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# Factors threatening grassland specialist plants - A multi-proxy study on the vegetation of isolated grasslands

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ABSTRACT

Land use changes have resulted in the loss and isolation of semi-natural habitats worldwide. In intensively used agricultural landscapes the remnants of natural flora only persist in small habitat islands embedded in a hostile matrix. In the steppe zone burial mounds, so-called kurgans, have the potential to preserve the natural flora and act as local biodiversity hotspots. Exploration of the factors driving biodiversity in isolated habitat fragments is crucial for understanding the ecological processes shaping their vegetation and for designing effective strategies for their protection. We sampled the vegetation of 44 isolated kurgans in East-Hungary and studied the effects of habitat area, slope, recent disturbance, past destruction and the level of woody encroachment on the species richness and cover of grassland specialist and problem species (competitor weedy species). We used model selection techniques and linear models for testing relevant factors affecting specialist species in grassland fragments. We found that the biodiversity conservation potential of kurgans is supported by their steep slopes, which provide adequate habitat conditions and micro-climate for steppic specialist plant species. Specialist species are threatened both by recent disturbances and encroachment of alien woody species, especially black locust. Factors supporting specialist species suppressed problem species by providing unfavourable environmental conditions and putting them at a competitive disadvantage. We identified that woody encroachment and current disturbances affect the vast majority of kurgans, posing a serious threat to grassland specialist species. Thus, there is an urgent need to integrate active conservation measures into the current passive protection of kurgans.


## 1. Introduction

Land use changes over past centuries have resulted in a considerable loss of natural habitats from local to global scales (Heinken and Weber, 2013; Lindborg et al., 2014; Helsen et al., 2013). Grassland habitats with fertile soils have been especially threatened by landscape transformation over the past centuries, as they were suitable for intensive agricultural utilisation (Deák et al., 2016). Lowland steppes and forest steppes of continental Eurasia have been severely affected by habitat loss and isolation over the past centuries (Brinkert et al., 2016). Even though the original extent of the steppes was about 8–13 million km$^2$, their former area has been reduced by 57% mainly due to the agricultural intensification of the last century (Wesche and Treiber, 2012). Loss of steppe habitats is the most pronounced in the western part of the steppe zone, especially in Ukraine and Hungary (Sudnik-Wójcikowska et al., 2011; Wesche et al., 2016). In Hungary for the 20th century only 6.8% of the original forest steppes remained, and only 3% of the remaining stands has a favourable nature conservation status, mainly represented by sandy and loess steppe grasslands (Molnár et al., 2008).

As a consequence of habitat loss, in many cases semi-natural habitats have become fragmented and remaining patches are isolated by a hostile matrix (Fahrig, 2003). In intensively used agricultural landscapes the semi-natural habitats and their species can usually persist only on field margins, roadside verges and mid-field islets, which act as refuges for the flora and fauna (Kleijn and Báldi, 2005; Lindborg et al., 2014). The biodiversity of these habitats is threatened both by isolation per se, and also by its consequences such as loosing core areas, increasing perimeter-area ratio of remaining habitat patches, and difficulties in management (Kuussaari et al., 2009). Given their low dispersal abilities, isolation may considerably decrease the population size of fragment-area sensitive specialist species or even result in species extinctions in the long run (Lindborg et al., 2014; Villemey et al., 2015). This effect is magnified when the remaining habitat patches are surrounded by a hostile matrix such as intensively used agricultural land or tree plantations (Auffret et al., 2015).

In the steppe zone, ancient burial mounds, the so-called 'kurgans' often harbour remnants of dry grasslands. They have a decisive role in preserving steppe biodiversity, especially in regions characterised by considerable agricultural landscape conversion (Deák et al., 2016; Dembicz et al., 2016). Kurgans are soil monuments created by ancient cultures from the late copper age until the medieval period. They are

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widespread across the whole steppe and forest steppe zone. Their estimated recent number is between 400,000 and 600,000 in Eurasia (Deák et al., 2016). Based on the surveys of Tóth (2006) and Bede (2012), the estimated number of kurgans ranges from several thousands to ten thousand in the Hungarian Great Plain, approximately 30% of which is covered by grassland. Kurgans have a hemi-spherical shape with an area usually ranging between a few hundreds of square metres to 0.3 ha and a height of up to 15 m (Dembicz et al., 2016). In spite of their small area they often harbour an outstandingly high biodiversity of grassland species (Sudnik-Wójcikowska et al., 2011), which underlines their disproportional conservation value and their importance as biodiversity hotspots. It is especially important in intensively used agricultural landscapes where small habitat elements such as kurgans, rocky outcrops, field margins, roadside verges and other areas unsuitable for arable farming represent the only grassland habitats in the intensively utilised hostile matrix. The special attributes of kurgans are their stability, uniform shape, relatively long isolation time and their high cultural and historical importance compared to other small habitat elements (Deák et al., 2016). This stability is especially important because during the 20th century agricultural collectivisation and intensification often led to the elimination of small habitat elements (Batáry et al., 2015). In many regions kurgans are the only refugia and stepping stones for grassland specialist plants and animals, which underlines the urgent need for the exploration of their biodiversity and developing proper strategies for their conservation (Deák et al., 2016).

Loess steppes on kurgans are good representatives of the isolated grasslands of Eurasia, which makes them excellent objects for studying factors affecting the vegetation of isolated grasslands. We aimed to explore the mechanisms affecting the cover of specialist and problem species (weedy species with good competitor ability) on isolated grassland stands to support conservation planning. By selecting study sites surrounded by a hostile matrix we could largely filter out the effects of the surrounding semi-natural dry grasslands, given that most specialist species have limited dispersal ability. Thus we could focus on the effects of local abiotic filters driving the species composition of habitat fragments (Table 1).

We tested the following hypotheses: (i) the proportion of specialist species increases, whereas the proportion of problem species decreases with increasing habitat area, which moderates the effects of the surrounding hostile matrix. (ii) Steeper slopes moderate the effects of the hostile matrix, by decreasing the probability of ploughing and other types of human influence; thus, support the persistence of specialist species and suppress problem species. (iii) Both recent disturbance and past destruction decrease the proportion of specialist species, and increase the proportion of problem species by providing open microsites for their establishment. (iv) Woody encroachment suppresses specialist species and enhances problem species by shading and nutrient enrichment.

## 2. Material and methods

### 2.1. Study area

The study area is in the northern part of the Great Hungarian Plain, comprising 8700 km$^2$ (Map *A*1). The region is characterised by a continental climate with a mean annual temperature of 9.5 °C, and a mean annual precipitation of 550 mm. The potential vegetation of the region consists of loess- and alkali steppic grasslands, meadows and wetlands (Deák et al., 2014; Molnár et al., 2008). Until now, most of the natural and semi-natural habitats have been transformed into croplands or urbanised areas. Overall, loess steppic grasslands have been the most severely affected by land transformation due to their fertile chernozemic soils, which has led to a serious habitat loss and fragmentation of the remaining habitat patches (Deák et al., 2016). In spite of their reduced area (<3% of their original stands remained) loess steppic grasslands of the studied region are important refugia for several red-listed plant species such as *Centaurea sadleriana*, *Phlomis tuberosa*, *Ranunculus illyricus* and *Sisymbrium polymorphum* (Molnár et al., 2008). Besides these unique species they preserve further specialist species such as *Agropyron cristatum*, *Astragalus austriacus*, *Inula germanica* and *Stipa capillata*, which became locally threatened due to the intensive land transformations of the last centuries. The uniqueness of this habitat is acknowledged by the Habitats Directive of the European Union, where Pannonic loess steppic grasslands are listed as a priority habitat.

### 2.2. Factors affecting species composition

Based on the review of Deák et al. (2016) we selected the most important factors affecting specialist species on kurgans, such as the area of the habitat patch, the negative impact of surrounding hostile matrix, recent disturbance, past destruction, and the encroachment of native and alien woody species (Table 1, Fig. A1).

### 2.3. Selection of studied kurgans

We studied isolated kurgans located in a hostile matrix, but still harbouring loess grasslands; thus, having a high nature conservation value. We identified 548 kurgans in the northern part of the Great Hungarian Plain as a basic dataset using the available literature, military topographic maps and our own database. We aimed to survey kurgans which harboured semi-natural loess grasslands. Consequently, we excluded kurgans harbouring croplands, settlements, tree plantations,

**Table 1**
Factors potentially affecting the species composition of isolated grasslands on kurgans (based on Deák et al., 2016), measured proxies and underlying mechanisms.

| Local factors | Measured proxy | Mechanism |
|---|---|---|
| Area | Surface area | Based on the classical theory of island biogeography (MacArthur and Wilson, 1967) proportion of species is expected to be influenced by the area of the habitat patch on kurgans surrounded by a hostile matrix. |
| Land conversion | Slope | Ploughing is a significant detrimental factor threatening the vegetation of kurgans. The probability of ploughing is reduced by steep slopes; thus, kurgans with steeper slopes are expected to maintain a higher proportion of specialists and to be less exposed to the encroachment of problem species (Deák et al., 2016). |
| Past destruction | Level of past physical destruction | The most reliable indicator of past disturbance is the level of physical disturbance originating from grave robberies or past soil extractions (Deák et al., 2016). |
| Recent disturbance factors | Level of recent disturbance such as soil extraction, soil disturbance, building, burning, trampling, fox and badger holes | Recent disturbance suppresses specialists and support problem species by providing open disturbed soil surfaces and decreasing competition (MacDougall et al., 2013). |
| Woody encroachment | Cover of native and alien woody species | High cover of woody species suppresses light-demanding specialist species and enhances the encroachment of problem species (Gazol et al., 2012). Furthermore nitrogen-fixing species such as black locust can alter the species composition by changing soil properties (Cierjacks et al., 2013). |