Geomorphology 254 (2016) 121–129

Contents lists available at ScienceDirect

Geomorphology

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

Development of erosional microforms and soils on semi-natural and anthropogenic influenced solonetzic grasslands

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ARTICLE INFO

Article history:
Received 18 April 2015
Received in revised form 12 November 2015
Accepted 25 November 2015
Available online 2 December 2015

Keywords:
Erosion
Deposition
Pedogenic microforms
Vertic solonetz
Grassland
Hortobágy

ABSTRACT

The rate of berm erosion and its effect on soil properties and vegetation were investigated at two sampling plots, one semi-natural and the other heavily affected by anthropogenic influences, between 1998 and 2012. The two sampling areas are similar in terms of natural characteristics, and adjacently located in the Hortobágy, a very flat plain with Solonetz soils. In the course of berm-formation, both erosion and deposition take place within a few meters' range, so we were able to obtain the rate of each process for both experimental plots. The erosion rates of the DS plot under semi-natural conditions, and the MS plot affected by anthropogenic influences, were 1.99 and 4.49 kg m^{-2} $year^{-1}$, respectively, and the rate of deposition were 2.12 and 2.78 kg m^{-2} $year^{-1}$. The recession speed of the berm edges was determined to be 10 ± 3 mm $year^{-1}$ for the DS plot and 26 ± 8 mm $year^{-1}$ for the MS plot. During the period of our investigation, all the calcium-carbonate content, pH_{H_2O}, pH_{KCl}, electrical conductivity ($EC_{1:2.5}$), exchangeable cation content ($\Sigma_{cations}$), and exchangeable Na percentage (*ESP*) of the soil in the MS plot showed significant changes, whereas in the soil of the DS plot only $EC_{1:2.5}$ and $\Sigma_{cations}$ changed significantly. Both $EC_{1:2.5}$ and $\Sigma_{cations}$ decreased in both soil profiles. At the DS plot, *ESP* did not change substantially, whereas at the MS plot it increased significantly.

The results of the experiments revealed that in the course of berm erosion, the rates of the spatially extremely versatile, mosaic-like erosion and deposition processes show significant differences even within a small area, depending on environmental influences. Although this tendency may only prevail over shorter distances because of the exceptionally low relief energy, and can be balanced out in larger spatial ranges, both erosion and deposition are considerably more intensive and accelerated in areas affected by anthropogenic influences.

1. Introduction

By definition, berm erosion is the process of the removal of the weakly structured or loose top soil layers which lie above the stronger consistency subsoil, and is typical of soils with well-expressed texture differentiation, and results in a range of scale-shaped (scalariform) microforms (Arany, 1956). The process can be initiated by even the lowest level of relief energy, on an almost perfectly level surface (<2 m km^{-2}), providing the topographical and pedological prerequisites are given (Tóth and Rajkai, 1994; Tóth and Kertész, 1996). The mosaic-like, partially barren alkaline biotops, resulting from berm erosion and fragmented by terrain benches few dm high, represent habitat types typical of areas covered by Solonetz soils and are exceptionally valuable in terms of nature conservation (Molnár and Borhidi, 2003). Their main value lies in ensuring appropriate conditions for halophyte plant species and communities that are adapted to extreme habitats and appear in high diversity, even within a small area (Bodrogközy, 1965). The process of berm erosion is affected by a number of natural and anthropogenic factors (Tóth and Kuti, 1999; Tóth and Novák, 2001), since with a lack of active erosion any further processes would either slow down or stop completely. At the same time, due to powerful anthropogenic effects (e. g. tilling and landscaping), the small forms of only a few cm or dm in height preformed by the original, natural soil horizonation may disappear irretrievably. However, in the course of natural and semi-natural land use, activities such as grazing, trampling (Lavado and Alconada, 1994), treading on grass and other long-present anthropogenic activities also affect the rate of berm erosion (Bui et al., 1998). At the same time, this process also occurs in areas distant and is almost completely free from any anthropogenic effects. It has been established that the rate of berm erosion is strongly affected by climatic, vegetation-dynamic and anthropogenic influences (Arany, 1956; Bodrogközy, 1965; Rakonczai and Kovács, 2000). However, our knowledge regarding the differences between the rates of erosion under natural, semi-natural or anthropogenic-influenced conditions, as well as the recession rate of the berms, is still incomplete.

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http://dx.doi.org/10.1016/j.geomorph.2015.11.018
0169-555X/

We studied a complex surface-forming process, manifesting in an alternation of erosion and accumulation even within a few square meters, and resulting in a micro-relief that is exceptionally rich in topographic microforms (Tóth et al., 2015). This is rarely mentioned in the literature of erosion studies, because the redeposition processes are usually balanced out when considered over larger spatial units (Tóth, 2010). Nevertheless, even if its role in redeposition is not essential, this process modifies the surface soil characteristics significantly, and is present in extensive areas which have Solonetz soils with undisturbed soil horizonation.

2. Study sites

2.1. General setting

For our study we chose two sampling sites located in the Hortobágy, a microregion covered predominantly by Solonetz soils, where the erosional micro-morphology is generally present, due to the erosion of the A horizon of the Solonetz soil (Tóth et al., 2015). We presumed that in the areas affected by more powerful anthropogenic influences the berm recession is faster, the material displacement is more intense, and the scale of erosion is larger. We also assumed that the different rates of berm collapse would also influence the characteristics of the soils and the covering vegetation.

The dominant parent material consists of fluvial clay from the early and late Holocene period, as well as aleurite, infusion loess from the late Pleistocene period (Gyalog, 2005), whose subsurface layers became more and more transformed by a continuous process of alkalization (Szöőr et al., 1991) under the highly alkaline character of shallow groundwater. The surface of the area is nearly flat, with very small relative relief, which, on the macroform level, is characterized by remnants of the fluvial forms developed in the Pleistocene period. Because of the loss of the main water-courses, the floodplain-type development of the area ended more than 20,000 years ago (Félegyházi and Tóth, 2001, 2003; Tóth et al., 2001). The studied area is very deficient in other surface elements, and according to some theories, the formation of its almost perfectly level surface could be considered a long term result of the process of berm erosion.

According to the Köppen–Geiger climate classification, the region is located in a warm temperate, fully humid zone with warm summers (Kottek et al., 2006). The annual mean temperature is 10.1 °C, and the average annual rainfall is 520 mm, although there are significant differences between the total sum of rainfall in drier and more humid years. The average annual rainfall of the studied period (1998–2012) was 571 mm, the lowest annual average was 366 mm in 2002, and the highest was 910 mm in 2010 (Rásó and Csiha, 2012). The annual actual evapotranspiration is between 482 and 527 mm (Ács et al., 2007). Monthly average precipitation was 47.6 ± 35.3 mm during the investigated period, with lowest amounts in March and February (29.6 and 36.1 mm), and highest in July and June (72.7 and 61.0 mm). The water balance in the region is characterized by an extremely low density of constant water-courses, and shallow but extensive ephemeral minor streams, retained by the limited infiltration of frozen soil at wintertime, or by the soil's low permeability due to its high swelling clay content and the expressed texture differentiation of Solonetz soils (Lyubimova and Grachev, 1995; Novikova and Kovalivnich, 2011). According to measurements taken by Arany (1956), the infiltration capacity of the A and B horizons in Solonetz soils differs significantly, being 690–930 and 12–59 mm h^{-1}. The groundwater surface can be found close to the soil surface (0.5–4 m deep); both its seasonal level fluctuations and salt content are considerable. The characteristic soil types belong to the Solonetz and Vertisol reference groups (Szabolcs, 1981; Szabolcs and Rédly, 1989; Jones et al., 2005). Despite the small absolute elevation differences, the surface height is an essential influencing factor in terms of the development of the mosaic-like soil surface (Miller and Pawluk, 1994; Tóth and Rajkai, 1994; Tóth and Jozefaciuk, 2002; Pal et al., 2003). The natural vegetation consists of Pannonian halophytic plant communities (Molnár and Borhidi, 2003), with a dominance of *Alopecurus pratensis* and *Agrostis stolonifera* in the wet areas, whereas the drier grass consists primarily of *Festuca pseudovina*, *Artemisia santonicum*, and *Achillea setacea*. On the sparsely vegetated patches exposed to rapid recent erosion, and in the areas with most disadvantageous soil conditions included in the study, almost completely bare patches appear sporadically, with low coverage of *Puccinellia limosa*, *Pholiurus pannonicus*, *Camphorosma annua* and other halophytes (Bodrogközy, 1965; Tóth and Kertész, 1996). The sites selected for erosion studies are both currently and traditionally used for grazing, mainly by sheep, and occasionally, by cattle.

2.2. Sampling sites for erosion studies

In one of the two selected sites semi-natural conditions prevail, while the other site is affected by strong anthropogenic influences (Fig. 1). The first is a quasi-natural developing surface, devoid of considerable anthropogenic effects, in a part of the Dögös area (hereafter DS, N 47°21′33.9″; E 21°4′41.1″; 86.5–86.9 m a.s.l.), which is only moderately grazed, mostly by sheep and in certain years by cattle, depending on the weather conditions. No other factor that might significantly affect the erosion process prevails in this area. Here we installed a 10 × 13 m plot for field erosion measurement (Table 1).

The second is Makkod (hereafter MS, N 47°22′ 4.9″; E 21° 6′ 7.1″; 86.7–87.4 m a.s.l.). In the 1970s, a service road leading to a stockyard was constructed, and for drainage of the surrounding area, a ditch was dug. It increased the surface runoff, and because of the increased height difference due the ditch construction, erosion of the berm areas accelerated (Fig. 2). In the direct vicinity of the measuring plot, extensive

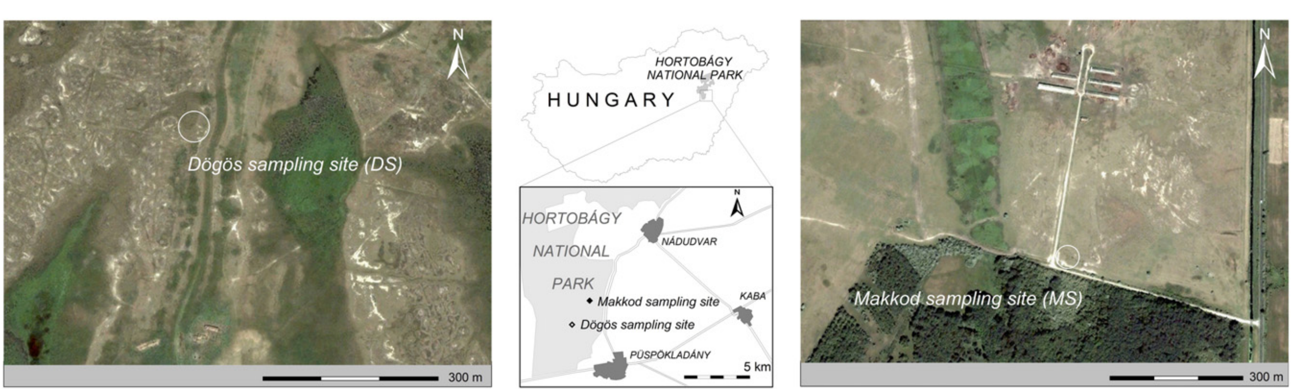

Fig. 1. Location of the study area and sampling sites in Hortobágy National Park, Hungary.