UNIVERSITY OF PÉCS

Flora, vegetation pattern and ecological conditions in the dolines of the Mecsek Mountains

PhD Theses

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I. Introduction

Investigation of karst surfaces and karst environments is currently in the focus of research and conservation efforts. Approximately 12% of the mainland is composed by calcium carbonate stones, 7-10% of which show the phenomenon of karst development. Karst landforms, together with soils, hydrological systems, flora and fauna play important roles in the function of karst system, therefore karst surfaces are very important both from a geological and from a biological point of view. The damage of any particular member of this system entails the damage of the others. Further, anthropogenic activities in general and climate change in particular have an influence on the taxa and communities of karst surfaces. Most anthropogenic disturbances may be rapid and destructive, while climate change causes a continuous stress. To reduce the effects of climate change, some species have restricted their distribution to cold refugees such as dolines. Dolines are funnel- and bowl-shaped closed depressions, from a few meters to a few hundred meters in diameter and depth, formed by water infiltration, having a cold microclimate.

Up to now, only a few information have been given in literature about the vegetation of the dolines of the Mecsek Mts (southern Hungary). In contrast with the dolines of the Bükk Mts and the Aggtelek Karst region, all of these depressions are covered by sub-Mediterranean type oak-hornbeam and beech forests. On the karst surface of the Mecsek Mts, there are more than 2000 dolines located between 250 and 500 m above sea level. The diameter of the largest doline is over 200 m and its depth exceeds 30 m.

II. Aims

The following questions are addressed:

1. What is the role of the dolines in preserving relict and cool-adapted species?
2. What kind of species occurs in the dolines, and how can we estimate the flora of the different-sized dolines?
3. What is the relation between plant associations of the larger dolines and plant associations of the surrounding areas?
4. What is the extent of vegetation inversion in different-sized dolines in a woodland-area?
5. Which environmental variables influence the vegetation pattern on the slopes?
6. How important is the vegetation of the dolines from a nature conservation point of view?
7. How can we preserve the special vegetation of dolines?

III. Methods

I have used different kinds of methods to answer these questions. 20 different-sized dolines were selected to reveal the floristic characteristic and the small-scale vegetation patterns on the slopes. Dolines ranked by diameter are identified with capital letters from A to T. The following selection was applied:

1. all size categories of dolines were investigated
2. the investigated dolines occur on plateaus or on gentle slopes
3. the investigated dolines have a funnel-like form
4. dolines were selected in sites that did not show signs of wood-cutting

Investigations were performed at 3 different levels: at the level of each doline; at the level of all dolines; and finally, at the level of the whole karst surface.

Vascular plant species lists were compiled between 2006 and 2011 for the 20 different-sized dolines of the Mecsek Mts. Another species list was also compiled according to 1000 dolines. Finally, a species list of the karst surface was obtained from the database of the Central European (CEU) flora mapping, as well as from field observations, and from the literature. All vascular plant species found in the area were classified syntaxonomically. Finally, 13 large groups of species were established as follows: (1) species of dry oak forests, (2) species of mesic oak forests, (3) species of Central European beech forests, (4) species of Illyrian beech forests, (5) species of deep ravines and gorges, (6) species of wet forests, (7) species of dry grasslands, (8) species of mesic hay meadows, (9) species of marshes, (10) weed species, (11) adventives, (12) indifferent species, (13) species of other habitats. Species-area relations were assessed for all plant species, as well as for the groups of different plant species, according to the well-known equation $\log S = \log C + Z\log A$. The „Nestedness Temperature Calculator (NTC)" was used to explore various features of nestedness of the flora of dolines.

To reveal the large-scale vegetation patterns, phytosociological relevés were taken in the lower part of 20 larger dolines in the Mecsek Mts applying the Central European method. The cover of the species of the upper canopy, lower canopy, shrub layer and herb layer was estimated visually in the 20 m × 20 m plots. The 20 relevés were compared to the 120 relevés published by other botanists from the associations surrounding the dolines. Species composition, structural characteristics and diagnostic species of the dolines were also determined.

The herb layer of larger dolines was sampled along 2 m wide transects consisting of 1 m × 1 m contiguous plots. In smaller dolines, only 1 m wide transects were surveyed. Transects were established across 20 dolines in north-south direction traversing the deepest point of the depressions. Percentage cover of each vascular plant species of the summer aspect was estimated visually in the plots. For comparison, 405 plots of 1 m × 1 m were randomly taken from the three habitat types (mixed-oak forests, beech forests and ravine forests) occurring in the neighbourhood of the dolines. I studied a total of 4017 plots on the karst of Mecsek Mts: 3612 plots in dolines and 405 plots in the surrounding vegetation types. Vegetation-environment relationships were investigated with redundancy analysis ordination (RDA) and with the relative ecological indicator values (TWRNL). Altitude values were measured along the transects of the 20 dolines. Air temperature and air humidity were also measured in 2 dolines, while soil moisture was measured in 10 dolines. Differential species of the vegetation surrounding the dolines (405 plots) were determined by statistical fidelity measures. In this scale, fidelity measurement resulted in 3 groups of differential species in the herb layer of the mixed-oak forests, the beech forests and the ravine forests. Finally, I classified each 1 m × 1 m plot along the doline transects into plot types with the use of the differential species groups. For example, if the number of differential species of the ravine forest was the highest in the target doline plot, I considered it a plot dominated by ravine forest species. Moving split window (MSW) analysis and PCoA ordination were also used to reveal the vegetation patterns on the slopes.

IV. Results and discussion

A prominent finding of my dissertation is that the low-lying dolines (250 to 500 m asl) of the Mecsek Mountains provide good refuge areas for many species adapted to cool and moist habitats. This is a consequence of the morphologic characteristics of karst depressions, which strongly determine both abiotic (e.g., air humidity, air temperature, soil moisture) and biotic (e.g., vegetation pattern) parameters of dolines. The extent of refuge areas shows a positive correlation with doline size in the Mecsek Mountains. In general, the extent of cool and moist habitats in the dolines increases with diameter, due to the fact that wider dolines are usually deeper. Dolines of the Mecsek Mountains harbour many vascular plant species that are missing or are very rare in the surrounding habitats, and they can be considered habitat islands in the "ocean" of local beech and mixed-oak forests. According to the well-known species-area relationship, species number is related to area by the function $S = CA^z$, where S is species number, A is area of island, and C and z are positive constants. When all species of the studied dolines are considered, the z value is 0.25, which is in good agreement with the z values received for many oceanic and habitat islands in island biogeography. In contrast, when only the group of cool-adapted species is considered, the z value is considerably higher (z = 0,45; or z = 0,65; depending on the selection of these species). When only the group of mixed-oak forest species and beech forest species is considered, the z value is lower (z = 0,20). Accordingly, my results suggest that the habitat topography of large dolines is complex and the extent of cool and moist habitats considerably increases with doline size, so larger dolines may preserve many more vascular plant species adapted to cool and moist habitats (i.e., relicts, mountain species and wet-woodland species) than smaller dolines. Most of these species also occur in the deep, humid and rocky ravines and valleys of the study site.

30 protected and 11 mountain species were detected on the slopes of the dolines in the Mecsek Mts. The relict plant *Stachys alpina* and the mountain fern *Dryopteris affinis* have the greatest conservation value. Due to the high variety of expositions, different groups of species can be found in the dolines, which contribute to the enhancement of the biodiversity. The strong environmental gradients that occur across the dolines also play an important role in the preservation of different groups of species. Dry oak forest and mesic oak forest species often occur on the S-facing slopes, species of Central European beech forests on the N-facing slopes, while ravine forest species, wet-woodland species and marsh species on the bottom of the dolines.

Community composition of the vascular plant species of dolines seemed to exhibit a highly significant nested subset pattern. There are lots of species (e.g., *Carex pilosa*, *Melica uniflora*) that occur in all dolines, or in all larger dolines (e.g. *Circaea lutetiana*, *Dryopteris carthusiana*, *Polystichum aculeatum*), explaining the species nestedness pattern. However, there are a few species (e.g. *Fraxinus excelsior*, *Galanthus nivalis*, *Mercurialis perennis*) that decrease the nestedness. These species are frequent in the southern and eastern part of the karst surface, but absent from the western parts, indicating a local floristic gradient. The smaller dolines of the study site are dominated by species of mesic oak forests and species of Central European beech forests, while in larger dolines some other species groups (e.g., ravine forest species, wet-woodland species) also play an important role.

Considering the vegetation texture and species composition, the vegetation of the dolines in Western Mecsek resembles mainly the local beech and ravine forests. The structure of the canopy in the larger dolines is different from that of the surrounding oak-hornbeam and beech forests, in which *Carpinus betulus* and *Fagus sylvatica* are dominant. The upper canopy of the dolines resembles that of the ravine forests and is primarily composed of *Acer pseudoplatanus*. The shrub layer is primarily composed of young trees of the canopy. While *Sambucus nigra* is also typical in this level, other shrubs occur sporadically. The herb layer is dominated by Carpino-Fagetea species, such as *Allium ursinum*, *Galeobdolon luteum* s.l., and *Galium odoratum*, but some Tilio-Acerion species (e.g., *Actaea spicata*, *Polystichum aculeatum*) also occur on the deeper parts of the slopes. However, the surrounding ravine forests contain more Tilio-Acerion species (e.g., *Aruncus dioicus*, *Asplenium scolopendrium*, *Silene dioica*). Differential species of the dolines are: *Athyrium filix-femina*, *Atropa bella-donna*, *Dryopteris carthusiana*, *Paris quadrifolia*. This vegetation type occurs only in small patches, and, in my opinion, its stands are disjunct and isolated ravine forest fragments in the matrix of Illyrian beech and oak-hornbeam forests. Distinction of the vegetation of the dolines as a separate association is not supported by the analyses.

Vegetation of the smaller dolines does not differ from that of the surrounding areas, and the slopes are floored by vegetation characteristic only of beech forests or mixed-oak forests. In contrast, in larger dolines (diameter > 50-60 m, depth > 10 m), south-facing slopes are dominated by mixed-oak forests or beech forests, north-facing slopes by beech forests, and the bottom of dolines by ravine forests. Vegetation inversion is well pronounced only in the largest dolines, where beech forest vegetation replaces that of mixed-oak forests on the deeper parts of the slopes. The similar species composition of the vegetation types of dolines makes the determination of boundaries difficult and arbitrary. The moving split window (MSW) technique often indicates significant boundaries on the S-facing slopes and in the doline bottom, but it can not distinguish the different vegetation types on the N-facing slopes. The method based on fidelity measurement gave better results, but field observations are necessery in both cases.

Vegetation of the S-facing slopes of dolines indicates drier, warmer and less nutrient-rich habitats, than that of the other slopes of the dolines. The doline bottom is the coldest and the moistest with the highest level of nutrient supply. The redundancy analysis ordination (RDA) revealed that the vegetation pattern of larger dolines is significantly influenced by soil moisture, air temperature, air humidity and altitude. The S-facing edges and S-facing slopes are the driest and warmest, while the doline bottom is the moistest and coldest. Plots of the N-facing edges and N-facing slopes occupy a transitional area in the ordination space.

Considering the special microclimatic conditions, geomorphological features, vegetation pattern and species composition, dolines are especially important and valuable for scientific research and nature conservation.

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