Estimation of carbon storage in Indonesian peatlands

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Summary

Land conversion and recurrent fires in tropical peatlands cause the release of large amounts of the greenhouse gas CO_2. To estimate the carbon storage in Indonesian peatlands we determined the peat extent and volume by means of satellite imagery (Landsat ETM+, SRTM) and 750 *in situ* peat thickness measurements. It was found that a correlation between the convex peat surface and bedrock exists. Applying 3D modelling, the peat volume of selected, typical peat domes in Central Kalimantan, South Sumatra and West Papua was calculated. On the basis of these investigations it is suggested that 55-61 Gt carbon are stored in the Indonesian peatlands. If major peatland conservation and restoration measures are not implemented immediately the significant influence on the global climate resulting from CO_2 release of degraded tropical peatlands will continue. A global CO_2 increase of up to 6.5 ppm, caused by oxidation and burning of Indonesian peatlands alone, is possible within the next decade.

Key index words: tropical peat, peat volume, spatial modelling, carbon, climate change

Introduction

Within the context of the ongoing climate change discussions the importance of tropical peatlands as carbon stores is now realised (Hooijer *et al.*, 2006). The widespread drainage for agricultural use and plantation establishment leads to increased peat oxidation and hence slow emission of the greenhouse gas CO_2. Additionally, fires in degraded peatlands can result in a quick release of significant amounts of CO_2 (Page *et al.*, 2002). Thus, the recognition and monitoring of degraded peatlands is not only of regional but also of global importance. In Indonesia huge amounts of peat are stored with recorded thicknesses of up to 20 metres (e.g. Page *et al.*, 1999). Estimates of the extent reach from about 19.0 million ha (RePPProT, 1990) to 22.5 million ha (Hooijer *et al.*, 2006) which amounts to more than 50% of the global tropical peatland area.

In this study we try to improve on the current, imprecise estimates of carbon storage in Indonesian peatlands by using satellite-derived terrain height measurements, *in situ* peat drillings and GIS modelling techniques. Remote sensing data were combined with ground measurements in order to delineate peat domes, calculate peat volumes and hence estimate carbon storage. Six representative peat domes distributed on the three major Indonesian islands of Sumatra, Borneo and Papua New Guinea were selected for the modelling process (Fig. 1) and carbon storage was extrapolated to whole of Indonesia. An advantage of these calculations over previous estimates is the integration of a digital elevation model (SRTM), consideration of the dome-shaped appearance of peatlands as well as an improved delineation of the extent of peat covered surfaces.

Materials and methods

A total of 750 peat thickness determinations were carried out in Central Kalimantan and South Sumatra, using manually operated peat corers. Because peat drillings and surface measurements are difficult, time-consuming and expensive to obtain in the field the use of remote sensing data was investigated. Optical satellite images acquired by the Landsat ETM+ sensor and a Digital Elevation Model (DEM) generated from satellite radar data during the Shuttle Radar Topography Mission (SRTM) proved to be very useful for peat dome delineation and volume calculations.

The volume of the selected peat domes must be determined in order to estimate the amount of carbon stored and was obtained by 3D modelling using a combination of DEM, *in situ* peat thickness data and spatial interpolation. For modelling it was assumed that the Indonesian ombrogenous peat domes show their usual biconvex cross-section, which results from their formation on basin-shaped depressions in the landscape and the different rates of peat accumulation in the centre of the dome compared to the margins (e.g. Rieley and Page, 2005). SRTM-derived peat surface measurements correlated strongly ($r > 0.8$) with *in situ* peat thickness drillings. On forested peat domes the canopy had to be considered and spatial interpolation between deforested patches was applied because the SRTM C-band sensor does not penetrate dense vegetation cover. The *in situ* peat thickness measurements were inserted into the 3D model and used for verification.

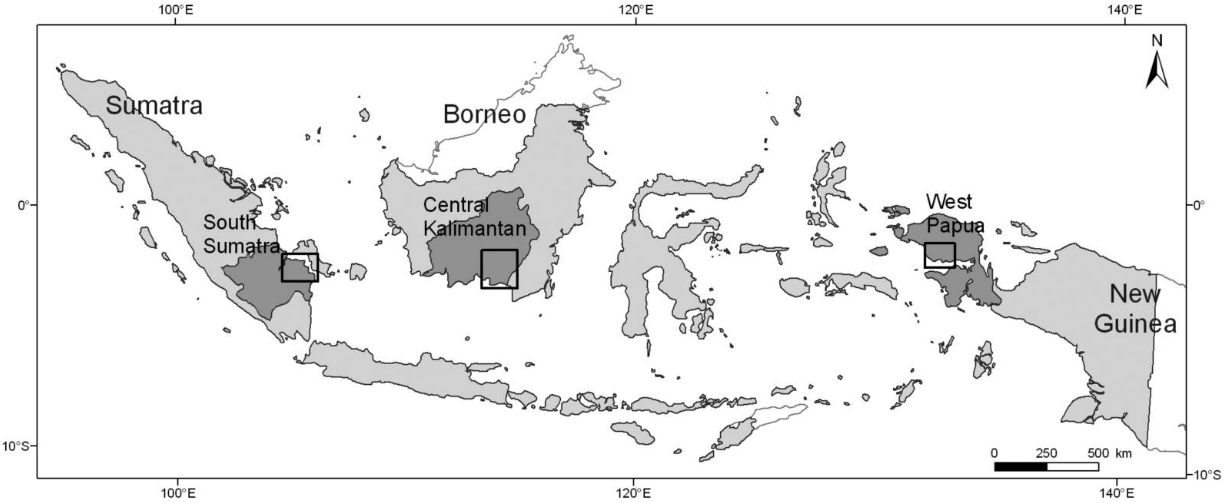

Figure 1. The investigated peat domes are marked by rectangles and are located in the Indonesian provinces of South Sumatra, Central Kalimantan and West Papua.

Results

It was found that the dome shape of Indonesian peatlands can be clearly detected with SRTM data. Fig. 2 shows an example of the very good agreement of SRTM and *in situ* surface gradients by means of an elevation profile in Block C, located in the former Mega Rice Project area in Central Kalimantan. Also evident in Fig. 2 is the biconvex structure of the dome. Similar results were found along other peatland cross-sections in Central Kalimantan and South Sumatra. Furthermore, SRTM surface profiles were investigated across the whole of Indonesia and reflect the predominant dome-shaped appearance of the tropical peatlands with height differences of between 4 and 10 m from the margin to the top.

The result of the modelling of 'Block C' peat dome is shown in Fig. 3. The modelled peat thicknesses range from 0.5 m at the margins to a maximum of 6.7 m in the centre of the peat dome. The volume of 'Block C' is 13.17 km³ with a mean peat thickness of 3.65 m. The peat volumes for all peat domes modelled range from about 0.84 km³ for a peat dome in West Papua (188 km² area) up to ca. 39.64 km³ for 'Sebangau' peat dome in Central Kalimantan with an area of 7,347 km². The volume mainly depends on the size of the peatland. Assuming an average carbon content in tropical peat of 58 kg m^{-3} [1], it is estimated that there is total storage of 4.15 ± 0.89 Gt carbon in the selected Indonesian peat domes which cover collectively an area of 14,960 km². The error margin results from a direct comparison of the peat thickness models with *in situ* measurements. The large deviation results probably from bedrock roughness, which is not considered in the model. However, it may be expected that deviations from a convex bedrock shape through discontinuities in the mineral ground topography are balanced by spatial interpolation. Other uncertainties in the model volume calculations are introduced by the spatial resolution of the satellite data and determination of the peat extent, but both are small compared to the large extent of the peatlands in Indonesia.

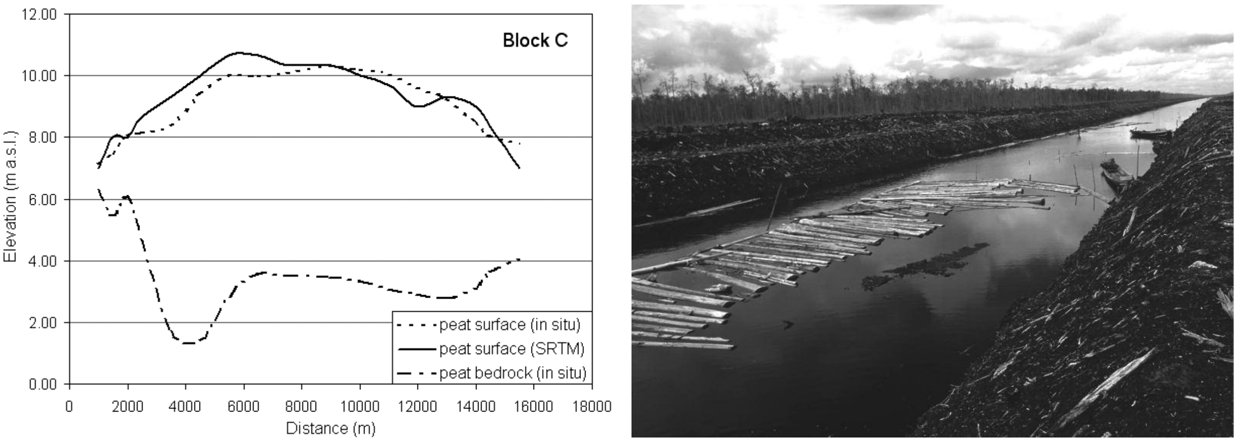

Figure 2. SRTM and in situ surface measurements of "Block C" peat dome in Central Kalimantan agree very well. The peat dome shows a biconvex cross-section. The in situ data was collected along a drainage canal where access is relatively easy and part of the large peat deposits visible.

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[1] A dry bulk density of 0.1 g/cm³ together with a carbon content of 58% can be regarded as an average for the tropical peat in Indonesia (e.g. Neuzil, 1997; Shimada *et al.*, 2001).

Discussion

The study shows that, even though a large number of 750 peat drilling measurements were available, these data alone are not sufficient for carbon storage estimation of the vast peat domes in Indonesia. Additional analysis of remote sensing imagery, especially SRTM radar, was necessary to supplement the *in situ* data. With SRTM elevation data it was possible to detect the dome-shaped surface of many peatlands in Indonesia. Thus, the dome-shaped appearance of peat could be considered for 3D modelling of peat volumes, which is an advantage over other peat carbon storage estimations. This remote sensing investigation, supported by a large number of ground measurements of representative peat domes of Central Kalimantan, South Sumatra and West Papua provides an estimate of the total carbon storage of Indonesian peatlands in the region of 55-61 Gt. The estimation is based on an average peat depth determined in the three study sites and the total peatland area of 21.1 million ha, given by Wetlands International. Comparison with satellite imagery of the three study sites suggests that the peatland area may have been underestimated by 10% by Wetlands International. A further uncertainty might be introduced by the conversion of peat volumes into carbon storage. The stratigraphy of peat is not considered and an average value of 58 kg C per m^3 was assumed. However, values of 45 kg/m^3 and over 90 kg/m^3 have also been reported for peatlands in Kalimantan (Page *et al.*, 2004 and Wetlands International, 2004, respectively).

With carbon storage of about 60 Gt and continuing degradation, the tropical peatlands of Indonesia have the power to negatively influence the global climate. According to the latest IPCC report (2007) the CO_2 emissions were about 8.8 Gt C yr^{-1} in recent years causing an average annual increase of CO_2 concentration in the atmosphere of 1.9 ppm. Assuming that up to half of the carbon stored in the Indonesian peatlands potentially becomes oxidized (by drainage for oil palm) and burnt within the next decade, a global CO_2 increase of about 6.5 ppm, caused by Indonesian land use change only, is possible.

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References

Hooijer, A., Silvius, M., Wösten, H. and Page, S. (2006). PEAT-CO_2, *Assessment of CO_2 emissions from drained peatlands in SE Asia*. Delft Hydraulics report Q3943.

IPCC (2007). Summary for Policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge and New York.

Neuzil, S.G. (1997). Onset and Rate of Peat and Carbon Accumulation in Four Domed Ombrogenous Peat Deposits, Indonesia. In J.O. Rieley and S.E. Page (eds.), *Biodiversity and Sustainability of Tropical Peatlands*, 55-72. Samara Publishing, Cardigan.

Page, S.E., Rieley, J.O., Shotyk, W. and Weiss, D. (1999.) Interdependence of peat and vegetation in a tropical peat swamp forest. *Proceedings of the Royal Society* **B 354**, 1-13.

Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A. and Limin, S. (2002). The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* **420**, 61-65.

Page, S.E., Wüst, R.A., Weiss, D., Rieley, J.O., Shotyk, W. and Limin, S.H. (2004). A record of Late Pleistocene and Holocene carbon accumulation and climate change from an equatorial peat bog (Kalimantan, Indonesia): Implications for past, present and future carbon dynamics. *Journal of Quaternary Science* **19(7)**, 625–635.

RePPProT (1990). *A National Overview from the Regional Physical Planning Programme for Transmigration*. UK Overseas Development Administration and Directorate BINA Programme, Ministry of Transmigration, Jakarta.

Rieley, J.O. and Page, S.E. (eds.) (2005). *Wise Use of Tropical Peatlands: Focus on Southeast Asia*. Alterra, Netherlands. www.restorpeat.alterra.wur.nl.

Shimada, S., Takahashi, H., Haraguchi, A. and Kaneko, M. (2001). The carbon content characteristics of tropical peats in Central Kalimantan, Indonesia: Estimating their spatial variability. *Biochemistry* **53**, 249-267.

Wetlands International (2004). *Map of Peatland Distribution Area and Carbon Content in Kalimantan 2000-2002*. Wetlands International –