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The effects of Land-use History and Landscape Context on Habitat Naturalness: An Assessment Using Relative Naturalness Indicator Values

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Abstract Nature conservation issues concerning temperate forest-steppes are among the most interesting and challenging issues in current ecology. A considerable proportion of the Pannonian biogeographical region was covered by forest-steppes prior to intensive human impacts, but most of these forest-grassland mosaics have disappeared or suffered some modifications. Century-long grazing activity enabled the continuous existence of grasslands, but woody vegetation diminished or disappeared from large areas, both in highland and lowland forest-steppes. With the cessation of grazing, forest patches started to regenerate. Forest patches in the highland forest-steppes had a better regeneration potential, because propagule sources were available in the immediate vicinity. In contrast, forest patches of the lowland forest-steppes had a considerably worse chance to recover, since propagule sources were lacking in extremely large areas. In this study, we compared the naturalness of the forest and grassland components in a highland and a lowland forest-steppe reserve, in order to understand how land-use history and landscape context influenced their present state. We used the ability of plant species to indicate the degradation of their habitat. We estimated the percentage cover of the plant species within permanent plots, and, using their indicator scores, we computed mean naturalness values for the plots. Grasslands proved to have higher naturalness values than forests (although the difference was significant for the lowland forest-steppe only). This may be explained by the continuous history of the grasslands, and the discontinuous history of the forests. In addition, we found that the forest component of the highland site was more natural than that of the lowland site, which may be attributed to the better regeneration capacity of the highland site, due to the nearby propagule sources. We conclude that lowland forest-steppe remnants may serve as "stepping-stones" for the regeneration of those forest-steppes that are located farther away from potential propagule sources.

Keywords: *forest-steppe, regeneration, Pannonian biogeographical region, vegetation mosaic, degradation*

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1. Introduction

Heterogeneous forest-grassland ecosystems with alternating woody and herbaceous vegetation patches belong to the most current study objects in ecology [10,26]. These ecosystems include, among others, tropical savannas, shrublands, and temperate forest-steppes. Prior to intensive human impacts, large areas of the Pannonian biogeographical region were covered by forest-steppes [23,28,32]. Pannonian forest-steppes have been profoundly influenced by human activities during the past few millennia, but the intensity of the modifications has considerably varied among the different plant associations [34]: some of them have disappeared almost completely, others suffered only moderate or minor changes.

There are two basic categories of Pannonian forest-steppes: highland and lowland forest-steppes. Highland forest-steppes grow on south-facing hill slopes and mountain slopes, whereas lowland forest-steppes can be found on mostly flat areas. Both highland and lowland forest-steppes had been usually used as pastures until the previous century [1,12,40]. As a result of grazing, the proportion of woody vs. herbaceous cover changed markedly. In fact, grazed areas were often completely or almost completely treeless in the Pannonian region. However, grazing activity started to decrease during the 19th century, and in several regions, grazing was completely abandoned by the 20th century. As grazing pressure diminished and disappeared, forests had a chance to regenerate. However, although the land-use history of highland and lowland forest-steppes is very similar, forest regeneration capacity differs considerably, due to the different landscape contexts.

In the case of highland forest-steppes, grazing was usually restricted to the southern slopes, whereas there was a continuous forest cover on the north-facing mountain sides. Thus forest regeneration has been relatively easy, as the propagule sources of forest-related species have been in the immediate vicinity: propagules only have to cover distances of some tens or hundreds of meters.

In contrast, forest patches in the lowland forest-steppes have poor regeneration capacities. In lowland regions, extremely large areas were grazed, and all forests and shrublands disappeared from large areas, except for those along streams and rivers [20]. Consequently, regeneration has been slow, as propagules of forest-related species have not been available in the immediate proximity. It has been observed that most specialist and sensitive forest-related species are restricted to those lowland forest-steppes that are close to hilly or mountainous regions, from where recolonization has been possible [22,24]. Forest-steppes lying farther from propagule sources have fewer specialist species, but have several plants with good dispersal capabilities (e.g. ferns and orchids), plus generalists that were able to survive under solitary trees or in settlements [18].

To have an understanding on how land-use history and landscape context affect habitat quality, we used the concept of naturalness [31]. Naturalness is usually assessed on the basis of community structure, species composition, ecosystem processes, or a combination of the above parameters [8,11,14]. One promising approach makes use of the well-known fact that plant species have different tolerances against degradation. In theory, the species composition of a given site or habitat is able to reveal its naturalness (or degradation) state, allowing the estimation of the effects of land-use history and landscape context.

Considering the land-use history and landscape context of highland and lowland forest-steppes, we may formulate two hypotheses. While grazing obviously hinders forest and shrubland survival, it does enable the continuous existence of grasslands. Therefore, our first hypothesis is that the grassland components of both the highland and the lowland forest-steppes have a higher naturalness (due to their continuous history of grasslands), while the forest components are expected to show a lower naturalness (because of their discontinuous history).

The land-use history of highland and lowland forest-steppes is quite similar, but the regeneration processes differ markedly. Therefore, our second hypothesis is that the forest components themselves differ in naturalness, with the highland type having a higher naturalness owing to its better regeneration chances.

In this paper, we made an attempt to scrutinize the above hypotheses. Therefore, we compared the naturalness of the forest and grassland components in one highland and one lowland forest-steppe, based on their species composition, using the indicative power of the plant species.

2. Materials and Methods

2.1. Study Sites

For our study, two forest-steppe mosaics were selected from southern Hungary (Figure 1). The highland forest-steppe was represented by the southern slope of Mt Szársomlyó (N 48°51’15”, E 18°24’45”) in the Villány Mts, where the mean annual temperature is 10.5°C and the mean annual precipitation is 670 mm [15]. The bedrock is limestone and the plant communities grow on rendzina soils [30]. The vegetation mosaic is formed by oak scrub patches (*Inulo spiraeifoliae-Quercetum pubescentis*) scattered in a fescue steppe matrix (*Sedo sopianae-Festucetum dalmaticae*). Land-use historical analyses have shown that the whole southern slope was grazed and mostly treeless from at least the 13th century till the 1950s (older historical data are lacking, but grazing can be assumed in earlier times as well). After the cessation of grazing, oak scrubs have been encroaching rapidly [19]. The area is legally protected since 1944.

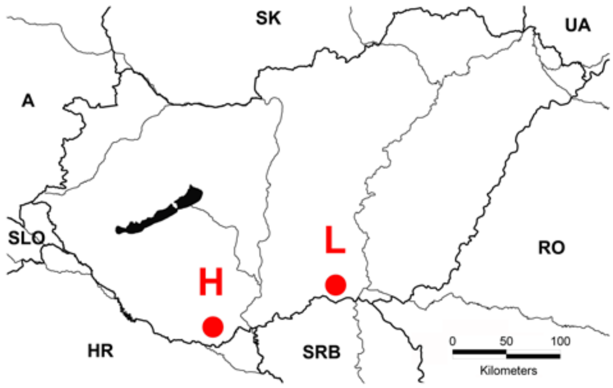

Figure 1. Location of the study sites in southern Hungary. H: highland forest-steppe, L: lowland forest-steppe

The lowland forest-steppe was represented by a nature reserve in the southeastern part of the Danube-Tisza Interfluve, near Ásotthalom (N 46°12’51”, E 19°47’25”). Mean annual temperature is 10.6 °C and the mean annual precipitation is 565 mm [15]. The bedrock is sand, soils are humus-poor sandy soils [3]. The vegetation is a mosaic of poplar-oak forests patches (*Populo canescenti-Quercetum roboris*) and fescue steppes (*Festucetum vaginatae*). The site has been grazed and mostly treeless from at least the 15th century until the early 1800s [20] (again grazing activity was most probably present in earlier periods as well). The area is protected since 1908.

Although edaphic factors may seem quite different at first glance (limestone vs. sand bedrock), several parameters are similar in highland and lowland forest-steppes. Most importantly both of the represent extreme environments, being shallow, warm and usually exteremely dry. As a consequence, the flora of the highland and lowland forest-steppes is rather similar, which has been recognized early in the botanical literature [4,6,36]. More specifically, in our case, a relatively high number of species is common in both sites (e.g. *Acinos arvensis*, *Linaria genistifolia*, *Potentilla arenaria*, *Stachys recta*, *Teucrium chamaedrys*). Nevertheless, floristic differences cannot be neglected either: in several cases, strongly related but different species live in the two sites (e.g. in the case of *Alyssum*, *Festuca*, *Stipa*).

2.2. Field Works

Within both sites, 2 m^2 permanent plots were placed randomly within forest interiors (20 plots) and grasslands (20 plots), resulting in a total of 80 plots (2 study sites × 2 habitats × 20 replicates). The cover of all vascular plant species of the herb layer, including tree saplings and low shrubs, was estimated in April (spring aspect) and July (summer aspect). Summer and spring records were combined before the data analyses.

2.3. Data Analyses

For assessing habitat naturalness, we used the relative naturalness indicator values of Borhidi [5]. Given their different tolerances against habitat degradation, plant species are able to indicate habitat naturalness [27,29,43]. Thus, similarly to relative ecological indicator values [17], species may receive scores on an ordinal scale, according to whether they prefer degraded (low scores) or natural (high scores) habitats. Borhidi's [5] naturalness values (i.e. scores) vary between -3 (species tolerating or preferring disturbance) to +6 (sensitive species that cannot tolerate disturbance). Earlier studies have revealed that the categories of Borhidi [5] are reliable and enable a good estimation of habitat naturalness [21,42]. The naturalness indicator values of the species found in our study are given in Table 1 of the online supporting information.

Unweighted and cover-weighted mean naturalness indicator values were calculated for each plot. Given the ordinal nature of indicator values, the calculation of means has received some criticism [35]. Nevertheless, mean indicator values are widely used in vegetation science, and they have proven to be efficient [16,38,41]. Data were tested for normality with the Shapiro-Wilk test. We compared the different habitats (forest vs. grassland), and the different sites (lowland vs. highland). For the unweighted means (normal distribution), we used one-way ANOVA and subsequent Tukey's HSD post-hoc tests. For the cover-weighted means (non-normal distribution), the Kruskal-Wallis test was applied with pairwise Mann-Whitney comparisons as post-hoc tests. Computations were carried out using SPSS 22.0 (SPSS Inc). Results were visualized with box-plots.

Plant association names follow Borhidi et al. [7], plant names are used according to Simon [39].

3. Results

We found a total of 152 species in the highland site, and 102 species in the lowland site.

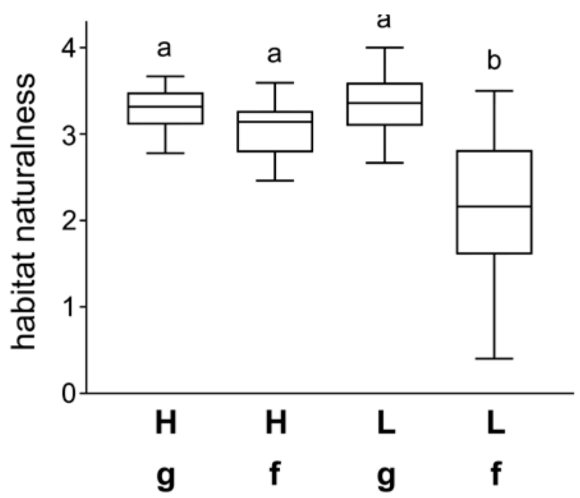

Figure 2. Habitat naturalness based on unweighted mean naturalness indicator values. H: highland forest-steppe, L: lowland forest-steppe, g: grassland, f: forest. Different letters above the boxes indicate significant differences

Unweighted and cover-weighted mean indicator values gave generally similar results. The one-way ANOVA showed that the unweighted mean naturalness values of the four groups under study were significantly different ($F=29.12$, $p<0.001$). In the case of highland forest-steppes, grasslands seemed to be somewhat more natural than forests (Figure 2), but the post-hoc test showed that the difference was not significant ($p=0.456$). In contrast, grasslands of the lowland forest-steppe were significantly ($p<0.001$) more natural than the forests.

When considering our second hypothesis, results clearly showed that the forest component of the highland forest-steppe had significantly ($p<0.001$) higher naturalness values than that of the lowland forest-steppe (Figure 2).

According to the Kruskal-Wallis test, there was a significant difference among the cover-weighted mean naturalness of the four groups ($\chi2=36.362$, $p<0.001$). In conformity with our first hypothesis, grasslands seemed to have a higher naturalness than forests in both the highland and the lowland forest-steppes (Figure 3). However, as indicated by the post-hoc tests, the difference was significant ($p<0.001$) for the lowland forest-steppe only, while the difference proved to be non-significant ($p=0.2184$) for the highland type.

Regarding our second hypothesis, results from the cover-weighted mean indicators showed that there was a significant ($p<0.05$) difference in the naturalness of the forest components of the highland and lowland forest-steppes, the highland forests being more natural (Figure 3).

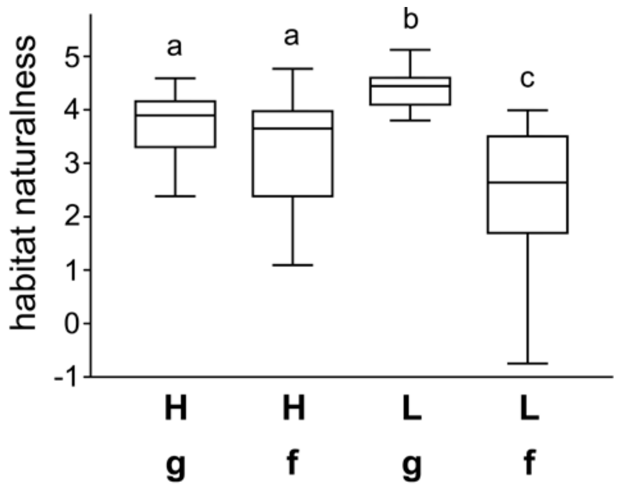

Figure 3. Habitat naturalness based on cover-weighted mean naturalness indicator values. H: highland forest-steppe, L: lowland forest-steppe, g: grassland, f: forest. Different letters above the boxes indicate significant differences

Interestingly, the cover-weighted mean naturalness indicators revealed an additional difference: the grassland components of the lowland forest-steppes proved to have significantly ($p<0.001$) higher naturalness values than the grasslands of the highland forest-steppe (Figure 3).

4. Discussion

It has been long recognized that the land-use history of a given site may have a profound influence on its present vegetation [33]. It seems clear, however, that the very same land-use practice can have fundamentally different effects on different vegetation types. For example, it is plausible that a long treeless period can maintain a valuable grassland, but at the same time it contributes to the degradation or disappearance of forested vegetation. In the forest-steppes of the Pannonian biogeographical region, grazing usually suppressed woody vegetation for centuries. Although some of the forests have re-established by now (after the cessation of grazing), it is probable that the effects of the treeless period prevail up to now. It is likely that the landscape context has a considerable influence on the regeneration of the forest patches in the Pannonian region. If propagule sources are available in the immediate vicinity, this supports a relatively fast regeneration. However, no detailed analyses have been carried out on these topics yet.

Our purpose with this study was to analyze the effects of land-use history and landscape context on habitat naturalness, with two selected forest-steppe reserves. We relied on the ability of plant species to indicate the naturalness of their habitat. We found that grasslands had higher naturalness values than forests, although the difference was not significant in the case of highland forest-steppes (Figure 2 and Figure 3). In addition, the naturalness of the forest component in the highland forest-steppe was significantly higher than the naturalness of the forests in the lowland forest-steppe. It is probable that the landscape context was responsible for this pattern: as propagule sources are available on the northern slope, forests were able to regenerate relatively easily, and even the most sensitive species could recolonize the forest patches. In the case of lowland forest-steppes, the difference between the naturalness of the forest vs. grassland component was highly significant, indicating that species with lower naturalness scores dominated within the forests. These species tolerate or even favour disturbances, and are able to survive under scattered trees or shrubs, and in or around settlements. They were able to recolonize the forest patches easily from these sources. In contrast, most sensitive species disappeared from the whole region during the long treeless period. The recolonization will obviously need much more time in this case.

Some earlier studies have noted that forest-steppes of the southeastern part of the Danube-Tisza Interfluve, where our lowland site is located, are often poor in typical forest-related species, especially if sensitive plant species are considered [3,22,24]. Three hypotheses have been proposed to explain this phenomenon [22]. First, the higher aridity (i.e. higher temperature and lower precipitation) in the central and southeastern parts of the Danube-Tisza Interfluve may prevent the survival of many forest-related species that cannot tolerate such arid conditions. Second, unfavourable soil properties in the region may also counteract the establishment and survival of forest-related plants. Third, hilly and mountainous areas in the northern and western part of the Pannonian biogeographical regions are far away, thus recolonization after the treeless period is expected to be slow. Although we think that the three explanations are not mutually exclusive, our results clearly support the third explanation.

It has been recognized that "stepping-stones" are able to enhance landscape connectivity, thus they may increase recolonization success in fragmented patches [25,36]. Unfortunately, the overwhelming majority of the original lowland forest-steppes have been eradicated by humans [34], and the existing forest-steppe remnants are highly isolated. Although forest patches were able to reoccupy areas where grazing stopped (and where legal protection excluded land development), naturalness remained low, as shown by our results. We think that a strict protection of all remaining lowland forest-steppes, and a restoration of forest-steppe habitats where possible would be essential to increase landscape connectivity to sensitive species. A network of "stepping-stones" could facilitate the recolonization of forest patches, contributing to their increasing naturalness.

Cover-weighted mean indicators have shown that lowland grasslands have higher naturalness values than highland grasslands (Figure 3). It is possible that the grazing activity resulted in a certain level of disturbance. As grazing ended earlier in the lowland grasslands than in the highland ones, they had more time to regenerate. On the other hand, sandy grasslands are known to have a good regeneration capacity [9,13,34], which may also contribute to their higher naturalness values.

5. Conclusions

Our analysis revealed that both land-use history and landscape context are important factors in influencing the present naturalness state of forest-steppe habitats in the Pannonian biogeographical region.

However, the limitations of our study should also be noted. First, we only used the species of the herb layer, and did not consider the shrub and the canopy layers. Thus all of our results relate to the herb layer only.

Second, we analysed two sites only. Although our field experience suggests that our results are probably valid for the other forest-steppes in the region, it is clear that more case studies are needed, using a higher number of study sites.

Nevertheless, even with the limitations of our study, we irmly believe that our findings have important nature conservation implications. Most importantly, our results emphasize the extremely high conservation value of the lowland forest-steppe remnants: not only are they important habitats in their own right, but they may also serve as "stepping-stones" for the regeneration of those forest-steppes that are located far away from potential propagule sources. We conclude that every effort has to be made to legally protect all lowland forest-steppe sites. In addition, habitat restoration programs should be started where possible.

Statement of Competing Interests

The authors have no competing interests.

References

[1] Biró, M., Horváth, F., Révész, A., Molnár, Zs. and Vajda, Z., "Száraz homoki élőhelyek és átalakulásuk a Duna-Tisza közén a 18. századtól napjainkig," *Rosalia*, 6, 383-421. 2011.

[2] Biró, M., Révész, A., Molnár, Zs., Horváth, F. and Czúcz, B., "Regional habitat pattern of the Danube-Tisza Interfluve in Hungary II," *Acta Botanica Hungarica*, 50, 19-60. 2008.

[3] Bodrogközy, Gy., "Hydroecology of the vegetation of sandy forest-steppe character in the Emlékerdő at Ásotthalom," *Acta Biologica Szegediensis*, 28, 13-39. 1982.

[4] Borbás, V., *A Balaton tavának és partmellékének növényföldrajza és edényes növényzete*, Magyar Földrajzi Társaság Balaton Bizottsága, Budapest, 1900.

[5] Borhidi, A., "Social behaviour types, the naturalness and relative ecological indicator values of the higher plants in the Hungarian flora," *Acta Botanica Hungarica*, 39, 97-181. 1995.

[6] Borhidi, A., "Kerner és az Alföld növényföldrajza mai szemmel", *Kanitzia*, 6, 7-16. 1998.

[7] Borhidi, A., Kevey, B. and Lendvai, G., *Plant communities of Hungary*, Academic Press, Budapest, 2012.

[8] Bölöni, J., Molnár, Zs., Horváth, F. and Illyés, E., "Naturalness-based habitat quality of the Hungarian (semi-)natural habitats," *Acta Botanica Hungarica*, 50(Suppl.), 149-160. 2008.

[9] Bölöni, J., Molnár, Zs. and Kun, A., *Magyarország élőhelyei*, MTA ÖBKI, Vácrátót, 2011.

[10] Breshears, D.D., "The Grassland-Forest Continuum: Trends in Ecosystem Properties for Woody Plant Mosaics?," *Frontiers in Ecology and the Environment*, 4, 96-104. 2006.

[11] Brūmelis, G., Jonsson, B.G., Kouki, J., Kuuluvainen, T. and Shorohova, E., "Forest naturalness in northern Europe: perspectives on processes, structures and species diversity," *Silva Fennica*, 45, 807-821. 2011.

[12] Centeri, Cs., Herczeg, E., Vona, M., Balázs, K. and Penksza, K., "The effects of land-use change on plant-soil-erosion relations, Nyereg Hill, Hungary," *Journal of Plant Nutrition and Soil Science*, 172, 586-592. 2009.

[13] Csecserits, A. and Rédei, T., "Secondary succession on sandy old-fi elds in Hungary," *Applied Vegetation Science*, 4, 63-74. 2001.

[14] Dierschke, H., "Natürlichkeitsgrade von Pflanzengesellschaften unter besonderer Berücksichtigung der Vegetation Mitteleuropas," *Phytocoenologia*, 12, 173-184. 1984.

[15] Dövényi, Z., (ed.) *Magyarország kistájainak katasztere*, MTA Földrajztudományi Kutatóintézet, Budapest, 2010.

[16] Dzwonko, Z., "Assessment of light and soil conditions in ancient and recent woodlands by Ellenberg indicator values," *Journal of Applied Ecology*, 38, 942-951. 2001.

[17] Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W. and Paulißen, D., "Zeigerwerte von Pflanzen in Mitteleuropa," *Scripta Geobotanica*, 18, 1-248. 1992.

[18] Erdős, L., Cseh, V. and Bátori, Z., "New localities of protected and rare plants in southern Hungary," *Tiscia*, 39, 17-21. 2013.

[19] Erdős, L., Cserhalmi, D., Bátori, Z., Kiss, T., Morschhauser, T., Benyhe, B. and Dénes, A., "Shrub encroachment in a wooded-steppe mosaic: combining GIS methods with landscape historical analysis," *Applied Ecology and Environmental Research*, 11, 371-384. 2013.

[20] Erdős, L., Tölgyesi, Cs., Cseh, V., Tolnay, D., Cserhalmi, D., Körmöczi, L., Gellény, K. and Bátori, Z., "Vegetation history, recent dynamics and future prospects of a Hungarian sandy forest-steppe reserve: forest-grassland relations, tree species composition and size-class distribution," *Community Ecology*, 16, 95-105. 2015.

[21] Erdős, L., Tölgyesi, Cs., Dénes, A., Darányi, N., Fodor, A., Bátori, Z. and Tolnay, D., "Comparative analysis of the natural and semi-natural plant communities of Mt Nagy and other parts of the Villány Mts (south Hungary)," *Thaiszia Journal of Botany*, 24, 1-21. 2014.

[22] Fekete, G., Kun A. and Molnár, Zs., "Chorológiai gradiensek a Duna-Tisza közi erdei flórában," *Kitaibelia*, 4: 343-346. 1999.

[23] Fekete, G., Molnár, Zs., Kun, A. and Botta-Dukát, Z., "On the structure of the Pannonian forest steppe: grasslands on sand," *Acta Zoologica Hungarica*, 48, 137-150. 2002.

[24] Fekete, G., Somodi, I. and Molnár, Zs., "Is chorological symmetry observable within the forest steppe biome in Hungary? A demonstrative analysis of floristic data," *Community Ecology*, 11, 140-147. 2010.

[25] Gilpin, M.E., "The role of stepping-stone islands," *Theoretical Population Biology*, 17,247-253. 1980.

[26] House, J.I., Archer, S., Breshears, D.D. and Scholes, R.J., "Conundrums in mixed woody-herbaceous plant systems," *Journal of Biogeography*, 30, 1763-1777. 2003.

[27] Kim, Y-M., Zerbe, S. and Kowarik, I., "Human impact on flora and habitats in Korean rural settlements," *Preslia*, 74, 409-419. 2002.

[28] Kovács-Láng, E., Kröel-Dulay, Gy., Kertész, M., Fekete, G., Bartha, S., Mika, J., Dobi-Wantuch, I., Rédei, T., Rajkai, K. and Hahn, I., "Changes in the composition of sand grasslands along a climatic gradient in Hungary and implications for climate change," *Phytocoenologia*, 30, 385-407. 2000.

[29] Kowarik, I., 1990. "Some responses of flora and vegetation to urbanization in Central Europe," in: Sukopp, H., Hejný, S. and Kowarik, I., (eds.) *Urban ecology: Plants and plant communities in urban environments.* SPB Academic, The Hague, 45-74. 1990.

[30] Lehmann, A., "A Villányi-hegység földrajzi jellemzői," *Földrajzi Közlemények*, 103, 276-281. 1979.

[31] Machado, A., "An index of naturalness," *Journal for Nature Conservation*, 12, 95-110. 2004.

[32] Magyari, E.K., Chapman, J.C., Passnore, D.G., Allen, J.R.M., Huntley, J.P. and Huntley, B., "Holocene persistence of wooded steppe in the Great Hungarian Plain," *Journal of Biogeography*, 37, 915-935. 2010.

[33] Molnár, Zs. and Biró, M., "A néhány száz évre visszatekintő, botanikai celú történeti tájökológiai kutatások módszertana," in: Szilassi, P. and Henits, L., (eds.) *Tájváltozás értékelési módszerei a XXI. században.* JatePress, Szeged, 151-180. 2010.

[34] Molnár, Zs., Biró, M., Bartha, S. and Fekete, G., "Past trends, present state and future prospects of Hungarian forest-steppes," in Werger, M.J.A. and van Staalduinen, M.A., (eds.) *Eurasian Steppes.* Springer, Berlin, 209-252. 2012.

[35] Möller, H., "Zur Verwendung des Medians bei Zeigerwertberechnungen nach Ellenberg," *Tuexenia*, 12, 25-28. 1992.

[36] Murphy, H.T. and Lovett-Doust, J., "Context and connectivity in plant metapopulations and landscape mosaics: Does the matrix matter?," *Oikos*, 105, 3-14. 2004.

[37] Rapaics, R., "Az Alföld növényföldrajzi jelleme," *Erdészeti Kísérletek*, 20, 1-164. 1918.

[38] Seidling, W. and Fischer, R., "Deviances from expected Ellenberg indicator values for nitrogen are related to N throughfall deposition in forests," *Ecological Indicators*, 8, 639-646. 2008.

[39] Simon, T., *A magyarországi edényes flóra határozója*, Nemzeti Tankönyvkiadó, Budapest, 2000.

[40] Somodi, I., Virágh, K. and Aszalós, R., "The effect of the abandonment of grazing on the mosaic of vegetation patches in a temperate grassland area in Hungary," *Ecological Complexity*, 1, 177-189. 2004.

[41] Tölgyesi, Cs. and Körmöczi, L., "Structural changes of a Pannonian grassland plant community in relation to the decrease of water availability," *Acta Botanica Hungarica*, 54, 413-431. 2012.

[42] Török, K. and Szitár, K., "Long–term changes of rock grassland communities in Hungary," *Community Ecology*, 11, 68-76. 2010.

[43] Wulf, M., "Plant species as indicators of ancient woodland in northwestern Germany," *Journal of Vegetation Science*, 8, 635-642. 1997.