities of all terrestrial ecosystems. Tropical peatlands,  
53  
54 23 particularly in Southeast Asia, combine a large carbon forest sink with an even larger  
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56 24 peat carbon store, thus policies that promote avoided deforestation and degradation as  
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3 1 well as peatland rehabilitation (Page *et al.*, 2009b) would yield high benefits per  
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6 2 hectare if applied to tropical peat swamp forest.  
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For Review Only

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For Review Only

## 1 **References**

- 2 Adams JM, Faure H, Faure-Denard L, McGlade JM, Woodward FI (1990) Increases  
3 in terrestrial carbon storage from the Last Glacial Maximum to the present. *Nature*,  
4 **348**, 711-714.
- 5 Agus F (2008) Reducing emissions from peatland deforestation and degradation: carbon  
6 emission and opportunity costs. In: J.O. Rieley, C.J. Banks & B. Radjagukguk (Eds.)  
7 *Carbon-Climate-Human Interaction on Tropical Peatland. Proceedings of the*  
8 *International Symposium on Tropical Peatland*. Yogyakarta, Indonesia, 27-29 August  
9 2007. EU CARBOPEAT and RESTOPEAT Partnership, Gadjah Mada University,  
10 Indonesia and University of Leicester, United Kingdom. Pp. 249-252.
- 11 Anderson JAR (1961) *The Ecology and Forest Types of the Peat Swamp Forests of*  
12 *Sarawak and Brunei in Relation to their Sylviculture*. Ph.D. Thesis, University of  
13 Edinburgh, UK.
- 14 Anderson JAR (1964) The structure and development of peat swamps of Sarawak and  
15 Brunei. *Journal of Tropical Geography*, **18**, 7-16.
- 16 Anderson JAR (1983) The tropical peat swamps of western Malesia. In: *Ecosystems*  
17 *of the World: Mires: Swamp, Bog, Fen and Moor* (ed Gore AJP), pp. 181-199. 4B,  
18 Regional Studies. Elsevier, New York.
- 19 Anderson JAR, Marsden D (1988) *Brunei Forest Resources and Strategic Planning*  
20 *Study*. Report to the Government of His Majesty the Sultan and Yang Di-Pertuan of  
21 Negara Brunei Darussalam. Anderson and Marsden Forestry Consultants Ltd,  
22 Singapore.
- 23 Andriess JP (1988) *Nature and Management of Tropical Peat Soils*. FAO Soils  
24 Bulletin 59. Food and Agriculture Organisation of the United Nations, Rome.
- 25 Armentano TV, Menges EG (1986) Patterns of change in the carbon balance of

- 1 organic soil-wetlands of the temperate zone. *Journal of Ecology*, **74**, 755-774.
- 2 Batjes NH (1996) Total carbon and nitrogen in the soils of the world. *European*
- 3 *Journal of Soil Science*, **47**, 151-163.
- 4 Bord na Mona (1984) *Fuel Peat in Developing Countries*. Dublin, Ireland.
- 5 Bouwman AF (1990) Global distribution of the major soils and land cover types. In:
- 6 *Soils and the greenhouse effect, Proceedings of the International Conference on Soils*
- 7 *and the Greenhouse Effect* (Bouwman AF ed.), p. 31-59. John Wiley & Sons, New
- 8 York.
- 9 Bridgham SD, Megonigal JP, Keller JK, Bliss NB, Trettin C (2006) The carbon
- 10 balance of North American wetlands. *Wetlands*, **26**, 889-916.
- 11 Brown S, Iverson LR, Prasad A, Liu D (1993) Geographical distributions of carbon in
- 12 biomass and soils of tropical Asian forests. *Geocarto International*, **4**, 45-59.
- 13 Canadell J, Ciais P, Cox P, Heimann P (2004) Quantifying, understanding and
- 14 managing the carbon cycle in the next decade. *Climatic Change*, **67**, 147-160.
- 15 Chimner RA, Karberg JM (2008) Long-term carbon accumulation in two tropical
- 16 mountain peatlands, Andes Mountains, Ecuador. *Mires and Peat*, **3**, 1-10.
- 17 Cohen AD, Raymond RJr, Mora S, Alverado A, Malavassi L (1985) Economic
- 18 characteristics of the peat deposits of Costa Rica: preliminary study. *Proceedings of*
- 19 *the Symposium: Tropical Peat Resources – Prospects and Potential*. 25 February – 1
- 20 March 1985, Kingston, Jamaica. International Peat Society, Helsinki, Finland. Pp.
- 21 146-169.
- 22 Egglesmann R (1976) Peat consumption under influence of climate, soil condition and
- 23 utilization. *Proceedings of the 5<sup>th</sup> International Peat Congress*, Poznan, Poland, 21-25
- 24 September, 1976. Volume 1, pp. 233-247. International Peat Society, Jyväskylä,
- 25 Finland.

- 1  
2  
3 1 Eswaran H, Van den Berg E, Reich P (1993) Organic carbon in soils of the world. *Soil*  
4  
5 2 *Science Society of America Journal*, **57**, FAO-ISRIC.  
6  
7  
8 3 Fargione J, Hill J, Tilman D, Polasky S, Hawthorne P (2008) Land clearing and the  
9  
10 4 biofuel carbon debt. *Science*, **319**, 1235-1238.  
11  
12 5 Franzén IG (2006) Increased decomposition of subsurface peat in Swedish raised  
13  
14 6 bogs: are temperate peatlands still net sinks of carbon? *Mires and Peat*, Volume1,  
15  
16 7 Article 03, pp. 8-9. <http://www.mires-and-peat.net>  
17  
18 8 Garcia MJ, de Oliveira PM, de Siqueira E, Fernandes RS (2004) A Holocene  
19  
20 9 vegetational and climatic record from the Atlantic rainforest belt of coastal State of  
21  
22 10 São Paulo, SE Brazil. *Review of Palaeobotany and Palynology*, **131**, 181-199.  
23  
24 11 GPD (2004) *Global Peatland Database*. International Mire Conservation Group.  
25  
26 12 Available at: <http://www.imcg.net/gpd/gpd.htm> (last updated 5th February 2004).  
27  
28 13 Gorham, E. (1991) Northern peatlands: Role in the carbon cycle and probable  
29  
30 14 responses to climatic warming. *Ecological Applications*, **1**, 182-195.  
31  
32 15 Gruber N, Friedlingstein P, Field CB, Valentini R, Heimann M, Richey JF, Romero P,  
33  
34 16 Schulze E-D, Chen A (2004) The vulnerability of the carbon cycle in the 21st  
35  
36 17 Century: An assessment of carbon-climate-human interactions. In: Global Carbon  
37  
38 18 Cycle, integrating human, climate, and the natural world, Field CB, Raupach M (eds).  
39  
40 19 Island Press, Washington, DC., pp 45–76  
41  
42 20 Hirano T, Segah H, Harada T, Limin S, June T, Hirata R, Osaki M (2007) Carbon  
43  
44 21 dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia. *Global*  
45  
46 22 *Change Biology*, **13**, 412-425.  
47  
48 23 Hooijer A, Silvius M, Wösten H, Page S (2006) *PEAT-CO2, Assessment of CO<sub>2</sub>*  
49  
50 24 *Emissions from Drained Peatlands in SE Asia*. Delft Hydraulics report Q3943, Delft,  
51  
52 25 The Netherlands.  
53  
54  
55  
56  
57  
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59  
60



- 1  
2  
3 1 Hooijer, A., Page, S.E., Canadell, J.G., Silvius, M., Kwadijk, J., Wösten, H. and  
4  
5 2 Jauhiainen, J. (2009) Current and future CO<sub>2</sub> emissions from drained peatlands in  
6  
7 3 Southeast Asia. *Biogeosciences-Discuss.*, 6: 7207-7230 (Online access:  
8  
9 4 <http://www.biogeosciences-discuss.net/6/7207/2009/> (published July 2009).  
10  
11 5 Hoscilo A, Page SE, Tansey KJT, Rieley JO (submitted) Repeated fire as the main  
12  
13 6 driver of land cover change in the tropical peatland of Central Kalimantan, Indonesia.  
14  
15 7 *Landscape Ecology*.  
16  
17 8 Immirzi CP, Maltby E, Clymo RS (1992) *The Global Status of Peatlands and their*  
18  
19 9 *Role in Carbon Cycling*. A report for Friends of the Earth by the Wetlands  
20  
21 10 Ecosystems Research Group, Department of Geography, University of Exeter, UK.  
22  
23 11 Friends of the Earth, London.  
24  
25 12 IPCC (2007) Summary for policymakers. In: *Climate Change 2007: The Physical*  
26  
27 13 *Science Basis. Contribution of Working Group I to the Fourth Assessment Report of*  
28  
29 14 *the Intergovernmental Panel on Climate Change* (eds. Solomon S, Qin D, Manning  
30  
31 15 M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL). Cambridge University  
32  
33 16 Press, Cambridge.  
34  
35 17 IPS (1985) *Tropical Peat Resources – Prospects and Potential*. Proceedings of  
36  
37 18 Symposium held in Kingston, Jamaica, 25 February – 1 March 1985, International  
38  
39 19 Peat Society, Helsinki, Finland.  
40  
41 20 Jaenicke J, Rieley JO, Mott C, Kimman P, Siegert F (2008) Determination of the  
42  
43 21 amount of carbon stored in Indonesian peatlands. *Geoderma*, **147**, 151-158.  
44  
45 22 Jali DHD (2002) *Nitrogen mineralization, litter production and cellulose*  
46  
47 23 *decomposition in tropical peat swamps*. Ph.D. Thesis, Royal Holloway College,  
48  
49 24 University of London.  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 1 James DMD (1984) *The Geology and Hydrocarbon Resources of Negara Brunei*  
4  
5 2 *Darussalam*. Brunei Museum, Brunei.  
6  
7  
8 3 Jansen JC, Diemont WH, Koenders N (1985) *Peat Development for Power*  
9  
10 4 *Generation in West Kalimantan - An Ecological Appraisal*. The Netherlands  
11  
12 5 Economic Institute 3062 PA Rotterdam, The Netherlands, Rotterdam.  
13  
14  
15 6 Jauhiainen J, Takahashi H, Heikkinen JEP, Martikainen PJ, Vasander H (2005)  
16  
17 7 Carbon fluxes from a tropical peat swamp forest floor. *Global Change Biology*, **11**,  
18  
19 8 1788-1797.  
20  
21  
22 9 Jauhiainen J, Limin S, Silvennoinen H, Vasander H (2008) Carbon dioxide and  
23  
24 10 methane fluxes in drained tropical peat before and after hydrological restoration.  
25  
26 11 *Ecology*, **89**, 3503-3514.  
27  
28  
29 12 Jaya A (2007) *Ecological Planning of Tropical Peatland for Carbon and Water*  
30  
31 13 *Conservation*. Ph.D. thesis, University of Nottingham. 178 pp.  
32  
33  
34 14 Joosten H, Clarke D (2002) *Wise Use of Mires and Peatlands – Background and*  
35  
36 15 *Principles, including a Framework for Decision-making*. International Mire  
37  
38 16 Conservation Group/International Peat Society, Jyväskylä, Finland.  
39  
40  
41 17 Kivinen E, Pakarinen P (1980) Peatland areas and the proportion of virgin peatlands in  
42  
43 18 different countries. *Proceedings of the 6<sup>th</sup> International Peat Congress, “The Role of*  
44  
45 19 *Peatlands in a World of Limited Resources – Energy, Food, Fiber and Natural Areas*.  
46  
47 20 17-23 August 1980. Duluth, Minnesota, USA. International Peat Society, Helsinki,  
48  
49 21 Finland.  
50  
51  
52 22 Kivinen E, Pakarinen P (1981) Geographical distribution of peat resources and major  
53  
54 23 peatland complex types in the world. *Annals of the Academy of Science, Fennicae*  
55  
56 24 *(Geology and Geography)*, III **132**: 1-28.  
57  
58  
59  
60

- 1  
2  
3 1 Klemetti V, Sänkiaho K, Oravainen H (1996) Feasibility study of Philippine peat  
4  
5 2 resources. In: E. Lappalainen (Ed.) *Global Peat Resources*. Pp 189-192. International  
6  
7 3 Peat Society, Jyväskylä, Finland.  
8  
9  
10 4 Koh PK, Butler RA, Bradshaw CJA (2009) Conversion of Indonesia's peatlands.  
11  
12 5 *Frontiers in Ecology and the Environment*, **7** (5), 238-238.  
13  
14  
15 6 Korpijaakko M (1985) The peat deposits of the Niayes area of Senegal and their  
16  
17 7 potential. *Proceedings of the Symposium: Tropical Peat Resources – Prospects and*  
18  
19 8 *Potential*. 25 February – 1 March 1985, Kingston, Jamaica. Pp 136-145. International  
20  
21 9 Peat Society, Helsinki, Finland.  
22  
23  
24 10 Lähteenoja O, Ruokoleinen K, Schulman L, Oinonen M (2009) Amazonian peatlands:  
25  
26 11 an ignored C sink and potential source. *Global Change Biology*, **15**, 2311-2320.  
27  
28  
29 12 Langner A, Miettinen J, Siegert F (2007) Land cover change 2002-2005 in Borneo  
30  
31 13 and the role of fire derived from MODIS imagery. *Global Change Biology*, **13**, 2329-  
32  
33 14 2340.  
34  
35  
36 15 Langner A, Siegert F (2009) Spatiotemporal fire occurrence in Borneo over a period  
37  
38 16 of 10 years. *Global Change Biology*, **15**, 48-62.  
39  
40  
41 17 Lappalainen E (ed) (1996) *Global Peat Resources*. International Peat Society,  
42  
43 18 Jyväskylä, Finland.  
44  
45  
46 19 Lappalainen E, Zurek S (1996a) Peat in other African Countries. In: E. Lappalainen  
47  
48 20 (Ed.) *Global Peat Resources*. Pp 239-240. International Peat Society, Jyväskylä,  
49  
50 21 Finland.  
51  
52  
53 22 Lappalainen E, Zurek S (1996b) Peat in other Central and South America. In: E.  
54  
55 23 Lappalainen (Ed.) *Global Peat Resources*. Pp 279-282. International Peat Society,  
56  
57 24 Jyväskylä, Finland.  
58  
59  
60

- 1  
2  
3 1 Lézine AM, Chateaufneuf JJ (1991) Peat in the “Niayes” of Senegal: depositional  
4 environment and Holocene evolution. *Journal of African Earth Sciences*, **12**, 171-  
5  
6 2  
7 3 179. Li W, Dickinson RE, Fu R, Niu G-Y, Yang Z-L, Canadell JG (2007) Future  
8 precipitation changes and their implications for tropical peatlands. *Geophysical*  
9  
10 4  
11 5  
12 13  
14 15  
15 6 Ma X, Wang R (1992) Peat in south coastal area of China. *Proceedings of the*  
16  
17 7  
18 8  
19 9  
20 10  
21 11  
22 9 Mahli Y, Roberts JT, Betts RA, Killeen, TJ, Li W, Noble CA (2008) Climate change,  
23  
24 10  
25 11  
26 12  
27 11 Markov VD, Olunin AS, Ospennikova LA, Skobeeva EI, Khoroshev PI (1988) World  
28  
29 12  
30 13  
31 14  
32 13 Moore PJ, Bellamy DJ (1974) *Peatlands*. Paul Elek Scientific Books Ltd, London.  
33  
34 14 Murdiyarso D, Suryadiputra N, Dewi S, Agus F (2008) How can REDD scheme  
35  
36 15  
37 16  
38 17  
39 16 *Future of Tropical Peatlands in Southeast Asia as Carbon Pools and Sinks; papers*  
40  
41 17  
42 18  
43 18 *presented at the special session on tropical peatlands at the 13<sup>th</sup> International Peat*  
44  
45 19  
46 19 *Congress, Tullamore, Ireland, 10<sup>th</sup> June 2008* (eds Rieley, JO, Banks CJ, Page SE),  
47  
48 20  
49 20  
50 21  
51 21  
52 22  
53 22 Mutalib AA, Lim JS, Wong MH, Koonvai L (1992) Characterization, distribution and  
54  
55 23  
56 23  
57 24  
58 24  
59  
60

- 1  
2  
3 1 NEDECO Euroconsult (1984) *Nationwide Study of Coastal and Near-coastal*  
4  
5 2 *Swampland in Sumatra, Kalimantan and Irian Jaya*. Volume 1, Main Report.  
6  
7  
8 3 Neuzil SG (1997) Onset and rate of peat and carbon accumulation in four domed  
9  
10 4 ombrogenous peat deposits, Indonesia. In: *Biodiversity and Sustainable Management*  
11  
12 5 *of Tropical Peatlands* (eds Rieley JO, Page SE), pp. 55-72. Samara, Cardigan, UK.  
13  
14  
15 6 Oravainen H, Sänkiaho K, Klemetti, V, Crisologo S, Abando R, Herrera N (1989) *Pre-*  
16  
17 7 *feasibility Study of the Philippine Peat Resources*. Final Report. Technical Research  
18  
19 8 Centre of Finland, Vapo Oy Finland and Office of Energy Affairs of the Philippines.  
20  
21 9 Jyväskylä, Finland.  
22  
23  
24 10 Oraveinen H, Crisologo EJ, Abando R, Herrera N, Sankiaho K, Klemetti V (1992) Pre-  
25  
26 11 feasibility study of the Philippines peat resources. *Proceedings of the International*  
27  
28 12 *Symposium on Tropical Peatland*. Kuching, Sarawak, Malaysia, 1991, pp. 49-56.  
29  
30  
31 13 Page SE, Rieley, JO, Shotyk W, Weiss D (1999) Interdependence of peat and  
32  
33 14 vegetation in a tropical peat swamp forest. *Philosophical Transactions of the Royal*  
34  
35 15 *Society, Series B*, **354**, 1885-1897.  
36  
37  
38 16 Page SE, Siegert F., Rieley JO, Boehm H-DV, Jaya A, Limin SH (2002) The amount  
39  
40 17 of carbon released from peat and forest fires in Indonesia during 1997. *Nature*, **420**,  
41  
42 18 61-65.  
43  
44  
45 19 Page SE, Wüst RAJ, Weiss D, Rieley JO, Shotyk W, Limin SH (2004) A record of  
46  
47 20 Late Pleistocene and Holocene carbon accumulation and climate change from an  
48  
49 21 equatorial peat bog (Kalimantan, Indonesia): implications for past, present and future  
50  
51 22 carbon dynamics. *Journal of Quaternary Science*, **19**, 625-635.  
52  
53  
54 23 Page SE, Rieley JO, Wüst RAJ (2006) Lowland tropical peatlands of Southeast Asia.  
55  
56 24 In: *Peatlands: Evolution and Records of Environmental and Climate Changes* (eds.  
57  
58  
59  
60

- 1  
2  
3 1 Martini IP, Martinez Cortizas A, Chesworth W). Developments in Earth Surface  
4  
5 2 Processes 9, Elsevier, Amsterdam. Pp. 145-172.  
6  
7  
8 3 Page SE, Hoscilo, A, Langner A, Tansey K, Siegert F, Limin S, Rieley J (2009a)  
9  
10 4 Tropical peatland fires in Southeast Asia. In: *Tropical Fire Ecology: Climate Change,*  
11  
12 5 *Land Use, and Ecosystem Dynamics* (ed Cochrane MA), Springer-Praxis Books,  
13  
14 6 Heidelberg. Pp. 263-287.  
15  
16  
17 7 Page SE, Hoscilo A, Jauhiainen J *et al.* (2009b) Ecological restoration of tropical  
18  
19 8 peatlands in Southeast Asia. *Ecosystems* 10.1007/s10021-008-9216-2.  
20  
21  
22 9 Pajunen H (1985) The mires in the Akanyaru Valley in Burundi. *Proceedings of the*  
23  
24 10 *Symposium: Tropical Peat Resources – Prospects and Potential.* 25 February – 1  
25  
26 11 March 1985, Kingston, Jamaica. Pp. 186-197. International Peat Society, Helsinki,  
27  
28 12 Finland.  
29  
30  
31 13 Pamungkas AH, Soepardi HG (1997) Practical aspects of developing inland peat for  
32  
33 14 productive and sustainable agriculture. In: JO Rieley and SE Page (Eds.) *Biodiversity*  
34  
35 15 *and Sustainability of Tropical Peatlands. Proceedings of the International Symposium*  
36  
37 16 *on Biodiversity, Environmental Importance and Sustainability of Tropical Peat and*  
38  
39 17 *Peatlands*, Palangka Raya, Central Kalimantan, Indonesia, 4-8 September 1995, pp.  
40  
41 18 335-340. Samara Publishing, Cardigan, UK.  
42  
43  
44 19 Phillips S, Rouse GE, Bustin M (1997) Vegetation Zones and Diagnostic Pollen  
45  
46 20 Profiles of a Coastal Peat Swamp, Bocas del Toro, Panamá. *Palaeogeography,*  
47  
48 21 *Palaeoclimatology, Palaeoecology* 128: 301-338.  
49  
50  
51  
52 22 Polak, B. (1952) Veen en veenontginning in Indonesia. M.I.A.I. Nos 5 & 6,  
53  
54 23 Vorkink, Bandung .  
55  
56  
57 24 Rayment AF, Hore FR (1976) Hydraulic conductivity and bulk density changes in the  
58  
59 25 cultivated layer of a Newfoundland peat soil and initial effects of soil amendments.  
60

- 1  
2  
3 1 *Proceedings of the 5<sup>th</sup> International Peat Congress*, Poznan, Poland, 21-25  
4  
5 2 September, 1976. Volume 1, pp. 282-292. International Peat Society, Jyväskylä,  
6  
7 3 Finland.  
8  
9  
10 4 RePPPProt (1988-1990) *A National Overview from the Regional Physical Planning*  
11  
12 5 *Programme for Transmigration*. UK Overseas Development Administration and  
13  
14 6 Directorate Bina Program. Ministry of Transmigration, Jakarta.  
15  
16  
17 7 Rieley JO, Page SE (eds) (2005) *Wise Use of Tropical Peatlands – Focus on*  
18  
19 8 *Southeast Asia*. Alterra, Wageningen, The Netherlands.  
20  
21 9 ([http://www.restorpeat.alterra.wur.nl/p\\_download.htm](http://www.restorpeat.alterra.wur.nl/p_download.htm) )  
22  
23  
24 10 Rieley JO, Ahmad-Shah AA, Brady MA (1996) The extent and nature of tropical peat  
25  
26 11 swamps. In: E Maltby, CP Immirzi, RJ Safford (Eds.) *Tropical Lowland Peatlands of*  
27  
28 12 *Southeast Asia, Proceedings of a Workshop on Integrated Planning and Management*  
29  
30 13 *of Tropical Lowlands Peatlands*, Cisarua, Indonesia, 3-8 July 1992, pp. 17-53. IUCN,  
31  
32 14 Gland, Switzerland.  
33  
34  
35 15 Rieley JO, Wüst RAJ, Jauhiainen J *et al.* (2008) Tropical peatlands: carbon stores,  
36  
37 16 carbon gas emissions and contribution to climate change processes. In: M. Strack  
38  
39 17 (Ed.) *Peatlands and Climate Change* pp. 148-181, International Peat Society,  
40  
41 18 Jyväskylä, Finland.  
42  
43  
44 19 Ruokalainen, K, Schulman L, Tuomisto H (2001) On Amazonian peatlands.  
45  
46 20 International Mire Conservation Group Newsletter. Issue 2001/4, 8-10.  
47  
48  
49 21 Rydin H, Jeglum J (2006) *The Biology of Peatlands*. Oxford University Press, United  
50  
51 22 Kingdom. p. 232.  
52  
53  
54 23 Sajarwan A, Notohadiprawiro T, Radjagukguk B, Hastuti S (2002) Diversity of  
55  
56 24 tropical peat characteristics in intact peatland forest, under the influence of forest  
57  
58 25 type, peat thickness, and position of peat deposit. In: *Peatlands for People: Natural*  
59  
60

- 1  
2  
3 1 *Resource Functions and Sustainable Management* (eds Rieley, JO, Page, SE, Setiadi,  
4 B), pp. 119-124. Proceedings of the International Symposium on Tropical Peatland,  
5  
6 2 B), pp. 119-124. Proceedings of the International Symposium on Tropical Peatland,  
7  
8 3 Jakarta, Indonesia. BPPT (Badan Pengkajian dan Penerapan Teknologi) and  
9  
10 4 Indonesian Peat Association, Jakarta.
- 11  
12 5 Sayok, A.K., Nik, A.R., Melling, L., Samad, R.A. and Efransjah, E. (2008) Some  
13  
14 6 characteristics of peat in Loagan Bunut National Park, Sarawak, Malaysia. In; J.O.  
15  
16 7 Rieley, C.J. Banks & B. Radjagukguk, *Carbon-Climate-Human Interactions on*  
17  
18 8 *Tropical Peatland. Proceedings of the International Symposium and Workshop on*  
19  
20 9 *Tropical Peatland*, Yogyakarta, 27-29 August 2007, EU CARBOPEAT and  
21  
22 10 RESTORPEAT Partnership, Gadjah Mada University, Indonesia and University of  
23  
24 11 Leicester, United Kingdom. Pp. 95-100.
- 25  
26 12 Scott DA (1991) Latin America and the Caribbean. In: M Finlayson & M Moser (Eds.)  
27  
28 13 *Wetlands – Facts on File*. Oxford. Pp. 85-114.
- 29  
30 14 Shier CW (1985) Tropical peat resources - an overview. *Proceedings of the Symposium*  
31  
32 15 *on Tropical Peat Resources - Prospects and Potential*, Kingston, Jamaica, pp. 29-46.  
33  
34 16 International Peat Society, Helsinki.
- 35  
36 17 Shimada S, Takahasahi H, Kaneko M, Haraguchi A (2000) The estimation of carbon  
37  
38 18 resource in a tropical peatland: a case study in Central Kalimantan,  
39  
40 19 Indonesia. *Proceedings of the International Symposium on Tropical Peatlands*, Bogor,  
41  
42 20 Indonesia, 22-24 November 1999, pp 9-18. Graduate School of Environmental Earth  
43  
44 21 Science, Hokkaido University, Japan and Research and Development Centre for  
45  
46 22 Biology, The Indonesian Institute of Sciences, Bogor, Indonesia.
- 47  
48 23 Shimada S, Takahashi H, Haraguchi A, Kaneko M (2001) The carbon content  
49  
50 24 characteristics of tropical peats in Central Kalimantan, Indonesia: estimating their  
51  
52 25 spatial variability in density. *Biogeochemistry*, **53**, 249–267.
- 53  
54  
55  
56  
57  
58  
59  
60



- 1  
2  
3 1 Soepraptohardjo M, Driessen, PM (1976) The lowland peats of Indonesia, a challenge  
4  
5 2 for the future. *Soil Research Institute, Bogor Bulletin* **3**, 11-19  
6  
7  
8 3 Strack M (ed) (2008) *Peatlands and Climate Change*. International Peat Society,  
9  
10 4 Jyväskylä, Finland.  
11  
12 5 Suzuki S, Ishida T, Nagano T, Wijaroen S (1999) Influences of deforestation on  
13  
14 6 carbon balance in a natural tropical peat swamp forest in Thailand. *Environmental*  
15  
16 7 *Control in Biology*, **37**, 115-128.  
17  
18  
19 8 Tarnocai C, Canadell JG, Shuur EAG, Kuhry P, Mazhitova G, Zimov S (2009) Soil  
20  
21 9 organic carbon pools in the northern circumpolar permafrost region. *Global*  
22  
23 10 *Biogeochemical Cycles*, **23**, GB2023, doi:10.1029/2008GB003327.  
24  
25  
26  
27 11 Uraepepatanapong C, Pitayakajornwute P (1996) The peat swamp forests of Thailand.  
28  
29 12 In: E Maltby, CP Immirzi, RJ Safford (Eds.) *Tropical Lowland Peatlands of*  
30  
31 13 *Southeast Asia, Proceedings of a Workshop on Integrated Planning and Management*  
32  
33 14 *of Tropical Lowlands Peatlands*, Cisarua, Indonesia, 3-8 July 1992, pp. 119-128.  
34  
35 15 IUCN, Gland, Switzerland.  
36  
37  
38 16 Van Engelen V, Huting J (2002) *Peatlands of the World*. An interpretation of the  
39  
40 17 World Soil Map. ISRIC, Wageningen, unpublished. GPI Project 29 GPI 1.  
41  
42  
43 18 van der Werf, G.R., Randerson, J.T., Collatz, G.J., et al. (2004) Continental-scale  
44  
45 19 partitioning of fire emissions during the 1997 to 2001 El Niño/La Niña period.  
46  
47 20 *Science*, **303**, 73-76.  
48  
49  
50 21 van der Werf GR, Dempewolf J, Trigg SN, Randerson JT, Kasibhatla PS, Gigliof L,  
51  
52 22 Murdiyarso D, Peters W, Morton DC, Collatz GJ, Dolman AJ, DeFries RS (2008)  
53  
54 23 Climate regulation of fire emissions and deforestation in equatorial Asia. *Proceedings*  
55  
56 24 *of the National Academy of Sciences of the United States of America*, **105**, 20350-  
57  
58 25 20355.  
59  
60

- 1  
2  
3 1 Vijarnson P (1996) Peatlands in Southeast Asia: a regional perspective. In: E Maltby,  
4 CP Immirzi, RJ Safford (Eds.) *Tropical Lowland Peatlands of Southeast Asia*,  
5  
6 2 *Proceedings of a Workshop on Integrated Planning and Management of Tropical*  
7  
8 3 *Lowlands Peatlands*, Cisarua, Indonesia, 3-8 July 1992, pp. 75-96. IUCN, Gland,  
9  
10 4 Switzerland.  
11  
12  
13  
14  
15 6 Wayi BM, Freyne DF (1992) The distribution, characterisation, utilisation and  
16  
17 7 management of peat soils in Papua New Guinea. *Proceedings of the International*  
18  
19 8 *Symposium on Tropical Peatland*. Kuching, Sarawak, Malaysia, 1991, pp. 28-32.  
20  
21  
22 9 Weiss D, Shotyck W, Rieley JO, Page SE, Gloor M, Reese S, Cortizas-Martinez A  
23  
24 10 (2002) The geochemistry of major and selected trace elements in a forested peat bog,  
25  
26 11 Kalimantan, SE-Asia, and its implications for past atmospheric dust deposition.  
27  
28 12 *Geochimica et Cosmochimica Acta*, **66**, 2307-2323.  
29  
30  
31 13 Wooler MJ, Morgan R, Fowell S, Behling H, Fogel M (2007) A multiproxy peat  
32  
33 14 record of Holocene mangrove palaeoecology from Twin Cays, Belize. *The Holocene*,  
34  
35 15 **17**, 1129-1139.  
36  
37  
38 16 World Energy Council (2004) *2004 Survey of Energy Resources*. Elsevier, Oxford.  
39  
40  
41 17 Yefremov SP, Yefremova TT (2001) Present stocks of peat and organic carbon in bog  
42  
43 18 ecosystems of west Siberia. In: *Carbon Storage and Atmospheric Exchange by West*  
44  
45 19 *Siberian Peatlands* (eds Bleuten W, Lapshina, ED), pp. 73-78. Physical Geography,  
46  
47 20 Utrecht University, Utrecht, Netherlands.  
48  
49  
50  
51  
52  
53  
54  
55  
56  
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## 1 **Tables**

2

3 Table 1: Area of tropical peatland on a country and regional basis expressed as best  
4 estimate, maximum and minimum area values (km<sup>2</sup>) (see notes for details).

5

6 Table 2: Thickness of tropical peat on a country and regional basis expressed as  
7 maximum, range, mean and best estimate (m) (see notes for details).

8

9 Table 3: Volume of tropical peatland on a country and regional basis expressed as  
10 best estimate, maximum and minimum values (m<sup>3</sup> x 10<sup>6</sup>) (calculated from area in  
11 Table 1 and peat thickness in Table 2).

12

13 Table 4: Bulk density and carbon concentration of tropical peat obtained from the  
14 literature (psf: peat swamp forest; BD: bulk density) with some values for temperate  
15 peat for comparison.

16

17 Table 5: Carbon store in tropical peatland on a country and regional basis expressed  
18 as best estimate, maximum and minimum values (Gigatonne) (calculated from volume  
19 in Table 1, bulk density of 0.09 g cm<sup>-3</sup> and carbon concentration of 56% (0.56))

20

21 Table 6: Updated estimates of global and tropical peatland areas derived from Immirzi  
22 *et al.* (1992) and this assessment.

23

24 Table 7: Updated estimates of global and tropical peat volumes derived from Immirzi  
25 *et al.* (1992) and this assessment.

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27 Table 8: Updated estimates of global and tropical peatland carbon pools derived from  
28 Immirzi *et al.* (1992) and this assessment.

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**Table 1: Area of tropical peatland on a country and regional basis expressed as best estimate, maximum and minimum area values (km<sup>2</sup>) (see notes for details).**

Region	Country	Minimum area (km <sup>2</sup> )	%	Best estimate of area (km <sup>2</sup> )	%	Shallow Histosols and organic soils (km <sup>2</sup> )	%	Maximum area (km <sup>2</sup> )	%	Notes
AFRICA	Angola	100	0	2640	1	7621	4	10,261	2	Min from Andriess (1988). WSM <sup>3</sup> in GDB (2004) gives 10,261 km <sup>2</sup> as max for Histosols.
	Botswana	2500	1	2625	1	375	0	3000	0	Max and Min from Sliva (pers. comm.) mentioned in GPD (2004).
	Burundi	140	0	323	0	555	0	878	0	Min from Bord na Mona (1984). WSM in GPD (2004) gives 878 km <sup>2</sup> as max for Histosols.
	Cameroon	100	0	1077	0	2930	1	4007	1	Min from Joosten & Clarke (2002) but source not given; Max from WSM in GPD (2004).
	Congo	2900	1	6220	1	9957	5	16177	2	Min from Bord na Mona (1984); WSM in GPD (2004) gives 16,177 km <sup>2</sup> as max for Histosols.
	Democratic Republic of Congo	400	0	2800	1	7,200	3	10000	2	Most inventories give the 400 km <sup>2</sup> cited in Shier (1985); Andriess (1988) and GPD (2004) give higher value.
	Gabon	80	0	548	0	1,403	1	1951	0	Min from Joosten & Clarke (2002) but source not given; Max from WSM in GPD (2004).
	Ghana	49	0	59	0	41	0	100	0	Min from WSM in GPD (2004); Max from Joosten & Clarke (2002)
	Guinea	853	0	1952	0	3,298	2	5250	1	Min from WSM in GPD (2004); Max from Bord na Mona (1984) but includes mangroves.
	Ivory Coast	300	0	725	0	1,275	1	2000	0	Min from Bord na Mona (1984); Max from Markov (1988) in GPD (2004).
	Kenya	1600	0	2440	1	2,519	1	4959	1	Min from Lappalainen & Zurek (1996), source credited to Markov (1988) in GPD (2004); Max from WSM in GPD (2004).
	Liberia	26	0	120	0	280	0	400	0	Min from WSM in GPD (2004); Max from Bord na Mona (1984).
	Madagascar	1903	0	1920	0	50	0	1970	0	Min from WSM in GPD (2004); Max and Best Estimates from Bord na Mona (1984).
	Malawi	353	0	492	0	418	0	910	0	Min from WSM in GPD (2004); Max from Bord na Mona (1984).
	Mauritania	60	0	60	0	0	0	60	0	Joosten & Clarke (2002); source not given.
	Mauritius	1	0	1	0	0	0	1	0	Joosten & Clarke (2002); source not given.
	Mozambique	100	0	575	0	1,425	1	2000	0	Min from Andriess (1988); Max from Grundling (pers. comm.) in GPD (2004).
	Nigeria	120	0	1600	0	5,400	2	7000	1	Min from Joosten & Clarke (2002) but cannot be verified. Max from Lappalainen & Zurek (1996) but cannot be verified, mostly mangrove and other wetland.
	Reunion	1	0	1	0	0	0	1	0	Joosten & Clarke (2002); source not given.
Rwanda	800	0	830	0	90	0	920	0	Min from Bord na Mona (1984); Max from WSM in GPD (2004).	

	Senegal	15	0	36	0	64	0	100	0	Min from Bord na Mona (1984); Max given by Markov (1988) in GPD (2004).
	Sierra Leone	3	0	3	0	0	0	3	0	Joosten & Clarke (2002); source not given.
	Sudan	1000	0	9068	2	24,202	11	33270	5	Min Lappalainen & Zurek (1996); Max WSM in GPD (2004); mostly non-peat wetlands.
	Uganda	5000	1	7300	2	6,900	3	14200	2	Min by Markov in GPD (2004); Max from Bord na Mona (1984) referring to Kivinen & Pakarinen (1981).
	Zambia	11060	3	12201	3	3,424	2	15625	2	Min from Markov (1988) in GPD (2004); Max from WSM in GPD (2004) for Histosols.
	<b>SUB-TOTAL</b>	<b>29464</b>	<b>8</b>	<b>55616</b>	<b>13</b>	<b>79,427</b>	<b>37</b>	<b>135043</b>	<b>21</b>	
ASIA (SOUTH EAST)	Brunei	909	0	909	0	75	0	984	0	Max from Anderson (1964); Min from Anderson and Marsden (1984).
	Indonesia	206950	54	206950	47	63,680	29	270630	41	Min and Best Estimate are from REPPROT (1988-1990) soil survey; Max from Pusat Penelitian Tanah (1981) quoted in Pamungkas & Soepardi (1997).
	Malaysia	22490	6	25889	6	1,392	1	27281	4	Min from Anderson (1983); Max. from GPD (2004); Best Estimate from Mutalib <i>et al.</i> (1992).
	Myanmar (Burma)	500	0	1228	0	2,182	1	3410	1	Min from Markov (1988) in GBD (2004); Max is Histosols from WSM in GBD (2004).
	Papua New Guinea	5000	1	10986	3	17,956	8	28942	4	Min from Andriess (1988); Max from Wayi & Freyne (1992).
	Philippines	60	0	645	0	1,755	1	2400	0	Min from Bord na Mona (1984); Ma. from Oravainen <i>et al.</i> (1989, 1992) quoted in Klemetti <i>et al.</i> (1996).
	Thailand	638	0	638	0	0	0	638	0	Gov. statistics quoted in Uraepatanapong & Pitayakajornwute (1996).
	Vietnam	100	0	533	0	1,297	1	1830	0	Min from Markov <i>et al.</i> (1988); Max from Bord na Mona (1984) for Histosols.
	<b>SUB-TOTAL</b>	<b>236722</b>	<b>62</b>	<b>247778</b>	<b>56</b>	<b>88,337</b>	<b>41</b>	<b>336115</b>	<b>51</b>	
ASIA (OTHER)	Bangladesh	300	0	375	0	225	0	600	0	Min from Joosten & Clarke (2002) but without the source; Max from Bord na Mona (1984).
	China	4159	1	5312	1	3,459	2	8771	1	Min is based on total area of 41,590 km <sup>2</sup> from Bord na Mona (1984); Max is based on total Histosols of 87,711 km <sup>2</sup> from WSM in GPD (2004). (Assuming 10% of China's peatland is in the tropical zone.)
	India	320	0	490	0	510	0	1000	0	Min from Bord na Mona (1984); Max from Markov (1988) in Lappalainen & Zurek (1996).
	Sri Lanka	25	0	158	0	407	0	565	0	Min from Bord na Mona (1984); Max is WSM in IMCG (2004).
	<b>SUB-TOTAL</b>	<b>4804</b>	<b>1</b>	<b>6335</b>	<b>1</b>	<b>4,601</b>	<b>2</b>	<b>10936</b>	<b>2</b>	
CENTRAL AMERICA & CARIBBEAN	Belize	680	0	735	0	165	0	900	0	Min from Andriess (1988) based on FAO World Soil Map; Max from Bord na Mona (1984).
	Costa Rica	370	0	370	0	0	0	370	0	From Bord na Mona (1984).
	Cuba	2300	1	5293	1	2,377	1	7670	1	Min from Casanova (1986); Max from Bord na Mona (1984).
	El Salvador	90	0	90	0	0	0	90	0	From Bord na Mona (1984).
	Haiti	1	0	120	0	4,630	2	4750	1	Min from Joosten & Clarke (2002), source unknown; Max from Lappalainen & Zurek (1996) quoting Scott (1991).
	Honduras	4530	1	4530	1	0	0	4530	1	From Bord na Mona (1984) based on FAO World Soil Map.
	Jamaica	100	0	128	0	82	0	210	0	Min from Joosten & Clarke (2002), source unspecified; Max from Bord na Mona (1984).
	Nicaragua	3710	1	3710	1	0	0	3710	1	From Bord na Mona (1984).
	Panama	7870	2	7870	2	0	0	7870	1	From Bord na Mona (1984).

	Puerto Rico	100	0	100	0	0	0	100	0	From Bord na Mona (1984).
	Trinidad and Tobago	10	0	10	0	0	0	10	0	From Bord na Mona (1984).
	<b>SUB-TOTAL</b>	<b>19761</b>	<b>5</b>	<b>22956</b>	<b>5</b>	<b>7,254</b>	<b>3</b>	<b>30210</b>	<b>5</b>	
PACIFIC	Australia (Queensland)	150	0	150	0	0	0	150	0	From Kivinen & Pakarinen (1980) based on a survey carried out by the International Peat Society in 1979.
	Fiji	40	0	40	0	0	0	40	0	From Bord na Mona (1984).
	<b>SUB-TOTAL</b>	<b>190</b>	<b>0</b>	<b>190</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>190</b>	<b>0</b>	
SOUTH AMERICA	Bolivia	9	0	509	0	1,491	1	2000	0	Min from Bord na Mona (1984); Max from Ruokalainen <i>et al.</i> (2001), source not given.
	Brazil	13500	4	23875	5	31,125	14	55000	8	Min from Bord na Mona (1984); Max from Ruokoleinen <i>et al.</i> (2001), source not given.
	Chile	1047	0	1047	0	0	0	1047	0	Total area from Bord na Mona (1984) is 10,470 km <sup>2</sup> of which 10% is in tropical zone.
	Colombia	3390	1	5043	1	4,957	2	10000	2	Min from Bord na Mona (1984); Max from Ruokalainen <i>et al.</i> (2001), source not given.
	Ecuador	5000	1	5000	1	0	0	5000	1	From Ruokalainen <i>et al.</i> , (2001), source not given.
	French Guyana	1620	0	1620	0	0	0	1620	0	From Bord na Mona (1984) but may be mostly freshwater swamp.
	Guyana	8139	2	8139	2	0	0	8139	1	From Bord na Mona (1984).
	Peru	50000	13	50000	11	0	0	50000	8	From Ruokalainen <i>et al.</i> (2001), source not given.
	Surinam	1130	0	1130	0	0	0	1130	0	From Bord na Mona (1984).
	Venezuela	10000	3	10000	2	0	0	10000	2	From Bord na Mona (1984) citing geological survey data.
	<b>SUB-TOTAL</b>	<b>93835</b>	<b>24</b>	<b>106363</b>	<b>24</b>	<b>37,573</b>	<b>17</b>	<b>143936</b>	<b>22</b>	
<b>TOTAL</b>		<b>384776</b>	<b>100</b>	<b>439238</b>	<b>100</b>	<b>217,192</b>	<b>100</b>	<b>656430</b>	<b>100</b>	

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1 **Table 2: Thickness of tropical peat on a country and regional basis expressed as**  
2 **maximum, range, mean and best estimate (m) (see notes for details).**

Region	Country	Maximum peat thickness (m)	Peat thickness range (m)	Peat thickness mean (m)	Best estimate Peat thickness (m)	Notes
AFRICA	Angola	N.I.	N.I.	N.I.	0.5	No information available.
	Botswana	4	N.I.	N.I.	1	Sliva (pers. comm.) in GPD (2004).
	Burundi	32.7	N.I.	N.I.	8	Pajunen (1985).
	Cameroon	N.I.	N.I.	N.I.	0.5	No information available.
	Congo	30	N.I.	N.I.	7.5	Markov (1988) in GPD (2004).
	Democratic Republic of Congo	30-60	1-15	N.I.	4	Shier (1985); Bord na Mona (1985).
	Gabon	N.I.	N.I.	N.I.	0.5	No information available.
	Ghana	N.I.	N.I.	N.I.	0.5	No information available.
	Guinea	N.I.	N.I.	N.I.	0.5	According to Bord na Mona (1984) all peats are shallow.
	Ivory Coast	5-7	N.I.	N.I.	1.5	Markov (1988) in GPD (2004).
	Kenya	N.I.	N.I.	N.I.	0.5	No information available.
	Liberia	0.5	N.I.	N.I.	0.5	Bord na Mona (1984); Shier (1985).
	Madagascar	10.5	2-10.5	N.I.	2.5	Markov (1988) in GPD (2004); Straka (1960) in GPD (2004).
	Malawi	3.2	N.I.	N.I.	1	GPD (2004).
	Mauritania	N.I.	N.I.	N.I.	0.5	No information available.
	Mauritius	1.9	N.I.	N.I.	0.5	Markov (1988) in GPD (2004).
	Mozambique	5	0.4-3	N.I.	1.5	Markov (1988) in GPD (2004).
	Nigeria	1.2-20	1.2-20	N.I.	5	
	Reunion	3.6	N.I.	N.I.	1	Markov (1988) in GPD (2004).
	Rwanda	20	3-20	11	11	Bord na Mona (1984); Shier (1985).
Senegal	10	7.7-10	3.5	3.5	Bord na Mona (1984); Shier (1985); Korpijaakko (1985); Lézine & Chateaufneuf (1991).	
Sierra Leone	N.I.	N.I.	N.I.	0.5	No information available.	
Sudan	3	N.I.	N.I.	1	GPD (2004).	
Uganda	16	1-10-16	N.I.	4	Bord na Mona (1984).	
Zambia	N.I.	N.I.	N.I.	0.5	No information available.	
ASIA (SOUTHEAST)*	Brunei	10	10-15	N.I.	3	James (1984); Jali (2002); Stoneman (1997).
	Indonesia	20	4-6	N.I.	5.5	Derived from values from Neuzil (1997); Page <i>et al.</i> (1999); Jaya (2007); Jaenicke <i>et al.</i> (2008).
	Malaysia	20	4-10	N.I.	7	Based on peat profiles in Anderson (1961) and Sayok <i>et al.</i> (2008).
	Myanmar (Burma)	2	1-2	N.I.	1.5	From Markov <i>et al.</i> (1988) quoted in GPD (2004).
	Papua New Guinea	10	1-10	N.I.	2.5	Wayi & Freyne (1992).
	Philippines	12	0.5-12	5.3	5.3	Bord na Mona (1984).
	Thailand	3	1-3	0.6-1	1	Urapeepatanapong & Pitayakajornwute (1996).
	Vietnam	2	N.I.	N.I.	0.5	GPD (2004).
ASIA (OTHER)*	Bangladesh	0.3-4 Av. 1.5	0.3-4	1.5	1.5	Max mean value from GPD (2004); mean from Bord na Mona (1984).
	China	30	1-2-30	N.I.	1	Ma & Wang (1992); mostly buried by marine sediments; peat layers are generally less than 1 m.
	India	9	N.I.	4	4	Markov (1985) in GPD (2004).
	Sri Lanka	6.5	N.I.	4	4	Bord na Mona (1984).

CENTRAL AMERICA & CARIBBEAN	Belize	8	N.I.	N.I.	0.5	Shier (1985); Wooler <i>et al.</i> (2007); Monacci <i>et al.</i> (2009).
	Costa Rica	3.5	1.5-3.5	N.I.	1	Cohen <i>et al.</i> (1985).
	Cuba	3	1-3	1.8	1.8	Lappalainen & Zurek (1996b).
	El Salvador	N.I.	N.I.	N.I.	0.5	No information available.
	Haiti	N.I.	N.I.	N.I.	0.5	No information available.
	Honduras	N.I.	N.I.	N.I.	0.5	No information available.
	Jamaica	16	0.3-15	4-7	5	Bord na Mona (1985); Shier (1985); Wade & Reeson (1985).
	Nicaragua	N.I.	N.I.	N.I.	0.5	No information available.
	Panama	12	N.I.	6	6	Phillips <i>et al.</i> (1997).
	Puerto Rico	N.I.	N.I.	N.I.	0.5	No information available.
	Trinidad and Tobago	N.I.	N.I.	1.3	1.3	Shier (1985) but without source.
PACIFIC	Australia (Queensland)	N.I.	N.I.	N.I.	0.5	No information available.
	Fiji	5	N.I.	N.I.	1.5	Bord na Mona (1984).
SOUTH AMERICA	Bolivia	N.I.	N.I.	N.I.	0.5	No information available.
	Brazil	13	0.3-13	2	2	Bord na Mona (1984); Garcia <i>et al.</i> (2004).
	Chile	N.I.	N.I.	N.I.	0.5	No information available.
	Colombia	1.15	0.5-1.15	N.I.	0.5	No information available.
	French Guiana	N.I.	N.I.	N.I.	1	No information available.
	Ecuador	4	N.I.	N.I.	1	Chimner & Karberg (2008).
	Guyana	2	0.3-2	N.I.	0.5	Bord na Mona (1984).
	Peru	5.9	0.3-5.9	1.75	1.75	Ruokalainen <i>et al.</i> (2001); Lahteenoja <i>et al.</i> (2008).
	Surinam	9	N.I.	1	1	Shier (1985).
	Venezuela	10	N.I.	4	4	Bord na Mona (1984); Shier (1985).

1 N.I. = No information found

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1 **Table 3: Volume of tropical peatland on a country and regional basis expressed as best**  
 2 **estimate, maximum and minimum values ( $\text{m}^3 \times 10^6$ ) (calculated from area in Table 1 and**  
 3 **peat thickness in Table 2).**

Region	Country	Minimum peat volume ( $\text{m}^3 \times 10^6$ )	%	Best estimate peat volume ( $\text{m}^3 \times 10^6$ )	%	Volume of shallow Histosols and organic soils ( $\text{m}^3 \times 10^6$ )	%	Maximum peat volume ( $\text{m}^3 \times 10^6$ )	%
AFRICA	Angola	50	0	1320	0	2286	4	3606	0
	Botswana	2500	0	2625	0	113	0	2738	0
	Burundi	1120	0	2584	0	167	0	2751	0
	Cameroon	50	0	539	0	879	1	1418	0
	Congo	21750	1	46650	3	2987	5	49637	3
	Democratic Republic of Congo	1600	0	11200	1	2160	3	13360	1
	Gabon	40	0	274	0	421	1	695	0
	Ghana	25	0	30	0	12	0	42	0
	Guinea	427	0	976	0	989	2	1965	0
	Ivory Coast	450	0	1088	0	383	1	1471	0
	Kenya	800	0	1220	0	756	1	1976	0
	Liberia	13	0	60	0	84	0	144	0
	Madagascar	4758	0	4800	0	15	0	4815	0
	Malawi	353	0	492	0	125	0	617	0
	Mauritania	30	0	30	0	0	0	30	0
	Mauritius	1	0	1	0	0	0	1	0
	Mozambique	150	0	863	0	428	1	1291	0
	Nigeria	600	0	8000	0	1620	2	9620	1
	Reunion	1	0	1	0	0	0	1	0
	Rwanda	8800	1	9130	1	27	0	9157	1
Senegal	53	0	126	0	19	0	145	0	
Sierra Leone	2	0	2	0	0	0	2	0	
Sudan	1000	0	9068	1	7261	11	16329	1	
Uganda	20000	1	29200	2	2070	3	31270	2	
Zambia	5530	0	6101	0	1027	2	7128	0	
<b>SUB-TOTAL</b>		<b>70103</b>	<b>4</b>	<b>136380</b>	<b>8</b>	<b>23829</b>	<b>37</b>	<b>160209</b>	<b>9</b>

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ASIA (SOUTHEAST)*	Brunei	6888	0	6363	0	23	0	6386	0
	Indonesia	1138225	70	1138225	65	19104	29	1157329	64
	Malaysia	157430	10	181223	10	418	1	181641	10
	Myanmar (Burma)	750	0	1842	0	655	1	2497	0
	Papua New Guinea	12500	1	27465	2	5387	8	32852	2
	Philippines	318	0	3419	0	527	1	3946	0
	Thailand	638	0	638	0	0	0	638	0
	Vietnam	50	0	267	0	389	1	656	0
<b>SUB-TOTAL</b>		<b>1316799</b>	<b>81</b>	<b>1359442</b>	<b>77</b>	<b>26503</b>	<b>41</b>	<b>1385945</b>	<b>76</b>
ASIA (OTHER)*	Bangladesh	450	0	563	0	68	0	631	0
	China	4159	0	5312	0	1038	2	6350	0
	India	1280	0	1960	0	153	0	2113	0
	Sri Lanka	100	0	632	0	122	0	754	0
<b>SUB-TOTAL</b>		<b>5989</b>	<b>0</b>	<b>8467</b>	<b>0</b>	<b>1381</b>	<b>2</b>	<b>9848</b>	<b>1</b>
CENTRAL AMERICA & CARIBBEAN	Belize	340	0	368	0	50	0	418	0
	Costa Rica	370	0	370	0	0	0	370	0
	Cuba	4140	0	9527	1	713	1	10240	1
	El Salvador	45	0	45	0	0	0	45	0
	Haiti	1	0	60	0	1389	2	1449	0
	Honduras	2265	0	2265	0	0	0	2265	0
	Jamaica	500	0	640	0	25	0	665	0
	Nicaragua	1855	0	1855	0	0	0	1855	0
	Panama	47220	3	47220	3	0	0	47220	3
	Puerto Rico	50	0	50	0	0	0	50	0
Trinidad and Tobago	13	0	13	0	0	0	13	0	
<b>SUB-TOTAL</b>		<b>56799</b>	<b>4</b>	<b>62413</b>	<b>4</b>	<b>2177</b>	<b>3</b>	<b>64590</b>	<b>4</b>
PACIFIC	Australia (Queensland)	75	0	75	0	0	0	75	0
	Fiji	60	0	60	0	0	0	60	0
<b>SUB-TOTAL</b>		<b>135</b>	<b>0</b>	<b>135</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>135</b>	<b>0</b>

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SOUTH AMERICA	Bolivia	5	0	255	0	447	1	702	0
	Brazil	27000	2	47750	3	9338	14	57088	3
	Chile	524	0	524	0	0	0	524	0
	Colombia	1695	0	2522	0	1487	2	4009	0
	Ecuador	5000	0	5000	0	0	0	5000	0
	French Guiana	810	0	810	0	0	0	810	0
	Guyana	4070	0	4070	0	0	0	4070	0
	Peru	87500	5	87500	5	0	0	87500	5
	Surinam	1130	0	1130	0	0	0	1130	0
	Venezuela	40000	2	40000	2	0	0	40000	2
<b>SUB-TOTAL</b>		<b>167734</b>	<b>10</b>	<b>189561</b>	<b>11</b>	<b>11272</b>	<b>17</b>	<b>200833</b>	<b>11</b>
<b>TOTAL</b>		<b>1617559</b>	<b>100</b>	<b>1756398</b>	<b>100</b>	<b>65162</b>	<b>100</b>	<b>1821560</b>	<b>100</b>

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**Table 4: Bulk density and carbon concentration of tropical peat obtained from the literature (psf: peat swamp forest; BD: bulk density) with some values for temperate peat for comparison.**

	Authority	Location	Position in profile	Bulk density (g cm <sup>-3</sup> )	Carbon concentration (%)	
Tropical peat	Andriess (1974)	Sarawak	Surface	0.09 - 0.12		
	Driessen & Rochimah (1976)	Durian-Rasau, West Kalimantan	Surface	0.08 - 0.23		
		Sabangau, Central Kalimantan	Surface	0.11 - 0.14		>0.2 if well hu
	Cohen <i>et al.</i> (1985)	Costa Rica	Surface	0.20 - 0.22		
	Korpijaakko (1985)	Senegal	Surface	0.09 - 0.17		
			Mean	0.13		
	Oravainen <i>et al.</i> (1992)	Philippines		0.20 - 0.22		
	Vijamson (1996)	Thailand	Surface	0.1 - 0.32		Shallow Histos
	Anshari (pers.comm.)	Danau Sentarum, West Kalimantan	5 cores	0.08 - 0.12	51-54	Mean BD 0.10 53%
	Brady (1997)	Sarawak	0 - 20 cm	0.10 - 0.19	54.9 - 56.4	
			20 - 40 cm	0.10 - 0.14	56.7 - 59.4	
			below 40 cm	0.05 - 0.07	-	
	Neuzil (1997)	Central Kalimantan	7 m core	0.10 - 0.18	55 - 57	Higher BD val
		Riau, Sumatra	10 m core	0.07 - 0.10	56 - 62	BD mostly low
		Benkalis, Sumatra	8 m core	0.07 - 0.09	49 - 56	
		West Kalimantan	7 m core	0.08 - 0.12	53 - 57	Higher BD val
	Shimada (2000)	Central Kalimantan	Several cores	0.08 - 0.12	55.5 - 57.8	
	Kurnain <i>et al.</i> (2002)	Central Kalimantan	Surface	0.15 - 0.17		
			Surface (burnt)	0.24 - 0.18		
	Sajarwan <i>et al.</i> (2002)	Central Kalimantan	0 - 50 cm	0.20 - 0.24	41.6 - 57.7	
			50 - 100 cm	0.19 - 0.23	57.4 - 58.9	
	Jali (2002)	Brunei	Several cores	0.05 - 0.14	46.1 - 53.9	
	Dradjad <i>et al.</i> (2003)	South Kalimantan	0 - 25 cm	0.39 - 0.62		Shallow peat, n 2240 cm
25 - 50 cm			0.39 - 0.64			
Page <i>et al.</i> (2004)	Central Kalimantan (Sabangau)	10 m core	0.03 - 0.18	48.1 - 62.0	Mean BD 0.08	
Melling <i>et al.</i> (2005)	Sarawak	Surface (drained)	0.15±0.004	47.8±0.87		
		Surface (sago plantation)	0.16±0.006	44.6±0.96		
		Surface (oil palm plantation)	0.20±0.007	44.7±1.09		
Jaya (2007)	Central Kalimantan (Block C)	5 peat cores	0.02 - 0.70	23.8 - 58.0	Includes non-p BD values are	
		Surface	0.10 - 0.12	56.7 - 57.0		
Lähteenoja <i>et al.</i> (2009)	Peru		0.02 - 0.20	22.0 - 56.0		

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4	Temperate peat	Rayment & Hore	Newfoundland, Canada	Virgin bog	0.08 – 0.09	
5		(1976)		Cultivated bog	0.11 – 0.13	
6						
7		Eggesmann (1976)	Various locations in Europe		0.03 – 0.12	
8						
9		Rydin & Jeglum (2006)	Restiad bogs in New Zealand	Surface	0.102±0.024	Chatham Island
10				Surface	0.059±0.022	Waikato (9 plots)
11				Surface	0.065±0.026	Waikato (18 plots)
12		Franzen (2006)	Sweden	14 peat cores	0.01 – 0.12	Minimum and maximum
13					0.03 – 0.08	Means of similar sites

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For Review Only

1 **Table 5: Carbon store in tropical peatland on a country and regional basis expressed as**  
 2 **best estimate, maximum and minimum values (Gigatonne) (calculated from volume in**  
 3 **Table 1, bulk density of 0.09 g cm<sup>-3</sup> and carbon concentration of 56% (0.56))**

Region	Country	Minimum carbon store (Gt)	%	Best estimate carbon store (Gt)	%	Carbon store in shallow Histosols and organic soils (Gt)	%	Maximum peat carbon store (Gt)	%
AFRICA	Angola	0.003	0	0.067	0	0.114	4	0.181	0
	Botswana	0.126	0	0.132	0	0.006	0	0.138	0
	Burundi	0.056	0	0.13	0	0.008	0	0.138	0
	Cameroon	0.003	0	0.027	0	0.044	1	0.071	0
	Congo	1.096	1	2.351	3	0.149	5	2.5	3
	Democratic Republic of Congo	0.081	0	0.564	1	0.108	3	0.672	1
	Gabon	0.002	0	0.014	0	0.021	1	0.035	0
	Ghana	0.001	0	0.002	0	0.001	0	0.003	0
	Guinea	0.022	0	0.049	0	0.049	2	0.098	0
	Ivory Coast	0.023	0	0.055	0	0.019	1	0.074	0
	Kenya	0.04	0	0.061	0	0.038	1	0.099	0
	Liberia	0.001	0	0.003	0	0.004	0	0.007	0
	Madagascar	0.24	0	0.242	0	0.001	0	0.243	0
	Malawi	0.018	0	0.025	0	0.006	0	0.031	0
	Mauritania	0.002	0	0.002	0	0	0	0.002	0
	Mauritius	0	0	0	0	0	0	0	0
	Mozambique	0.008	0	0.043	0	0.021	1	0.064	0
	Nigeria	0.03	0	0.403	0	0.081	2	0.484	1
	Reunion	0	0	0	0	0	0	0	0
	Rwanda	0.444	1	0.46	1	0.001	0	0.461	1
Senegal	0.003	0	0.006	0	0.001	0	0.007	0	
Sierra Leone	0	0	0	0	0	0	0	0	
Sudan	0.05	0	0.457	1	0.363	11	0.82	1	
Uganda	1.008	1	1.472	2	0.104	3	1.576	2	
Zambia	0.279	0	0.307	0	0.051	2	0.358	0	
<b>SUB-TOTAL</b>		<b>3.536</b>	<b>4</b>	<b>6.872</b>	<b>8</b>	<b>1.19</b>	<b>37</b>	<b>8.062</b>	<b>9</b>

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ASIA (SOUTHEAST)*	Brunei	0.347	0	0.321	0	0.001	0	0.322	0
	Indonesia	57.367	70	57.367	65	0.955	29	58.322	64
	Malaysia	7.934	10	9.134	10	0.021	1	9.155	10
	Myanmar (Burma)	0.038	0	0.093	0	0.033	1	0.126	0
	Papua New Guinea	0.63	1	1.384	2	0.269	8	1.653	2
	Philippines	0.016	0	0.172	0	0.026	1	0.198	0
	Thailand	0.032	0	0.032	0	0	0	0.032	0
	Vietnam	0.003	0	0.013	0	0.019	1	0.032	0
<b>SUB-TOTAL</b>		<b>66.367</b>	<b>81</b>	<b>68.516</b>	<b>77</b>	<b>1.324</b>	<b>41</b>	<b>69.84</b>	<b>76</b>
ASIA (OTHER)*	Bangladesh	0.023	0	0.028	0	0.003	0	0.031	0
	China	0.21	0	0.268	0	0.052	2	0.32	0
	India	0.065	0	0.099	0	0.008	0	0.107	0
	Sri Lanka	0.005	0	0.032	0	0.006	0	0.038	0
<b>SUB-TOTAL</b>		<b>0.303</b>	<b>0</b>	<b>0.427</b>	<b>0</b>	<b>0.069</b>	<b>2</b>	<b>0.496</b>	<b>1</b>
CENTRAL AMERICA & CARIBBEAN	Belize	0.017	0	0.019	0	0.003	0	0.022	0
	Costa Rica	0.019	0	0.019	0	0	0	0.019	0
	Cuba	0.209	0	0.48	1	0.036	1	0.516	1
	El Salvador	0.002	0	0.002	0	0	0	0.002	0
	Haiti	0	0	0.003	0	0.069	2	0.072	0
	Honduras	0.114	0	0.114	0	0	0	0.114	0
	Jamaica	0.025	0	0.032	0	0.001	0	0.033	0
	Nicaragua	0.093	0	0.093	0	0	0	0.093	0
	Panama	2.38	3	2.38	3	0	0	2.38	3
	Puerto Rico	0.003	0	0.003	0	0	0	0.003	0
	Trinidad and Tobago	0.001	0	0.001	0	0	0	0.001	0
<b>SUB-TOTAL</b>		<b>2.863</b>	<b>4</b>	<b>3.146</b>	<b>4</b>	<b>0.109</b>	<b>3</b>	<b>3.255</b>	<b>4</b>
PACIFIC	Australia (Queensland)	0.004	0	0.004	0	0	0	0.004	0
	Fiji	0.003	0	0.003	0	0	0	0.003	0
<b>SUB-TOTAL</b>		<b>0.007</b>	<b>0</b>	<b>0.007</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0.007</b>	<b>0</b>

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SOUTH AMERICA	Bolivia	0	0	0.013	0	0.022	1	0.035	0
	Brazil	1.361	2	2.407	3	0.467	14	2.874	3
	Chile	0.026	0	0.026	0	0	0	0.026	0
	Colombia	0.085	0	0.127	0	0.074	2	0.201	0
	Ecuador	0.252	0	0.252		0	0	0.252	
	French Guiana	0.041	0	0.041	0	0	0	0.041	0
	Guyana	0.205	0	0.205	0	0	0	0.205	0
	Peru	4.41	5	4.41	5	0	0	4.41	5
	Surinam	0.057	0	0.057	0	0	0	0.057	0
	Venezuela	2.016	2	2.016	2	0	0	2.016	2
<b>SUB-TOTAL</b>		<b>8.453</b>	<b>10</b>	<b>9.554</b>	<b>11</b>	<b>0.563</b>	<b>17</b>	<b>10.117</b>	<b>11</b>
<b>TOTAL</b>		<b>81.529</b>	<b>100</b>	<b>88.522</b>	<b>100</b>	<b>3.255</b>	<b>100</b>	<b>91.777</b>	<b>100</b>

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1 **Table 6: Updated estimates of global and tropical peatland areas derived from**  
 2 **Immirzi *et al.* (1992) and this assessment.**

Peatland Area	Minimum (km <sup>2</sup> )	Best Estimate <sup>1</sup> (km <sup>2</sup> )	Maximum (km <sup>2</sup> )
Global <sup>2</sup>	3,858,374	3,971,895	4,085,416
Tropical <sup>2</sup>	333,820	415,485	497,119
Boreal and temperate <sup>2</sup>	3,524,554	3,556,410	3,588,297
Revised tropical <sup>3</sup>	384,776	439,238	656,430
Revised global <sup>3</sup>	3,909,330	3,995,648	4,244,727
Tropical (% of revised global area)	9.8	11.0	15.5
Southeast Asia <sup>3</sup>	236,722	247,778	336,115
Southeast Asia (% of revised global area)	6.1	6.2	7.9

<sup>1</sup> Immirzi *et al.* (1992) calculated the mean of the maximum and minimum values without assessing their degree of certainty (i.e. likelihood of being correct); we considered the provenance of the data available and assessed, using criteria described in the text, whether or not data were likely to be correct or not (hence best estimate)

<sup>2</sup> Immirzi *et al.* (1992) estimates of global, boreal/temperate and tropical peatland areas

<sup>3</sup> Area of tropical peatland from this assessment

1 **Table 7: Updated estimates of global and tropical peat volumes derived from**  
 2 **Immirzi *et al.* (1992) and this assessment.**

	Minimum	Best Estimate	Maximum
Area of boreal and temperate peatland (km <sup>2</sup> ) <sup>1</sup>	3,524,554	3,556,410	3,588,297
Boreal/temperate peat volume 1 (Gm <sup>3</sup> ) <sup>2</sup>	5,286	5,335	5,383
Tropical peat volume (Gm <sup>3</sup> ) <sup>3</sup>	1,618	1,756	1,822
New global peat volume 1 (Gm <sup>3</sup> )	6,904	7,091	7,205
Tropical peat volume (% of global 1)	23%	25%	25%
Southeast Asian peat volume (Gm <sup>3</sup> ) <sup>3</sup>	1,317	1,359	1,386
Southeast Asian peat volume (% of global 1) <sup>2</sup>	19%	19%	19%
Boreal/temperate peat volume 2 (Gm <sup>3</sup> ) <sup>4</sup>	8,107	8,180	8,253
Tropical peat carbon pool (Gm <sup>3</sup> ) <sup>3</sup>	1,618	1,756	1,822
New global peat volume 2 (Gm <sup>3</sup> )	9,725	9,936	10,075
Tropical peat volume (% of global 2)	17%	18%	18%
Southeast Asian peat volume (Gm <sup>3</sup> )	1,317	1,359	1,386
Southeast Asian peat volume (% of global 2)	14%	14%	14%

<sup>1</sup> Immirzi *et al.* (1992)

<sup>2</sup> Based on Boreal/Temperate peat mean thickness of 1.5 m (This is the mean thickness of global peat applied by Immirzi *et al.* (1992)).

<sup>3</sup> This assessment

<sup>4</sup> Based on Boreal/Temperate peat mean thickness of 2.3 m (This is the mean thickness of global peat suggested by Gorham *et al.* (1991) for boreal and sub-arctic peat).

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1 **Table 8: Updated estimates of global and tropical peatland carbon pools derived**  
 2 **from Immirzi *et al.* (1992) and this assessment.**

	Minimum	Best Estimate	Maximum
Area of boreal and temperate peatland (km <sup>2</sup> ) <sup>1</sup>	3,524,554	3,556,410	3,588,297
Carbon density for peat thickness 1.5 m (t ha <sup>-1</sup> ) <sup>1</sup>	1099.5	1099.5	1099.5
Boreal/temperate peat carbon pool (Gt) <sup>2</sup>	387.5	391.1	394.5
Tropical peat carbon pool (Gt) <sup>3</sup>	81.5	88.5	91.8
Global peat carbon pool (Gt)	469.0	479.6	486.3
Tropical peat carbon pool (% of global)	17%	19%	19%
Southeast Asian peat carbon pool (Gt)	66.4	68.5	69.8
Southeast Asian peat carbon pool (%)	14%	14%	14%
Carbon density of boreal and temperate peatland for peat thickness of 2.3 m (t ha <sup>-1</sup> ) <sup>1</sup>	1466	1466	1466
Boreal/temperate peat carbon pool (Gt) <sup>2</sup>	516.7	521.4	526.1
Tropical peat carbon pool (Gt) <sup>3</sup>	81.5	88.5	91.8
Global peat carbon pool (Gt)	598.2	609.9	617.9
Tropical peat carbon pool (% of global)	14%	15%	15%
Southeast Asian peat carbon pool (Gt)	66.4	68.5	69.8
Southeast Asian peat carbon pool (%)	11%	11%	11%

<sup>1</sup> Immirzi *et al.* (1992)

<sup>2</sup> Gt – Gigatonnes – Billion tonnes = g x 10<sup>9</sup>

<sup>3</sup> This assessment