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Response of a warm temperate peatland to Holocene climate change in northeastern Pennsylvania

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ABSTRACT

Studying boreal-type peatlands near the edge of their southern limit can provide insight into responses of boreal and sub-arctic peatlands to warmer climates. In this study, we investigated peatland history using multi-proxy records of sediment composition, plant macrofossil, pollen, and diatom analysis from a ^{14}C-dated sediment core at Tannersville Bog in northeastern Pennsylvania, USA. Our results indicate that peat accumulation began with lake infilling of a glacial lake at ~9 ka as a rich fen dominated by brown mosses. It changed to a poor fen dominated by Cyperaceae (sedges) and *Sphagnum* (peat mosses) at ~1.4 ka and to a *Sphagnum*-dominated poor fen at ~200 cal yr BP (~AD 1750). Apparent carbon accumulation rates increased from 13.4 to 101.2 g C m^{-2} yr^{-1} during the last 8000 yr, with a time-averaged mean of 27.3 g C m^{-2} yr^{-1}. This relatively high accumulation rate, compared to many northern peatlands, was likely caused by high primary production associated with a warmer and wetter temperate climate. This study implies that some northern peatlands can continue to serve as carbon sinks under a warmer and wetter climate, providing a negative feedback to climate warming.

Introduction

Northern (boreal and sub-arctic) peatlands contain a large carbon pool of up to ~500 Gt (1 Gt = 10^{15} g), about one-third of the world's soil organic carbon, although they cover only about 3% of the earth's land surface (e.g., Gorham, 1991; Turunen et al., 2002; Yu et al., 2010). Peat accumulation is determined by the processes of production and decomposition of organic matter. The peat accumulation rate varies among peatlands owing to their differences in latitudes, climate, age, and peatland types (Vasander and Kettunen, 2006). Climatic change (variations in temperature and precipitation) and induced changes in hydrology and vegetation would have significant effects on the rate of peat decay, the rate of peat addition into the anaerobic layer (the catotelm), and therefore the peat accumulation rates. Changes between carbon source (peat degradation) and carbon sink (peat accumulation) in peatlands, especially in response to climate change, can significantly affect the global carbon cycle.

Peat accumulates whenever the rate of organic matter production exceeds the rate of decay. Peat accumulation rates increase for two reasons: higher production at the peat surface or lower decomposition. Warmer climate with a longer growing season and/or higher moisture conditions can favor primary production in peatlands (Belyea and Malmer, 2004). A longer growing season and/or higher temperature may result in greater evaporation and a longer seasonal drawdown of water table, which exposes more peat to be oxidized; meanwhile, the decomposition rate is positively correlated with soil temperature (Carroll and Crill, 1997; Frolking et al., 2001). However, wetter climate or higher precipitation would affect the dynamics of hydrology in peat, likely resulting in higher primary productivity and higher water table, which impedes decomposition of peat. A good number of carbon dynamics studies have been focused on peatlands in boreal and subarctic regions (e.g., Ovenden, 1990; Warner et al., 1993; Charman et al., 1994; Botch et al., 1995; Tolonen and Turunen, 1996; Yu et al., 2003; Roulet et al., 2007), whereas responses of peatland carbon dynamics to climatic variations under a warmer climate have been poorly understood (Wieder and Yavitt, 1994).

In this study, we used multi-proxy data derived from peat cores to document the peat accumulation pattern and accumulation rate, peat decomposition, and climate variations at a temperate tree-covered poor fen. The results were compared with data from northern peatlands to evaluate the differences between temperate and boreal peatlands, and to understand the effects of warmer climate on peat accumulation. Climate change was inferred from regional vegetation, local vegetation and moisture conditions using pollen, plant macrofossil, and diatom analysis, to study the influence of climate change on local vegetation change and peat carbon accumulation.

Regional setting and study site

Tannersville Bog (also called Cranberry Swamp) is located near the edge of the Pocono Mountains in Monroe County, Pennsylvania (75°16′W, 41°02′N; Fig. 1), with a surface area of 3 km^2. The

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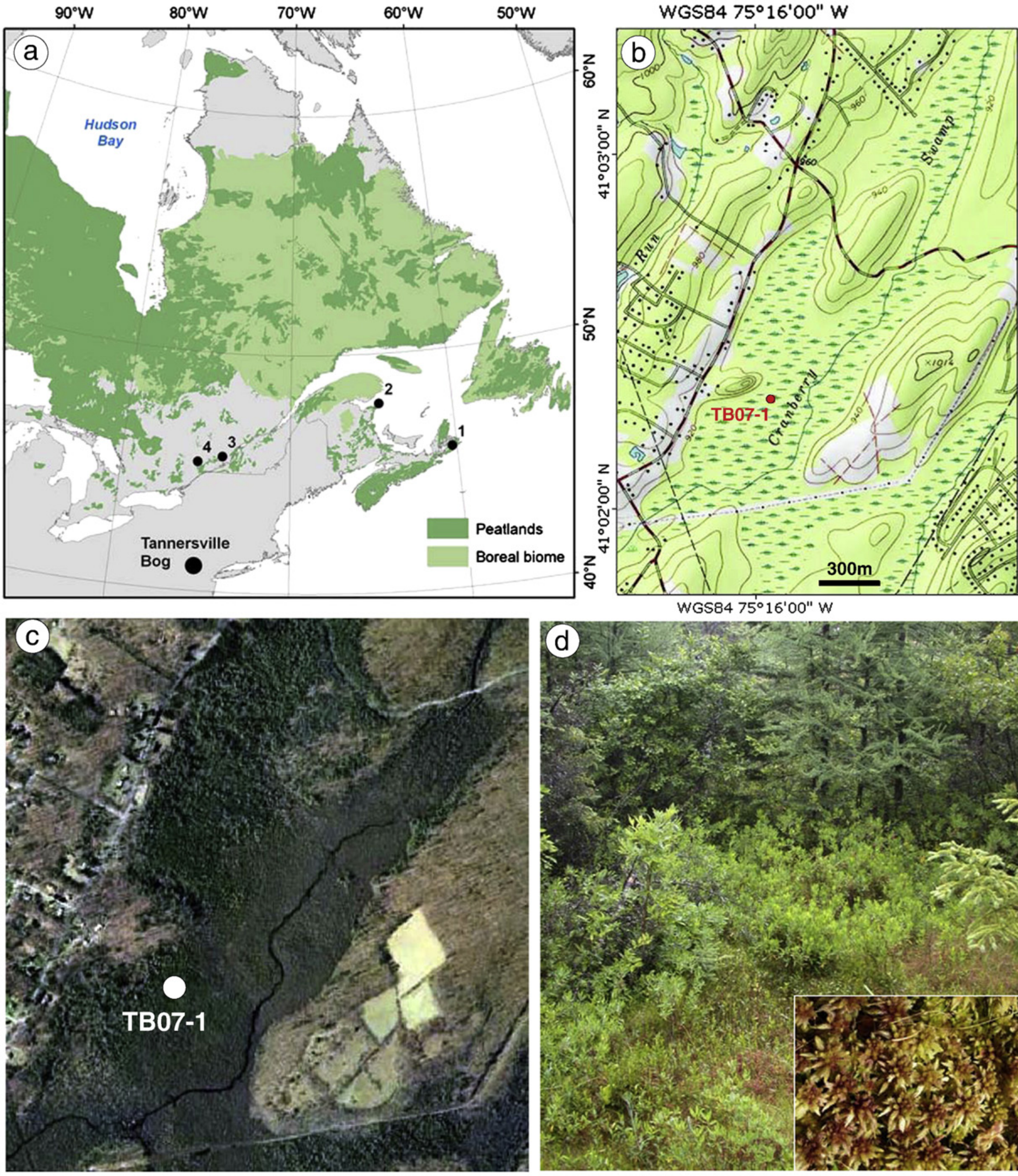

Figure 1. Maps and setting. (a) Map showing the location of Tannersville Bog in Pennsylvania (large circle) related to the distributions of boreal biome and northern peatlands in northeastern North America (map modified from Yu et al., 2009). The peatland areas (dark green) represent regions with abundant peatlands (≥5%; Tarnocai et al., 2002). Other carbon accumulation sites are: (1) Fourchou, Nova Scotia (Gorham et al., 2003); (2) Miscou, New Brunswick (Gorham et al., 2003); (3) Mirabel Bog, Québec (Muller et al., 2003); and (4) Mer Bleue, Ontario (Roulet et al., 2007). (b) Topographic map showing the coring location of core TB07-1 in Tannersville Bog (also called Cranberry Swamp); (c) air photo of Tannersville Bog (from Google Earth Image); and (d) ground photo of Tannersville Bog, Pennsylvania, with inset showing ground layer dominated by peat mosses (*Sphagnum*).

bedrock in the region consists of gently dipping Paleozoic age (570–225 Ma) strata containing sandstones and shales; during the Pleistocene the landscapes were eroded by advancing glaciers and covered by glacial deposits (Hirsch, 1977). Tannersville Bog was occupied by a glacial valley before the Holocene and developed by the lake-infilling process (Watts, 1979). The study area has a temperate climate with a mean annual temperature of ~10°C and mean annual precipitation of 1256 mm (Stroudsburg weather station, about 10 km from Tannersville Bog). Tannersville Bog is located in the extreme warm end of climate space for northern peatlands (Fig. 2; Yu et al., 2009).

The upland vegetation around Tannersville Bog is mostly secondary oak (*Quercus* spp.) forest. *Pinus rigida* (pitch pine) is present locally, and large *Fagus* (beech) occurs generally in the Pocono Mountains (Gehris, 1964; Watts, 1979). Open areas in the middle of Tannersville Bog are dominated by *Sphagnum* (mostly *S. magellanicum*) with patches of *Vaccinium macrocarpon* (cranberry), *Ledum groenlandicum* (Labrador tea), and *Chamaedaphne calyculata* (leatherleaf). Dominant trees are *Picea mariana* (black spruce) and *Larix laricina* (tamarack) rooted in hummocks of *Sphagnum* moss. Tannersville Bog is one of the southern-most (41°N) low-altitude (277 m above sea level) *Sphagnum*-dominated poor fens along the