Extent, significance and vulnerability of the tropical peatland carbon pool: past, present and future prospects

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Summary

Data analysis indicates tropical peatlands have a current area of ~400,000 km^2, mostly located in Indonesia, Malaysia and Papua New Guinea, with a conservative estimate of the carbon store in South-east Asia alone of ~52 Gt, i.e. ~10-26% of the global peat carbon store. This carbon pool has accumulated over millennial timescales but is at high risk of destabilisation from land-use change activities that convert a carbon sink to a carbon source, with positive feedbacks to climate warming. This paper argues improved understanding of the spatial extent and magnitude of this carbon store is essential given current interest in greenhouse gas emissions from developed and degraded peatlands and the role that tropical peatlands could play in carbon offset and trading agreements.

Key index words: tropical peatland, extent, carbon accumulation, carbon pool, carbon source

Introduction

As part of the Carburet project (www.carbopeat.org) we have been involved in collecting and synthesising data to determine the past, current and future importance of tropical peatlands as carbon (C) stores, with a particular focus on ascertaining the extent and magnitude of the contemporary peat C store in South-east Asia. This paper reviews the current state of knowledge and degree of uncertainty on the extent of tropical peatlands globally and their C stocks, with the intention of providing a basis on which to evaluate the magnitude of emissions from them and their importance in climate change processes. It is hoped that highlighting data uncertainties and gaps will lead to more detailed field and remote sensing surveys and more accurate data inventories. This is vital given present international interest in the socio-economic drivers of greenhouse gas (GHG) emissions from deforestation and land management, in which tropical peatlands play a significant part; policy initiatives to reduce GHG emissions from deforestation and forest degradation in developing countries (REDD, UNFCCC); and the potential for peatlands to play a role in the financial arena with regard to C offset and trading agreements.

Materials and methods

In order to estimate the past and current carbon sequestration potential of tropical peatlands, information is needed on the age of the deposits, their genesis, depth, bulk density (BD), carbon (C) content, peat and C accumulation rates. Data on the developmental history of tropical peatlands are very limited; there have been some palaeoecological studies of South-east Asian peatlands but almost none for deposits in other tropical regions. The most recent summary of this information for South-east Asia is provided by Wüst *et al.* (2007) and their review forms the basis of the C accumulation rates used in this paper. We accept that these figures are derived from a small number of peat cores with limited geographical distribution.

We used a number of data sources to provide estimates of the contemporary extent (area and thickness) of tropical peatlands. These data were combined with information on peat BD and C content to provide an estimate of the peat C store which, with best estimates of current peat and C accumulation rates, we used to calculate C sequestration potential. Principal data sources and uncertainties associated with using these sources were reviewed by Page *et al.* (in press). There are also significant data gaps for tropical peat BD and C content values; thus uncertainties in peat volume estimates are compounded. A further consideration is that there has been considerable land use change since 1990 in most of the countries with extensive tropical peatland deposits. As many of the values for area are derived from pre-1990 sources and since deforestation and drainage can lead to rapid oxidative losses of organic material (Hooijer *et al.*, 2006), there has likely been a more recent reduction in the area (and thickness) of peatland which is not accounted for in these estimates. The figures presented are, therefore, a best estimate of the near-recent tropical peatland resource.

Results

In South-east Asia, the onset and development of contemporary peat deposits range from the Late Pleistocene to the Holocene (Page *et al.*, 2004; Wüst *et al.*, 2007). Palaeoenvironmental studies indicate that the extensive coastal deposits are the youngest peatlands, with accumulation commencing around 3,500-6,000 cal yrs BP, whilst the sub-coastal and inland peatlands, particularly in Borneo, commenced accumulation earlier, in the Late Pleistocene (~40,000 ^{14}C yrs BP to ~23,000 ^{14}C yrs BP) through to the early Holocene (10,000-7,000 ^{14}C yrs BP). Unfortunately, scarcity of dated cores prohibits an accurate reconstruction of the development of South-east Asia's peatlands, which could be used to assess their carbon sink potential and their role as a carbon store during the Late Quaternary. Available data indicate that peat accumulation rates over both the Late Pleistocene and Holocene range mainly between 0 to 3 mm yr^{-1}, with a median accumulation rate of ~1.3 mm yr^{-1}, which is about 2 to 10 times the rate for boreal and subarctic peatlands (~0.1-0.8 mm yr^{-1}) (Wüst *et al.*, 2007). Carbon accumulation rates over the same time period vary between 30-270 g C m^{-2} yr^{-1}, whilst values for rates of near-recent surface peat / C accumulation range from 2.2 mm yr^{-1} (85 g C m^{-2} yr^{-1}) for Central Kalimantan (Page *et al.,* 2004), to 1.5 mm yr^{-1} (81 g C m^{-2} yr^{-1}) for Riau, Sumatra (Neuzil, 1997) and 1.4 mm (74-85 g C m^{-2} yr^{-1}) for West Kalimantan (Neuzil, 1997).

Tables 1 and 2 provide our best estimates of the near-contemporary area of tropical peatland by region and for South-east Asian countries; they also indicates values for minimum, maximum and range. Our best estimate of near-current peatland area in South-east Asia is 253,204 km^2, representing 67.1% of the total global resource; South America and Africa rank second and third, with 50,336 km^2 (13.3%) and 48,365 km^2 (12.8%), respectively. Within South-east Asia, Indonesia has a best estimate of 206,950 km^2 of peatland (i.e. 82% of the region's and 55% of the world's tropical peatland resource), followed by Malaysia (25,180 km^2) and Papua New Guinea (16,950 km^2). Using best estimate values of area (Table 2) and a default peat depth of 0.3 m, except in Philippines, Indonesia, Malaysia and Brunei where values of 0.5 m, 5 m, 3 m and 3 m have been used respectively, volumes of peat have been calculated and are given in Table 3 (values are based on published estimates, including Bord na Móna (1984) for the Philippines, Page *et al.* (2002) for Indonesia, and Hooijer *et al.* (2006) for Malaysia and Brunei). It is clear that small variations in mean depth values result in large variations in the resulting volume. The mass of C stored in tropical peat in South-east Asian countries is also given in Table 3 and this is based on a volumetric C density of 45 kg m^{-3}. As with volume, small variations in density can lead to significant differences in the C store.

Table 1. Best estimate, minimum, maximum and range of area of tropical peatland (km^2); the figures in parentheses show the percentage of the global tropical values. Caution should be taken when using the best estimate value as the range of values is more appropriate.

Region	Best estimate (km^2; % of total)	Minimum (km^2; % of total)	Maximum (km^2; % of total)	Range (km^2; % of total)
AFRICA	48365 (12.8%)	26607 (10.0%)	94591 (16.7%)	67984 (22.8%)
ASIA (MAINLAND)	820 (0.2%)	622 (0.2%)	6295 (1.1%)	5673 (1.9%)
ASIA (SOUTHEAST)	253204 (67.1%)	188654 (70.6%)	342437 (60.5%)	153783 (51.5%)
CENTRAL AMERICA	24428 (6.5%)	13991 (5.2%)	25940 (4.6%)	11949 (4.0%)
PACIFIC	190 (0.1%)	190 (0.1%)	190 (0.0%)	0 (0.0%)
SOUTH AMERICA	50336 (13.3%)	37136 (13.9%)	96380 (17.0%)	59244 (19.8%)
Grand Total	**377,343**	**267,200**	**565,833**	**298,633**

Table 2. Maximum and minimum tropical peatland area (km^2) by country in Southeast Asia. Best estimate value is an averaged area (km^2). Caution should be taken when using the best estimate value as the range of values is more appropriate.

Country	Best estimate (km^2)	Min Area (km^2)	Max Area (km^2)
Brunei	1000	100	1000
Indonesia	206950	160000	270630
Malaysia	25180	22500	27305
Myanmar (Burma)	500	500	9650
Papua New Guinea	16950	5000	28942
Philippines	400	60	2400
Thailand	394	394	680
Vietnam	1830	100	1830

Table 3. Volume and carbon store of tropical peat by Southeast Asian country based on areas in Table 2, the depth values given and an assumed volumetric carbon density of 45 kg m^{-3}. Caution should be taken when using the best estimate value as the range of values is significant and may be more appropriate.

REGION	Best estimate ($x10^9$ m^3) (depth used, m)	Best estimate (Gtonnes)
Brunei	3 (3)	0.135
Indonesia	1034.75 (5)	46.564
Malaysia	75.54 (3)	3.399
Myanmar (Burma)	0.15 (0.3)	0.007
Papua New Guinea	5.085 (0.3)	0.229
Philippines	0.2 (0.5)	0.009
Thailand	0.1182 (0.3)	0.005
Vietnam	0.549 (0.3)	0.025
Total	**1119.4**	**50.373**

Table 3 suggests that South-east Asian peatlands represent a near-recent C store of 50.4 Gt; this compares with a value for global tropical deposits of 52.2 Gt. South-east Asian peatlands therefore represent 96.6% of the global tropical peat C sink. This dominance of South-east Asian peat is similarly represented in the total global volume of tropical peat of 1159.3 x 10^9 m^3 compared to the South-east Asian volume of 1119.4 x 10^9 m^3 (96.6%). Owing to the compounding of uncertainties through the use of ranges of the variables the best estimate values should be cited with extreme caution. As an example, the range of values of C content can vary by an order of magnitude.

Applying the range of surface peat C accumulation rates of 74-85 g C m^{-2} yr^{-1} (from Page *et al.* (2004) and Neuzil (1997)), to our best estimate of the peatland area in Indonesia (206,950 km^2) produces a potential C sink of 15.3 - 17.6 Mt yr^{-1}, whilst for all South-east Asian peatlands (253,204 km^2) the estimated potential C sink is 18.7 - 21.5 Mt yr^{-1}.

Discussion and conclusions

Tropical peatlands have, at a best estimate, a global area of 380,000 km^2 with the largest amount located in South-east Asia (253,204 km^2) mostly in Indonesia, Malaysia and Papua New Guinea. These peatlands hold a vast store of organic C. The peatlands of South-east Asia have an estimated store of 52 Gt C and a storage potential of 18.7 - 21.5 Mt C yr^{-1}. These values compare with estimated values for the global peat C store of 202-500 Gt (Post *et al.*, 1982; Markov *et al.*, 1988) and a recent estimate of the total C storage potential for global peatlands of 76 Mt C yr^{-1} (Vasander and Kettunen, 2006). Thus peatlands in South-east Asia comprise of around 10-26% of the global peat C store; provide between 25 and 28% of the total global peatland C storage potential and 3.7% of the total soil C pool (1395 Gt C; Adams *et al.*, 1990). It should be noted, as with previous estimates of the global tropical peatland resource, that there is *considerable* variation in published values for the magnitude of both global peat and soil C stores.

The tropical peatland C pool has accumulated over millennial timescales but is currently at high risk of destabilisation as a result of land use change, in particular conversion to plantation agriculture, drainage and fire. These activities convert peatlands from C sinks to C sources, with positive feedbacks to climate warming. Over the last decade the C sequestration function of South-east Asian peatlands has been either severely impaired or completely destroyed. Land use changes have removed the sequestration machinery (peat swamp forest) and led to lowered water tables and hence oxidative conditions which promote rapid loss of the C store. It is estimated that 130,000 km^2 of peatland in South-east Asia are currently deforested and either being used for agriculture or have been abandoned (Hooijer *et al.*, 2006). This represents a potential loss of C sink function of 9.6-11.0 Mt C yr^{-1}. According to figures for fossil-fuel burning, cement production, and gas flaring in 2004 (http://cdiac.esd.ornl.gov/trends/emis/top2004.tot), this is almost equivalent to the total emissions of CO_2 from the Republic of Ireland (11.5 Mt C yr^{-1}). In addition, it is predicted that further large areas of tropical peatland will be lost to large-scale agricultural development in the next few years, particularly to oil palm and pulpwood plantations. It should be noted that the values for loss of C sink function do not take into account C emissions resulting from loss of forest biomass, peat oxidation and fire; *both* components (i.e. loss of C sink potential *plus* C emissions) are required to complete a full account of the impact of different land uses on the peatland C budget (see Rieley and Page, this volume, for a more detailed discussion of this issue).

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