Catena 86 (2011) 86–97

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Hydrologic controls on water chemistry, vegetation and ecological patterns in two mires in the South-Eastern Alps (Italy)

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ARTICLE INFO

Article history:
Received 15 April 2010
Received in revised form 28 October 2010
Accepted 21 February 2011

Keywords:
Bog
Decomposition
Fen
Map
Nutrient
Production

ABSTRACT

We examined how hydrology influenced water chemistry, vegetation, nutrient status, aboveground net primary production (ANPP) and litter decomposition rates in two mires on the South-Eastern Alps of Italy. One of the mires had a modest hydraulic gradient and prevalently acted as a recharge system, although there were short phases of vertical flow reversal during dry periods. This mire was, therefore, prevalently fed by rainwater and was covered by bog-like vegetation, mainly hummocks and scrubs with a ground layer rich in *Sphagnum* mosses. The other mire presented a steeper hydraulic gradient, with the surface being fed by mineral water either by surface runoff or by vertical, upwards directed ground water flow. Compared to the bog-dominated mire, the pore water was less acidic and richer in telluric cations. This mire was covered by fen-like vegetation, prevalently fen meadows. Nitrogen (N) content in the vegetation was very similar in the two mire sites, while phosphorus (P) content was lower in the fen-dominated site. Contrary to our expectations, ANPP did not differ significantly between the two mire sites while litter decomposition rates were significantly lower in the fen-dominated mire, presumably because of P limitation of decomposers. This suggests that the development of ombrogenous mires in this region need not be due to increased accumulation of peat during succession from mineralwater-fed to rainwater-fed conditions.

1. Introduction

Peatlands are widespread in high-latitude territories of the northern hemisphere, especially boreal and subarctic regions, where they cover vast areas (Mitsch and Gosselink, 2000) and store about one-third of the total soil carbon (C) pool (Gorham, 1991). In spite of their abundance, peatlands represent vulnerable ecosystems, strongly depending on delicate equilibria among water input, nutrient loading, climate and major ecological processes, especially plant production and organic-matter decomposition (Rydin and Jeglum, 2006). Paleoecological records of peat deposits have documented repeated changes in the vegetation of northern peatlands during the Holocene. Most of these changes were triggered by climatic variations, in turn implying modifications in peatland hydrology (Charman, 2007; Hughes and Barber, 2003). In the last few decades, peatlands underwent environmental changes at an unprecedented rapid pace as an effect of human activities (Mauquoy and Yeloff, 2008). Water-table drawdown and/or increased evapotranspiration under warmer climatic conditions result in drying of the peatland surface (Gerdol et al., 2008; Strack et al., 2006). This will probably interact with increased nutrient, particularly nitrogen (N), input in affecting processes and patterns in peatland ecosystems. In particular, dryness and/or eutrophication are expected to reduce net C sequestration by accelerating C losses either as dissolved organic C (Strack et al., 2008) or as gaseous CO_2 emissions (Lund et al., 2007). The latter will presumably exert a positive feedback effect on atmospheric CO_2 concentration (Moore, 2002).

Peatlands also occur in mid-latitude territories, especially on mountains. In mountainous northern regions, especially the Alps, peatlands usually are situated in rather densely populated areas where, in spite of depopulation and modifications in the traditional land-use practice (Tappeiner et al., 2008), anthropic pressure generally is stronger than in high-latitude remote territories. Future changes in the structure and functioning of these ecosystems will decrease soil C stocks (Leifeld et al., 2005) and will, furthermore, imply a decline of the landscape value (Gret-Regamey et al., 2008) in terms of scenic beauty, recreation services and biodiversity. In the Southern Alps of Italy peatlands cover a modest fraction of the territory, well below 1% of the total area. Nonetheless, they possess a particularly high scientific and conservation importance because this region represents the southernmost outpost in Europe for several endangered species and priority habitat types of community interest (Gerdol and Tomaselli, 1997).

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doi:10.1016/j.catena.2011.02.008

Peatland ecosystems are primarily characterized by their hydrology, with origin of water input representing the main basis for peatland typification (Mitsch and Gosselink, 2000). In particular, a major distinction has been made for several decades between minerogenous peatlands (fens), receiving water from the mineral soil, and ombrogenous peatlands (bogs), receiving water from precipitation (Du Rietz, 1954; Sjörs, 1948). Peatland ecology in the South-Eastern Alps has been the object of several papers, mostly based on plant community composition and occasional analyses of pore water chemistry (see Gerdol and Tomaselli, 1997 and references therein). However, no study has so far investigated relationships among peatland hydrology, vegetation and ecological patterns in this region. As the ecological features and, eventually, the very existence of peatlands closely depend on amount and quality of water input, it is important to understand how hydrology controls vegetation composition and ecosystem functioning in these habitats. The latter point is, in turn, a fundamental basis for any policy of peatland conservation and/or restoration.

The objective of this paper was to analyze relationships between hydrology, on one hand, and vegetation composition and ecological processes, on the other hand, in peatlands on the South-Eastern Alps. To this purpose, we chose two pristine peatlands strongly differing from each other as regards both water chemistry and vegetation cover, with one of the two sites being prevalently covered by bog-like vegetation and the other by fen-like vegetation. We hypothesized that the bog-dominated mire was mostly fed by rain water while the fen-dominated mire was prevalently fed by ground water, surface runoff or both. We also hypothesized that rates of organic-matter production and decomposition were slower in the bog-dominated mire than in the fen-dominated mire (Gore, 1983; Moore and Bellamy, 1974).

2. Material and methods

2.1. Study sites

The study was carried out during the years 2005 and 2006 at two mires in the Carnic Alps, municipality of Comelico superiore, province of Belluno (46°39′N, 12°26′E). The two mires lie 700 m apart at ca 1800 m on a geologic substrate consisting of phyllites and sandstones of late Paleozoic age. Phyllites are metamorphic rocks composed by recrystallized phyllosilicates with lenses and nodules of quartz, quartzite and graphite. Sandstones are sedimentary rocks rich in quartz and phyllosilicates. The chemistry of both parent materials is acidic and low in calcium. As a consequence, ground water flowing inside these rocks (and potentially recharging peat pore water) has low concentrations of dissolved electrolytes and low Ca/Mg ratio. The climate is cool with mean annual temperature of ca 4 °C and mean total annual precipitation of ca 1200 mm.

The first mire (Coltrondo W; elevation 1830 m, area 1.2 ha) is located on a saddle and has a peat thickness barely exceeding 2.5 m and is mostly covered by bog-like vegetation, so that it will be henceforth named 'bog site'. The second mire (Coltrondo S; elevation 1790 m, area 2.1 ha) is located in a structural elongated depression, with a small perennial creek draining the mire. The thickness of the peat body attains 7 m in the central part of the mire. Coltrondo S is mostly covered by fen-like vegetation, so that it will be henceforth named 'fen site'.

2.2. Hydrology and water chemistry

In early June 2005 a number of 1-m^2 plots were set up at the two mires (26 at the bog site and 18 at the fen site). The plots were located along transects in order to account for the whole range of habitat variation. Within each plot a 1-m long perforated PVC pipe (internal diameter 14 mm, wall thickness 2 mm) was inserted into the peat, with the top at the level of the mire surface. In each of these pipes (henceforth called phreatimeters) water-table depth was measured manually, at weekly intervals, from June to November 2005 and 2006. The measurements of water-table depth were referred to the ground level, with positive values indicating water table above ground and negative values water table below ground.

Furthermore, 24 open-stand PVC piezometers (inside diameter 52 mm, wall thickness 4 mm) were set up in early October 2005. The piezometers, consisting in 0.5-1 m long modules with threaded joint and a 10-cm long slotted portion, were arranged in eight clusters of three piezometers each (3 at the bog site and 5 at the fen site). At each piezometer cluster the modules were assembled by positioning the slotted part at different depths in order to determine vertical profiles of head. The vertical profiles sampled at the two mires did not match, as regards depth of sampling, since the thickness of the peat body differed substantially between mires. The depths were chosen in relation to the peat stratigraphy recorded at each cluster site and grouped into three intervals (1) from ground surface down to 0.5 m depth; (2) in the middle portion of the peat body and (3) in the lower portion of the peat body.

The piezometers were drilled by an Eijkelkamp probe (Eijkelkamp, Van Essen Instruments, Schlumberger), attaining a maximum depth of 7 m below ground level. Collapse of the peat mass around the pipes prevented hydraulic short-circuiting along the annulus between borehole and casing. Measurements of water level inside the upper piezometers and phreatimeters, referred to a fixed external benchmark, were taken manually in order to obtain a detailed picture of water-table morphology. Indeed, the water levels recorded in the upper piezometers and phreatimeters correspond to the unconfined ground water hosted in the upper part of the peat body (acrotelm). Conversely, the water level recorded in the middle and lower piezometers represent the hydraulic head of peat water in correspondence of the slotted portion of the piezometers.

In early June 2006 two of the piezometer clusters (one at each mire) were instrumented with DIVER type probes (Eijkelkamp, Van Essen Instruments, Schlumberger) for continuous monitoring of head during June–September 2006. Each probe consisted of a totally submerged, 12.5-cm long stainless steel mini pressure transducer, equipped with a sealed data-logger recording, at hourly intervals, absolute fluid pressure (water pressure + atmospheric pressure). The raw data were barometrically compensated through a BaroDIVER atmospheric pressure probe installed close to the piezometer clusters. The head data were compared with hourly records of precipitation obtained at a meteorologic station (Passo Monte Croce Comelico) ca 2 km apart. Barometric compensation was needed because submerged transducers measure total fluid pressure above the probe, so that daily and seasonal barometric variations can significantly affect long-time monitoring of head data.

In August 2006 a water sample was collected from all phreatimeters and piezometers. The pH was measured in the field by a portable instrument (CRISON PH 25, Crison Instruments, Alella). Subsequently, the water samples were stored in polyethylene bottles and deep frozen within a day until laboratory analyses. Concentrations of major telluric cations (Ca^{2+} and Mg^{2+}) were determined by atomic absorption spectrophotometry (Solaar 969, Unicam, Cambridge) after adding lanthanum to reduce anionic interference.

2.3. Vegetation

The vegetation of the two mires was surveyed during Summer 2005. Six main vegetation types were identified based on a combination of vegetation structure and ground morphology, the latter implying major differences as regards depth to the water table.

1) Hummocks: raised areas with a ground layer (namely the lower vegetation layer formed of non-vascular plant species) rich in *Sphagnum* mosses and a field layer (namely the taller vegetation layer formed of vascular plant species) consisting in a mixture of dwarf shrubs and graminoids.