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Assessment of soil and vegetation changes due to hydrologically driven desalinization process in an alkaline wetland, Hungary

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ABSTRACT

This study investigates a soil–water–vegetation system in a drying-out alkaline sodic wetland altered by climate change and artificial drainage by evaluating the habitat pattern and the physical and chemical attributes of the upper soil. The spatial and temporal alteration of the vegetation was monitored by detailed coenological investigations and habitat mapping during a 13-year period (2002–2014) to analyse the succession trend of the habitat in the changing environment. The spatial structures of the physical and chemical attributes of the soil were surveyed by topsoil sampling along a regular network to detect the desalinization process and to reveal the discrepancies between the soil attributes and the typical habitats because anomalies between the habitat and its optimal soil properties can project a possible vegetation change in a dynamically changing sodic ecosystem. The micro-topography was investigated to detect the effect of the elevation difference on the hydrologic conditions, soil and vegetation attributes. Statistical analyses were performed to describe the characteristic pedological processes and the spatial structures of the soil parameters. An overlapping analysis was conducted to compare the soil, vegetation pattern and topography to explore the relationships in the altering soil–water–vegetation system.

Rapid alterations of the habitats, species composition, and soil desalinization processes were clearly recognised. The rate of change reflects degradation beyond the natural dynamics of vegetation processes. The desalinization process was extremely rapid due to the sandy sediment. The significant changes in the vegetation and soil pattern led to the loss of diversity in the short term; annual salt pioneer swards and Puccinellia swards became highly threatened. The main driving factors in the desalinization process are water shortage caused by artificial drainage and climate change, furthermore extreme high precipitation which intensifies leaching. The degradation process can be mitigated by adequate water management because habitats have a high naturalness reflecting good regeneration potential.

1. Introduction

Unique saline wetland ecosystems, determined by numerous characteristic plants and adjoining fauna, have become endangered in recent decades all over the world (Aladin and Plotnikov, 1993; Poiani et al., 1995; Williams, 2002; Timms, 2005; Harvey et al., 2007; Boros et al., 2013). Saline wetland ecosystems occur in coastal areas where the dissolved salts are delivered by tidal transport (Jagtap et al., 2002; Perillo et al., 2009), in isolated continental basins determined by arid climate where evaporation plays an important role in salt accumulation (Smith, 2003), and in inland groundwater discharge zones where subsurface aquifers are the main sources of saline water (Sánchez Navarro et al., 2001; Harvey et al., 2007). The species composition, formation and alteration of these ecosystems are influenced by several natural processes and attributes of the wetland system (e.g., climate, hydrology, wetland geomorphology, soil chemical properties, or plant tolerance) and also by anthropogenic activities (e.g., surface flow diversions, groundwater extraction and mining, or grazing) (Harper et al., 1995; Casanova and Brock, 2000; Maltby and Barker, 2009; Campion and Venzke, 2011; Deák et al., 2015). The availability, movement and chemical attributes of water determine the nature of wetlands (Smith et al., 1994). Therefore, any changes in the water regime and the attendant soil alterations highly influence the cycles of salinisation and desalinization processes (Adams, 1963; Snow and Vince, 1984; Bertness and Ellison, 1987;

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Fitzpatrick et al., 2003), making these ecosystems highly vulnerable. Due to the increasing natural and anthropogenic influences, the investigation of the physiological tolerance of species, vegetation dynamics and the alterations in the interdependent system of landscape factors are key issues. Proper wetland management must consider the hydrogeology (level of hydrological complexity, both internal and at the landscape level), topography, land use and climate (JNCC, 2004).

Wetland disappearance and changes in salt-rich grasslands were also reported from the Pannonian lowland (Carpathian Basin), contributing to the biodiversity loss and population decrease of the adjoining fauna (Dajić Stevanović et al., 2008; Eliáš et al., 2013; Melečková et al., 2014). These wetlands, the Pannonic salt steppes and salt marshes (Natura 2000 habitat type, code: 1530, IMEUH, 2007), occur only in the Carpathian Basin and belong to the most threatened European plant communities (Šefferová Stanová et al., 2008). In the case of these inland wetlands, salt accumulation in the soil is due to both the high evaporation rate of groundwater during the summer and the groundwater discharge zones. Compared with other salt lakes and marshes of the world, the alkaline lakes of the Carpathian Basin are characterised by a lower salt content but by higher alkalinity (Boros et al., 2013). Controlled by micro relief conditions and surface water logging, these ecosystems have the characteristic zonation of salt-tolerant vegetation (Tóth and Kertész, 1996; Tóth, 2002; Zalatnai et al., 2008).

Alkaline sodic wetlands in the Danube–Tisza Interfluve are highly endangered because both anthropogenic and natural factors (e.g., the construction of an extensive drainage system in the middle of the 20th century, groundwater overexploitation, aridification and increasing climate extremes as consequences of climate change) have contributed to changing the hydrological conditions (decreasing groundwater table and surface water logging) of the region (Kuti et al., 2002; Rakonczai, 2007). The rate and cumulative consequences of these factors are of high spatial and temporal variability; thus, in certain cases the triggers for the landscape changes can hardly be distinguished. The changing hydrological conditions have a significant impact on the soil and vegetation. The horizontal and vertical salt transport has transformed, causing altered pedological processes (Tóth et al., 2003; Ladányi et al., 2009; Puskás et al., 2012), and the changes in water supply and salt accumulation have contributed to the alteration and degradation of natural saline habitats (Molnár, 1997; Deák and Kevei-Bárány, 2006; Biró et al., 2008; Ladányi et al., 2009; Hoyk and Sipos, 2010; Rakonczai, 2011).

In this study, the alteration of the soil–vegetation–groundwater connection system was investigated in a dried-out alkaline sodic lake formed on sandy land in the SE Danube–Tisza Interfluve by evaluating the habitat pattern and the physical and chemical upper soil attributes. The aim was to combine high spatial resolution soil and topographical data and multiple vegetation survey data into a detailed statistical analysis to quantify and better understand the progress of the ongoing landscape processes in the lake bed induced by the draining effect of the crossing channel and, indirectly, the consequences of climate change. The observed degradation of the habitats can call attention to the negative consequences of inadequate water management, and the results can support the sustainable management of these saline habitats on an ecological and pedological basis, enabling sustainable grassland management and the maintenance of extreme sodic habitats and salt efflorescence.

2. Study area

The study area is a former alkaline sodic lake (Kancsal Lake) in Southeast Hungary near the Hungarian-Serbian border. It was selected based on the naturalness and biodiversity of habitat types demonstrating the phenomenon of drying out in the Danube-Tisza Interfluve. The typical periodical inundation occurred only in 2010 in the last decade due to extreme precipitation (Fig. 1). The groundwater is characterised by sodium-carbonate.

The study area is located in the southern end of two connected deflation hollows formed by the prevailing northwestern winds in a blown-sand area. Around the lake bed, residual ridges and sand sheets can be detected. The main water sources are precipitation and local and regional groundwater flows coming from the higher elevated parts of the Danube-Tisza Interfluve. In 1972 a channel crossing the lake bed in a north-south direction was excavated to drain water from the area. Thus, except for early spring water inundations in humid years, water has not been stored in the lake bed. A sluice gate was set in the channel to control the outflow from the lake bed; however, it is not operable at present. Salt-affected soils (mostly solonchak and solonchak-solonetz) are typical in the lake bed (Kreybig, 1943). In the early 1970s, probably before the construction of the drainage, 13.5 ha of open water surface (Table 1) with saline habitats and *Bolboschoenus maritimus* in the littoral zone were surveyed (Andó, 1975). The lake bed is covered by steppe and wet inland halophytic vegetation (Török et al., 2012). The past and current management of the study site is mowing.

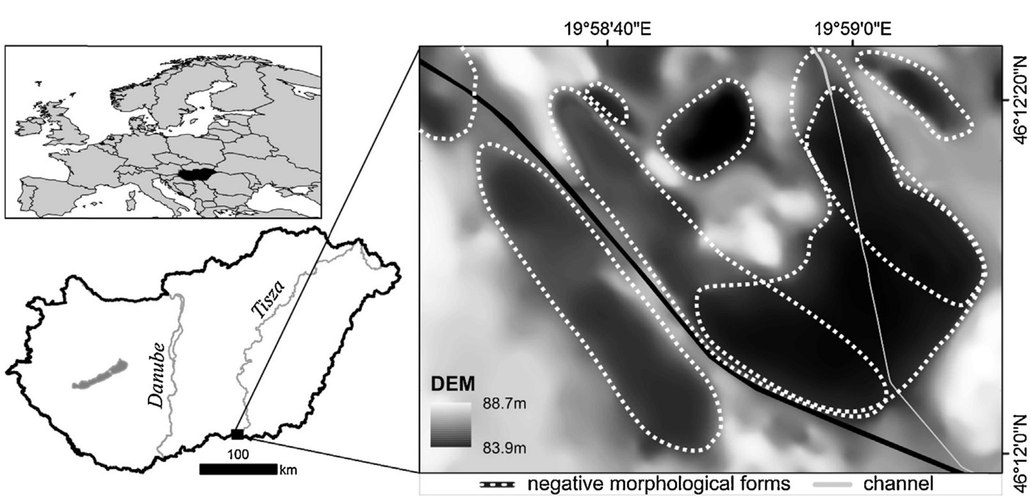

Fig. 1. Location and the digital elevation model of the study area allocating the deflation hollows with dotted lines.