Organic soils of the Lake Luknajno biosphere reserve, North-east Poland

Andrzej Lachacz and Magdalena Domanska

Department of Soil Science and Soil Protection, University of Warmia and Mazury in Olsztyn , plac Lodzki 3, PL-10-957 Olsztyn, Poland
Phone: +48-895233879, Fax: +48-895234821, e-mail: andrzej.lachacz@uwm.edu.pl

Summary

The nature reserve 'Lake Luknajno' was established in order to protect its population of mute swan *Cygnus olor* and other bird species. 'Lake Luknajno' is also a Biosphere Reserve established by UNESCO in 1977 and a Ramsar site. The reserve encompasses a shallow lake surrounded by peatlands. Various processes resulted in the gradual lowering of the water level in the lake. Organic matter mineralisation is currently the main soil-forming process in organic soils. As a result, muck soils and mucky soils developed there. Nowadays peat soils at the stage of organic matter accumulation occur primarily under permanently waterlogged rushes surrounding the lake. Thick deposits of calcareous gyttja have accumulated in the lake basin.

Key index words: peatlands, soil cover, organic matter mineralization, eutrophic lake

Introduction

The nature reserve 'Lake Luknajno' has been legally protected since 1947. This bird sanctuary safeguards a refuge of the mute swan *Cygnus olor*. In total, 175 species of water and mud birds were observed there, including 95 nesting bird species. In 2004 the reserve area was expanded from 710.0 to 2 049.4 ha. 'Lake Luknajno' is also a Biosphere Reserve established by UNESCO in 1977. It was recognised as a Ramsar site in 1978. It is also protected within the Natura 2000 network.

The objective of this study was to characterise the soil cover of the nature reserve 'Lake Luknajno', with special emphasis on the evaluation of organic soils in the lake's direct vicinity. Soil processes in the catchment area have a significant impact on the lake ecosystem (Kufel and Kufel, 1997; Gotkiewicz *et al.* 2002).

Methods of investigation

A field survey was carried out to evaluate the soil cover, and it involved the mapping of transects from the lake shore in the direction of mineral soils situated at higher altitudes. Soil profiles were described and soil samples were taken for laboratory analyses. The properties of soil samples were determined to support the identification of soil formations and their classification (Sapek and Sapek, 1992; Okruszko, 1994; FAO, ISRIC and ISSS, 1998).

General description of the nature reserve

The nature reserve 'Lake Luknajno' is situated around 3 km east of the town of Mikolajki (Province of Warmia and Mazury), north-west of Lake Sniardwy in the Great Masurian Lakes Region (part of the Masurian Lakeland) (Fig. 1). In most part, the region is occupied by lakes which are interconnected by channels to create a single system, stabilising the water table at an altitude of 115.7 m a.s.l. The first channels, built in 1764-1765, connected Lake Mamry, Lake Niegocin and Lake Sniardwy.

The catchment basin of Lake Luknajno is situated in the marginal zone of the maximum limit of the Pomeranian phase of Vistulian glaciation (Lisicki, 2001; Krzywicki, 2002). The lake was formed as a result of dead ice melting in the early Holocene, probably at the turn of Alleröd and the Younger Dryas period. Local relief features were ultimately shaped by Holocene processes which contributed to the formation of biogenic accumulation plains (extensive lowland bogs surrounding the lakes).

The lake's water table is situated at an altitude of 115.7 m a.s.l., and the biogenic accumulation plain surrounding the lake has a slightly higher location. Lake Luknajno is at an advanced stage of ageing. During 11 000 years of existence, the lake's basin was filled with bottom sediments in around 90% (Wieckowski, 1968). Due to a high content of calcium carbonate in the mineral deposits of the catchment area, the lake's basin features calcareous gyttia deposits in excess of ten meters. In the Masurian Lakeland, calcareous gyttia deposits are often encountered on the surface and form the parent rock of Quaternary limestone soils (rendzinas) (Uggla, 1976; Gasiorowski, 2001).

The most spectacular effect of human activity was the fluctuation in the lake's water level which had stabilised at an altitude of 117-118 m above sea level only 1000 years ago. Reclamation works initiated in 1827 lowered the water level in Lake Luknajno by nearly 2.5 m, which led to a subsequent drop in water level in the surrounding bogs. Water is evacuated from the catchment area by a network of drainage ditches.

At present, the lakes occupies an area of 680 hectares and has a water volume of 4 351 000 m^3, with a maximum depth of 3 m and an average depth of only 0.6 m. Lake

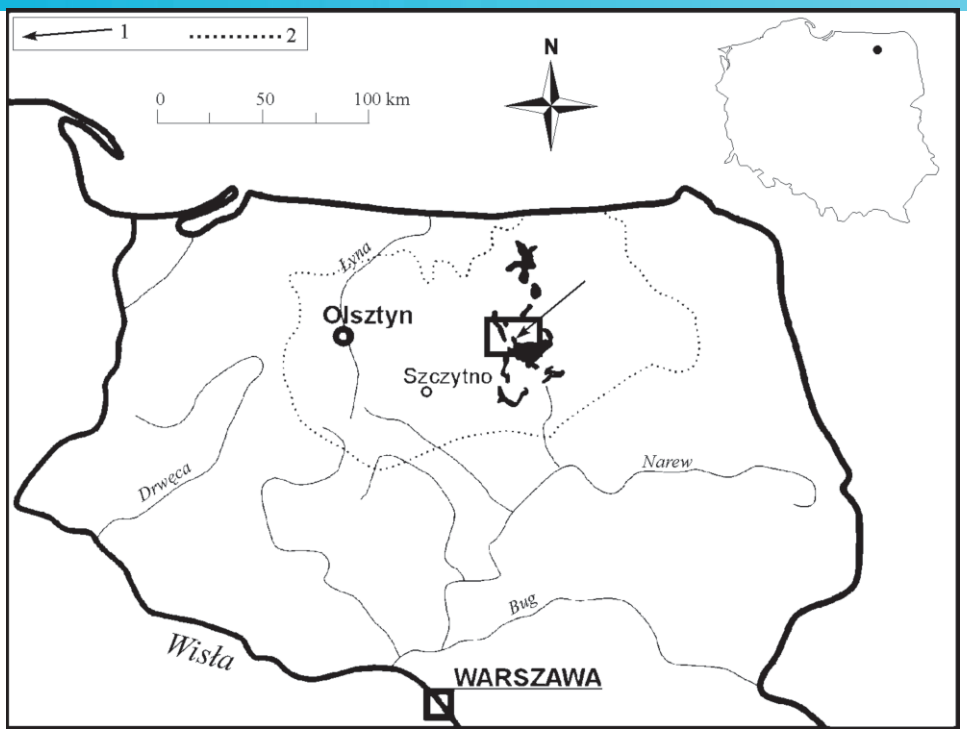

Figure 1. Location of the area studied: 1 – Luknajno Lake, 2 – boundaries of the Mazurian Lakeland

Luknajno has the following parameters: length – 3 300 m, width – 2 900 m, shoreline length – 10.2 m. The lake's catchment basin has an area of 48.4 km^2.

Plant cover

The lake's slimy and muddy bottom is overgrown by dense clusters of stoneworts (*Chara*). The lake's flat shores are surrounded by a belt of reeds (*Phragmites*) with a width of 30 to 150 m which grow on organic calcareous gyttia as well as on peat and sand. In addition to *Phragmites australis*, the local plant cover includes also *Typha angustifolia*, *Schoenoplectus lacustris* and *Rumex hydrolapathum*. Sedge rushes (*Carex appropinquata*, *C. elata*) are found further away from the lake's shore (Polakowski *et al.*, 1973). Vast areas are covered by scrub vegetation, mainly willows (*Salix* spp.). Osier communities (*Salicetum pentandro-cinereae*) grow on peat soils, mainly in the lake's direct vicinity, forming a mosaic-like system with rush vegetation. Alder carr wood (*Ribeso nigri-Alnetum*) is found in a similar habitat on peat soils with a high groundwater table, mainly along the lake's southern and eastern shores. Stinging nettles (*Urtica dioica*) and umbellifers (*Apiaceae*) are found in great abundance on reclaimed soils where meadows are no longer mown and where the drainage system has been left in neglect. The above is due to a high content of mineral nitrogen in the soil, which is released during the peat mucking process. Such meadows occupy a vast area in the south-western parts of the lake's shore zone.

Soil cover

Holocene organic deposits are the predominant type of sediments that make up the investigated area. Due to drainage, they comprise mostly decayed peat. Carbonate gyttia, detrital carbonate gyttia and bog lime are frequently encountered sediment layers. Holocene mineral deposits comprise sand, gravel and lake silt, colluvial sand and clay, shore bank sand. Surface mineral deposits include post-glacial (Pleistocene) sand, gravel and till, outwash sand and gravel, kame sand, gravel and till. Most of the above deposits are rich in carbonate rock fragments.

The soil cover has a concentric arrangement (Fig. 2). The catchment basin features soil toposequences developed under the influence of local hydrological conditions. The hydrogenic soil sequence in the lake's direct vicinity gently merges into a semi-hydrogenic soil complex and mineral soils (brown soils, rusty soils, pararendzinas), which are not affected by groundwater. Hydrogenic soils in the catchment area comprise bog peat and gyttia soils in the lake's direct vicinity, in particular in the western and northern part, post-boggy muck soils in greater contours of the western and northern part of the catchment basin, as well as mucky soils in the lake's easternmost vicinity. Semi-hydrogenic soils in the hollow areas between hills comprise mostly gley soils.

The extensive area of flat lacustrine plains is subject to swamp-forming processes of gyttia accumulation in the shallow water zone, peat-forming processes in the rush and osier hope zone, and mucking processes in drained peat soils situated further away from the lake. Some peat soils which were drained and used as grasslands in the past are now turning back into swamps since the drainage system has been left in neglect.

General description of organic soils in the nature reserve

There are great fluctuations in the organic matter content of surface soil layers in the investigated reserve. Organic soils are the richest source of organic matter as well as organic carbon and nitrogen. Loss-on-ignition reaches from 71.3% in the muck layer to 93.5% in the slightly decomposed layer of alder

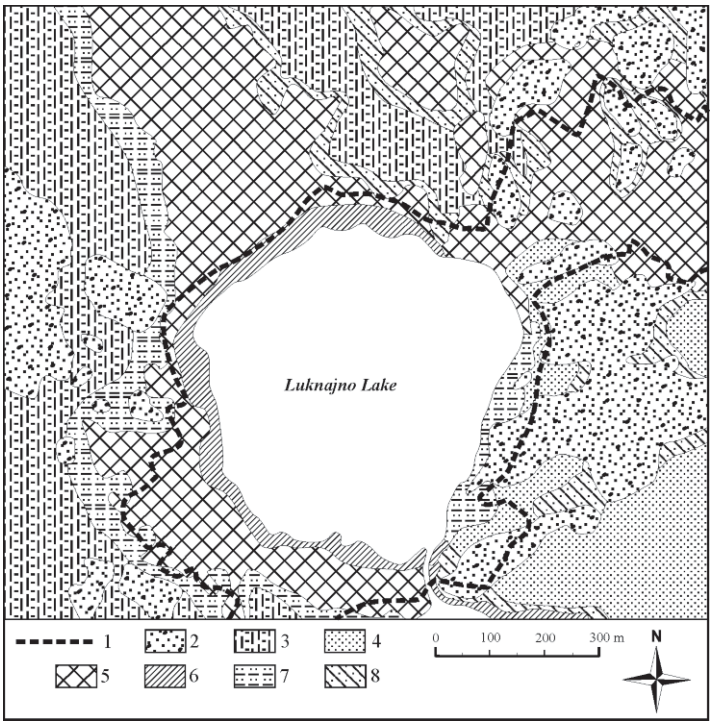

Figure 2. Soil cover of the Luknajno Lake catchment:
1 – boundaries of nature reserve
2 – pararendzinas (Calcaric Regosols)
3 – brown soils (Cambisols)
4 – rusty soils (Arenosols)
5 – peat-muck soils (Eutri-Sapric Histosols)
6 – peat soils and gyttja soils (Histosols)
7 – mucky soils (Areni-Humic Histosols)
8 – gley soils (Haplic Gleysols)

and rush peat. The highest content of organic carbon was determined in organic soils (22.4%-53.8%). Total nitrogen content in the investigated organic soils was also high. It is usually higher in muck layers (2.73%-2.95%) than in peat layers (2.07%-2.68%). The broadest C:N ratio (27.6) was reported in the alder and rush lowmoor peat layer. The narrowest C:N ratio (13.7-16.1) was observed in muck layers.

The value of the C:N ratio in the investigated area is determined by:

– degree of peat decomposition – the higher the degree of decomposition, the narrower the C:N ratio,

– degree of mucking – the more advanced the mucking process, the narrower the C:N ratio,

– presence of calcium carbonate – the higher the calcium carbonate content, the narrower the C:N ratio.

Peat and muck soils where organic nitrogen bonds undergo mineralization occupy a vast part of the lake's catchment basin. Mineral nitrogen compounds and other biogenic elements migrate to ground and lake waters, leading to the lake's eutrophication (Lachacz, 2001; Gasiorowski and Hercman, 2005).

Calcium carbonate occurs commonly in the soils of the catchment area of Lake Luknajno. The highest calcium carbonate content was reported in carbonate gyttia under peat soils (22.3-62.5%). High quantities of calcium carbonate are also observed in the mineral deposits of the catchment basin (gravel, sand, loam). In pararendzinas, calcium carbonate is found already on the surface and its content reaches 20-30% in deeper layers. The soils of the investigated nature reserve are marked by a relatively high pH. The highest pH in H_2O (alkaline reaction) was reported in the parent rock of pararendzinas (pH of up to 8.7) and in carbonate gyttia (pH of 7.9-8.6). Organic soils were marked by pH of 6.4 in the muck layer to 7.4 in the strongly decomposed layer of lowmoor moss peat.

Conclusions

The main surface deposits (parent rocks) in the natural reserve 'Lake Luknajno' are: Holocene organic deposits (mostly lowmoor peats, largely decayed), lake deposits (gyttia), colluvial deposits, Pleistocene outwash, kame and end moraine deposits.

The soil cover of the catchment basin of Lake Luknajno has a concentric arrangement. The following soil types were identified: hydrogenic soils (bog peat and gyttia soils, post-boggy muck and mucky soils), semi-hydrogenic soils (gley soils), autogenic soils (mostly typical rusty and typical brown soils) and lithogenic soils (pararendzinas).

The migration of water-carried calcium carbonate into mineral deposits and its accumulation in the lake basin has resulted in the formation of thicker calcareous gyttia layers. Due to the lowering of the water table, calcareous gyttia layers are now found close to the surface and underlay organic soils in the investigated area, thus affecting their physical and chemical properties.

Vast quantities of nitrogen compounds are mineralised and released in peat soils situated further away from the lake's shore.

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