132. Jahrgang (2015), Heft 3, S. 145–168

Austrian Journal of Forest Science

Centralblatt für das gesamte Forstwesen

Phytosociology and nature conservation value of thermophilous oak forests in a South Hungarian karst area

Pflanzensoziologie und Naturschutzwert der thermophilen Eichenwälder in einem Karstgebiet in Südungarn

by László Erdős[1], Andrea Dénes[2], Dolly Tolnay[1], Martin Magnes[1], Zoltán Bátori[3], Csaba Tölgyesi[3], Balázs Kevey[4]

Key words: Villány Mts, Protected species, Red-listed species, Xeric plant communities

Summary

Thermophilous oak forests are among the most diverse forest communities in Europe, and they are important both from a phytosociological and a conservation perspective. In Hungary, they occupy large areas, including the south-facing slopes of karst mountains. Although detailed studies are available from some regions, there has been no in-depth analysis of the thermophilous forests of the Villány Mountains, the southernmost mountain region in Hungary. The aim of this study is to fill this

1 Institute of Plant Sciences, University of Graz, A-8010 Graz, Holteigasse 6, Austria, e-mails: erdos.laszlo@bio.u-szeged.hu, martin.magnes@uni-graz.at, dolly.tolnay@gmail.com
2 Department of Natural History, Janus Pannonius Museum, H-7621 Pécs, Szabadság u. 2., Hungary, e-mail: denes.andrea@jpm.hu
3 Department of Ecology, University of Szeged, H-6726 Szeged, Közép fasor 52., Hungary, e-mails: zbatory@gmail.com, festuca7@yahoo.com, fax: +36-62-546-949
4 Department of Ecology, University of Pécs, H-7624 Pécs, Ifjúság útja 6., Hungary, e-mail: keveyb@gamma.ttk.pte.hu

gap, by providing a basic phytosociological characterization and revealing the conservation importance of four thermophilos forest associations. A total of 200 coenological relevés were prepared, which were analyzed by PCoA-ordinations. Significant diagnostic species were identified for the associations. We calculated the number of all species, protected species and red-listed species that are present in two or more of the studied associations, and those that are restricted to only one community. The four associations were also compared based on the proportion of species with mainly Mediterranean distribution. We found that despite their obvious syntaxonomical relations, the four associations had rather different structural characteristics and species composition. Generally, the oak scrub *Inulo spiraeifoliae-Quercetum pubescentis* seemed to host the highest conservation value; thus the current focus of conservation efforts on oak scrubs can be justified. Nevertheless, we identified several species, including protected and red-listed ones that occurred only in one of the other associations under study. This emphasizes that focusing on one association will not be sufficient; instead, representatives from all associations should be recognized as having high conservation importance. New nature conservation areas would be desirable in two areas, Mt Tenkes and Mt Csukma, because both of them host all the four studied forest associations, allowing the protection of a high diversity in relatively small areas. Mt Nagy also has an extremely high protection value because of its near-natural oak scrubs.

Zusammenfassung

Thermophile Eichenwälder gehören zu den Waldgesellschaften mit der höchsten Biodiversität in Europa, und sie sind sowohl aus pflanzensoziologischer als auch aus naturschutzfachlicher Perspektive bedeutend. In Ungarn bedecken diese Eichenwälder große Flächen, darunter auch die Südhänge vieler Karstbergen. Obwohl ausführliche Studien aus einigen Regionen vorliegen, gibt es bisher keine detaillierte Analyse der thermophilen Wälder der Villányer-Gebirge, der südlichsten Bergregion von Ungarn. Ziel unserer Studie war es, diese Lücke zu schließen, eine pflanzensoziologische Charakterisierung zu erarbeiten und die naturschutzfachliche Bedeutung der vier im Villányer-Gebirge vorkommenden thermophilen Waldgesellschaften nachzuweisen. Es wurden zweihundert zönologische Aufnahmen gemacht und mit PCoA-Ordinationen analysiert. Signifikante diagnostische Arten wurden für die Assoziationen bestimmt. Wir berechneten die Anzahl aller Arten, der geschützten und Rote-Liste Arten die in mindestens zwei der untersuchten Assoziationen vorkommen, und solche, die nur in einer Assoziation nachgewiesen werden konnten. Die vier Assoziationen wurden auch anhand des Anteils der Arten mit mediterranem Arealschwerpunkt verglichen. Es zeigte sich, dass die vier Assoziationen, trotz offensichtlicher syntaxonomischer Verwandtschaft, deutlich in Struktur und Artenzusammensetzung unterscheidbar sind. Im Allgemeinen schien das Eichengebüsch *Inulo spiraeifoliae-Quercetum pubescentis* den höchsten Naturschutzwert zu haben; so ist der aktuelle Fokus der Natur-

schutzbemühungen auf diese Assoziation begründet. Trotzdem konnten wir mehrere Arten, darunter auch geschützte und Rote-Liste Arten finden, die nur in einer der anderen drei Assoziationen vorkommen. Diese Nachweise legen den Schluss nahe, dass der Schutz des Eichengebüsches nicht ausreichend ist, sondern die Vertreter aller Verbände geschützt werden sollten. Neue Naturschutzgebiete sollten in zwei Gebieten, auf dem Tenkes-Berg und Csukma-Berg eingerichtet werden, da diese Berge alle vier untersuchten Assoziationen beherbergen. So könnte man auf relativ kleinen Gebieten eine hohe Diversität erhalten. Wegen seiner wertvollen Eichengebüsche hat auch der Nagy-Berg einen hochen Naturschutzwert.

1. Introduction

Thermophilous oak forests are widespread in Europe, although their distribution concentrates to the southeastern parts of the continent (Jakucs, 1960, 1972; Ellenberg, 1988; Borhidi et al., 2012). They belong to the most diverse forests in Europe (Ellenberg, 1988), and are particularly rich in rare plant species (Chytrý, 1997). Consequently, they have been in the focus of research interest in several Central European countries, including Austria (e.g. Eggler, 1941; Wallnöfer, 2003; Willner et al., 2005), the Czech Republic (e.g. Chytrý, 1997; Chytrý and Horák, 1997; Roleček, 2007), Germany (e.g. Rühl, 1954; Förster, 1979) and Hungary (e.g. Jakucs, 1961; Borhidi and Kevey, 1996; Borhidi et al., 2012). Also, thermophilous oak forests are well documented in southeastern Europe (e.g. Horvat et al., 1974; Butorac et al., 2008; Čarni et al., 2009). In the Carpathian Basin, thermophilous forests occupy extensive areas in the lowlands and the hilly and mountainous regions as well (Borhidi et al., 2012).

Karst regions are well-known for supporting valuable forest plant communities (e.g. Bátori et al., 2009; Redžić, 2011) and grassland plant communities (e.g. Pipenbaher et al., 2011; Redžić, 2011). Thermophilous oak forests are typical communities of karst regions, especially on the southern mountain slopes. In Hungary, they have been extensively studied in the Mecsek Mts (e.g. Horvát, 1969, 1972; Kevey and Borhidi, 1998), the Transdanubian Mountain Ranges (e.g. Debreczy, 1968, 1973; Isépy, 1970; Jakucs, 1972) and the North Hungarian Mountain Ranges (e.g. Jakucs and Fekete, 1957; Fekete and Jakucs, 1968; Fekete and Kovács, 1982).

In the Villány Mts, the southernmost mountain region of Hungary, there are four types of thermophilous forest communities: the calcareous scrub *Inulo spiraeifoliae-Quercetum pubescentis*, the top-forest *Aconito anthorae-Fraxinetum orni*, the hairy oak-chestnut oak forest *Tamo-Quercetum virgilianae*, and the turkey oak-sessile oak forest *Potentillo micranthae-Quercetum dalechampii* (Kevey, 2008). They are considered valuable plant communities, deserving special conservation attention (Borhidi and Sánta, 1999). They usually host a high number of protected and rare species, and due to the considerable Mediterranean influences, they are also interesting from a phytosociological point of view.

Despite their apparent phytosociological and nature conservation importance, our knowledge on the thermophilous forests of the Villány Mts is rather limited. Calcareous scrubs have been well studied in the area (Dénes, 1994; Erdős et al., 2011, 2014a), but other types of thermophilous forests are poorly documented. Moreover, most of the conservation activities have focused on xeric grasslands and oak scrubs, although some studies suggest that other thermophilous forests may also have considerable nature conservation importance (Kevey, 2012).

The first aim of this paper is to provide a basic comparative phytosociological analysis of the thermophilous oak forests of the Villány Mts. Our second aim is to examine the nature conservation importance of these forests. We evaluate the compositional distinctness of these forest associations, with an emphasis on species of special conservation importance. We also want to answer the question whether it is possible to conserve most natural values with the protection of just one or two of the associations in a few localities, or if it is necessary to protect representatives of all associations from more localities.

2. Material and methods

2.1 Study area

The Villány Mts are situated in southern Hungary (Fig. 1a). The bedrock is mainly limestone, but dolomite also occurs at some places (Lovász, 1977). The mean annual temperature is 10.5 °C (Fodor, 1977), the mean annual precipitation is 680 mm (Ambrózy and Kozma, 1990). Near-natural vegetation can primarily be found in the central and eastern parts of the Villány Mts (Fig. 1b). In these areas, most of the south-facing slopes as well as the upper sections of the north-facing slopes are covered by thermophilous forest communities (Erdős et al., 2012, 2014b) (Fig. 1c). The Villány Mts belong to the most diverse areas of Hungary, in terms of both plant species and plant communities, with a high number of protected, endemic and relict species and unique associations (Dénes, 2000).

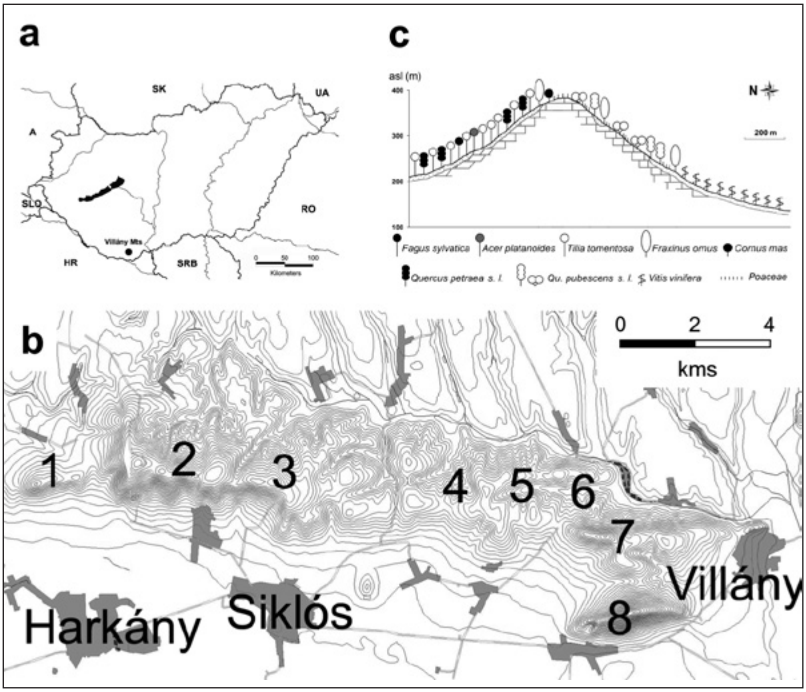

Figure 1: (a) Position of the Villány Mts in Hungary (b) The central and eastern parts of the Villány Mts. 1: Mt Nagy, 2: Mt Tenkes, 3: Mt Csukma, 4: Kecskeháti-forest, 5: Luca-karéj, 6: Siklósi-valley, 7: Mt Fekete, 8: Mt Szársomlyó (c) Typical vegetation profile of the Villány Mts, where the southern slopes are occupied by thermophilous tree species

Abbildung 1: (a) Geographische Lage der Villányer-Berge in Ungarn (b) zentrale und östliche Teile der Villány Berge. 1: Nagy-Berg, 2: Tenkes-Berg, 3: Csukma-Berg, 4: Kecskeháti-Wald, 5: Luca-karéj, 6: Siklósi-Tal, 7: Fekete-Berg, 8: Szársomlyó-Berg (c) typisches Vegetationsprofil der Villányer-Berge an Südhängen mit thermophilen Baumarten

2.2 Field data collection

Fifty coenological relevés were prepared in each community (*Aconito anthorae-Fraxinetum orni, Tamo-Quercetum virgilianae, Potentillo micranthae-Quercetum dalechampii, Inulo spiraeifoliae-Quercetum pubescentis*), resulting in a total of 200 relevés. Plot sizes were 40 m × 40 m for most forest types, based on our extensive minimum-area surveys in the region (Kevey, 2008). For *Inulo spiraeifoliae-Quercetum pubescentis* stands, plots were 7 m × 7 m, because of the small size of these forest patches (Erdős et al., 2011). Species cover was estimated according to the Braun-Blanquet scale, but only presence-absence data were used in the analyses. Field work was done in April and July. Spring and summer records were combined for data analyses. During field works, major structural characteristics and habitat parameters were also recorded (exposition, elevation, soil type, height and total cover of each vegetation layer).

2.3 Data analyses

A PCoA-ordination was carried out on the 200 coenological relevés, to analyze the similarity of the four communities. Four additional PCoA-ordinations were done, using only the relevés from each individual community. In all cases, presence-absence data of the species were used, and the Baroni-Urbani-Buser index was applied as comparative function. The analyses were carried out with the program package SYN-TAX 2000 (Podani, 2001).

We identified diagnostic species, i.e. species that are typical of one of the communities, while absent or rare in the other three communities. For this purpose, phi-coefficients were calculated, as the most appropriate indicators of fidelity (i.e. species concentration in one of the studied communities) (Tichý and Chytrý, 2006). The phi coefficient varies between -1 and +1; higher values reflect higher diagnostic values. In practice, usually only positive diagnostic values are taken into consideration. Significant ($p<0.001$) diagnostic species were identified with the software JUICE 7.0 (Tichý, 2002). Only species with phi values >0.300 were considered during our work.

To have an understanding of the nature conservation role of the studied communities, total numbers of all species, protected species and red-listed species (Király, 2007) were calculated for all communities. Moreover, we prepared Venn-diagrams to identify the number of all species, protected species and red-listed species that are present in two or more forest communities, and those that are restricted to one community. We used the Venn-diagram generator of the Bioinformatics and Systems Biology Group of the Department of Plant Systems Biology at the Ghent University (http://bioinformatics.psb.ugent.be/webtools/Venn/).

In Hungary, species with a Mediterranean or sub-Mediterranean geographical distribution have a particular nature conservation importance. Therefore, we calculated the proportion of species with a Mediterranean character (including sub-Mediterranean, Balcanic and Illyrian species). Species' geographical distributions were determined based on the FLÓRA database (Horváth et al., 1995). Results were visualized in box-plots. The four communities were compared with One-way ANOVA and Tukey's pairwise comparisons. Analyses were carried out using SPSS 17.0 (SPSS Inc.).

Nomenclature follows Simon (2000) for plant species and Borhidi et al. (2012) for plant associations.

3. Results

3.1 Habitat conditions and structural characteristics

In the followings, we describe basic habitat conditions and general structural characteristics of the four associations, based exclusively on our field works from the Villány Mts.

Aconito anthorae-Fraxinetum orni forests can mostly be found on mountain tops or in northern exposures, always between 300 and 400 m asl. Their soil is rendzina. The upper canopy (height range: 12-20 m, cover: 50-80%) is dominated by *Fraxinus ornus* and *Quercus pubescens* agg., but *Acer campestre* and *Tilia tomentosa* can also play an important role occasionally. *Fraxinus ornus* is the single dominant species in the lower canopy (7-10 m, 10-50%). In the shrub layer (2-3.5 m, 50-80%), *Cornus mas* is by far the most frequent and abundant species. Other wide-spread shrubs include *Crataegus monogyna* and *Ligustrum vulgare*. In the herb layer (5-50 cm, 50-100%), *Ruscus aculeatus* is dominant, and the high cover of several mesic plants (e.g. *Corydalis cava, Ranunculus ficaria*, and *Helleborus odorus*) is also typical.

Tamo-Quercetum virgilianae stands occur on southern slopes, between 260 and 400 m asl. Their soil is also rendzina. The forest community usually opens up, allowing the formation of small grassland patches. The upper canopy layer (height: 10-16 m, cover: 50-80%) is composed of *Fraxinus ornus*, *Quercus pubescens* agg. and *Tilia tomentosa*. The lower canopy (7-10 m, 10-50%) consists primarily of *Fraxinus ornus* and *Quercus pubescens* agg. The most abundant species of the shrub layer (2-4 m, 50-80%) are *Cornus mas, Crataegus monogyna, Euonymus verrucosus* and *Ligustrum vulgare*. Abundant species of the herb layer (5-50 cm, 20-85%) include *Buglossoides purpureo-coerulea, Carex michelii, Melica uniflora, Ruscus aculeatus* and *Tamus communis*.

The forest community *Potentillo micranthae-Quercetum dalechampii* is characteristic of mountain tops and northern slopes near the ridges, between 200 and 400 m asl. This community grows on brown forest soil. The upper canopy (height: 20-28 m, cover: 70-85%) consists of *Quercus cerris* and *Quercus petraea* agg., and to a lesser extent *Tilia tomentosa*. The lower canopy (10-20 m, 10-40%) is co-dominated by *Fraxinus ornus* and *Tilia tomentosa*. The shrub layer (1.5-4 m, 30-70%) is formed mainly by saplings of *Fraxinus ornus* and *Tilia tomentosa*, accompanied by shrubs like *Ligustrum vulgare*. Dominant species of the herb layer (5-50 cm, 25-90%) are *Carex pilosa, Lonicera caprifolium, Melica uniflora* and *Ruscus aculeatus*.

The association *Inulo spiraeifoliae-Quercetum pubescentis* appears mainly in southern expositions, but can be found on east-, west-, or even north-facing slopes occasionally, between 160 and 440 m asl. The soil of this community is rendzina. The forest stands are small, forming patches scattered in a matrix of xeric grasslands (mostly open rock swards). The canopy layer (height: 4-6 m, cover: 50-80%) consists almost exclusively of *Fraxinus ornus* and *Quercus pubescens* agg. In the shrub layer (1-3 m, 10-60%), *Cornus mas, Crataegus monogyna* and *Ligustrum vulgare* are the most frequent and abundant species. Typical and abundant plants of the herb layer (5-50 cm, 25-85%) are, among others, *Corydalis solida, Festuca valesiaca, Iris variegata, Polygonatum odoratum, Ruscus aculeatus*, and *Teucrium chamaedrys*.

3.2 Species composition and nature conservation importance

In the 200 plots, we found a total of 398 species, 56 of which are protected and 36 are red-listed (Table 1). When all relevés within a given association were considered, *Tamo-Quercetum virgilianae* proved to be the most species-rich, while *Potentillo micranthae-Quercetum dalechampii* had the lowest number of species. Regarding protected and red-listed species, differences among the four associations were not very pronounced, but it is noteworthy that *Potentillo micranthae-Quercetum dalechampii* had the lowest number of species in both categories. However, it is even more important to emphasize that *Inulo spiraeifoliae-Quercetum pubescentis*, despite the small plot sizes, had the highest number of red-listed species, and, together with *Tamo-Quercetum virgilianae*, the highest number of protected species.

Table 1: The number of all species, protected species and red-listed species in all relevés, and in the four individual associations

Tabelle 1: Gesamtartenzahl, Anzahl geschützter und Rote-Liste Arten in allen relevés sowie in den vier untersuchten Assoziationen

	Number of species	**Number of protected species**	**Number of red-listed species**
Total	398	56	36
Aconito anthorae-Fraxinetum orni	228	30	17
Tamo-Quercetum virgilianae	267	32	20
Potentillo micranthae-Quercetum dalechampii	181	26	9
Inulo spiraeifoliae-Quercetum pubescentis	221	32	21

In the ordination scattergram, *Potentillo micranthae-Quercetum dalechampii* relevés formed a dense and relatively distinct group (Fig. 2). *Inulo spiraeifoliae-Quercetum* *pubescentis* relevés were in an even more distinct, although less dense, group. *Tamo-Quercetum virgilianae* and *Aconito anthorae-Fraxinetum orni* communities proved to be somewhat similar to each other, with a moderate overlap.

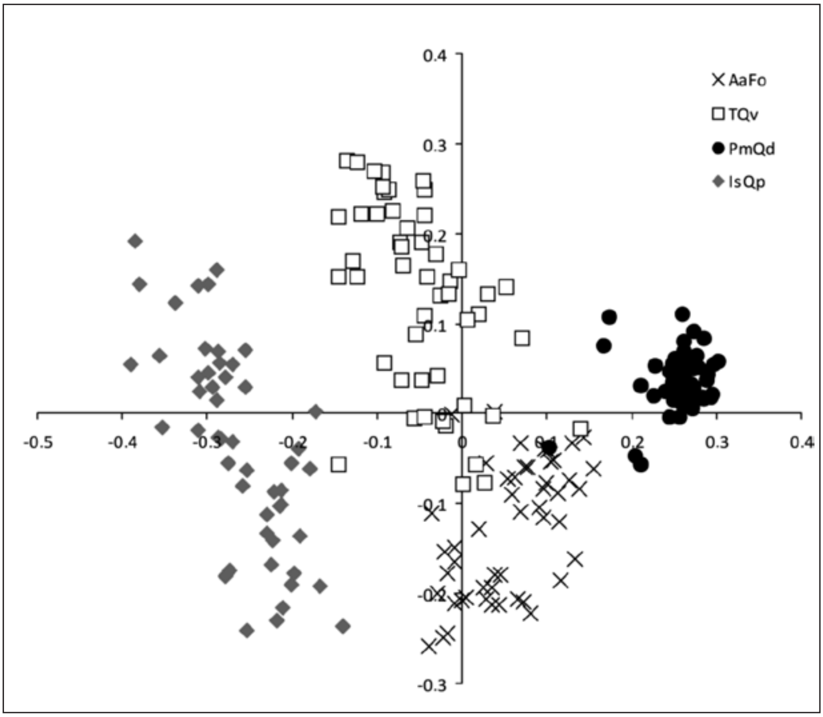

Figure 2: PCoA ordination scattergram of the 200 coenological relevés. Percentage variances explained by the first and second axes are 19.22% and 8.42%, respectively. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

Abbildung 2: PCoA Ordinations-Streudiagramm der 200 relevés (erste Achse erklärt 19.22%, zweite Achse 8.42% der Varianz). AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis.

Aconito anthorae-Fraxinetum orni relevés formed well-defined groups according to their locations (Fig. 3a). The situation was quite different for *Tamo-Quercetum virgilianae* (Fig. 3b). Here, variation was also considerable, but relevés were not separated according to their localities. The majority of the *Potentillo micranthae-Quercetum dalechampii* relevés originated from Mt Csukma. The ordination revealed that relevés from other sites (Kecskeháti-forest, Siklósi-valley, Luca-karéj and Mt Tenkes) had a rather different species composition (Fig. 3c). In the case of *Inulo spiraeifoliae-Quercetum pubescentis*, relevés were not separated according to the sites, except for those on Mt Nagy, which formed a separate group (Fig. 3d).

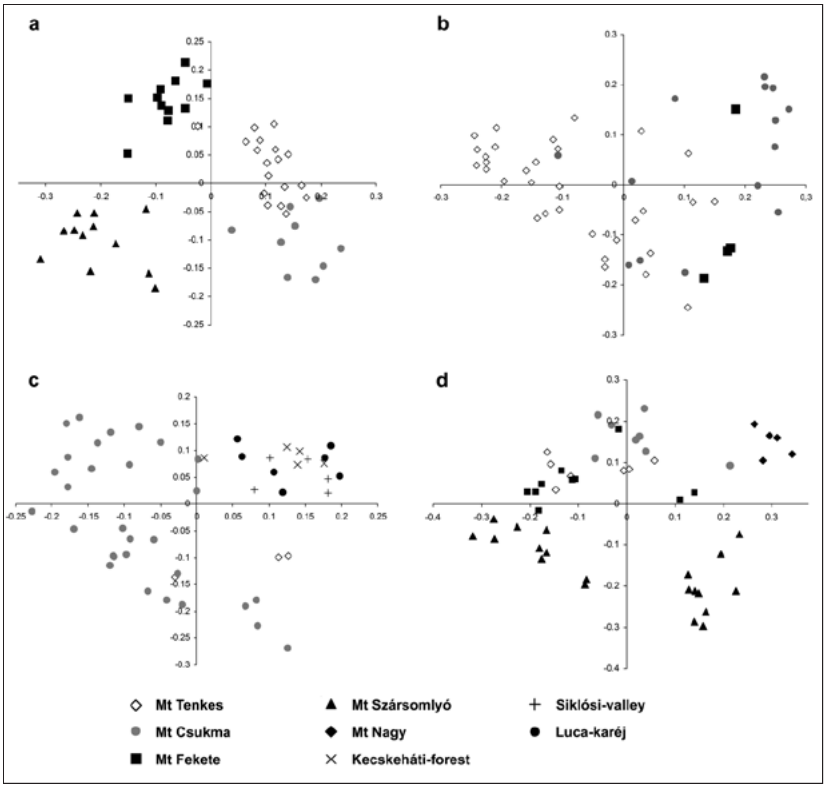

Figure 3: PCoA ordination scattergrams for each association. Percentage variances explained by the first and second axes are given in parentheses (a) Aconito anthorae-Fraxinetum orni (15.06%, 7.74%). (b) Tamo-Quercetum virgilianae (16.66%, 8.51%). (c) Potentillo micranthae-Quercetum dalechampii (11.30%, 9.26%). (d) Inulo spiraeifoliae-Quercetum pubescentis (14.25%, 9.75%)

Abbildung 3: PCoA Ordinations-Streudiagramm für die einzelnen Assoziationen. Varianzen, die von der ersten bzw. zweiten Achse erklärt werden stehen in Klammer (a) Aconito anthorae-Fraxinetum orni (15.06%, 7.74%). (b) Tamo-Quercetum virgilianae (16.66%, 8.51%). (c) Potentillo micranthae-Quercetum dalechampii (11.30%, 9.26%). (d) Inulo spiraeifoliae-Quercetum pubescentis (14.25%, 9.75%)

All studied associations had several significant ($p<0.001$) diagnostic species (*Aconito anthorae-Fraxinetum orni*: 29, *Tamo-Quercetum virgilianae*: 38, *Potentillo micranthae-*

Quercetum dalechampii: 42, *Inulo spiraeifoliae-Quercetum pubescentis*: 35) (Table 2).

Table 2: Significant (p<0.001) diagnostic species of the four associations under study, and corresponding phi coefficients. Only species with phi values >0.300 were considered. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

Tabelle 2: Signifikante (p<0.001) diagnostische Arten für die vier untersuchten Assoziationen mit den entsprechenden phi-Koeffizienten. Es sind nur Arten mit phi > 0.300 angeführt. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

	AaFo	TQv	PmQd	IsQp
Gagea lutea	74,3			
Viola odorata	66,1			
Galanthus nivalis	64,9			
Sambucus nigra	57,9			
Anemone ranunculoides	50,7			
Ornithogalum sphaerocarpum	48,5			
Aconitum anthora	47,4			
Corydalis solida	45,5			
Corydalis cava	44,1			
Urtica dioica	43,6			
Arum maculatum	41,5			
Gagea minima	40,8			
Geranium robertianum	38,6			
Bryonia alba	38,6			
Carex muricata	38,2			
Fallopia dumetorum	37,4			
Chaerophyllum temulum	37,2			
Lamium maculatum	37			
Sedum telephium	35,5			
Bromus sterilis	34,1			
Arum orientale	33,9			
Tilia platyphyllos	33,9			
Chelidonium majus	33,7			
Iris variegata	33,6			
Bromus ramosus agg.	31,5			
Moehringia trinervia	31,5			
Scilla vindobonensis	31,4			
Mercurialis perennis	31			

	AaFo	TQv	PmQd	IsQp
Carex michelii		68,3		
Inula conyza		66,7		
Poa angustifolia + pratensis		65,5		
Verbascum chaixii		65,2		
Thalictrum minus		58,3		
Calamintha menthifolia		58,2		
Muscari comosum		58		
Hypericum perforatum		52,8		
Campanula bononiensis		50,2		
Thlaspi perfoliatum		47,2		
Carex spicata		46,8		
Dorycnium herbaceum		45,6		
Brachypodium pinnatum		45,3		
Festuca rupicola		45		
Achillea pannonica		43,6		
Chamaecytisus supinus		42,9		
Vincetoxicum hirundinaria		42,5		
Viola hirta		42,1		
Clinopodium vulgare		38,5		
Euphorbia cyparissias		38,5		36,3
Brachypodium sylvaticum		37,3		
Verbascum phoeniceum		37		
Buglossoides purpureo-co-erulea		36,9		
Agrimonia eupatoria		36,4		
Adonis vernalis		35,9		
Dictamnus albus		35,4		
Peucedanum cervaria		34,8		
Teucrium chamaedrys		34,3		32,1
Torilis japonica		32,5		
Fragaria viridis		32,4		
Cleistogenes serotina		31,6		
Viola suavis s.l.		31,4		
Silene nutans		31,4		
Tordylium maximum		31,4		
Campanula rapunculus		31,3		
Euonymus europaeus		31,1		

	AaFo	TQv	PmQd	IsQp
Carex pilosa			87,6	
Quercus petraea agg.			80,9	
Rubus hirtus			79,6	
Cardamine bulbifera			75,7	
Lathyrus niger			74,2	
Lathyrus vernus			73,1	
Viola reichenbachiana			73,1	
Galium odoratum			66,4	
Carex sylvatica			63,7	
Polygonatum multiflorum			62,2	
Ajuga reptans			59,6	
Melittis melissophyllum			59,5	
Convallaria majalis			56,3	
Acer tataricum			56	
Carex divulsa ssp. divulsa			55,7	
Lathyrus venetus			55	
Quercus cerris			51,8	
Sorbus torminalis			51,6	
Pulmonaria officinalis			51,5	
Rumex sanguineus			49,6	
Primula vulgaris			49,5	
Cornus sanguinea			49,1	
Rosa arvensis			48,2	
Lysimachia punctata			47,7	
Cerasus avium			44,9	
Ranunculus ficaria	38		44,4	
Hypericum hirsutum			43,8	
Euphorbia amygdaloides			43,7	
Galium schultesii			42,8	
Stellaria holostea			41,9	
Melica uniflora			41,7	
Malus sylvestris			40,8	
Neottia nidus-avis			38,6	
Staphylea pinnata			38,4	
Lonicera caprifolium		30	36,5	
Heracleum sphondylium			35,8	
Viola alba		31,5	35,7	
Campanula trachelium			34	
Hieracium sabaudum agg.			33,7	
Carpinus betulus			32,5	
Carex digitata			31,4	
Symphytum tuberosum			30,1	

	AaFo	TQv	PmQd	IsQp
Galium lucidum				89,9
Fallopia convolvulus				76,6
Allium flavum				69,6
Dianthus giganteiformis				58
Festuca valesiaca				51,5
Hesperis tristis				49,5
Convolvulus cantabrica				46,8
Polygonatum odoratum				46,2
Melica ciliata				45,7
Viola arvensis + kitaibeliana				45,6
Verbascum lychnitis				44,9
Vicia lathyroides				44,9
Potentilla arenaria				43,6
Fragaria moschata				42,9
Tragopogon pratensis				42,9
Koeleria cristata				42,9
Ranunculus illyricus				42,8
Stachys recta				42,1
Lactuca viminea				41,9
Geranium molle				41,5
Thymus spp.				41,5
Artemisia alba				40,8
Elymus hispidus				40,7
Geranium sanguineum				38,9
Pseudolysimachion spicatum				38,6
Taraxacum erythrospermum				38,6
Helianthemum ovatum				38
Festuca dalmatica				36,4
Sanguisorba minor				34
Silene nemoralis				31,5
Berteroa incana				31,4
Carex praecox				31,4
Eryngium campestre				31,3

Our analysis revealed that 74 species could be found in all four associations, and the number of species occurring in two or three associations was also considerable (Fig. 4). Nevertheless, there were several species restricted to only one of the four associations under scrutiny. *Inulo spiraeifoliae-Quercetum pubescentis* had by far the largest number of species that did not occur elsewhere. *Potentillo micranthae-Quercetum dalechampii* had the lowest number of species confined to relevés from this association. As for the protected species, most of them occurred in two or more associations, although there were some protected plants that were found only in one association (Fig. 5). *Inulo spiraeifoliae-Quercetum pubescentis* proved to have the highest number of protected species occurring only in this association. Results were generally similar in the case of red-listed species (Fig. 6).

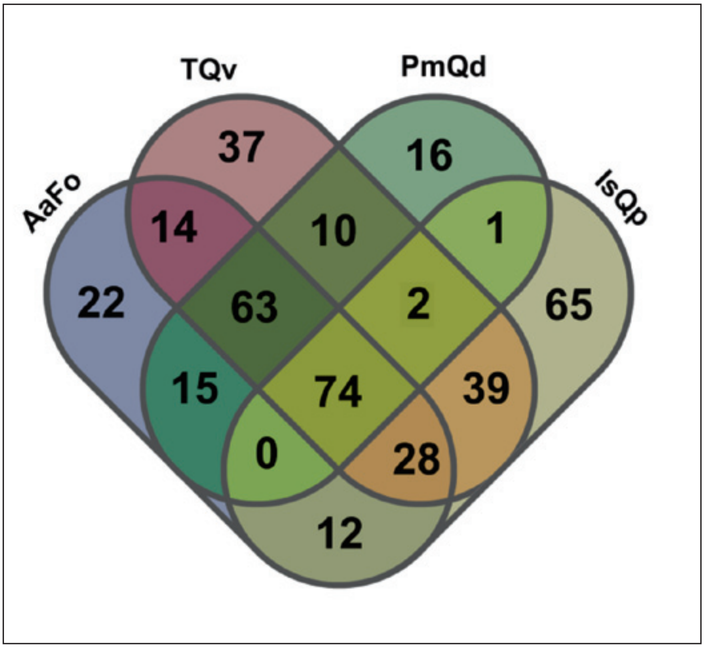

Figure 4: Venn-diagram of all species encountered in the study, according to the associations in which they were found. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

Abbildung 4: Venn-Diagramm aller in der Studie nachgewiesenen Arten nach den Assoziatonen, in denen sie auftraten. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

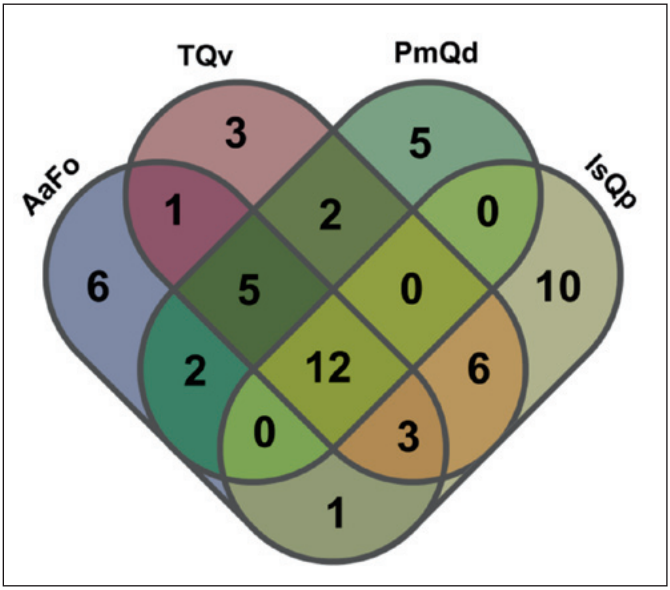

Figure 5: Venn-diagram of the protected species encountered in the study, according to the associations in which they were found. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

Abbildung 5: Venn-Diagramm aller in der Studie nachgewiesenen geschützten Arten nach den Assoziationen, in denen sie auftraten. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

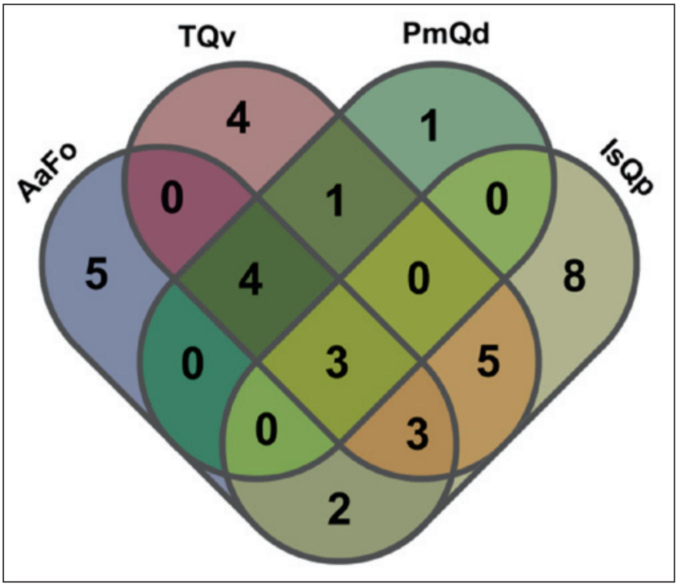

Figure 6: Venn-diagram of the red-listed species encountered in the study, according to the associations in which they were found. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

Abbildung 6: Venn-Diagramm aller Rote-Liste-Arten, die in der Studie nachgewiesen wurden nach den Assoziationen, in denen sie auftraten. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis

According to the ANOVA, the percentage of Mediterranean species differed significantly among the four associations (F=24.89, p<0.001). Tukey's pairwise comparisons showed that *Tamo-Quercetum virgiliane* had the highest, and *Aconito anthorae-Fraxinetum orni* the lowest proportion of species with Mediterranean distribution, while *Potentillo micranthae-Quercetum dalechampii* and *Inulo spiraeifoliae-Quercetum pubescentis* were intermediate (Fig. 7).

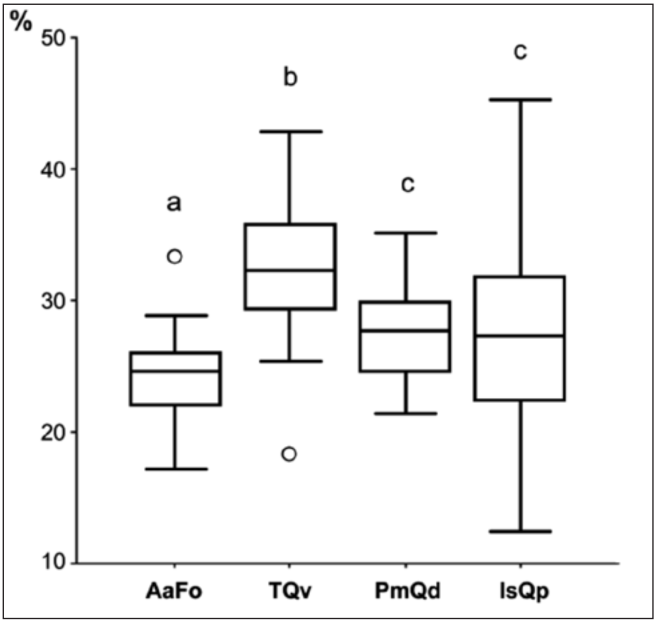

Figure 7: Proportion of plants with a Mediterranean (including sub-Mediterranean, Balcanic and Illyrian) distribution in the four studied associations. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis. Different letters above the boxes indicate significant differences

Abbildung 7: Anteil von Arten mit mediterranem (inkl. sub-mediterranem, balkanischem und illyrischem) Arealschwerpunkt in den vier untersuchten Assoziationen. AaFo: Aconito anthorae-Fraxinetum orni, TQv: Tamo-Quercetum virgilianae, PmQd: Potentillo micranthae-Quercetum dalechampii, IsQp: Inulo spiraeifoliae-Quercetum pubescentis. Unterschiedliche Buchstaben über den Boxen zeigen signifikante Unterschiede

4. Discussion

Thermophilous forests are important both from a phytosociological and a nature conservation perspective (e.g. Ellenberg, 1988; Chytrý, 1997). Although there are in-depth studies from several Hungarian regions, thermophilous forests of the Villány Mts have largely been neglected, except for the oak scrub *Inulo spiraeifoliae-Quercetum pubescentis* (Dénes, 1994; Erdős et al., 2014a). The aim of the present study was to give a phytosociological characterization of the four thermophilous forest associations of the study region, as well as to assess their conservation importance.

Nature conservation of the forests in the Villány Mts has focused on oak scrubs. Our analysis revealed that the primary focus on oak scrubs as important nature conservation targets can be justified: their species number proved to be relatively high, despite the small study quadrates used (Table 1). Moreover, this association hosted the largest number of protected and red-listed species (Table 1). Also, there were several species (Fig. 4), among them protected (Fig. 5) and red-listed (Fig. 6) plants that could not be found in the other three forest associations. Finally, the mosaic-like habitat with xeric grasslands increases spatial heterogeneity (e.g. Erdős et al., 2011), resulting in a high beta-diversity and representing a considerable landscape value. *Inulo spiraeifoliae-Quercetum pubescentis* stands of Mt Szársomlyó and Mt Fekete are protected. However, we would like to emphasize that the remaining stands also have a high conservation value. In particular, Mt Nagy seems to have a distinct group of relevés (Fig. 3), and certainly deserves the establishment of a new nature conservation area. Similarly, Borhidi and Sánta (1999) and Haraszthy (2014) suggested that all stands of this community should be protected legally.

Although *Inulo spiraeifoliae-Quercetum pubescentis* undoubtedly seems to be the most valuable thermophilous forest in the Villány Mts, our study has clearly shown that the other three associations are also of high conservation importance. Thermophilous forests are syntaxonomically related and have a large number of common species, but even so, they have considerable structural and compositional differences (Fig. 2, Table 2). There are several species, including protected (Fig. 5) and red-listed (Fig. 6) ones that do not occur in all thermophilous forest associations under study. This points out that focusing on one or two associations will not be enough; instead, representatives from all associations may be regarded as being valuable candidates for nature conservation activities.

Tamo-Quercetum virgilianae proved to be especially valuable (Table 2, Figs. 5 and 6), emphasizing that its stands have a top conservation priority. This community is also important because of its natural openings occupied by xeric steppe grassland fragments. These have been shown to host extremely high plant diversity (Dénes, 1997), suggesting that the heterogeneous mosaic has an especially high nature conservation value. This conclusion is in good agreement with the evaluation of the conservation importance of Hungarian plant communities by Borhidi and Sánta (1999) and Haraszthy (2014).

Regarding *Aconito anthorae-Fraxinetum orni*, it seems that its composition varies according to stand location (Fig. 3a), meaning that in order to represent the full compositional range, stands from all localities should be protected, if possible. Similarly, Kevey and Borhidi (1998) and Borhidi and Sánta (1999) emphasized the uniqueness and conservation value of this association.

Potentillo micranthae-Quercetum dalechampii proved to have the lowest species number, and had the fewest protected and red-listed species (Table 1). Also, the uniqueness of this community seemed to be rather low, since most of their species-pool (Fig. 4), protected (Fig. 5) and red-listed (Fig. 6) species could be found in other associations as well. *Potentillo micranthae-Quercetum dalechampii* is not regarded as a threatened association by Borhidi and Sánta (1999), but Haraszthy (2014) points out that even so, only certain forest management practices are acceptable, and clear-cutting should be avoided. Our analysis suggests that at least two types of the *Potentillo micranthae-Quercetum dalechampii* should be preserved: as the stands of the Kecskeháti-forest, Siklósi-valley and Luca-karéj form a group that is rather distinct from the stands of Mt Csukma (Fig. 3c), representatives from both groups should be preserved.

The present study showed that the proportion of species with a Mediterranean character is relatively high in all four associations (Fig. 7): in most cases, it is well above 20%, occasionally exceeding 40%. In similar forest communities of the Transdanubian Mountain Ranges and the North Hungarian Mountain Ranges, the proportion of Meditearranean and sub-Mediterranean elements is generally lower (e.g. Fekete and Jakucs, 1968; Isépy, 1970). It has been observed by Jakucs (1961) that Balcanic and Mediterranean, sub-Mediterranean influences are very strong in the Mecsek Mts, situated in the south of Hungary, about 40 km north of the Villány Mts.

Mediterranean influence seemed to be the most pronounced in the *Tamo-Quercetum virgilianae* stands, somewhat smaller in the *Potentillo micranthae-Quercetum dalechampii* and the *Inulo spiraeifoliae-Quercetum pubecentis*, and the lowest in the case of *Aconito anthorae-Fraxinetum orni* (Fig. 7). Earlier studies in the nearby Mecsek Mts and the surrounding hilly regions indicated that either *Tamo-Quercetum virgilianae* (Horvát, 1970), or *Inulo spiraeifoliae-Quercetum pubescentis* (Horvát, 1960) showed the most prominent Mediterranean influence.

At present, large areas of Mt Szársomlyó and Mt Fekete are under legal protection. Our study indicates that other parts of the Villány Mts should also be put under protection. It is desirable to establish nature conservation areas in all study sites analyzed in this study. If this is not possible, then new protected areas should be designated so as to conserve the highest possible diversity. We think that Mt Tenkes and Mt Csukma are the most promising candidates for this, since both of them host representatives of all four thermophilous forest associations under study. In addition, Mt Nagy should also be protected, because of its *Inulo spiraeifoliae-Quercetum pubescentis* stands. Clear-cutting should be avoided even in non-protected thermophilous forests of the Villány Mts.

Acknowledgements

This work was supported by the Hungarian Eötvös Scholarship of the Hungarian Scholarship Board.

References

Ambrózy, P., Kozma, F., 1990. Éghajlat, Villányi-hegység (Climate of the Villány Mts). In: Marosi, S., Somogyi S., (eds.): Magyarország kistájainak katasztere II (Cadaster of the basic landscape units of Hungary II). MTA Földrajztudományi Kutató Intézet, Budapest, pp. 576–577.

Bátori, Z., Csiky, J., Erdős, L., Morschhauser, T., Török, P., Körmöczi, L., 2009. Vegetation of the dolines in Mecsek Mountains (South Hungary) in relation to the local plant communities. Acta Carsologica 38, 237-252.

Borhidi, A., Kevey, B., 1996. An annotated checklist of the Hungarian plant communities II. The forest vegetation. In: Borhidi, A., (ed.): Critical revision of the Hungarian plant communities. Janus Pannonius University, Pécs, pp. 95 - 138.

Borhidi, A., Kevey, B., Lendvai, G., 2012. Plant communities of Hungary. Akadémiai Kiadó, Budapest, 544 pp.

Borhidi, A., Sánta, A., (eds.) 1999. Vörös könyv Magyarország növénytársulásairól II (Red book of the Hungarian plant communities II). TermészetBúvár Alapítvány Kiadó, Budapest, 404 pp.

Butorac, B., Igić, R., Anačkov, G., Zlatković, B., Vukov, D., Boža, P., 2008. Orno-Cotino-Quercetum pubescentis ass. nova prov. on the slopes of Titel Hill (Serbia). Archives of Biological Sciences 60, 83-92.

Čarni, A., Košir, P., Karadžić, B., Matevski, V., Redžić, S., 2009. Thermophilous deciduous forests in Southeastern Europe. Plant Biosystems 143, 1-13.

Chytrý, M., 1997. Thermophilous oak forests in the Czech Republic: Syntaxonomical revision of the Quercetalia pubescenti-petraeae. Folia Geobotanica and Phytotaxonomica 32, 221-258.

Chytrý, M., Horák, J., 1997. Plant communities of the thermophilous oak forests in Moravia. Preslia 68, 193-240.

Debreczy, Zs., 1968. Der Flaumeichen-Hochwald (Orno-Quercetum pannonicum) des Balaton-Oberlandes (The hairy oak forests of the Balaton Uplands). Acta Botanica Hungarica 14, 261-280.

Debreczy, Zs., 1973. A balaton-felvidéki Péter-hegy és környéke cönológiai vizsgálata (Phytocoenological studies on Mt Péter and its surroundings in the Balaton Uplands). Veszprém Megyei Múzeumok Közleményei 12, 191-220.

Dénes, A., 1994. A Mecsek és a Villányi-hegység karsztbokorerdői (Oak scrubs of the Mecsek and the Villány Mts). A Janus Pannonius Múzeum Évkönyve 39, 5-31.

Dénes, A., 1997. Lejtősztyepprét tanulmányok a Villányi-hegységben (Slope steppe studies in the Villány Mts). Kitaibelia 2, 267-273.

Dénes, A., 2000. A Villányi-hegység flóra- és vegetációkutatásának története, eredményeinek összefoglalása, különös tekintettel a védett és ritka fajok előfordulására (History of the research on the flora and vegetation of the Villány Mountains, a summary of results, with special regard to the occurrence of rare and protected species). Dunántúli Dolgozatok Természettudományi Sorozat 10, 47-77.

Eggler, J., 1941. Flaumeichenbestände bei Graz (Hairy oak stands near Graz). Beihefte zum Botanischen Centralblatt 61, 261-316.

Ellenberg, H., 1988. Vegetation ecology of central Europe. 4th edition. Cambridge University Press, Cambridge, 731 pp.

Erdős, L., Gallé, R., Bátori, Z., Papp, M., Körmöczi, L., 2011. Properties of shrubforest edges: a case study from South Hungary. Central European Journal of Biology 6, 639-658.

Erdős, L., Méri, Á., Bátori, Z., Gallé, R., Körmöczi, L., 2012. North-south facing vegetation gradients in the Villány Mts: a case study on the population and the community level. Pakistan Journal of Botany 44, 927-932.

Erdős, L., Tölgyesi, Cs., Dénes, A., Darányi, N., Fodor, A., Bátori, Z., Tolnay, D., 2014a. 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.

Erdős, L., Zalatnai, M., Bátori, Z., Körmöczi, L., 2014b. Transitions between community complexes: a case study analysing gradients through mountain ridges in South Hungary. Acta Botanica Croatica 73, 63-77.

Fekete, G., Jakucs, P., 1968. Der xerotherme Eichenwald des Bükk-Gebirges (Corno-Quercetum) (The xerothermic oak forests of the Bükk Mts). Botanikai Közlemények 55, 59-67.

Fekete, G., Kovács, M., 1982. A fóti Somlyó vegetációja (Vegetation of Mt Somlyó near Fót). Botanikai Közlemények 69, 19-31.

Fodor, I., 1977. Levegő hőmérséklet, Villányi-hegység (Air temperature of the Villány Mts). In: Lovász, Gy., (ed.): Baranya megye természeti földrajza (Physical geography of Baranya county). Baranya Megyei Levéltár, Pécs, pp. 118-135.

Förster, M., 1979. Gesellschaften der xerothermen Eichenmischwälder des deutschen Mittelgebirgsraumes (Plant communities of the xerothermic mixed oak forests in the German low mountain ranges). Phytocoenologia 5, 367-446.

Haraszthy, L., (ed.) 2014. Natura 2000 fajok és élőhelyek Magyarországon (Natura 2000 species and habitats in Hungary). Pro Vértes Közalapítvány, Csákvár, 955 pp.

Horvát, A.O., 1960. Mecseki erdőtípus-tanulmányok (Studies on the forest-types in the Mecsek Mts). A Janus Pannonius Múzeum Évkönyve 5, 39-52.

Horvát, A.O., 1969. Die Flaumeichenwälder des Mecsek-Gebirges (The hairy oak forests of the Mecsek Mts). Vegetatio 19, 256-263.

Horvát, A.O., 1970. Über mediterran-mitteleuropäische Beziehungen in der Flora und Vegetation des Mecsek-Gebirges in Südungarn (On the mediterranean-central-European connections of the flora and vegetation of the Mecsek Mts, southern Hungary). Feddes Repertorium 81, 261-268.

Horvát, A.O., 1972. Die Vegetation des Mecsekgebirges und seiner Umgebung (Vegetation of the Mecsek Mts and its surroundings). Akadémiai Kiadó, Budapest, 376 pp.

Horváth, F., Dobolyi, Z.K., Morschhauser, T., Lőkös, L., Karas, L., Szerdahelyi, T., 1995. FLÓRA adatbázis 1.2 (FLORA database version 1.2). MTA ÖBKI, Vácrátót, 267 pp.

Horvat, I., Glavač, V., Ellenberg, H., 1974. Vegetation Südosteuropas (The vegetation of southeastern Europe). Gustav Fischer Verlag, Stuttgart, 768 pp.

Isépy, I., 1970. Phytozönologische Untersuchungen und Vegetationskartierung im südöstlichen Vértes-Gebirge (Phytocoenological studies and vegetation mapping in the southeastern Vértes Mts). Acta Botanica Hungarica 16, 59-110.

Jakucs, P., 1960. Nouveau classement cénologique des bois de chênes xérothermes (Quercetea pubescenti-petraeae cl. nova) de l'Europe (A new phytocoenological classification of European xerothermic oak forests). Acta Botanica Hungarica 6, 267-303.

Jakucs, P., 1961. Die Phytozönologischen Verhältnisse der Flaumeichen-Buschwälder Südostmitteleuropas (Phytocoenological connections of the hairy oak forests in southeastern Europe). Akadémia Kiadó, Budapest, 314 pp.

Jakucs, P., 1972. Dynamische Verbindung der Wälder und Rasen (Dynamic connections between forests and grasslands). Akadémiai Kiadó, Budapest, 227 pp.

Jakucs, P., Fekete, G., 1957. Der Karstbuschwald des Nordöstlichen Ungarischen Mittelgebirges (Quercus pubescens-Prunus mahaleb nova ass.) (The carstic oak scrub of the North Hungarian Mountain Ranges). Acta Botanica Hungarica 3, 253-259.

Kevey, B., 2008. Magyarország erdőtársulásai (The forest associations of Hungary). Tilia 14, 1-488.

Kevey, B., 2012. A Villányi-hegység molyhos-tölgyesei (The hairy oak forests of the Villány Mts). Acta Naturalia Pannonica 4, 35-58.

Kevey, B., Borhidi, A., 1998. Top-forest (Aconito anthorae-Fraxinetum oni), a special ecotonal case in the phytosociological system (Mecsek Mts, South Hungary). Acta Botanica Hungarica 41, 27-121.

Király, G., (ed.) 2007. Vörös Lista. A magyarországi edényes flóra veszélyeztetett fajai (Red list of the vascular flora of Hungary). Saját kiadás, Sopron, 73 pp.

Lovász, Gy., 1977. Geomorfológiai körzetek (Geomorphological regions). In: Lovász, Gy., (ed.): Baranya megye természeti földrajza (Physical geography of Baranya county). Baranya Megyei Levéltár, Pécs, pp. 43-93.

Pipenbaher, N., Kaligarič, M., Škornik, S., 2011. Floristic and functional comparison of karst pastures and karst meadows from the North Adriatic Karst. Acta Carsologica 40, 515-525.

Podani, J., 2001. SYN-TAX 2000, computer programs for data analysis in ecology and systematics. User's manual. Scientia Kiadó, Budapest, 53 pp.

Redžić, S., Barudanović, S., Trakić, S., Kulijer, D., 2011. Vascular plant biodiversity richness and endemo-relictness of the karst mountains Prenj–Čvrsnica–Čabulja in Bosnia and Herzegovina (W. Balkan). Acta Carsologica 40, 527-555.

Roleček, J., 2007. Formalized classification of thermophilous oak forests in the Czech Republic: what brings the Cocktail method? Preslia 79, 1-21.

Rühl, A., 1954. Ein Beitrag zur Kenntnis der Trockenwälder und Wärmeliebenden Waldgesellschaften Süddeutschlands (A contribution to the knowledge on the xeric and thermophilous forest communities of southern Germany). Angewandte Pflanzensoziologie (Sonderfolge) 1, 423-436.

Simon, T., 2000. A magyarországi edényes flóra határozója (Key to the vascular plants of the Hungarain flora). Nemzeti Tankönyvkiadó, Budapest, 846 pp.

Tichý, L., 2002. JUICE, software for vegetation classification. Journal of Vegetation Science 13, 451-453.

Tichý, L., Chytrý, M., 2006. Statistical determination of diagnostic species for site groups of unequal size. Journal of Vegetation Science 17, 809-818.

Wallnöfer, S., 2003. Thermophile Eichenwaldgesellschaften im Osten Österreichs (Thermophilous oak forest communities in eastern Austria). Verhandlungen der Zoologisch-Botanischen Gesellschaft in Österreich 140, 1-16.

Willner, W., Starlinger, F., Grabherr, G., 2005. Deciduous oak forests in Austria – preliminary results from a new survey of the Austrian forest communities. Botanika Chronika 18, 301-316.