Carbon dioxide emission from peatland in relation to hydrology, peat moisture, humification at the Vo Doi national park, Vietnam

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Abstract
The relationships of CO_2 emission with water table, peat moisture and humification was studied in secondary peat swamp forest floor at the Vodoi national park, Vietnam in order to propose a better water management system to maintain forest growth and restore peat. The recent artificially maintained high water level in the forest floor for most of the year in order to reduce risks of fire has led to bad growth of forest and death of some plants. The results of this study showed that the less humified top 10 cm peat (litter) layer has a major contribution to CO_2 emission from peat surface. The CO_2 release rate from peat oxidation decreased significantly when peat moisture became less than 80% of the water holding capacity. Deep water level in dry season, lower than 25 cm under the peat surface, might decrease the rate of CO_2 emission from peat oxidation and is good for forest-root respiration. Therefore, artificially maintaining a high water level in the dry season is not a good choice to restore peat and forest in the Vo Doi National Park.

Key Words
CO_2 emission, peat oxidation, water table level, peat humification.

Introduction
Vodoi National Park in the southern Vietnam holds one of the largest areas of intact peatland remaining in the country. The park has a peat area of around 1,150 ha, and a further area of about 2,000 ha where the peat has been burned by forest fires, and which has now been reforested (report of the Camau department of forestry 2003). In order to reduce the risk of further fires, a dike and canal system has been built around the peat area to maintain unnaturally high water levels. Consequently, the peat area was flooded for most of the year. Water table level depth in peat plays an important role in peat accumulation and decomposition dynamics, and thereby also in soil CO_2 emissions, all of which form important components in terrestrial carbon storage and soil-atmosphere greenhouse gas dynamics (Rieley and Page 2005). Appropriate water management may improve vegetation growth rate on peat, and thus increase the potential for peat accumulation in comparison to decomposition carbon losses. The objective of this study was to measure the rate of CO_2 emission from peatland in the Vodoi area in relation to the water table level, peat moisture content, and the degree of peat humification.

Materials and Methods
Water table level was measured with an automated water table logger. The logger was installed in a well-developed forest canopy area (October 2006 to July 2008). CO_2 emission was measured during the dry season at five permanent points located in the peat area. At each point, the depth of the water table level was recorded and peat moisture content above the water table was determined at 10 cm intervals up to the soil surface. For the measurement of the rate of CO_2 emission, a round aluminium chamber (with a diameter of 31 cm and a height of 12 cm) was inserted into the peat to a depth of 1 cm from lower edge, and the rate of CO_2 emission was calculated from concentration increase in the closed chamber detected by EGM-4 infrared gas analyzer. In another experiment, the CO_2 emission rate from the peat surface in the absence of plant root respiration was examined. For that, four intact peat columns of 60-cm diameter and 80-cm depth were put into plastic tanks of the same diameter and 1 m height for measuring CO_2 emission. Water in tanks was filled up to the surface by using water collected from the same sampling site. Water level in tanks was adjusted to different levels by withdrawing water through an outlet at the bottom of tanks. Measurement of CO_2 emission at each water level was conducted only one week after the water level was adjusted in order to stabilize moisture of peat above the water level.

The relationship between peat moisture and CO_2 flux from peat decomposition, without live roots, was measured at depths of 0-10cm, 10-20cm and 20-30cm. For this purpose, peat samples collected from each depth were put into air-tight boxes of 160cm diameter and 10 cm height. The peat was packed in the boxes to 5 cm thick layer. CO_2 respiration was measured by infrared gas analyzer after the peat material reached: water holding capacity, 80%, 60%, 40% and 20% of the water holding capacity. There were four replicates for each moisture level.

The degree of peat humification at different depths was assessed by collecting peat samples at 10 cm intervals in a peat profile from the soil surface, and analysing them for humic compounds and fulvic compounds by the Kononova method (Sokolov 1965) and for ash and organic matter contents.

Results

Peat humification status

The peat contained 90-94% organic matter. The top litter layer was 5-10 cm deep and contained lower levels of humic and fluvic compounds and a lower ratio of humic to fulvic compounds than deeper peat layers, indicating that the top litter layer was less humified than the deeper peat horizon (Table 1). However, the peat just above the underlying mineral soils also had relatively low levels of humic and fulvic compounds, suggesting that proximity to the underlying mineral soil retarded humification.

Table 1. The degree of peat humification.

Sample depth (cm)	OM (%)	Humic+fulvic matters (%)	Humic matter (%)	Fulvic matter (%)	Humic - fulvic ratio
0-10 (litters)	92.1	23.2	14.6	8.6	1.7
10-20	93.4	38.8	33.1	5.7	5.8
20-30	94.0	42.8	37.0	5.8	6.4
30-40	93.0	39.4	33.5	5.9	5.7
40-50	92.8	27.5	23.6	3.9	6.0
50-60	87.2	18.3	13.0	5.3	2.5
60-65	76.5	18.5	16.6	2.0	8.4

Peat water table level and moisture

The fluctuation of water table level during observed period from 10/2006 to 7/2008 showed that in the peat area was below the peat surface from February to May (from the middle to the end of the dry season), and the depth of water table level below the ground surface in dry season fluctuated by years and depended on how it was artificially maintained (Figure 1). At the deepest water level in 2006, peat above the water table had a moisture content of 70-82%, which is about 80-100% of its water holding capacity.

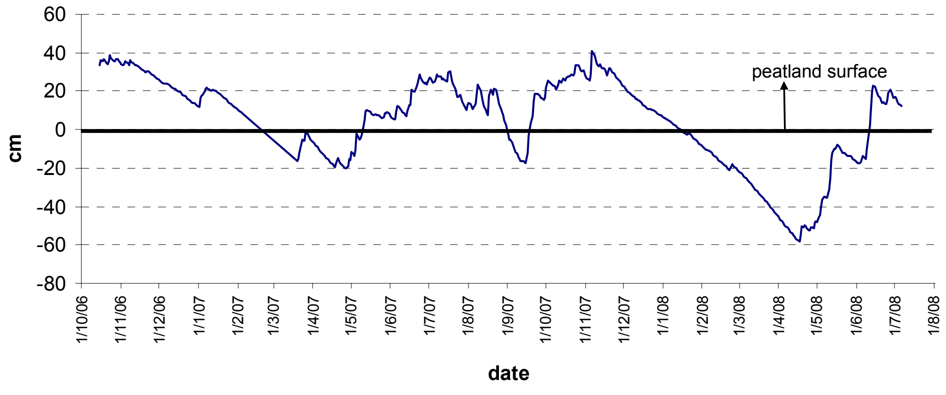

Figure 1. Water table level at the study site in Vodoi National Park.

Relationship between rate of peat oxidation and peat humification and moisture

The rate of CO_2 release from peat – that is, from decomposition and faunal activity but excluding root respiration – was significantly higher in the less humified top 10 cm (litter layer) than in the more humified deeper peat layers, irrespective of the moisture content (Figure 2). The highest CO_2 release rate from peat decomposition and faunal activity was found in the top 10 cm litter layer at a moisture content of 67-85% w/w (from the water holding capacity of 80%). By contrast, the rate of CO_2 release via decomposition and faunal activity in more humified peat material below the litter layer was very low, being less than 0.02 mg CO_2 /g/h at water content ranging from 60% to 100% of the water holding capacity, *i.e.* higher than 50%

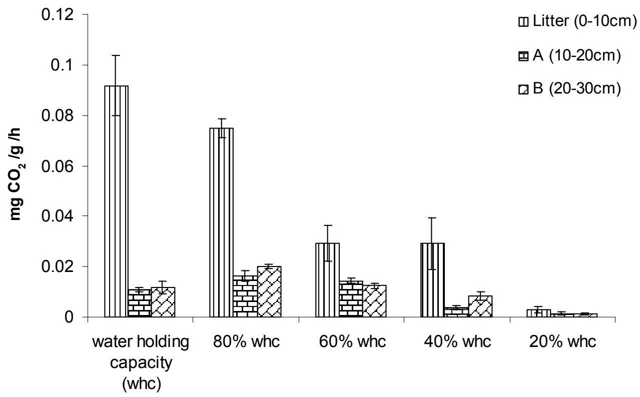

Figure 2. Relationship of CO_2 release from peat at various depths and peat moisture conditions.

moisture (w/w). The CO_2 release rate was even less at moisture content ≤40% of the water holding capacity. As the water table level in the forest floor did not sunk deeper than -30 cm below the soil surface and the peat moisture content above the water table was over 80% of the water holding capacity, we conclude that the near surface litter layer played the major role in CO_2 emission from peat materials in Vodoi National Park.

Gaseous CO_2 losses from peat

Root respiration, peat decomposition and faunal activity all contributed to CO_2 release from peat. The overall rate of CO_2 release, including all the aforementioned components, ranged from 0.8 g CO_2/m^2/ hr when the water table was near the peat surface to 1.8 g CO_2/m^2/hr when the water table was around -30 cm from the peat surface (Figure 3). Moisture of peat above water level when that ranged within 0-30 cm below ground surface was 80-100% peat water holding capacity. As mentioned above, this is the optimal range of moisture for peat oxidation. The figure 3 also showed the increasing tendency of CO_2 release with depth of water level. The reason might relate to better aerobic condition which favour peat oxidation and root respiration.

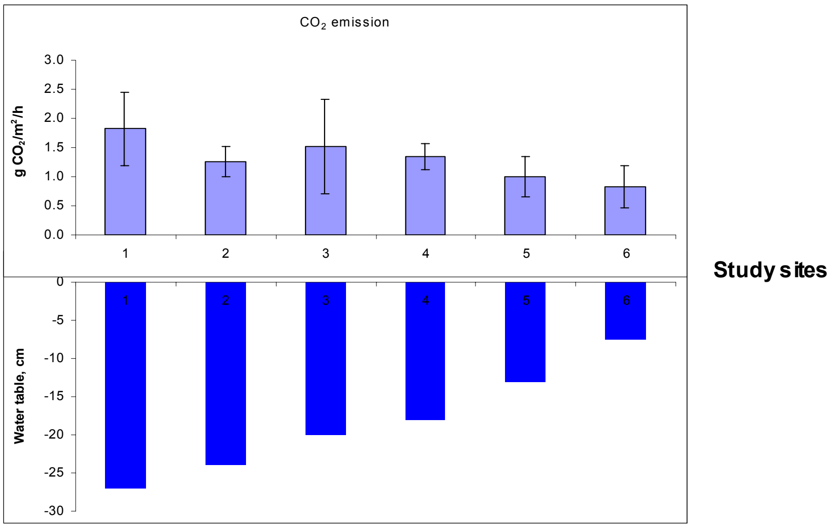

Figure 3. Relationship of CO_2 emission and water table level in the forest floor.

Comparing CO_2 emission from the peat surface in natural condition and in experiment with intact cut peat columns which killed tree roots can help to identify what factor mainly contributes to CO_2 emission from peat surface when water level descends. The rate of CO_2 emission in the absence of living roots, CO_2 considered to be from peat oxidation, was around 0.15-0.27 g/m^2/hr, much less than the rate in natural conditions (Figure 4). When the water table level went down lower than 25 cm, CO_2 release became less. It was also observed that when the water level was lower than 25 cm, the top-layer peat became a dryer. Thus lowering water level might make the top-layer dryer and reduce peat oxidation. Therefore, the period of low water level in peat area in the dry season may be beneficial for the peat ecosystem because it can enhance forest-root respiration and reduce oxidation of top peat material. It was also observed that many specimens of *Melaleuca cajuputi*, lianas and the grass *Stenechleana palustrie* are either growing poorly or have died in areas flooded all year round.

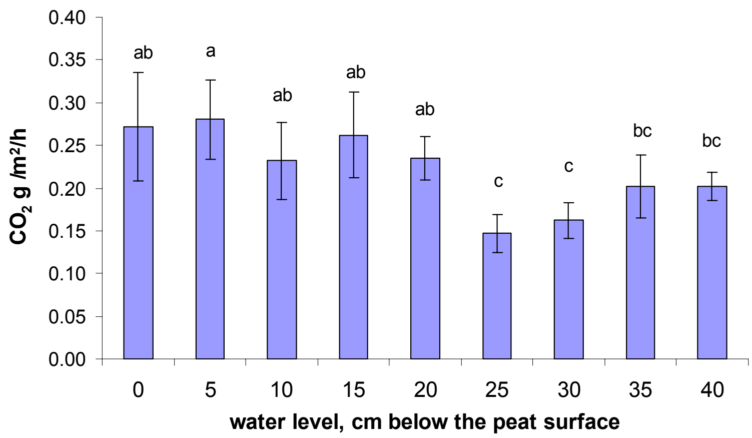

Figure 4. CO_2 release from peat surface at different water levels in the absence of living tree roots.

Conclusions

- CO_2 release rate from peat oxidation decreases with increasing peat humification degree. Top organic material (0-10 cm) has major contribution to CO_2 emission from the peat surface because of low humified degree and frequent exposure to the air in the dry season.
- The rate of CO_2 emission from peat surface relates to water level: high CO_2 emission at low water level in dry season might mainly come from root respiration, not from peat oxidation. Therefore, maintaining an artificially high water table level in the dry season to reduce the fire risk disturbs the natural hydrology of peatland and leads to high moisture of peat above the water table, high CO2 loss from peat oxidation and bad conditions for tree-root respiration, which may badly affect forest growth.

Acknowledgements

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