Risk assessment of tropical peatland carbon pools under different land uses and impacts

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Summary

Major risks to carbon pools stored in tropical peatlands are land use changes requiring different drainage regimes and fire. Assessment of these risks is demonstrated for oil palm and sago plantations. The relation between subsidence and water table depth is a crucial equation in this concept and its validity for different peatland regions is discussed. Also fires are a major risk to tropical peatland carbon pools. The occurrence of fires appears to be strongly correlated to prevailing water table depths with evidence that once these depths fall below a critical threshold, fire susceptibility increases dramatically. Adequate water management is the key tool to manage the risks that land use change and fire impose on tropical peatland carbon pools. In this context, effectiveness of dams to restore the hydrological integrity of peatlands is discussed.

Key index words: land use change; peat subsidence; fire susceptibility; water management; tropical peatland

Introduction

Large areas of globally important tropical peatland in Southeast Asia are under threat from land clearance, degradation and fire, jeopardizing their natural functions as reservoirs of biodiversity, carbon stores and hydrological buffers (Rieley and Page, 2005). Utilisation of this resource for agriculture or plantation crops requires drainage that, unavoidably, leads to irreversible loss of peat through subsidence, resulting in disturbances of the substrate and creating problems for cultivation and peoples' livelihoods. The challenge is often to strike a balance between, on the one hand, a sufficiently high water table to reduce subsidence and thus CO_2 emissions and, on the other hand, a sufficiently low water table to allow optimum growth of agricultural or plantation crops. Adequate water management is a key issue in this respect. The aim hereby is to maintain a constant, relatively shallow water table depth throughout the year. In practice this implies that the rainfall surplus of the wet season needs to be stored in the peatland area to compensate for the rainfall deficit of the dry season. The effect will be that flooding is prevented in the wet season while in the dry season low water table depths are avoided thereby reducing the fire risk. Once peatlands are degraded by the construction of legal and/or illegal drainage canals, restoration has to focus on reinstatement of the hydrological integrity of the peat swamp. This implies that many drainage canals have to be blocked in order to prevent water tables from dropping substantially below the peat surface for considerable periods of time. Only this rewetting of the peat can restore its natural resource functions and decrease peat oxidation and fire risk.

Methods

With respect to land use changes in peatlands, the sequential line of thinking is that a specific type of land use requires a specific optimal water table depth. This leads to a certain subsidence rate and implies a specific carbon emission to the atmosphere. In peatlands, the irreversible process of subsidence commences as soon as they are drained (Drajad *et al.*, 1986; Jaya, 2005). This continuing lowering of the level of the land surface can only be arrested through complete re-saturation of the peat. While in mineral soils such as clays and sands subsidence stops as time progresses in peat soils subsidence continues over time, albeit at decreasing rates. Total subsidence can be divided into an early, rapid consolidation component and an ongoing oxidation, leading to CO_2 emission, and shrinkage component (Wösten *et al.*, 1997). Fire susceptibility of peatlands increases dramatically after water table depths fall below a certain threshold value (Takahashi *et al.*, 2003; Usup *et al.*, 2004). This threshold value is used to demonstrate the fire susceptibility for intact and degraded peatlands in Central Kalimantan. Since water management is crucial in controlling the risks that land use change and fire impose on the peatland carbon pool, strategies are investigated which maintain water table depths close to the surface of the peatland throughout the year thereby minimising carbon losses (e.g. independent basin approach). Different types of dams are evaluated in terms of costs (big versus small), location (upstream versus downstream) and numbers (single versus cascade). The topic is exemplified by a case from Central Kalimantan.

Results

Subsidence

Generally speaking, subsidence of tropical peatlands can be described as a function of the water table depth as follows:

Peat subsidence rate ($cm\ y^{-1}$) = *0.x * depth of the water table (cm)*

The actual co-efficient value (0.x in the general form) depends on the peat characteristics, and it has been found to vary between 0.1 – 0.04 in Sarawak and Western Johore (Wösten *et al.,* 1997; Wösten and Ritzema, 2001). The equation can be used as a tool for converting the optimal water levels, as dictated by different land-uses, into subsidence rates. For example, the rate of subsidence of peat under sago cultivation with an optimal water table depth of 25 cm will be only half the rate of subsidence of peat under oil palm cultivation with an optimal water table depth of 50 cm. Combining these subsidence rates with the thickness of peat layers allows also to make an assessment of the time it will take for all peat to disappear and for the mineral subsoil - which is often a problematic acid sulphate soil - to become exposed. Based on the peat characteristics it can be calculated that each cm of subsidence results in a CO_2 emission of 13 tonnes per hectare per year. Fig. 1 shows a clear example of this subsidence process.

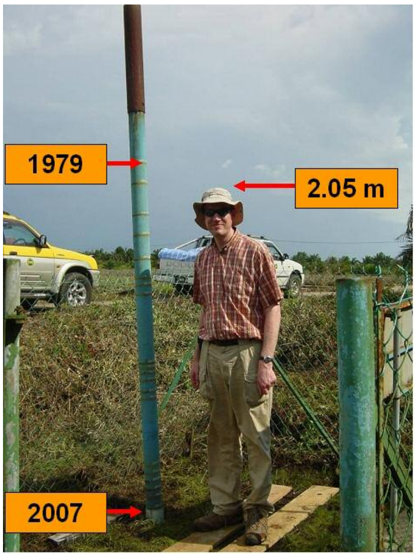

Figure 1.A total of 230 cm subsidence in 28 years resulting in an average subsidence rate of 8.2 cm per year in peatlands in Western Johore, Malaysia.

Fire

Unplanned events, including unauthorised (illegal) activities and natural disasters, affect seriously both natural and sector developed tropical peatlands. For example, severe drainage leads ultimately to collapse of the peat structure, increasing tree-fall and eventually complete loss of forest cover. Peat swamps influence the hydrology of entire catchments and excessive drainage destroys the sponge effect of peat swamps causing the loss of their water reservoir function. Exploitation of peat swamp forest reduces the ability of the ecosystem to regulate rainfall, and water is flushed more quickly into the rivers, causing flooding downstream. Despite the tropical wet climate, peat swamps suffer from water shortage during dry periods and they become prone to fire. Without water conservation, evaporation can lead to persistent moisture deficits and increased oxidation. Existing hydrological models are excellent tools to calculate fluctuations in water tables both in time and space. Research shows that areas where calculated water tables drop deeper than 40 cm below the surface correspond well with fire damaged areas.

Water management

Once peatlands are degraded by the construction of legal and/or illegal drainage canals, restoration has to focus on the restoration of the hydrological integrity of the peat swamp. This implies that many drainage canals have to be blocked in order to prevent water tables dropping substantially below the peat surface for considerable periods of time. Only this rewetting of the peat restores its natural resource functions and decreases peat oxidation and reduces the fire risk. Dams act as flow barriers but they cannot store water for long periods as it will seep away through the surrounding peat. Computer simulations show that a cascade of closely spaced dams is most effective for water control. The differences in water levels over each dam should be limited to about 50 cm to reduce seepage and prevent erosion (‘piping’). The distance between adjacent dams depends on the gradient of the peat dome, which in the central part is often less than 0.5 $m\ km^{-1}$ and increases to more than 2 $m\ km^{-1}$ near the edges. Consequently, distances between dams in the central part of the dome can be as far apart as 1 to 2 km, but this must be shorter towards the edges. As dams are intended as water barriers rather than water impoundment structures, they do not have to be watertight and thus their construction can be relatively simple. Dams have to be adapted to the characteristically high hydraulic conductivity and low load bearing capacity of tropical peat. Simple dams constructed from locally available material (timber and peat) prove to be effective in raising water levels. An additional benefit of using light timber and peat material is that expensive foundations are not required. It is recommended that dam construction starts in the relatively small drainage canals in the upper-catchment area and progresses towards the bigger canals further downstream. This way, pressure is gradually taken off from the system which reduces the risk of failure of bigger and more expensive dams in the downstream area during periods of peak water discharge. Fig. 2 shows a relatively simple dam which is effective as a water management strategy that mitigates carbon loss.

Acknowledgement

This study was supported by the European Union RESTORPEAT project (INCO-CT-2004-510931).

Figure 2. Dam in illegal logging canal in the Sabangau catchment, Central Kalimantan, Indonesia, constructed using local available material.

References

Drajad, M., Soekodarmodjo, S., Hidayat, M.S. and Nitisapto (1986). *Subsidence of peat soils in the tidal swamp lands of Barambai, South Kalimantan. Proceedings of the Symposium on Lowland Development in Indonesia,* 168-181. Research Papers ILRI, Wageningen.

Jaya, A. (2005). *Study of carbon and water on tropical peatlands for ecological planning (case study of the ex Mega Rice Project in Central Kalimantan), Indonesia.* PhD. thesis University of Nottingham, UK, 211pp.

Rieley, J.O. and Page, S.E. (eds.) (2005). *Wise Use of Tropical Peatlands – Focus on Southeast Asia.* Wageningen, Alterra, 168pp. + appendices.

Takahashi, H., Usup, A., Hayasaka, H. and Limin, S.H. (2003). Estimation of ground water levels in a peat swamp forest as an index of peat/forest fire. *Proceedings of the International Symposium on Land Management and Biodiversity in Southeast Asia*, *Bali, Indonesia, September 2002,* 311-314. Hokkaido University Japan and Indonesian Institute of Sciences.

Usup, A., Hashimoto, Y., Takahashi, H. and Hayasaka, H. (2004). Combustion and thermal characteristics of peat fire in tropical peatland in Central Kalimantan, Indonesia. *Tropics* **14**, 1-19.

Wösten, J.H.M., Ismail, A.B. and van Wijk, A.L.M. (1997). Peat subsidence and its practical implications: a case study in Malaysia. *Geoderma* **78,** 25-36.

Wösten, J.H.M. and Ritzema, H.P. (2001). Land and water management options for peatland development in Sarawak, Malaysia. *International Peat Journal* **11**, 59-66.