Formalized classification of thermophilous oak forests in the Czech Republic: what brings the Cocktail method?

Formalizovaná klasifikace vegetace teplomilných doubrav v České republice: co přináší metoda Cocktail?

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A formalized classification of Czech thermophilous oak forest vegetation is presented. It is based on the Cocktail algorithm, including the formulation of a set of explicit definitions of vegetation units that are used for unequivocal assignment of relevés to defined vegetation types. Eight out of 10 traditionally distinguished associations of thermophilous oak forests were formally defined: Bohemian warm and dry oak forest (*Lathyro versicoloris-Quercetum pubescentis*), Moravian warm and dry oak forest (*Pruno mahaleb-Quercetum pubescentis*), dry-mesic oak forest on basic rocky substrates (*Corno-Quercetum*), dry-mesic oak forest on acidic substrates (*Sorbo torminalis-Quercetum*), Moravian dry oak forest on acidic substrates (*Genisto pilosae-Quercetum petraeae*), dry-mesic oak forest on heavy soils (*Potentillo albae-Quercetum*), dry-mesic oak forest on sandy soils (*Carici fritschii-Quercetum roboris*) and dry oak forest on loess (*Quercetum pubescenti-roboris*). The specific features of Cocktail classifications are discussed. The complementarity of the traditional, imperfectly formalized classifications and modern formalized classifications is stressed.

Keywords: methodology, vegetation survey, phytosociology, *Quercetalia pubescenti-petraeae, Quercus*, syntaxonomy

Introduction

The traditional phytosociological approaches to vegetation description and classification are frequently criticized, both by opponents in other fields of plant ecology and phytosociologists themselves (Gleason 1933, Egler 1954, Gams 1954, Krahulec & Lepš 1989, Wiegleb 1989, Lepš & Hadincová 1992, Ewald 2003, Hédl 2005). Their objections focus on the phytosociological concept of community, sampling error, representativeness of phytosociological data, non-transparency of the classification process, etc. This criticism resulted in progressive phytosociologists attempting to develop new methods of vegetation classification, which eliminated some of the shortcomings pointed out previously. One of the latest and increasingly used classification approaches is Cocktail (Bruelheide 1995, 2000). The method is based on a formulation of a set of explicit definitions of vegetation units that are used to unequivocally assign relevés to defined vegetation types.

The aim of this paper is to test the ability of the Cocktail method to reproduce the traditional classification of Czech thermophilous oak forests and to discuss the basic features of the new Cocktail classification. Until now, the authors who compared traditional phytosociological and Cocktail classifications (Bruelheide 1995, Jandt 1999, Kočí et al. 2003, Lososová 2004, Hájková et al. 2006, Havlová 2006) focused on the description of newly defined vegetation types. Surprisingly, the general properties of Cocktail classifications and their fundamental differences from the traditional classifications have been rarely discussed. Since Cocktail has been used as the main classification method in the new vegetation survey of the Czech Republic, prepared within the project Vegetation of the Czech Republic (Chytrý 2007) and in the expert system designated for unsupervised assignment of relevés to syntaxa of this survey, I believe it is useful to present the guidance on how to interpret Cocktail classifications.

Material and methods

All the analyses were performed on a geographically and ecologically stratified data set of 21,794 relevés from the Czech National Phytosociological Database (Chytrý & Rafajová 2003), standardly used within the project Vegetation of the Czech Republic. The stratified resampling of the database, using the information on the geographical distribution of relevés, was necessary because of the uneven distribution of relevés across the Czech Republic (Knollová et al. 2005). A geographical grid used for the Central European flora and fauna mapping was implemented, each quadrate being further divided into 8 × 8 quadrates (each 1.25 longitudinal × 0.75 latitudinal minute, i.e. approximately 1.5 × 1.4 km). One relevé per quadrat per association (as indicated by the author of the relevé) was then selected, with a preference for more recent relevés and relevés with the moss layer composition recorded. In the resulting data set of 21,794 relevés, the records of juvenile trees and shrubs were deleted, as they were not recorded by all authors. The multiple records of species in different layers were lumped, so that each species has a single identity in the whole dataset. The records of mosses, lichens and macroscopic algae were kept, though not recorded in all relevés, as they are necessary for the meaningful classification of some vegetation types, e.g. mires (Chytrý 2007).

From this data set, a study set of 419 relevés of thermophilous oak forests was compiled, including all relevés assigned to the *Quercetalia pubescenti-petraeae* order by their authors. This subjective delimitation of the data set kept it within the methodology of the project Vegetation of the Czech Republic, which aims to follow the phytosociological tradition for pragmatic reasons. More formal delimitation of the study data would result in an analysis that is likely to yield rather speculative conclusions with respect to the evaluation of the procedure adopted in the new Czech vegetation survey.

In the first step of the classification, I confronted the traditional classification of Czech thermophilous oak forests (Chytrý 1997) with the results of several numerical analyses of the data set (ordinations, cluster analysis) to check the validity of the traditional associations. For those associations that were found to be meaningful (i.e. mainly ecologically interpretable, unique and broad enough), formal Cocktail definitions (Bruelheide 1995, 1997, 2000, Kočí et al. 2003) were formulated using JUICE software (Tichý 2002).

The Cocktail definitions are based on sociological species groups. Species groups consist of species with high fidelity, i.e. with a strong tendency to occur together. The fidelity was quantified using the phi coefficient (Sokal & Rohlf 1995, Chytrý et al. 2002). This coefficient ranges from –1 to +1, where values between 0 and +1 indicate a positive association between the species, values between 0 and –1 indicate a negative association, and 0 indicates independent occurrence of both species. Then, species with high fidelity were manually assembled into groups of usually three to five species. Such a low number of species was used to receive groups that are ecologically homogeneous.

In the next step, formal definitions of associations were created by combining the species groups with the logical operators AND, OR and NOT.

Example: *Potentillo albae-Quercetum* = Group Serratula tinctoria AND Group Lathyrus niger NOT Group Lithospermum purpurocaeruleum

The species groups include the following species:
Group Serratula tinctoria: *Betonica officinalis*, *Galium boreale* subsp. *boreale*, *Potentilla alba*, *Serratula tinctoria*
Group Lathyrus niger: *Carex montana*, *Festuca heterophylla*, *Lathyrus niger*, *Melittis melissophyllum*
Group Lithospermum purpurocaeruleum: *Cornus mas*, *Ligustrum vulgare*, *Lithospermum purpurocaeruleum*, *Quercus pubescens*

In words: The relevé is classified within the *Potentillo albae-Quercetum* association when it contains at least the threshold number of species from the groups Serratula tinctoria and Lathyrus niger, and when it contains less than the threshold number of species from the group Lithospermum purpurocaeruleum. The threshold number may be set arbitrarily; within the project Vegetation of the Czech Republic, one half of the number of group members is used as the threshold.

Then, the relevés satisfying the formal definition of the association were compared with the relevés traditionally assigned to it. The traditional assignment was derived from the original indication by the authors of the relevés that are stored in the header field "Syntaxon code" in the Czech National Phytosociological Database. In particular the ecological sense and the geographical distribution of both relevé groups were confronted. When they did not correspond, the definition was modified. The goal was to find the best fitting, but not too complicated definition.

After formulating the definitions of all associations, all relevés of the *Quercetalia pubescenti-petraeae* order were classified. For those few relevés that matched several definitions, the frequency-positive fidelity index (FPFI) was calculated. The FPFI compares the similarity of the species composition of a selected relevé and a group of relevés, upweighting the diagnostic species of the relevé group (Tichý 2005). The relevés were assigned to the group of relevés (i.e. the association) to which it showed the highest value of FPFI. The relevés that did not match any definition were once more explored using cluster analysis to check whether any coherent group, ecologically different from the already defined associations, emerged. As this did not happen, these relevés were excluded from the analysis (but see Discussion for other possible approach to unclassified relevés). A synoptic table was created and diagnostic species of the defined associations were determined using the fidelity calculation within JUICE software. As a measure of fidelity, the phi-coefficient standardized to group size equalling 15 percent of the total data set (Tichý & Chytrý 2006) was used and species with phi values higher than 0.25 and Fisher's exact test significance lower than 0.05 were designated as diagnostic. The Fisher's exact test was used to exclude rare species that could become diagnostic by chance.

Because this paper is focused on methodological questions, the description of the newly defined associations is rather brief. The important part of the description is a comparison of the traditional and the new formal delimitation of the associations. Their relationship is illustrated by a series of scatter plots, showing the position of the traditional and formal associations in the two-dimensional space of detrended correspondence analysis, performed using CANOCO software (ter Braak & Šmilauer 2002). The total numbers of relevés in the two scatter plots differ, as only relevés classified to the association level are shown; the number of relevés classified to association level is considerably lower in the Cocktail than in the traditional classification.

The nomenclature of plant species, including species aggregates denoted with the abbreviation “agg.”, follows Kubát et al. (2002). The delimitation of other species aggregates denoted with the abbreviation “s. lat.” follows the concept adopted within the new vegetation survey of the Czech Republic (Chytrý 2007). The nomenclature of syntaxa follows Chytrý (1997). For more detailed explanation of the principles of the Cocktail method see Bruelheide (1995, 1997, 2000), Kočí et al. (2003) and Chytrý (2007).

Results

Out of 10 vegetation types (nine associations and one community without rank) of thermophilous oak forests distinguished traditionally (Chytrý 1997), eight were found to be well-founded based on relevés and were defined formally using Cocktail definitions. The diagnostic and most frequent species of these eight associations are presented in Table 1. The composition of species groups used for definitions is presented in Table 2. Out of the 419 relevés involved in the analysis, 156 were assigned to some of the eight associations. Seven relevés were assigned to more than one association and were finally classified using the frequency-positive fidelity index. The *Asplenio cuneifolii-Quercetum petraeae* association and *Brachypodium pinnatum-Quercus robur* community could not be defined, as most relevés of both vegetation types represent vegetation dominated by *Pinus sylvestris* plantations and thus were not considered as oak forests.

Table 1. – Frequency table of Czech thermophilous oak forest associations defined formally. The numbers given in the table are percentage values of species frequency. Their upper indices are the fidelity value of a species for a particular vegetation type, expressed using the phi coefficient × 100; dashes mean negative phi values. Diagnostic species (D.S., phi-coefficient value higher than 0.25, Fisher’s exact test $P < 0.05$) are in bold on a grey background. Other abundant species are ranked by the sum of frequencies. LvQ – *Lathyro versicoloris-Quercetum*, PmQ – *Pruno mahaleb-Quercetum*, CQ – *Corno-Quercetum*, StQ – *Sorbo torminalis-Quercetum*, GpQ – *Genisto pilosae-Quercetum*, PaQ – *Potentillo albae-Quercetum*, CfQ – *Carici fritschii-Quercetum*, Qpr – *Quercetum pubescenti-roboris*.

Group No.	1	2	3	4	5	6	7	8
Vegetation type	LvQ	PmQ	CQ	StQ	GpQ	PaQ	CfQ	Qpr
No. of relevés	10	10	22	44	18	43	5	4
D.S. *Lathyro versicoloris-Quercetum*								
Cotoneaster integerrimus	**90**$^{75.3}$	10^{-}	18^{-}	5^{-}	6^{-}	2^{-}	.	.
Lathyrus pannonicus	**60**$^{64.6}$	10^{-}	5^{-}	.	.	2^{-}	.	.
Thlaspi montanum	**40**$^{56.8}$	.	5^{-}	.	.	.	.	.
Lotus corniculatus	**70**$^{56.3}$	40^{-}	9^{-}	7^{-}	.	.	.	.
Campanula trachelium	**60**$^{46.2}$	10^{-}	32^{-}	7^{-}	.	16^{-}	.	.
Sorbus aria s. lat.	**50**$^{44.6}$	20^{-}	5^{-}	5^{-}	11^{-}	5^{-}	.	.
Centaurea triumfettii	**40**$^{44.1}$	.	.	.	.	.	.	25^{-}
Silene nemoralis	**30**$^{44.0}$	.	9^{-}	.	.	.	.	.
Sesleria caerulea	**30**$^{43.4}$	10^{-}	.	.	.	.	.	.
Anthyllis vulneraria	**20**$^{42.4}$	.	.	.	.	.	.	.
Helianthemum grandiflorum	**40**$^{39.0}$	30^{-}	5^{-}	.	.	2^{-}	.	.
Clematis recta	**40**$^{38.8}$	10^{-}	18^{-}	2^{-}	.	7^{-}	.	.
Verbascum lychnitis	**30**$^{38.1}$	.	14^{-}	2^{-}	.	2^{-}	.	.

Group No.	1	2	3	4	5	6	7	8
Vegetation type	LvQ	PmQ	CQ	StQ	GpQ	PaQ	CfQ	Qpr
No. of relevés	10	10	22	44	18	43	5	4
Securigera varia	**70** $^{37.2}$	40 $^{-}$	32 $^{-}$	14 $^{-}$	.	7 $^{-}$	.	50 $^{-}$
Arabis hirsuta agg.	**40** $^{36.3}$	10 $^{-}$	9 $^{-}$	.	.	.	.	25 $^{-}$
Viola hirta	**80** $^{35.2}$	60 $^{-}$	59 $^{18.6}$	2 $^{-}$	.	33 $^{-}$	.	50 $^{-}$
Astragalus glycyphyllos	**70** $^{34.6}$	30 $^{-}$	27 $^{-}$	16 $^{-}$	.	21 $^{-}$	40 $^{-}$	25 $^{-}$
Pyrethrum corymbosum	**100** $^{34.2}$	90 $^{-}$	73 $^{-}$	61 $^{-}$	17 $^{-}$	74 $^{-}$	.	25 $^{-}$
Fraxinus excelsior	**60** $^{33.3}$	30 $^{-}$	36 $^{12.1}$	.	.	7 $^{-}$	.	50 $^{-}$
Poa pratensis s. lat.	**70** $^{32.4}$	40 $^{-}$	32 $^{-}$	14 $^{-}$	28 $^{-}$	21 $^{-}$	40 $^{-}$	.
D.S. *Pruno mahaleb-Quercetum*								
Aster amellus	20 $^{-}$	**100** $^{88.0}$	5 $^{-}$	.	.	.	.	.
Inula ensifolia	.	**100** $^{87.8}$	.	.	.	.	.	25 $^{-}$
Dorycnium pentaphyllum s. lat.	.	**60** $^{75.3}$	.	.	.	.	.	.
Elytrigia repens	.	**40** $^{60.7}$	.	.	.	.	.	.
Epipactis helleborine s. lat.	.	**40** $^{55.0}$	5 $^{-}$	2 $^{-}$	.	.	.	.
Adonis vernalis	.	**50** $^{52.7}$	.	.	.	.	.	25 $^{-}$
Stachys recta	20 $^{-}$	**60** $^{52.5}$	.	.	.	.	.	25 $^{-}$
Iris pumila	.	**30** $^{52.2}$	.	.	.	.	.	.
Pseudolysimachion spicatum	.	**30** $^{52.2}$	.	.	.	.	.	.
Peucedanum cervaria	.	**70** $^{44.0}$	23 $^{-}$	7 $^{-}$	.	30 $^{-}$	20 $^{-}$	25 $^{-}$
Potentilla patula	.	**20** $^{42.4}$	.	.	.	.	.	.
Erysimum durum s. lat.	.	**20** $^{42.4}$	.	.	.	.	.	.
Bothriochloa ischaemum	.	**20** $^{42.4}$	.	.	.	.	.	.
Polygala major	.	**20** $^{42.4}$	.	.	.	.	.	.
Inula ×stricta	.	**20** $^{42.4}$	.	.	.	.	.	.
Prunus fruticosa	.	**20** $^{42.4}$	.	.	.	.	.	.
Campanula bononiensis	10 $^{-}$	**40** $^{35.6}$	9 $^{-}$	2 $^{-}$	.	.	.	25 $^{-}$
Inula hirta	30 $^{-}$	**40** $^{32.2}$	.	.	.	2 $^{-}$	.	25 $^{-}$
Bupleurum falcatum	60 $^{-}$	**80** $^{31.2}$	45 $^{-}$	18 $^{-}$	17 $^{-}$	7 $^{-}$	40 $^{-}$	50 $^{-}$
Stipa capillata	10 $^{-}$	**30** $^{30.3}$	.	.	.	.	.	25 $^{-}$
Euphorbia epithymoides	.	**40** $^{26.6}$	27 $^{13.1}$	.	.	2 $^{-}$	.	50 $^{-}$
Festuca rupicola	10 $^{-}$	**50** $^{26.4}$	36 $^{13.8}$	5 $^{-}$	.	.	20 $^{-}$	50 $^{-}$
Inula salicina	.	**40** $^{25.6}$	5 $^{-}$	.	.	9 $^{-}$	20 $^{-}$	50 $^{-}$
Crataegus monogyna s. lat.	30 $^{-}$	**60** $^{25.3}$	41 $^{-}$	11 $^{-}$	.	19 $^{-}$	.	75 $^{-}$
D.S. *Corno-Quercetum*								
Alliaria petiolata	10 $^{-}$	.	**50** $^{40.5}$	9 $^{-}$	11 $^{-}$	2 $^{-}$	.	25 $^{-}$
Torilis japonica	.	.	**23** $^{36.2}$	7 $^{-}$	.	2 $^{-}$	.	.
Rhamnus cathartica	10 $^{-}$	20 $^{-}$	**32** $^{30.4}$	.	.	9 $^{-}$	.	.
Acer campestre	50 $^{-}$	50 $^{-}$	**68** $^{29.4}$	9 $^{-}$	.	28 $^{-}$	.	50 $^{-}$
Hepatica nobilis	60 $^{-}$	.	**50** $^{28.2}$	5 $^{-}$	.	47 $^{24.9}$	.	.
Viola mirabilis	.	30 $^{-}$	**27** $^{25.1}$	.	.	12 $^{-}$	.	.
D.S. *Sorbo torminalis-Quercetum*								
Digitalis grandiflora	.	.	5 $^{-}$	**34** $^{47.9}$	.	5 $^{-}$	.	.
Luzula luzuloides	.	.	5 $^{-}$	**61** $^{44.3}$	39 $^{-}$	33 $^{-}$	.	.
Hieracium murorum	20 $^{-}$	10 $^{-}$	5 $^{-}$	**68** $^{42.1}$	22 $^{-}$	51 $^{-}$	.	.
Hylotelephium telephium agg.	10 $^{-}$	30 $^{-}$	41 $^{-}$	**75** $^{37.6}$	44 $^{-}$	12 $^{-}$	.	25 $^{-}$
Silene nutans	30 $^{-}$	40 $^{-}$	9 $^{-}$	**73** $^{35.2}$	11 $^{-}$	37 $^{-}$	40 $^{-}$	.
Veronica officinalis	.	.	.	**48** $^{33.2}$	28 $^{-}$	30 $^{-}$	20 $^{-}$	.
Poa nemoralis	20 $^{-}$	30 $^{-}$	55 $^{-}$	**91** $^{33.2}$	61 $^{-}$	70 $^{-}$	.	50 $^{-}$
Mycelis muralis	.	.	9 $^{-}$	**20** $^{30.2}$	.	5 $^{-}$	.	.
Quercus petraea agg.	40 $^{-}$	30 $^{-}$	77 $^{-}$	**98** $^{28.8}$	100 $^{-}$	88 $^{-}$	.	50 $^{-}$

Group No.	1	2	3	4	5	6	7	8
Vegetation type	LvQ	PmQ	CQ	StQ	GpQ	PaQ	CfQ	Qpr
No. of relevés	10	10	22	44	18	43	5	4
Hieracium sabaudum	.	20^{-}	9^{-}	**66** $^{28.8}$	50^{-}	56^{-}	20^{-}	25^{-}
Cardaminopsis arenosa	.	.	.	**14** $^{27.8}$	6^{-}	.	.	.
Hieracium maculatum	.	.	5^{-}	**18** $^{27.3}$	.	9^{-}	.	.
D.S. *Genisto pilosae-Quercetum*								
Linaria genistifolia	.	.	.	2^{-}	**94** $^{95.5}$	.	.	.
Genista pilosa	.	10^{-}	.	7^{-}	**94** $^{88.0}$	.	.	.
Rumex acetosella	.	.	.	5^{-}	**83** $^{87.4}$	.	.	.
Jasione montana	.	.	.	.	**78** $^{86.8}$	.	.	.
Hieracium pilosella	.	10^{-}	9^{-}	27^{-}	**94** $^{75.5}$	2^{-}	.	.
Festuca pallens	.	.	.	2^{-}	**56** $^{70.5}$	.	.	.
Scleranthus perennis	.	.	.	.	**50** $^{68.3}$	.	.	.
Agrostis vinealis	.	.	.	2^{-}	**39** $^{57.7}$	.	.	.
Sedum reflexum	.	.	.	11^{-}	**44** $^{55.6}$	.	.	.
Dianthus carthusianorum s. lat.	10^{-}	.	5^{-}	9^{-}	**44** $^{48.7}$	.	.	.
Allium flavum	.	.	.	.	**22** $^{44.7}$	.	.	.
Calluna vulgaris	.	.	5^{-}	2^{-}	**28** $^{40.0}$	5^{-}	.	.
Thesium linophyllon	.	.	.	2^{-}	**22** $^{39.6}$	2^{-}	.	.
Phleum phleoides	.	10^{-}	.	7^{-}	**28** $^{36.6}$	.	.	.
Verbascum chaixii	.	30^{-}	14^{-}	30^{-}	**50** $^{36.2}$	.	.	.
Loranthus europaeus	.	10^{-}	.	.	**22** $^{35.0}$	.	.	.
Thymus praecox	10^{-}	10^{-}	5^{-}	.	**28** $^{32.5}$	.	.	.
Sedum sexangulare	10^{-}	.	5^{-}	5^{-}	**22** $^{29.1}$	.	.	.
Hypericum perforatum	20^{-}	20^{-}	18^{-}	48^{-}	**72** $^{28.7}$	23^{-}	60^{-}	25^{-}
Asperula cynanchica	.	30^{-}	5^{-}	2^{-}	**28** $^{27.3}$	.	.	.
Koeleria macrantha	20^{-}	.	5^{-}	.	**22** $^{25.3}$	2^{-}	.	.
D.S. *Potentillo albae-Quercetum*								
Anemone nemorosa	.	.	.	2^{-}	.	**49** $^{65.6}$	.	.
Carex montana	30^{-}	10^{-}	32^{-}	18^{-}	.	**91** $^{56.2}$	.	25^{-}
Galium sylvaticum	10^{-}	.	14^{-}	9^{-}	.	**65** $^{52.2}$	.	25^{-}
Lathyrus niger	20^{-}	10^{-}	59^{-}	50^{-}	.	**86** $^{48.7}$	.	.
Rubus fruticosus agg.	.	.	9^{-}	5^{-}	.	**33** $^{43.4}$	.	.
Maianthemum bifolium	.	.	.	.	.	**21** $^{43.4}$	.	.
Serratula tinctoria	10^{-}	10^{-}	9^{-}	.	.	**77** $^{43.2}$	80^{-}	25^{-}
Potentilla alba	10^{-}	.	9^{-}	7^{-}	.	**67** $^{42.0}$	80^{-}	.
Viola riviniana	10^{-}	.	.	7^{-}	.	**30** $^{39.1}$	.	.
Melampyrum pratense	.	.	18^{-}	25^{-}	6^{-}	**65** $^{36.1}$	80^{-}	.
Frangula alnus	.	.	.	.	6^{-}	**40** $^{35.4}$	40^{-}	.
Rosa gallica	.	.	.	.	.	**14** $^{35.3}$	.	.
Melica nutans	40^{-}	30^{-}	50^{-}	16^{-}	6^{-}	**65** $^{33.9}$	.	.
Asarum europaeum	.	10^{-}	5^{-}	.	.	**23** $^{33.0}$	.	.
Corylus avellana	10^{-}	20^{-}	23^{-}	9^{-}	6^{-}	**44** $^{33.0}$	.	.
Festuca heterophylla	.	.	18^{-}	7^{-}	.	**44** $^{32.3}$	20^{-}	25^{-}
Lathyrus vernus	40^{-}	10^{-}	50^{-}	14^{-}	.	**53** $^{30.3}$	.	.
Lilium martagon	.	.	5^{-}	7^{-}	.	**19** $^{29.6}$	.	.
Melampyrum nemorosum	.	40^{-}	5^{-}	.	.	**33** $^{29.4}$	.	.
Luzula pilosa	.	.	.	.	.	**9** $^{28.7}$	.	.
Dianthus superbus	.	.	.	.	.	**9** $^{28.7}$	.	.
Platanthera bifolia	.	.	.	2^{-}	.	**12** $^{28.6}$	.	.
Vaccinium myrtillus	.	.	.	2^{-}	.	**12** $^{28.6}$	.	.

Group No.	1	2	3	4	5	6	7	8
Vegetation type	LvQ	PmQ	CQ	StQ	GpQ	PaQ	CfQ	Qpr
No. of relevés	10	10	22	44	18	43	5	4
Galium boreale subsp. *boreale*	.	.	.	.	.	**35** $^{26.9}$	60 $^{-}$	.
Betula pendula	.	.	.	2 $^{-}$	17 $^{-}$	**28** $^{26.7}$	20 $^{-}$	.
Potentilla erecta	.	.	.	.	.	**28** $^{26.3}$	40 $^{-}$	.
Fragaria vesca	20 $^{-}$	10 $^{-}$	18 $^{-}$	41 $^{-}$	6 $^{-}$	**53** $^{25.9}$	20 $^{-}$	25 $^{-}$
Ajuga reptans	.	.	5 $^{-}$	.	.	**35** $^{25.7}$	60 $^{-}$	.
D.S. *Carici fritschii-Quercetum*								
Carex fritschii	.	.	.	.	.	.	**80** $^{88.2}$	.
Vicia cassubica	.	.	.	2 $^{-}$	.	.	**80** $^{86.7}$	.
Quercus robur	.	10 $^{-}$	5 $^{-}$	.	.	26 $^{8.0}$	**100** $^{82.0}$	.
Valeriana stolonifera	.	.	.	.	.	.	**60** $^{75.3}$	.
Arrhenatherum elatius	.	10 $^{-}$	9 $^{-}$	5 $^{-}$	6 $^{-}$	5 $^{-}$	**80** $^{71.2}$	.
Peucedanum oreoselinum	.	.	5 $^{-}$	.	.	2 $^{-}$	**60** $^{70.5}$	.
Anthoxanthum odoratum s. lat.	.	.	.	5 $^{-}$	22 $^{-}$	14 $^{-}$	**80** $^{68.5}$	.
Vicia sepium	10 $^{-}$	.	.	2 $^{-}$	.	9 $^{-}$	**60** $^{62.2}$	.
Silene vulgaris	.	.	5 $^{-}$	20 $^{-}$	11 $^{-}$	.	**80** $^{61.8}$	25 $^{-}$
Stachys sylvatica	.	.	.	.	.	.	**40** $^{60.7}$	.
Stellaria graminea	.	.	.	.	.	.	**40** $^{60.7}$	.
Cerastium arvense	.	.	.	.	.	.	**40** $^{60.7}$	.
Lysimachia vulgaris	.	.	.	.	.	.	**40** $^{60.7}$	.
Carex brizoides	.	.	.	.	.	.	**40** $^{60.7}$	.
Succisa pratensis	.	.	.	.	.	2 $^{-}$	**40** $^{58.6}$	.
Laserpitium prutenicum	.	.	.	.	.	2 $^{-}$	**40** $^{58.6}$	.
Ranunculus polyanthemos	.	20 $^{-}$	.	2 $^{-}$	.	9 $^{-}$	**60** $^{57.6}$	.
Viola reichenbachiana	.	.	5 $^{-}$	5 $^{-}$	.	23 $^{13.9}$	**60** $^{57.3}$	.
Platanthera chlorantha	.	.	.	2 $^{-}$	.	2 $^{-}$	**40** $^{56.7}$	.
Briza media	.	.	.	.	.	5 $^{-}$	**40** $^{56.7}$	.
Dactylis glomerata	.	30 $^{-}$	32 $^{-}$	16 $^{-}$	6 $^{-}$	21 $^{-}$	**100** $^{55.4}$	50 $^{-}$
Molinia caerulea s. lat.	.	10 $^{-}$	5 $^{-}$	2 $^{-}$	.	21 $^{10.1}$	**60** $^{55.1}$	.
Carex pallescens	.	.	.	.	.	7 $^{-}$	**40** $^{54.9}$	.
Achillea millefolium agg.	20 $^{-}$	30 $^{-}$	18 $^{-}$	9 $^{-}$	17 $^{-}$	12 $^{-}$	**80** $^{46.1}$	25 $^{-}$
Convallaria majalis	.	40 $^{-}$	23 $^{-}$	25 $^{-}$	.	60 $^{12.9}$	**100** $^{43.1}$	100 $^{-}$
D.S. *Quercetum pubescenti-roboris*								
Phlomis tuberosa	.	.	.	.	.	.	.	**50** $^{68.3}$
Anemone ranunculoides	.	.	.	.	.	2 $^{-}$	.	**50** $^{66.4}$
Carex michelii	10 $^{-}$	50 $^{21.7}$	32 $^{-}$	7 $^{-}$	.	2 $^{-}$	.	**100** $^{65.3}$
Euonymus verrucosa	.	20 $^{-}$	18 $^{-}$	2 $^{-}$	.	2 $^{-}$	.	**75** $^{64.3}$
Iris variegata	.	20 $^{-}$	.	.	.	.	40 $^{-}$	**75** $^{58.7}$
Diagnostic species common for two vegetation types								
Galium glaucum	**50** $^{36.7}$	**50** $^{36.7}$	9 $^{-}$	5 $^{-}$	6 $^{-}$	2 $^{-}$	.	.
Cornus mas	**80** $^{35.5}$	**90** $^{43.4}$	59 $^{18.9}$	2 $^{-}$	.	.	.	50 $^{-}$
Brachypodium pinnatum	**90** $^{34.8}$	**90** $^{34.8}$	27 $^{-}$	27 $^{-}$	6 $^{-}$	44 $^{-}$	20 $^{-}$	50 $^{-}$
Inula conyzae	**40** $^{32.6}$	**40** $^{32.6}$	9 $^{-}$	7 $^{-}$	.	.	.	.
Salvia pratensis	**50** $^{32.4}$	**60** $^{42.4}$	5 $^{-}$	.	.	.	.	25 $^{-}$
Teucrium chamaedrys	**80** $^{30.1}$	**80** $^{30.1}$	23 $^{-}$	16 $^{-}$	33 $^{-}$	5 $^{-}$	40 $^{-}$	50 $^{-}$
Ligustrum vulgare	**90** $^{29.9}$	**90** $^{29.9}$	73 $^{16.8}$	11 $^{-}$	6 $^{-}$	14 $^{-}$	20 $^{-}$	100 $^{-}$
Dictamnus albus	**70** $^{29.1}$	**90** $^{45.1}$	27 $^{-}$	5 $^{-}$	.	2 $^{-}$	.	75 $^{-}$
Carex humilis	**70** $^{26.1}$	**80** $^{33.9}$	9 $^{-}$	16 $^{-}$	67 $^{23.5}$	2 $^{-}$	.	50 $^{-}$
Cornus sanguinea	**70** $^{31.2}$	30 $^{-}$	**64** $^{26.0}$	5 $^{-}$	.	35 $^{-}$	.	50 $^{-}$
Asperula tinctoria	**100** $^{73.0}$	.	5 $^{-}$	2 $^{-}$	.	2 $^{-}$	**60** $^{36.0}$	.

Group No.	1	2	3	4	5	6	7	8
Vegetation type	LvQ	PmQ	CQ	StQ	GpQ	PaQ	CfQ	Qpr
No. of relevés	10	10	22	44	18	43	5	4
Melampyrum cristatum	**60**$^{31.9}$	30^{-}	9^{-}	.	6^{-}	2^{-}	**60**$^{31.9}$	25^{-}
Lithospermum purpurocaeruleum	40^{-}	**70**$^{29.4}$	**77**$^{35.2}$	2^{-}	.	2^{-}	.	75^{-}
Geranium sanguineum	30^{-}	**80**$^{36.2}$	.	9^{-}	.	7^{-}	**100**$^{52.1}$	50^{-}
Viburnum lantana	10^{-}	**50**$^{31.9}$	5^{-}	.	.	2^{-}	.	**75**$^{56.7}$
Lychnis viscaria	.	.	.	**68**$^{40.1}$	**89**$^{58.6}$	9^{-}	20^{-}	.
Festuca ovina	20^{-}	10^{-}	5^{-}	**80**$^{26.7}$	**100**$^{42.2}$	42^{-}	100^{-}	.
Luzula campestris agg.	.	.	5^{-}	18^{-}	**83**$^{51.4}$	12^{-}	**80**$^{48.4}$	.
Betonica officinalis	60^{-}	30^{-}	18^{-}	7^{-}	.	**86**$^{34.8}$	**100**$^{45.6}$	25^{-}
Diagnostic species common for three vegetation types								
Quercus pubescens	**90**$^{37.2}$	**90**$^{37.2}$	50$^{6.5}$	2^{-}	.	.	.	**100**$^{44.8}$
Other abundant species								
Vincetoxicum hirundinaria	30^{-}	80^{-}	41^{-}	89$^{21.0}$	67^{-}	12^{-}	100^{-}	75^{-}
Euphorbia cyparissias	70^{-}	80^{-}	41^{-}	66^{-}	67^{-}	19^{-}	60^{-}	50^{-}
Polygonatum odoratum	90^{-}	30^{-}	68^{-}	80$^{18.4}$	44^{-}	26^{-}	80^{-}	25^{-}
Anthericum ramosum	90^{-}	70^{-}	32^{-}	82$^{24.4}$	50^{-}	28^{-}	20^{-}	25^{-}
Veronica chamaedrys agg.	40^{-}	30^{-}	55^{-}	68^{-}	17^{-}	58^{-}	80^{-}	25^{-}
Trifolium alpestre	70^{-}	10^{-}	23^{-}	59$^{11.3}$	39^{-}	28^{-}	100^{-}	25^{-}
Clinopodium vulgare	40^{-}	50^{-}	50^{-}	41^{-}	.	35^{-}	80^{-}	50^{-}
Genista tinctoria	40^{-}	40^{-}	9^{-}	59$^{21.7}$	22^{-}	28^{-}	60^{-}	.
Campanula persicifolia	30^{-}	30^{-}	45^{-}	43^{-}	11^{-}	51^{-}	40^{-}	.
Fragaria moschata	30^{-}	30^{-}	18^{-}	14^{-}	.	40$^{10.0}$	40^{-}	50^{-}
Sorbus torminalis	50^{-}	60^{-}	50$^{19.7}$	11^{-}	.	19^{-}	.	25^{-}
Galium mollugo agg.	10^{-}	40^{-}	50$^{20.5}$	27^{-}	6^{-}	12^{-}	40^{-}	25^{-}
Carpinus betulus	50^{-}	20^{-}	36^{-}	41^{-}	11^{-}	42^{-}	.	.
Hieracium lachenalii	10^{-}	10^{-}	9^{-}	50^{-}	56^{-}	44^{-}	.	.
Melittis melissophyllum	20^{-}	30^{-}	36^{-}	7^{-}	.	35^{-}	.	50^{-}
Stellaria holostea	30^{-}	.	36^{-}	30^{-}	.	47$^{23.8}$	.	25^{-}
Ajuga genevensis	30^{-}	40^{-}	27^{-}	18^{-}	.	7^{-}	20^{-}	25^{-}
Primula veris	50^{-}	.	32^{-}	18^{-}	.	40$^{17.7}$	.	25^{-}
Rosa canina s. lat.	40^{-}	30^{-}	9^{-}	9^{-}	11^{-}	7^{-}	.	50^{-}
Campanula rapunculoides	50^{-}	.	36^{-}	20^{-}	.	23^{-}	.	25^{-}
Solidago virgaurea	10^{-}	40^{-}	5^{-}	11^{-}	6^{-}	35$^{16.2}$	40^{-}	.
Carex muricata agg.	30^{-}	10^{-}	36$^{17.8}$	7^{-}	6^{-}	7^{-}	.	50^{-}
Prunus spinosa	10^{-}	30^{-}	18^{-}	5^{-}	.	28$^{10.3}$	.	50^{-}
Origanum vulgare	30^{-}	40^{-}	9^{-}	25^{-}	11^{-}	.	.	25^{-}
Calamagrostis arundinacea	10^{-}	.	14^{-}	36^{-}	11^{-}	42$^{24.6}$	.	25^{-}
Cytisus nigricans	30^{-}	20^{-}	5^{-}	30^{-}	11^{-}	14^{-}	20^{-}	.
Pulmonaria officinalis s. lat.	.	30^{-}	9^{-}	5^{-}	.	35$^{19.4}$	.	50^{-}
Taraxacum sect. *Ruderalia*	30^{-}	40^{-}	18^{-}	5^{-}	.	9^{-}	20^{-}	.
Galium pumilum s. lat.	.	20^{-}	18^{-}	36$^{23.1}$	11^{-}	7^{-}	.	25^{-}
Geum urbanum	20^{-}	10^{-}	36$^{23.8}$	9^{-}	.	14^{-}	.	25^{-}
Veronica teucrium	20^{-}	30^{-}	9^{-}	2^{-}	.	2^{-}	.	50^{-}
Crataegus laevigata	10^{-}	10^{-}	18^{-}	5^{-}	.	28$^{15.4}$	40^{-}	.
Fragaria viridis	30^{-}	20^{-}	27^{-}	5^{-}	.	7^{-}	20^{-}	.
Campanula rotundifolia agg.	.	.	.	25^{-}	22^{-}	14^{-}	40^{-}	.
Melica uniflora	.	20^{-}	27^{-}	16^{-}	11^{-}	2^{-}	.	25^{-}

Table 2. – The composition of species groups used for the Cocktail definitions of Czech thermophilous oak forests.

Group	Species
Group Acer campestre	*Acer campestre*, *Cornus sanguinea*, *Crataegus laevigata*, *Ulmus minor*
Group Anthoxanthum odoratum	*Agrostis capillaris*, *Anthoxanthum odoratum* s. lat., *Festuca rubra* agg., *Luzula campestris* agg.
Group Asarum europaeum	*Asarum europaeum*, *Campanula trachelium*, *Polygonatum multiflorum*, *Pulmonaria officinalis* s. lat.
Group Geranium sanguineum	*Anthericum ramosum*, *Geranium sanguineum*, *Polygonatum odoratum*, *Vincetoxicum hirundinaria*
Group Hieracium sabaudum	*Hieracium lachenalii*, *H. murorum*, *H. sabaudum*, *Luzula luzuloides*, *Melampyrum pratense*
Group Inula ensifolia	*Aster amellus*, *Astragalus onobrychis*, *Dorycnium pentaphyllum* s. lat., *Inula ensifolia*
Group Iris variegata	*Carex michelii*, *Iris graminea*, *I. variegata*
Group Jasione montana	*Hieracium pilosella*, *Jasione montana*, *Rumex acetosella*
Group Lathyrus niger	*Carex montana*, *Festuca heterophylla*, *Lathyrus niger*, *Melittis melissophyllum*
Group Lathyrus pannonicus	*Asperula tinctoria*, *Lathyrus pannonicus*, *Melampyrum cristatum*, *Silene nemoralis*
Group Lathyrus vernus	*Galium sylvaticum*, *Hepatica nobilis*, *Lathyrus vernus*, *Melica nutans*
Group Linaria genistifolia	*Allium flavum*, *Genista pilosa*, *Linaria genistifolia*
Group Lithospermum purpurocaeruleum	*Cornus mas*, *Ligustrum vulgare*, *Lithospermum purpurocaeruleum*, *Quercus pubescens*
Group Lychnis viscaria	*Hylotelephium telephium* agg., *Lychnis viscaria*, *Silene nutans*
Group Serratula tinctoria	*Betonica officinalis*, *Galium boreale* subsp. *boreale*, *Potentilla alba*, *Serratula tinctoria*
Group Stachys recta	*Galium glaucum*, *Stachys recta*, *Teucrium chamaedrys*

1. Bohemian warm and dry oak forest
Lathyro versicoloris-Quercetum pubescentis Klika (1928) 1932

Formal definition: Group Lathyrus pannonicus AND Group Lithospermum purpurocaeruleum

Description: Warm and dry oak forests on base-rich soils in central and northern Bohemia. The open canopy is usually dominated by *Quercus pubescens* and *Q. petraea*. The understory is composed of the species of dry grassland and forest fringes. Compared to ecologically similar *Pruno mahaleb-Quercetum*, some thermophilous species typical of the Moravian warm lowlands are absent. The area of distribution includes limestone hills of the Český kras karst and the sunny slopes of neovolcanic mountain range České středohoří. It occurs rarely also on the calcareous marl slopes of the Bohemian Cretaceous basin.

Comparison of approaches: Formal delimitation generally corresponds to the traditional delimitation (Fig. 1); the association includes warm and dry forests with basiphilous species. In comparison with the traditional approach, more mesic stands from Český kras are excluded (they are assigned to *Corno-Quercetum*) and some of the warm and dry oak forests of České středohoří, transitional to the *Sorbo torminalis-Quercetum* association, do not fall within the definition. This is an example of intentional partial re-definition (narrowing) of a vegetation type, so that it reflects major ecological gradients rather than local ones.

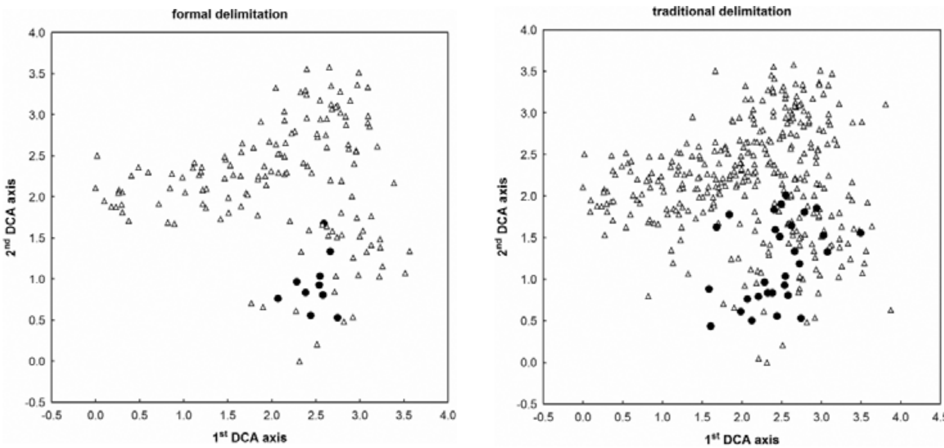

Fig. 1. – The relationship between the new formal (left) and traditional (right) delimitation of *Lathyro versicoloris-Quercetum pubescentis* association, as it appears when the positions of the relevant relevés are projected on the first two DCA axes. Black circles represent relevés of *Lathyro-Quercetum*, white triangles represent all other relevés of thermophilous oak forests. Relevés not classified to an association level by a given method are not shown.

2. Moravian warm and dry oak forest
Pruno mahaleb-Quercetum pubescentis Jakucs et Fekete 1957

Formal definition: Group Inula ensifolia AND Group Lithospermum purpurocaeruleum

Description: Warm and dry oak forests on base-rich soils in Moravia. The physiognomy and the floristic composition are basically similar to *Lathyro-Quercetum*. *Quercus pubescens*, *Q. petraea* and also *Q. robur* may dominate the tree layer. Frequent dominants of the herb layer are *Brachypodium pinnatum*, *Carex humilis* and *Festuca rupicola*. The presence of species confined to the Pannonian part of Moravia is characteristic (*Inula ensifolia*, *Euphorbia epithymoides*, *Euonymus verrucosa*, *Dorycnium pentaphyllum* s. lat., *Verbascum chaixii*, *Aconitum anthora*). The area of distribution includes southernmost promontory of the Western Carpathians and isolated localities on outcrops of base-rich rocks on the eastern margin of the Bohemian Massif.

Comparison of approaches: Formal delimitation follows the traditional delimitation (Fig. 2), based on the presence of geographically distinct species from the Inula ensifolia group. Nevertheless, this decision was not unequivocal, as many other relevés lack this species group. If more such relevés are added in the future, the geographical delimitation of warm and dry oak forest associations in the Czech Republic could change.

3. Dry-mesic oak forest on basic rocky substrates
Corno-Quercetum Máthé et Kovács 1962

Formal definition: Group Lithospermum purpurocaeruleum AND (Group Acer campestre OR Group Lathyrus vernus) NOT (Group Asarum europaeum OR Group Stachys recta)

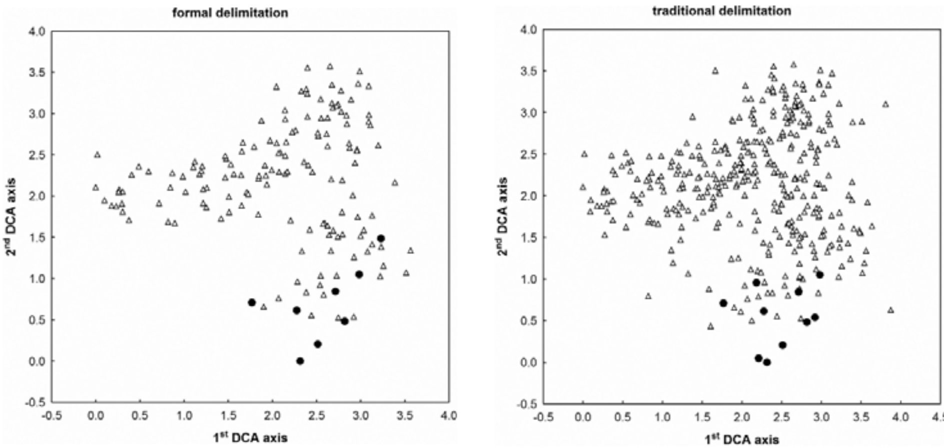

Fig. 2. – The relationship between the new formal (left) and traditional (right) delimitation of *Pruno mahaleb-Quercetum pubescentis* association. See the caption of Fig. 1 for explanation.

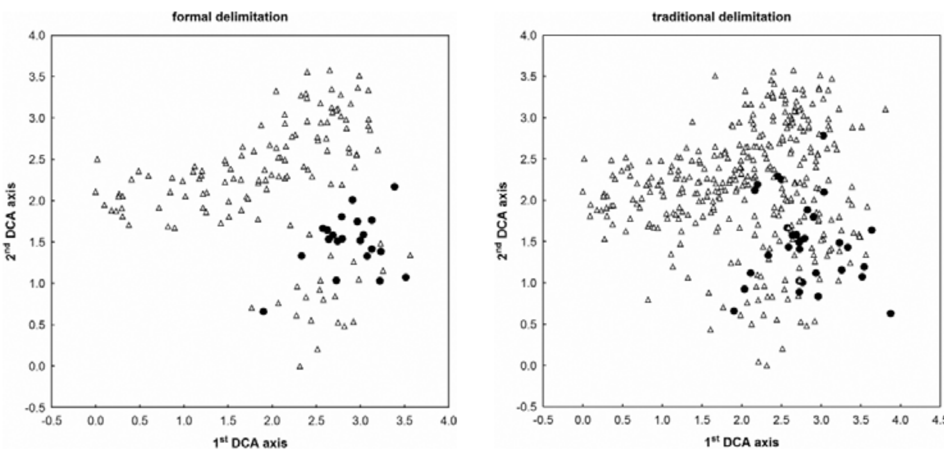

Fig. 3. – The relationship between the new formal (left) and traditional (right) delimitation of *Corno-Quercetum* association. See the caption of Fig. 1 for explanation.

D e s c r i p t i o n : Dry-mesic oak forests on base-rich soils, a transition between warm and dry oak forests and thermophilous oak-hornbeam forests. The tree layer is usually dominated by *Quercus petraea* or *Q. pubescens*, an admixture of mesophilous tree species (*Sorbus torminalis*, *Acer campestre*, *Carpinus betulus*, *Fraxinus excelsior*) is usual. The herb layer includes both thermophilous species of forest fringes (*Lithospermum purpurocaeruleum*, *Brachypodium pinnatum*, *Pyrethrum corymbosum*, *Polygonatum odoratum*, *Galium album* subsp. *pycnotrichum*, *Dictamnus albus*) and nemoral species; nitrophytes are frequent. This vegetation type is scattered across the warm regions of Bohemia and Moravia.

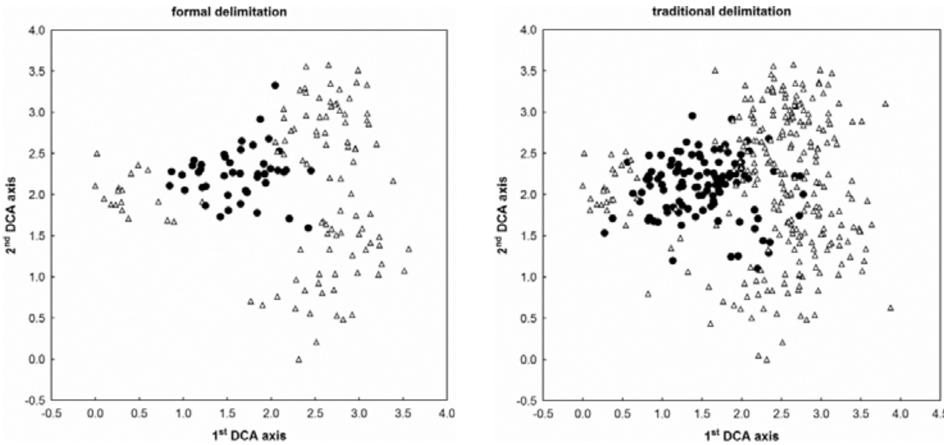

Fig. 4. – The relationship between the new formal (left) and traditional (right) delimitation of *Sorbo torminalis-Quercetum* association. See the caption of Fig. 1 for explanation.

Comparison of approaches: Formal delimitation generally corresponds to the traditional delimitation, but the former is somewhat narrower (Fig. 3). This narrowing is not a result of intentional redefinition of the vegetation type as in the case of *Lathyro-Quercetum*, but consequence of keeping the definition brief and consistent. Broader delimitation would mean either overlap with surrounding vegetation types (mainly thermophilous oak-hornbeam forests), or the definition would be too complicated. Thus, only a narrow core of the association was defined.

4. Dry-mesic oak forest on acidic substrates
Sorbo torminalis-Quercetum Svoboda ex Blažková 1962

Formal definition: Group Geranium sanguineum AND (Group Lychnis viscaria OR Group Hieracium sabaudum) NOT (Group Lithospermum purpurocaeruleum OR Group Serratula tinctoria OR Group Jasione montana)

Description: Dry and dry-mesic oak forests on acidic soils. The tree layer is usually dominated by *Quercus petraea*, which often forms homogeneous stands without any admixture. The understorey is typically poor in shrubs. The herb layer is most often dominated by *Poa nemoralis*, but other species tolerant of acidic soils can prevail (*Festuca ovina*, *Calamagrostis arundinacea*, *Luzula luzuloides*, *Vincetoxicum hirundinaria*, *Carex humilis*). Both thermophilous species (*Anthericum ramosum*, *Polygonatum odoratum*, *Allium senescens*, *Pyrethrum corymbosum*, *Campanula persicifolia*) and nemoral species may occur. It is one of the most widespread thermophilous oak forest types, on steep slopes penetrating deep into regions with a colder climate, both in Bohemia and Moravia.

Comparison of approaches: Formal delimitation is similar but narrower than the traditional delimitation (Fig. 4). As in *Corno-Quercetum*, this is a result of minimizing overlaps with surrounding vegetation types. Especially vegetation on slightly acidic substrates, composed of a mixture of basiphilous and acidophilous species and transitional to *Corno-Quercetum*, was therefore omitted.

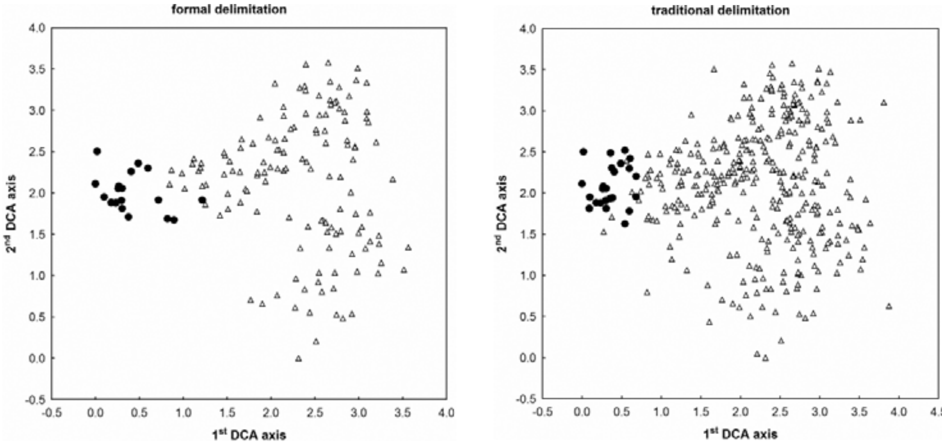

Fig. 5. – The relationship between the new formal (left) and traditional (right) delimitation of *Genisto pilosae-Quercetum petraeae* association. See the caption of Fig. 1 for explanation.

5. Moravian dry oak forest on acidic substrates
Genisto pilosae-Quercetum petraeae Zólyomi et al. ex Soó 1963

F o r m a l d e f i n i t i o n : Group Jasione montana AND Group Linaria genistifolia

D e s c r i p t i o n : Thermophilous oak forests of extremely dry habitats on shallow acidic soils. The tree layer is usually open and often shrubby. *Quercus petraea* dominates, *Pinus sylvestris*, *Sorbus aria* s. lat. or *Betula pendula* may be admixed. The herb layer is dominated by graminoids and dwarf shrubs preferring or tolerating acidic soils, mainly *Festuca ovina*, *Carex humilis* and *Genista pilosa*. The presence of heliophilous and drought-tolerant species typical of skeletal acidic soils is characteristic (*Hieracium pilosella*, *Rumex acetosella*, *Jasione montana*, *Scleranthus perennis, Hypericum perforatum*). Species typical of rocky habitats may also occur (*Festuca pallens*, *Sedum reflexum*, *Allium flavum*, *Seseli osseum*). This vegetation type is restricted to south-eastern margin of the Bohemian Massif, from the Dyje canyon in the south, to the Rokytná, Jihlava and Oslava valleys in the north.

C o m p a r i s o n o f a p p r o a c h e s : Formal delimitation corresponds to the traditional delimitation of the vegetation type (Fig. 5). The phytosociological data on this association are rather homogeneous, which can be ascribed either to the restricted area of its distribution or to the low number of authors of the relevés from this area. Nevertheless, analogous vegetation is also reported from Hungary and Austria (Borhidi 2003, Willner et al. 2005), which supports the decision to distinguish it as a separate association.

6. Dry-mesic oak forest on heavy soils
Potentillo albae-Quercetum Libbert 1933

F o r m a l d e f i n i t i o n : Group Serratula tinctoria AND Group Lathyrus niger NOT Group Lithospermum purpurocaeruleum

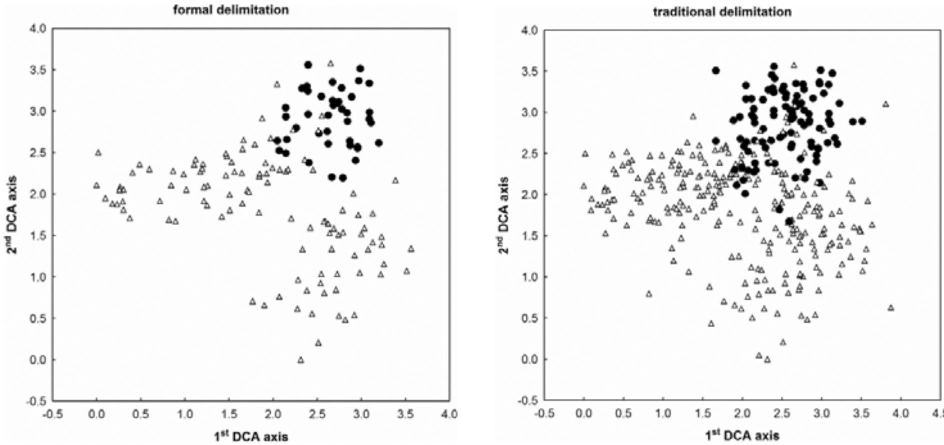

Fig. 6. – The relationship between the new formal (left) and traditional (right) delimitation of *Potentillo albae-Quercetum* association. See the caption of Fig. 1 for explanation.

Description: Moderately thermophilous oak forests on mesic sites, on deep and often heavy soils. The usual dominants *Quercus petraea* and *Q. robur* form open high stands, either without any admixture or with *Betula pendula*, *Pinus sylvestris* or some nemoral tree species. The herb layer is dominated by moderately thermophilous species (*Carex montana*, *Brachypodium pinnatum*) or nemoral species (*Poa nemoralis*, *Convallaria majalis*). The occurrence of the oligotrophic heliophilous species of *Molinion* meadows is characteristic (*Potentilla alba*, *Serratula tinctoria*, *Betonica officinalis*, *Galium boreale*, *Dianthus superbus*, *Molinia arundinacea*). Its area of distribution covers flat and rolling landscapes in moderately warm regions of the Czech Republic; it is more frequent in Bohemia, particularly in the Elbe basin.

Comparison of approaches: Formal definition conforms to the traditional delimitation of the association (Fig. 6).

7. Dry-mesic oak forest on sandy soils
Carici fritschii-Quercetum roboris Chytrý et Horák 1997

Formal definition: Group Geranium sanguineum AND Group Serratula tinctoria AND Group Anthoxanthum odoratum NOT Group Lathyrus niger

Description: Open high oak forests on dry-mesic sandy soils. The tree layer is dominated mainly by *Quercus robur*; *Betula pendula* is an alternative dominant, being confined to old openings and facilitating the growth of shade-sensitive species. The herb layer is characteristically species-rich and often reaches high cover. The most common dominants are *Convallaria majalis* and heliophilous graminoids (*Molinia arundinacea*, *Brachypodium pinnatum*, *Carex fritschii*, *Festuca ovina*). The occurrence of the oligotrophic species of *Molinion* meadows and many species of forest fringes is characteristic (*Melampyrum pratense*, *M. nemorosum*, *Silene vulgaris*, *Vicia sepium, Trifolium alpestre*, *Geranium sanguineum*, *Polygonatum odoratum*, *Iris variegata*, *Valeriana*

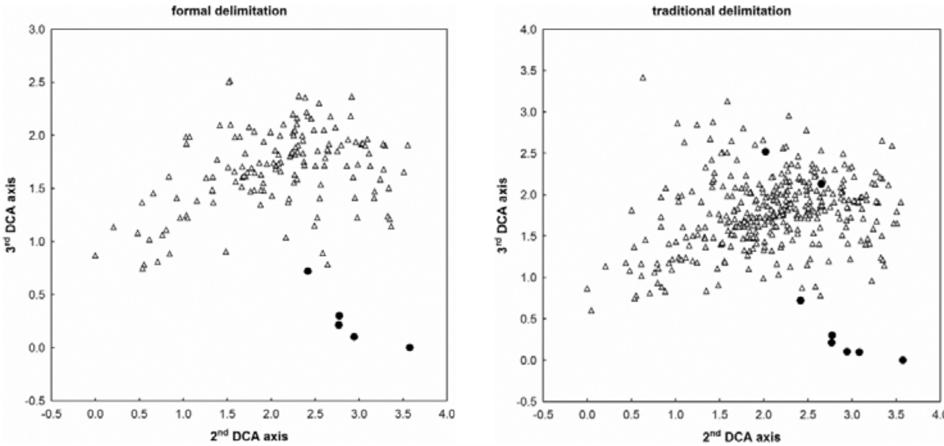

Fig. 7. – The relationship between the new formal (left) and traditional (right) delimitation of *Carici fritschii-Quercetum roboris* association. See the caption of Fig. 1 for explanation. Second and third DCA axes are projected.

stolonifera, *Asperula tinctoria*, *Peucedanum oreoselinum*). This is a narrow, but specific vegetation type, rich in relic heliophilous species (*Carex fritschii*, *Festuca amethystina*, *Daphne cneorum*, *Gladiolus palustris*, *Thalictrum simplex* subsp. *galioides*). It is confined to the southern part of the forest complex Dúbrava near Hodonín in the Czech Republic. It occurs also in adjacent Záhorská nížina lowland in Slovakia (Roleček 2004) and analogous vegetation occurs in Hungary.

Comparison of approaches: Formal delimitation fits well the traditional delimitation of this narrow vegetation type (Fig. 7). The vegetation data available are quite homogeneous, which is partly determined by its restricted distribution, but also by its specificity (Grulich & Grulichová 1986). In contrast to the traditional delimitation (Chytrý & Horák 1997), relevés of oak forests with *Carex fritschii* from Boří les forest near Břeclav do not fall within the formal delimitation.

8. Dry oak forest on loess
Quercetum pubescenti-roboris

Formal definition: Group Iris variegata AND Group Lithospermum purpurocaeruleum NOT Group Asarum europaeum

Description: Open oak forests of degraded chernozems, mainly on loess substrate. The tree layer is shrubby to high, dominated by *Quercus pubescens* or *Q. petraea*, rarely by *Q. robur*. The admixture of mesophilous tree species (*Fraxinus excelsior*, *Acer campestre*) is frequent. The herb layer is usually species-rich and dominated by *Brachypodium pinnatum* or *Festuca rupicola* in xeric sites, and *Convallaria majalis* or *Poa nemoralis* in more mesic sites. Basiphilous species of forest fringes and moderately thermophilous nemoral species are common. The occurrence of subcontinental forest-steppe species is characteristic (*Iris variegata*, *I. graminea*, *Phlomis tuberosa*, *Peucedanum alsaticum*). The area of distribution in the Czech Republic is limited to sev-

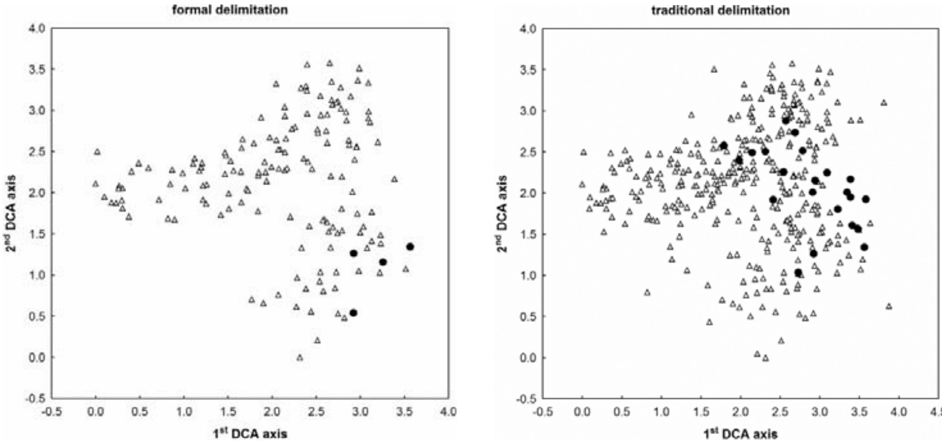

Fig. 8. – The relationship between the new formal (left) and traditional (right) delimitation of *Quercetum pubescenti-roboris* association. See the caption of Fig. 1 for explanation.

eral localities in the Pannonian part of southern Moravia. This vegetation type is endangered by succession, which occurs when traditional coppice or coppice-with-standards management ceases.

Comparison of approaches: This is an example of a redefinition of a traditional vegetation type (Fig. 8). Based on a comparison with relevés from Austria, Slovakia, and Hungary, only the xerophilous subtypes of the traditionally distinguished association were included in this syntaxon. More mesic stands belong partly to *Corno-Quercetum* and partly to *Primulo veris-Carpinetum* associations. *Convallario-Quercetum*, a syntaxon used for the description of the mesic subtype of this association in the surrounding countries (Willner et al. 2005, Roleček 2005), was not confirmed to be present in the Czech Republic, as many of its characteristic species (e.g. *Polygonatum latifolium*, *Viola suavis*, *Quercus cerris*) are absent from or very rare in the Czech relevés.

Discussion

The results presented confirm that the Cocktail method can be used to reproduce the traditional phytosociological classification rather precisely. This accords with the results of Kočí et al. (2003), who showed that the method is able to reproduce the traditional classification of subalpine tall-forb vegetation. From a practical point of view this means that the method can be used to formulate modern formalized vegetation classifications based on data sets compiled from relevés that were acquired by traditional phytosociological methods.

The more general finding is that formally defined vegetation types (associations in this case) are ecologically interpretable and accurately describe the main gradients of variation in the data set analysed. This is illustrated e.g. by the ordination scatter plots, in which the formally defined vegetation types cover most of the ordination space delimited by the first two DCA axes.

On the other hand, the fact that only 156 out of 419 relevés (37%) involved in the analysis match any of the Cocktail definitions might throw doubt on the practical usefulness of the method. However, this rather low success was expected, as stands composed of generalist species spatially prevail over those with specialists. Since Cocktail definitions are mainly based on species with a high fidelity (i.e. the specialists) few of the oak forest relevés satisfy these conditions. For the vegetation types where specialists are more abundant, the success is higher (Kočí et al. 2003). Indeed, it is possible to construct more complicated definitions, which would be more successful, but there is more to lose than to gain from such complicated definitions: (1) a complicated definition does not satisfy the condition of simplicity; while a simple definition extracts and delivers the message about the basic floristic features of a vegetation type, a complicated definition is difficult to comprehend; (2) complicated definitions are usually strongly database specific; when applied to a differently structured data set they are likely to be less successful.

Nevertheless, if the goal is not just to simplify and illustrate the structure of the data set, but also to classify all relevés, the Cocktail algorithm has to be complemented by another classification tool. For this reason, a method based on the frequency-positive fidelity index was proposed (Kočí et al. 2003, Tichý 2005). It is used for the assignment of unclassified relevés to the vegetation types defined by the Cocktail method based on their similarity in species composition (see Material and methods). This method is applied in this way within the project Vegetation of the Czech Republic, but not in this paper, so as to illustrate the behaviour of the Cocktail method more clearly.

Representativeness of the species groups

The essential condition for the formulation of ecologically meaningful species groups and syntaxon definitions is that the original phytosociological data set well represents the vegetation in the study area. This is rather tricky assumption, because most phytosociological data are collected using preferential sampling (Chytrý & Rafajová 2003, Knollová et al. 2005, Hédl 2005). Therefore it may happen that a species group accurately reflects the structure existing in the database analysed, but not the reality in nature. For example, several rare species may co-occur in vegetation plot data collected by few or only one author. Then the strong positive relationship between these species, revealed during the analysis of interspecific associations, may not result from similar habitat requirements, but accidentally, or due to the preference of particular author/authors for a particular species combination. Then it depends upon the knowledge and rigour of the author of the particular Cocktail classification, whether he/she reveals such artefacts and does not let them affect the final classification. More generally, the composition of species groups should be based on the results of database analyses, but at the same time should be ecologically or geographically interpretable. This is the main reason why I use a supervised formulation of species groups instead of an automated one, which is suggested by the author of the Cocktail method (Bruelheide 1995) and used by other authors (e.g. Jandt 1999).

Limitations imposed by the requirement for uniqueness of species groups

The criteria used for the formal vegetation classification within the project Vegetation of the Czech Republic include: (1) the species group is considered to be present in the relevé when at least one half of its species is present; (2) each species may be included in one species group only; (3) the species groups are in all cases invariant; and (4) the same species groups are used for forest and non-forest vegetation; forest and non-forest relevés are treated separately

These arbitrary rules make it difficult to define some vegetation types because suitable species are already included in some other species group. This can be illustrated by the example of the species group Potentilla arenaria (*Artemisia campestris*, *Asperula cynanchica*, *Carex humilis*, *Centaurea stoebe*, *Dianthus carthusianorum* s. lat., *Eryngium campestre*, *Koeleria macrantha*, *Potentilla arenaria*), which was primarily constructed for the formal definition of dry grassland vegetation types and which was thought to be suitable also for the definition of some thermophilous oak forest types. Unfortunately it turned out to be useless for the latter purpose, since four of its species would have to occur in the classified relevé to satisfy the criteria "at least one half of the species present". This is too strict a condition for oak forest vegetation, met by a few relevés, and makes it difficult to combine it with any other species group. Thus, another species group or combination of groups have to be sought.

Nevertheless, the existence of such limitations may not be an important weakness of the Cocktail classification method. These limitations were adopted within the project "Vegetation of the Czech Republic" with respect to the trade-off between local and global optimization of the classifications: several strict definitions were abandoned in favour of a simpler, clear and generally formulated classification system. More flexible rules could be adopted, but there is a lot of flexibility in the traditional classifications and it is time now to emphasize other qualities.

The same species groups were used for both forest and non-forest vegetation types, which necessitated the separate treatment of forest and non-forest relevés. The classification process thus begins with the assignment of each relevé to a forest or non-forest relevé group, based on the presence/absence of the tree layer. This involves one more arbitrary step in the classification process; on the other hand it facilitates the simplification of the definitions of floristically similar forest and non-forest vegetation types, such as warm and dry oak forests and shrubland.

Good definitions, bad definitions and redefinitions

As in the case of species groups, good definitions are those that reflect the ecological or geographical basis of the defined vegetation type, regardless of the structure of the underlying data set. For example, when it is necessary to define a Moravian warm and dry oak forest type, the definition should include species of warm and dry oak forests and species confined to the territory of Moravia and occurring in these forests. If it does not (e.g. when it is based on species that occur both in Moravia and Bohemia, but which are present only in Moravian relevés), there is a risk that new relevés with unusual combinations of species will appear in the future and be assigned incorrectly. Such definitions, whose distinguishing ability is dependent on the structure of the database, may be designated as database-specific.

It is necessary to point out, that the above definitions of Czech thermophilous oak forests are based on geographically and ecologically stratified selection from the Czech National Phytosociological Database and thus may be specific for this data set. This will not be interpreted as a mistake as it is a consequence of a right decision to produce the new formalized classification of Czech vegetation based on phytosociological data. Ecological and geographical representativeness of the data certainly varies across vegetation types and probably will improve in the course of time – as will the formal definitions of vegetation types, which do not have to be considered as final.

Nevertheless, bad definitions certainly may exist. Any vegetation type can be defined too narrowly or too broadly or ecologically heterogeneous mixtures of relevés can be defined. But, contrary to the previous case, this is not a methodological problem but one of doing a good phytosociological job. Fortunately, the quality of phytosociological work can be assessed by comparing the results of the formalized classification with those of other classification and ordination techniques (for this purpose DCA was used in this paper), or simply by comparing the diagnostic and constant species of formally defined vegetation types with field experience.

Intentional redefinitions of vegetation types are another case – they result from syntaxonomic decisions of the author of the classification, which are independent of the classification method. Many redefinitions may be considered as important contributions of modern phytosociology to the understanding and illustrative presentation of the general patterns of multiple species co-occurrence in nature, which were until now often obscured by a multitude of difficult-to-recognize local syntaxa – typical products of traditional phytosociology.

Methodological note on the relation between the traditional and formalized vegetation classifications

Finally it is necessary to emphasize the complementary relationship between the traditional, imperfectly formalized classifications and modern formalized classifications. Traditional local classifications are not just a source of phytosociological data for synthesis on a larger geographical scale, but often also a valuable documentation of the local diversity of vegetation in a particular place and time. The shift towards larger spatial and temporal scale and engagement of sophisticated classification tools, so typical of modern classifications, necessitates many simplifications and abstraction from local peculiarities on one hand and on the other it brings an opportunity for the generalization of the accumulated ecological knowledge across different regions, different periods and biological systems of different complexity.

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Souhrn

Klasifikační postupy tradiční fytocenologie jsou častým cílem více či méně opodstatněné kritiky rostlinných ekologů. Na tuto kritiku reagovaly progresivnější proudy fytocenologického myšlení pokusy o rozvoj nových klasifikačních postupů, reflektujících vytýkané nedostatky. Jedním z nejmodernějších a stále hojněji využívaných klasi-

fikačních postupů je algoritmus Cocktail, založený na formulaci explicitních definic vegetačních jednotek, jež jsou poté využívány k jednoznačnému přiřazení fytocenologických snímků k definovaným vegetačním typům. V předkládaném článku je na příkladu formalizované klasifikace českých teplomilných doubrav ukázána schopnost metody Cocktail reprodukovat tradiční fytocenologickou klasifikaci a jsou diskutovány vlastnosti takto vytvořené klasifikace. Vzhledem k využití metody v novém přehledu vegetace České republiky jsem považoval za důležité předložit botanické veřejnosti ilustrativní příklad, jak interpretovat klasifikaci formalizovanou pomocí algoritmu Cocktail.

Celkem bylo definováno osm z deseti tradičně rozlišovaných asociací teplomilných doubrav. Nové formální vymezení je většinou velmi podobné tradičnímu, což je ilustrováno sérií diagramů detrendované korespondenční analýzy. Závěrem je nutno poznamenat, že ani nová formalizovaná klasifikace si nečiní nárok na definitivnost. Má sice jasná pravidla a je založená na analýze velkého souboru dat z celé České republiky, otevřenou otázkou však zůstává mj. reprezentativnost těchto dat a vhodnost této klasifikace velkého prostorového a časového měřítka pro specifické účely v konkrétním čase a prostoru. Lze proto říct, že vztah mezi tradičními fytocenologickými klasifikacemi a moderní formalizovanou klasifikací vegetace není konkurenční, ale komplementární.

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