Land Use and GHG Fluxes in Tropical Peat

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It is generally accepted that the gradual increase in the mean temperature of the Earth's surface is primarily due to rising concentrations of greenhouse gases (GHG), especially carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the atmosphere. Tropical peat swamp forest can form one of the most efficient carbon sequestering and storing ecosystems because it combines substantial biomass production and biomass conservation capacity in nutrient-poor, waterlogged soil. Peat water table depth has crucial importance on peat GHG dynamics in the ecosystem because it regulates depth of aerobic peat horizon and thereby organic matter decomposition. Rainfall in excess of evaporation forms predominant peat hydrology-regulating parameter because evaporation and (groundwater) outflow are fairly constant in tropical peat. Peat drainage creates oxic condition deeper in peat profile and thus speeds up peat stored carbon oxidation.

Large areas of tropical peat have been drained, resulting in an abrupt and permanent shift in the ecosystem carbon balance from sink to source (e.g., Canadell et al., 2007; Rieley et al., 2008). Decomposition of drained peatlands in Indonesia is estimated to cause 632 Mt yr^{-1} CO_2 emissions (range 355–874 Mt yr^{-1}), which will likely increase every year for the first decades after 2000 unless peatland use practices are changed (Hooijer et al., 2006).

This work quantifies and compares most important greenhouse gas types, i.e., CO_2, CH_4, and N_2O related to peatland gas exchange in various land uses in tropical peat. Gas fluxes derived from intensive monitoring campaigns in typical hydrological conditions are compared in five land use types on tropical peat in Central Kalimantan, Indonesia. Land use types in the study include selectively logged undrained peat swamp forest, drainage affected peat swamp forest, fallow peatland used for agriculture, recovering forest on clear-felled drained peatland, and clear-felled, burned and uncontrollably drained peatland.

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Rapid Peatland Expansion and Carbon Accumulation in Alaska Caused by a Warm Climate and High Seasonality in the Early Holocene

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High latitudes are sensitive to climate warming owing to a number of important positive feedbacks, including albedo feedback resulting from changing sea ice extent, snow and vegetation cover, and carbon-cycle feedback. The fate of high latitude ecosystems and associated climate feedbacks in response to warming remains uncertain, particularly in boreal peatlands, which store roughly 1/3 of the global soil carbon pool.

In order to understand how peatlands respond to past climate warming, here we compiled basal dates from nearly 300 peatlands from across Alaska to examine the timing and spatial pattern of peatland initiation during the late glacial and Holocene. We also calculated Holocene carbon accumulation rates from four peatlands on the Kenai Peninsula, Alaska that have high-resolution dating and carbon analysis. Available pollen data from the North American Pollen Database (NAPD) and the Paleoenvironmental Arctic Sciences (PARCS) databases were used to examine associated vegetation distribution patterns. We synthesized these data sets to examine the connection between regional climate, peatland initiation and lateral expansion, and vertical accumulation; in particular focusing on the early Holocene during the Holocene Thermal Maximum (HTM) in Alaska, a time when the climate was warmer than today (Kaufman et al., 2004).

Our study reveals that the highest rates of carbon accumulation on the Kenai Peninsula occurred during the HTM, which also corresponds to the highest number of peat basal dates from both south-central Alaska and Alaska as a whole, indicating that not only vertical peat growth but also lateral peatland expansion was high. The basal date frequency of the nearly 300 sites reveals that ~70% of Alaska peatlands developed by 9000 cal yr BP, and the carbon accumulation rates from four south-central Alaska sites were nearly three times higher than during the rest of the Holocene. We suggest that the warm summers and a longer growing season during the early Holocene in Alaska resulted in high net primary productivity (NPP), rapid peat burial, and the greatest carbon accumulation rates. High accumulation rates and burial may have minimized the effects of aerobic decomposition. In addition, a change in the seasonal timing of precipitation and moisture availability and an increase in summer precipitation may have decreased drought stress, promoting peatland initiation and peat growth. Furthermore, lower than present winter insolation would have resulted in cold, dry winters, which would have limited winter respiration, further minimizing decomposition. We also speculate that the dominance of broad-leafed deciduous forests and abundant ferns at that time resulted in localized vegetation-climate feedbacks (Zhang and Walsh, 2006) that would have increased relative humidity, minimizing the potential effects of peatland drying as a result of warm summer temperatures. These findings have important implications for carbon storage and climate feedbacks in Arctic ecosystems under projected high-latitude warming, as warmer temperatures can potentially lead to net carbon storage and a negative climate feedback as long as summer growing season moisture availability remains high.

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The Impact of Changing Acidity on Carbon and Nitrogen Cycling in Peatlands

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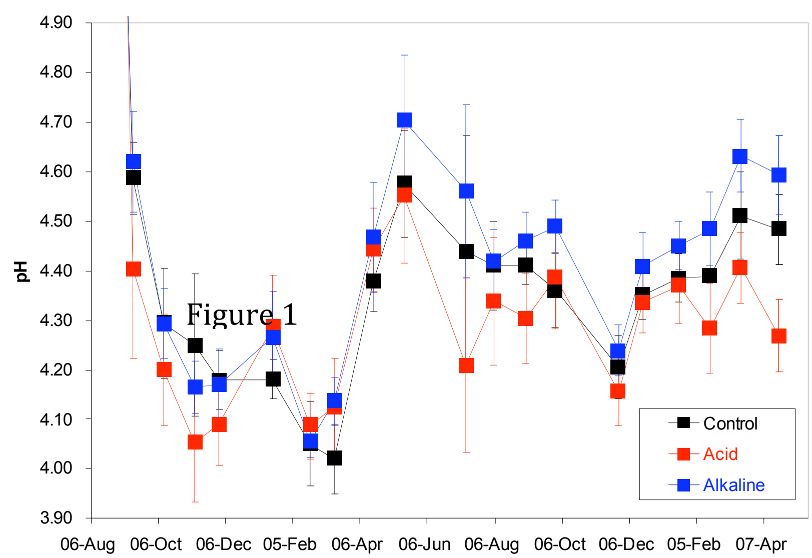
Peat soils have traditionally sequestered vast stores of carbon (C) (Gorham, 1991), but since the onset of the industrial revolution and the growth of agriculture, these ecosystems have been exposed to increased nitrogen (N) and sulphur (S) deposition, increasing the acidity of peatlands and potentially threatening their function as carbon sinks. While N deposition remains high, S deposition has declined sharply in the last few decades due to legislation on the use of fossil fuels, and many ecosystems are consequently recovering from acidification (Evans et al., 2001). We are testing the hypothesis that peatland C and N cycles are being strongly altered by acidity change and that rising pH will increase the loss of C and N as dissolved organic matter (DOM), due to both increases in biological production and increasing organic matter solubility. We have established plot-scale field experiments at two UK peat ecosystems exposed to low and high levels of N pollution and are manipulating soil pH with solutions aimed at replicating historic S deposition peaks and more alkaline pre-industrial conditions; after one full year of treatment additions, soil solution pH is now showing the expected responses (e.g., Figure at right). We will present measure-ments of C and N losses in gaseous (CO_2, CH_4, N_2O) and dissolved (DOC, DON, NO_3, NH_4) forms, quantify the relative importance of each loss pathway, and undertake an initial assessment of the response of each C and N flux to changes in soil acidity.



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Measurements of Carbon Dioxide Fluxes by Chamber Method at Rzecin Wetland

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The assessment of net ecosystem production (NEP) and respiration of ecosystem (Reco) of terrestrial ecosystems is necessary to measure to improve our knowledge in carbon cycle. The aims of this work were to present reliable measurements of CO_2 fluxes of a temperate peatland ecosystem located in Poland using a closed dynamic chamber system and to obtain daily dynamic course of CO_2 fluxes over the growing period of 2007 and the whole 2008. Measurements of CO_2 fluxes were carried out at four sites (with different plant species composition) at Rzecin peatland ecosystem using two different kinds of chamber. A dark chamber made from PVC was used for Reco measurements. The transparent chamber (made from Plexiglas) was used for NEP measurements. Both chambers have a cube shape with a volume of 0.3 m^3. Measurements were carried out every three weeks from June to October 2007 and the whole 2008. Individual measurement at each plot took between 2 to 5 minutes dependently on the chamber type, CO_2 concentration changes and weather conditions. Moreover, micrometeorological parameters, as air temperature, soil temperature at three depths (2, 5 and 10 cm), and photosynthetically active radiation (PAR) were recorded during measurement campaigns. Reco rates during the experiment period ranged from 2.65 to 14.76 μmol CO_2 m^{-2} s^{-1} for all four sites. Trend of daily dynamic of NEE was inversely proportional to daily trend of PAR and the values were from 0.06 to -11.82 μmol CO_2 m^{-2} s^{-1}. We found differences between CO_2 fluxes (NEE and Reco) with respect to the seasons and time of a day, when measurements were carried out. Environmental factors, such as PAR, air and soil temperature explained most of a diurnal and temporal courses of CO_2 fluxes at our ecosystem. However, vegetation composition, phenology of the vegetation and water depth play an important role in the spatial distribution of CO_2 fluxes

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Responses of Ecosystem CO_2 Exchange to Nutrient Addition in a Bog

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Atmospheric nitrogen (N) deposition or enhanced mineralization can alter the carbon (C) sequestration of wetlands. Experiments and gradient studies have shown that in bogs N input leads to decreased *Sphagnum* moss cover and increased vascular plant cover (e.g., Wiedermann et al., 2007). The change in vegetation can be fundamental, and can increase or even decrease the photosynthetic capacity of bog ecosystems (Bubier et al., 2007). Meanwhile, nutrient supply for microbes and the change in litter quality may promote carbon loss from these peatlands (e.g., Bragazza et al., 2004). To study how the plant community shift affects the C sequestration of bogs, we addressed the following questions: 1) How are the changes in ecosystem gas fluxes related to the changes in plant communities over the course of the nine years of nutrient addition? 2) Is leaf photosynthesis of dwarf shrubs affected by nutrient addition and does it affect ecosystem CO_2 exchange? We will discuss the effect of time and dose of nutrient input, and the effects of N and PK on the ecosystem responses.

The fertilization experiment has been conducted in Mer Bleue Bog, Canada, where background wet N deposition is ~0.8 g m^{-2} a^{-1}. Nitrogen was added (0, 1.6, 3.2, and 6.4 g m^{-2} a^{-1}) with or without phosphorus and potassium (P+K) fertilizer for four or nine years. We quantified the vegetation characteristics and measured the net ecosystem CO_2 exchange in full light (NEE_{max}), ecosystem photosynthesis (Pg_{max}), and ecosystem respiration (ER) from May to August using climate-controlled static chambers. Intact leaves of *Chamaedaphne calyculata*, *Ledum groenlandicum*, and *Vaccinium myrtilloides* were measured for photosynthesis in July–August of 2008.

Treatments had no effect on maximum rates of leaf photosynthesis (A_{max}). However, *Ledum* showed a significant increase in maximum rate of carboxylation (V_{cmax}) under low N and low N+PK addition treatments. This suggests that these nutrient addition levels do not harm photosynthetic properties of dwarf shrub leaves, and small N addition can enhance it. Greater ecosystem changes have occurred in the vascular plant growth, and moss cover under high N +PK additions. Loss of moss cover is presumably functionally compensated with increased shrub growth, measured, for example as doubled height, because relative to the changes in the vegetation parameters, the changes in ecosystem CO_2 exchange were small. In summer 2008, ecosystem NEE_{max} and Pg_{max} were not affected by the treatments, but ecosystem respiration was higher in the two highest N+PK treatments than in the control (+24–32%). This trend can lead to decreased ecosystem C gain under enhanced nutrient supply.

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