Ann. For. Res. 54(1): 73-88, 2011

ANNALS OF FOREST RESEARCH
www.e-afr.org

Phytosociological studies of the forests with sessile oak and Norway spruce from South-Eastern Transylvania

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Indreica A., Kelemen M. 2011. Phytosociological studies of the forests with sessile oak and Norway spruce from South-Eastern Transylvania. Ann. For. Res. 54(1): 73-88, 2011.

Abstract. The forests with sessile oak (*Quercus petraea*) and Norway spruce (*Picea abies*) from south-eastern Transylvania represent a peculiar type of phytocenoses, rather unusual for the present-day vegetation of Romania's territory. Aim of the study is to provide a detailed description of the vegetation and to identify the phytosociological and typological units to which it could belong. Beside this, stand structure and regeneration status of the main tree species are illustrated. The studied area is located around Carpathian intermountain depressions Braşov and Ciuc, where vegetation had a peculiar history and today sessile oak forests on high altitude exists, interfering with spruce forests. The hypothesis of the process naturalness is supported by vegetation history in the area, climate, stand structure and peculiarities of herb layer composition (the mixture of relic of both mountain-boreal origin and south-European origin, like *Vaccinium vitis-idaea, Pyrola rotundifolia* and respectively *Potentilla micrantha, Lathyrus venetus* respectively. Sintaxonomically, studied phytocenoses with sessile oak and spruce belong mainly to acidophilus oak forests (*Luzulo luzuloidis*-*Quercetum petraeae*), but some of them resemble oak-hornbeam forests (*Carici pilosae-Carpinetum*), indicating a more recent change in stand structure and suggesting that not the soil, but the climate is the driving force of succession. Regeneration of sessile oak is at least satisfactory, but the expansion of spruce in such stands could seriously restrict the survival of sessile oak. A new typological unit will be appropriate, for a better management of sessile oak forests with spruce admixture.
Keywords sessile oak – spruce forests, phytosociology, vegetation succession.

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Manuscript received February 1, 2010; revised December 14, 2010; accepted December 18, 2010; online first February 3, 2011.

Introduction

The natural admixture of oak and spruce seems completely unusual for the actual vegetation of Romania, as long as the biology of these species is different and their natural distributions are separated by a large belt of beech forests. The natural contact of oak and spruce exists at present in Northern and Eastern Europe (Falinski & Falinska 1986, Pallas 1996, Serebryanny 2002, Patalauskaite 2007), in hemiboreal regions, where the mesophilous species like *Fagus* and *Carpinus* are outside their area or ecological optimum. Thus, in the absence of competitors, the species more tolerant to the continental climate, like oak or lime could come in contact with the spruce. In Asia Minor, at 1100-1500 m altitude, *Quercus petraea* form mixed stands with the Caucasian spruce (*Picea orientalis*), which were ascribed to a distinct association: *Querco petraeae-Piceetum orientalis* (Eminagouglu et al. 2007).

In Romania, the mixed stands of oak and spruce have, in most cases, a man-made origin, especially because of spruce plantation outside its natural range (Marcu et al. 1974). But several authors stress the natural succession that occur between sessile/pedunculate oak and spruce in the area of intermountain depressions of Carpathians (Witting 1936, Constantinescu & Clonaru 1954, Petcuț 1957, Paşcovschi 1967, Csürös 1973). It was argued that the conifers are the actively successional species, favored in front of beech by seed dispersal and climate. The continental climate negatively affects the beech, and therefore the spruce became more competitive, also on lower altitudes (below 700-800 m), where it can substitute the oaks. Moreover, it was shown that an inappropriate forest management led to a faster replacement of oak with spruce, but the human impact act as secondary factor in this succession and not as cause-factor. The vegetation history of the area, documented by pollen spectra of peat bogs, reflects that the ranges of oaks and spruce were closer during postglacial time (Pop 1932, Pop & Ciobanu 1957, Pop & Diaconeasa 1967, Diaconeasa & Fărcaş 1996). The high proportion of species belonging to *Quercetum mixtum* indicates regional favorability for oaks. At present, the existence of oak stands at high altitude (Şofletea & Curtu 2001) confirms that. The mechanism of the process appears to be natural, increasing the interest to study it: e.g. what happens with the flora of the oak forests invaded by spruce? The spruce is shade tolerant, so it could develop in the understorey of oak stand and could induce changes in the environment of forest floor and respectively distribution and composition of species. Phytosociological approach of the dynamic stages of vegetation help to better understand the process of succession (Rameau 1993), as many forest understorey plants are sensitive indicators of environmental changes (Økland et al. 2004). No such study has been published so for in Romania regarding the oak-spruce forests.

Therefore, our objective is to provide a detailed description of the composition and structure of the vegetation communities with *Quercus petraea* and *Picea abies*, in order to analyze the variability and specificity of the plant assemblages, and to identify the corresponding vegetation units. Moreover, this study comes to improve the knowledge of a newly designated vegetation unit that appears on the recent map of Romanian forests (Doniță et al. 2008): 4F – "Mixed Norway spruce – silver fir – sessile oak (– beech – hornbeam) forests". This unit covers around 2725 ha, from which more than 90% are in the south-eastern side of Transylvania.

Materials and methods

Study area. The studied area (Figure 1) is located in the south-eastern part of Transylvania on the Eastern Carpathians, surrounding the depressions of Braşov and Ciuc. The site conditions and geographical location of each

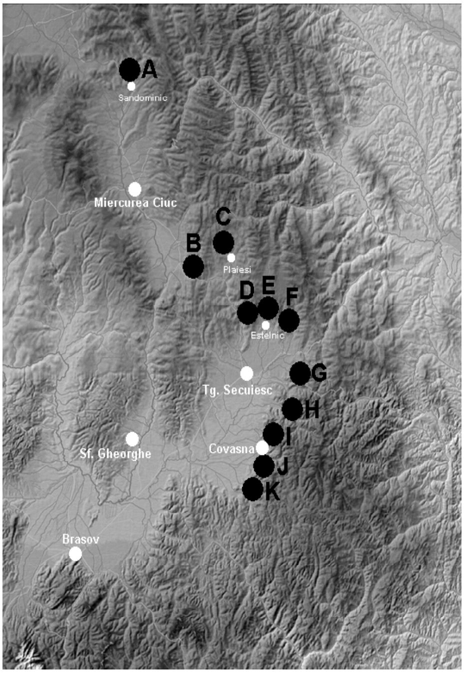

Figure 1 Distribution of studied sites

relevé are indicated in Table 1. Studied forests are located between 660 and 1050 m, on ridges or slopes with various aspects and a degree of inclination between 5 and 30°. The geologic substrate is either flysch or sandstones. The A horizon of the soil is strongly acidic (pH - 4.42–4.99), poor to very poor saturated with basic cations (BS% - 15–45%). Due to depression vicinity, the climate is characterized by a higher frequency of thermal inversions, extended from the bottom of the depressions to the foothill of the mountains. The eastern compartment of the intermountain basin is cooler and dryer than the rest, because of the continental air advection (Marcu & Huber 2003). The annual sum of precipitations is rather low (525 mm at Tg. Secuiesc, 599 mm at Covasna, 540 mm at Miercurea Ciuc), with two monthly minima recorded in February and September-October. The mean annual temperature is 6.5–7° C, the mean thermal amplitude exceeds 60-70° C and the mean air temperature of the coldest month (usually January) goes down below -10° C.

Sampling methods. Phytosociological relevés, each of 400 m^2, were sampled using the Braun-Blanquet methodology. The placement of relevés aims to cover all the area and conditions of the oak-spruce forests in the south-eastern Transylvania. There were surveyed the oak stands that had more than 10% cover of Norway spruce (*Picea abies*) in at least one layer. The following layers were considered: tree layer (E3) - trees > 7 m height; shrub layer (E2) - shrubs and trees of 1-7 m; herb layer (E1) - herbaceous plants, seedlings of trees and small shrubs < 1 m; moss layer (E0). Both, site and vegetation data were collected for each site: altitude, aspect, slope angle, relief form, plants' composition, cover and height. Evaluation of regeneration of tree species was performed on the basis of the total number of seedlings in 20 subplots of 1 m^2. The stand structure was illustrated for three cases, subjectively selected, to reflect the main situations observed during several years of studying oak-spruce forests. Data about stand structure were collected on an area of 10 x 40 m: horizontal coordinates of trees (X, Y), diameter of tree trunk at breast height, tree height, crown height and crown diameters.

Data analysis. Indicator values of the species according to Sanda et al. (1983), and Ciocârlan (2000) were used to evaluate the site conditions and ecological spectra of the flora. Some codes of indicator values for site conditions were used. For soil humidity (U): 1 means xeric, 2- meso-xeric, 3 - mesic, 4 - meso-hygric, 5 - hygric; for temperature (T): 1 - very cold climate, 2 - cold, 3 - cool, 4 - moderately warm, 5 - warm; for soil reaction (R): 1 - extreme acidic, 2 - acidic, 3 - acidic-neutral, 4 - slightly acidic-neutral, 5 - neutral-basic. Values of zero mean "indifferent".

Characterization of competitive relations among tree species was achieved through the "dendrological indicator value" (Barbu 1994): $VID = N\% + G\% + R\%$, an index that sum the participation degree (%) of a woody species in

Table 1 Characteristics of the relevés sites

Site code in fig.1	Relevé code	Nearest locality	Date of survey	Alt. (m)	Aspect	Slope (°)	Cover				
							E3 upper story	E3 lower story	E2	E1	E0
A	1	Sândominic	31.07.2008	850	SE	30	65	0	40	5	0
B	2	Cozmeni	20.05.2007	770	SW	15	85	0	30	30	0
B	3	Cozmeni	20.05.2007	830	SW	25	80	0	10	15	0
C	4	Plăieşi	30.06.2008	910	SE	30	60	0	15	30	1
D	5	Belani	22.05.2005	850	NE	10	85	10	5	70	1
D	6	Belani	06.07.2006	750	NNW	20	90	0	60	15	2
D	7	Belani	06.07.2006	840	SE	5	80	0	8	70	1
E	8	Estelnic	25.08.2006	790	VNW	7	70	0	7	20	3
E	9	Estelnic	26.08.2006	840	V	20	70	0	50	5	2
F	10	Lemnia	25.08.2007	780	SE	30	80	0	20	20	0
G	11	Mărtănuş	31.05.2003	800	SSE	10	90	0	10	60	0
G	12	Ojdula	02.05.2004	680	NW	10	60	0	5	50	1
G	13	Ojdula	30.07.2005	810	NW	20	40	60	20	30	1
H	15	Zăbala	07.09.2006	840	SE	20	80	10	5	30	1
H	16	Zăbala	08.09.2006	670	NW	10	70	10	40	10	1
I	14	Covasna	16.07.2005	750	W	5	70	20	5	60	2
J	17	Chiuruş	17.07.2005	690	W	5	50	20	5	5	1
J	18	Chiuruş	17.07.2005	700	NW	15	70	1	5	5	30
K	19	Zagon	30.07.2006	840	S	25	75	0	75	5	10
K	20	Zagon	30.07.2006	740	SSE	25	70	5	30	10	0
K	21	Zagon	07.10.2006	720	S	10	80	0	30	40	5
K	22	Zagon	11.10.2006	835	SW	25	80	5	30	80	0
K	23	Zagon	11.10.2006	890	SW	20	70	0	50	20	1
K	24	Păpăuți	12.10.2006	820	SW	30	70	5	25	30	0
K	25	Pădureni	01.07.2004	680	SSE	10	70	50	5	15	1

the stand regarding the number of trees (*N*), basal area (*G*) and regeneration (*R*).

Graphs of the stand structure were produced with the PROARB software (Popa 1999). Analyses of vegetation data were performed within the JUICE software (Tichý 2002). Variation in floristic composition and similarities between relevés were detected using TWINSPAN as classification method and detrended correspondence analysis (DCA) as ordination method (Jongman et al. 2002). Cover data were transformed to presence-absence data and rare species were down-weighted. The relationship between floristic composition and environment was extracted superimposing over the ordinogram the vectors of the ecological indicator values. The diagnostic species for each cluster were determined through the coefficient of fidelity *phi* (Chytrý et al. 2002), considering the threshold value of 0.30. Plant species names follow Ciocârlan (2000).

Results

Mixed forests with sessile oak and spruce were identified and analyzed in the Mountains Brețcu, Întorsurii, Nemira, Ciuc and Giurgeu, within the range of localities Zagon, Păpăuți, Chiuruş, Covasna, Zăbala, Ghelința, Ojdula, Mărtănuş, Lemnia, Estelnic, Belani (Covasna county), Cozmeni, Plăieşi, Sândominic

(Harghita county). The forests with sessile oak and spruce observed on the western side of Braşov depression (Bodoc, Baraolt, Întorsurii, Perşani and Postăvaru Mountains) were not considered here, because of the obvious artificial structure of the stand, or the significant admixture of beech.

Stand structure. In the figures 2 and 3 are

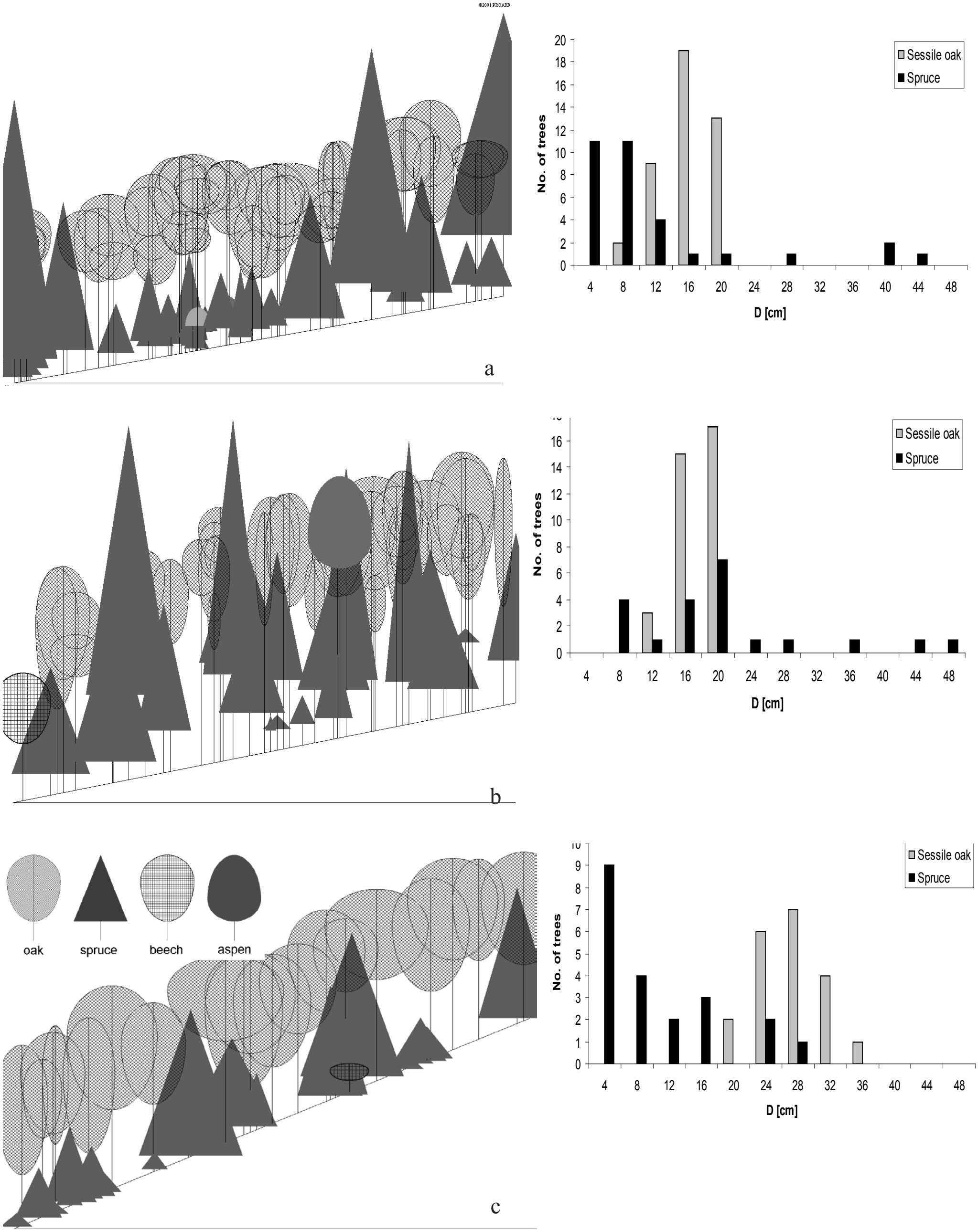

Figure 2 Vertical structure (left) and diameter-class distribution of tree species (right). Plots location: a – Zagon, b – Estelnic, c - Zăbala

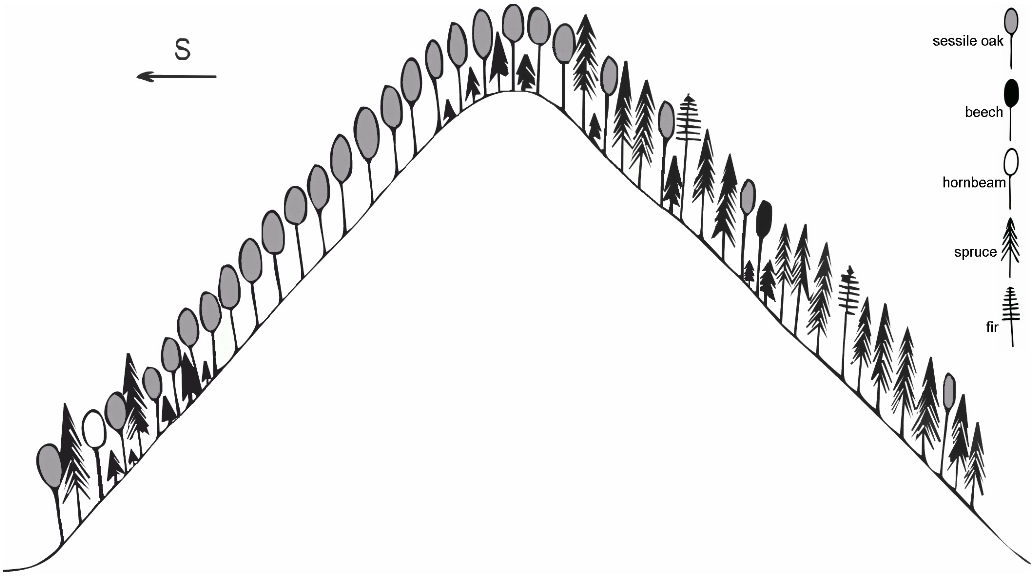

Figure 3 Vegetation profile near Ghelința village (Brețcu Mountains)

illustrated several situations of stand structure observed in the field: (a) sessile oak on a single storey and uneven-aged population of spruce, including individuals from seedlings to predominant trees, (b) sessile oak and spruce co-dominants, (c) sessile oak exclusively dominant on tree layer and abundant regeneration of spruce. Note that these are examples and a structure is not unique to a certain geographical point. In the same stand, one could see all the situations mentioned above. Obviously, the structure of spruce populations is more diverse than that of sessile oak regarding diameter, height or age (Figure 2). There is no correlation between the abundances of spruce in different development stages ($r < 0.3$, considering all the relevés). The canopy cover of the stands ranges between 60% and 90%. Other species participating to stand composition are: beech (in 24% of relevés, with reduced cover, in the lower storey), hornbeam (20%), silver fir (8%), aspen (8%) and birch (8%). Sessile oak trees originate in many cases from sprouts.

The shrub layer is always present, covering 5-75%, and is dominated by spruce, which sometimes becomes very dense and overwhelming. The structure of this layer is heterogeneous, depending on the canopy closure, position on the slope, relief form. Besides spruce, other species in shrub layer are present: *Corylus avellana* (with 48% frequency), *Juniperus communis* (28%), *Fagus sylvatica* (16%), *Abies alba* (16%), *Carpinus betulus* (12%), *Crataegus monogyna* (8%).

The herb layer covers 5-80% and usually is rich in species (20-60 taxa); the moss layer exhibit a variable presence and cover (0-30%), with 2-5 identified species.

A special case is represented by the forest near Sândominic (in Ciuc Depression area), which is more isolated from the natural range of oak and arouse a phytogeographical interest. Here, in the optimal area of *Picea abies*, the naturalness of oak could become questionable. However, the evidence of sprout regeneration and the stamps more than 60 cm in diameter indicate a prolonged existence of oak in this place.

Regeneration. Seedlings of the followring species (in descending order of frequency) were observed in the studied area: sessile oak, spruce, wild cherry, hornbeam, silver fir, beech, aspen, mountain ash, lime and field maple. The regeneration of sessile oak is maybe not accurately evaluated, because of the longer periodicity of fruiting, but it seems to evolve at least satisfactory in all stands, existing 20-180 seedlings/100 m^2. Spruce seedlings appear in almost all relevés, with a density of 10-150 individuals/100 m^2. Their distribution on surface is not uniform, being obvious the tendency of clumping, especially on the concave terrain, bottom of the slope or near the base of mature trees. In these places, it is probably a higher atmospheric humidity that compensates the dryness conditions of the south-facing slopes and lower altitude.

The *VID* index (Table 2) reveals a high competitive capacity for both sessile oak and spruce. No correlation was observed between *VID* values and altitude or geographical positions. It has to be consider that the numbers presented in Table 2 underestimate the spruce regeneration, as long as young spruce individuals over 1 m height are not counted as seedlings, but they often appeared in the plots with high cover values.

Vegetation. Phytocenoses with sessile oak and spruce do not have a homogeneous floristic pattern. In 25 relevés were identified 210 species; the number of species/relevé ranges between 26 and 67, with the mean value of 45. Numerical analysis of composition (Figure 4 and Appendix) reveals that the most important factors affecting species assemblage are humidity and light, and therefore two groups of relevés can be defined. The optimum number of clusters was chosen in accordance with the maximization of the total number of diagnostic species (Tichý 2002). Diagnostic species for the first group are common for spruce forests: mesophytes, shade tolerant species, acidophytes and mosses (*Vaccinium vitis-idaea, Maianthemum bifolium, Luzula pilosa, Orthilia secunda, Eurhynchium striatum, Hypnum cupressiforme*). For the second group,

Table 2 *VID* index for sessile oak, spruce and beech

Locality	Species	*N%*	*G%*	*R%*	*VID*	rel. *VID*
Estelnic	Oak	60	60	70	197	0.66
	Spruce	36	36	11	79	0.26
	Beech	2	1	0	3	0.01
Ojdula	Oak	76	85	27	188	0.63
	Spruce	19	14	36	69	0.23
	Beech	0	0	9	9	0.03
Păpăuți	Oak	54	89	18	161	0.54
	Spruce	46	11	63	120	0.40
	Beech	0	0	0	0	0.00
Zăbala	Oak	48	74	22	144	0.48
	Spruce	50	25	77	152	0.51
	Beech	2	1	0	3	0.01
Zagon (1)	Oak	56	65	55	176	0.59
	Spruce	43	34	42	119	0.40
	Beech	0	0	1	1	0.01
Zagon (2)	Oak	79	87	47	213	0.71
	Spruce	21	13	46	80	0.27
	Beech	0	0	2	2	0.01
Zagon (3)	Oak	24	57	11	93	0.31
	Spruce	44	29	8	81	0.27
	Beech	11	4	1	17	0.06

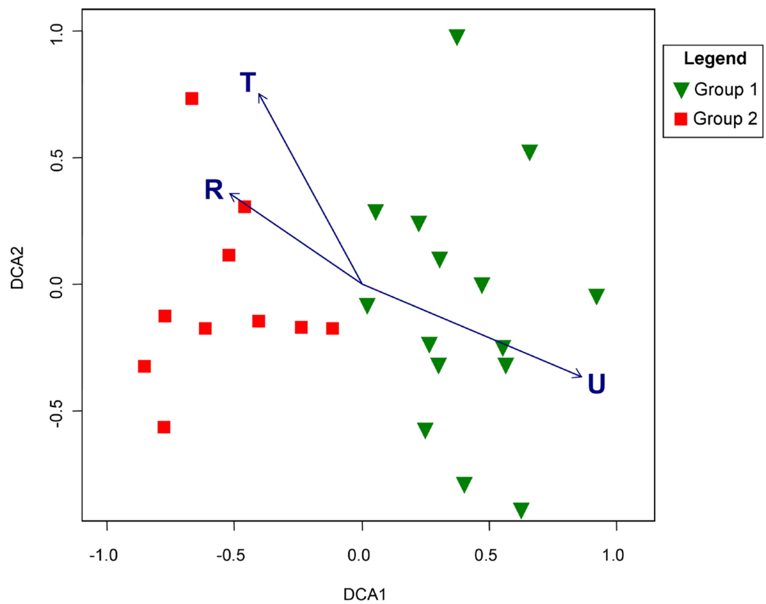

Figure 4 Diagram of indirect ordination (DCA) of relevés. The vectors of indicator values (U, T, R) are passively superimposed. Groups of relevés 1 and 2 are those separated by TWINSPAN

these are meso-xerophytes or light demanding species (*Sedum maximum, Campanula persicifolia, Hypericum perforatum, Polygonatum odoratum, Clinopodium vulgare*). Species with high frequencies are *Luzula luzuloides, Calamagrostis arundinacea, Vaccinium myrtillus, Carex montana, Cruciata glabra, Viola reichenbachiana, Hieracium murorum* etc. In half of the relevés appears *Carex pilosa*, sometimes with high coverage, but without fidelity for one of the two groups.

The distribution of species on ecological-classes (Sanda et al. 1983) for soil humidity, air temperature and soil reaction emphasizes the dominance of mesophilous, meso-thermophilous and moderately acidophilous species (Figure 5). Species tolerating low temperatures, unusual for sessile oak forests, are *Vaccinium vitis-idaea, Luzula pilosa, Gentiana asclepiadea, Monotropa hypopitys, Veronica urticifolia*. On the other hand, there are present thermophilous species, unusual for cold-cool climate: *Potentilla micrantha, Galium pseudaristatum, Lathyrus venetus*. A peculiar feature of floristic composition is the mixture of species tolerating poor soils (*Luzula luzuloides, Vaccinium sp.*) with those demanding very rich soils (*Lamium galeobdolon, Pulmonaria officinalis, Galium odoratum*).

Among the protected species in Romania (Oltean et al. 1994) were identified: *Platanthera bifolia* (in 7 relevés)*, Hierochloe australis* (4 relevés), *Cephalanthera rubra* (2 relevés)*, C. longifolia* (2 relevés)*, Phyteuma tetramerum* (2 relevés)*, Monotropa hypopitys* (2 relevés), *Festuca amethystina* (1 relevé)*, Hepatica transsilvanica* (1 relevé). Species richness and the presence of rare species are not related with the spruce cover.

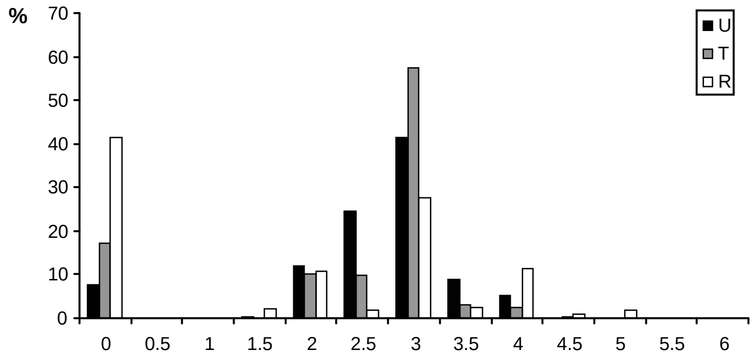

Figure 5 Proportion of species on ecological-classes of soil humidity (U), air temperature (T) and soil reaction (R)

Discussion

The analyzed forests of sessile oak and spruce are extended over relatively large area, as it was indicated previously (Witting 1936, Constantinescu & Clonaru 1954) and sometimes the surface of the stands reaches 10-20 ha. In the intermountain basins, the expansion of spruce on lower altitude seems to be natural, although in some cases could be under the human influence. There are some floristic characteristics that help to understand the vegetation of the area. First of all, according with the management plans, the origin of spruce trees is natural, the fact sustained by the lack of any "geometric" pattern of trees' distribution and the absence of *Picea abies* var. *europaea*.

Then, the presence in sessile oak forests of the area of isolated populations of thermophilous or xerophilous species with south-european optimal range (Danciu et al. 2000, Indreica 2007), like *Sedum cepaea, Silene viridiflora, Lathyrus venetus, Potentilla micrantha, Genista germanica*, indicates the favorability of site conditions for the preservation of natural old vegetation. Another peculiar group of species within the sessile oak forests of the area are those with mountain range, like *Vaccinium vitis-idaea*, *Festuca amethystina, Rubus saxatilis, Ranunculus oreophilus, Monotropa hypopitys*.

The sessile oak forests with spruce should be reported to the oak, not to the spruce vegetation units, considering the phyto-climatical conditions and floristic composition, which include many light demanding and/or drought tolerant species. Among the syntaxonomic units recognized in Romania, the most similar association is *Luzulo luzuloidis-Quercetum petraeae* Hilitzer 1932, from the alliance *Quercion robori-petraeae* Br.-Bl. 1932. The relevés of group 2 fall in the description of the *Campanula persicifolia* variant (Pallas 1996), representing the thermophilous subunit of the named association. There are also similarities with *Calamagrostio arundinaceae-Quercetum petraeae* (Hartmann 1934) Scamoni et Passarge 1959. This syntaxon was described from (North-) Eastern Europe and comprises mountain oak forests, with species of the *Vaccinio-Piceetea* class, being in contact with coniferous forests (Pallas 1996). Considering the whole floristic composition, was not possible to separate mesotrophic relevés (see the Appendix). For the classification of transitional vegetation communities, it will be reasonable to give priority to the species that are more demanding for ecological factors (Gafta 1996). Thus, relevés 13 and 22, having a larger group of (eu-)mesotrophic species (*Stellaria holostea, Lamium galeobdolon, Asarum europaeum, Carpinus betulus, Hepatica transsilvanica, Rubus hirtus, Galium schultesii*), should be reported to oak-hornbeam forests syntaxonomy, respectively to the association *Carici pilosae-Carpinetum* R. et Z. Neuh. 1964.

According with the Romanian classification of forest's herb layer (Beldie & Chiriță 1967), almost all studied phytocenoses correspond to *Luzula luzuloides* flora type. Several variants – typical, *Vaccinium myrtillus, Campanula persicifolia* or *Carex montana* – could be distinguish. In two cases (relevés nr. 13 and 22), *Carex pilosa* type is more appropriate. The most similar ecosystem type according to Doniță et al. (1990) is "Sessile oak forests with *Luzula luzuloides*". Inside of this type it is appropriate to separate a *Picea abies*-variant, to better reflect the regeneration peculiarities and succession tendencies (Paşcovschi 1967).

Comparisons with sessile oak forests around Braşov depression conducted by Morariu et al. (1970), Danciu (1972), Ularu (1972) and Fink (1977) suggest that no evident changes occured due to spruce admixture. In the context of Romanian oak forests, it appears that those around intermountain depression emphasize some unique characteristics of flora, induced, most probably, by the climate. So, the expansion of spruce follows the rule and do not create it. From another point of view, the composition of phytocenoses is not significantly contaminated with non-forest species, suggesting a low level of disturbance. Exceptions of species indicating disturbances are: *Moehringia trinervia* (36% frequency), *Prunella vulgaris* (12%), *Galeopsis pubescens* (4%), *G. speciosa* (4%), *Galium aparine* (4%), *Torilis japonica* (4%), but they are not concentrated in specific relevés, as number of taxa or individuals.

The relic sessile oak forests on higher altitude (over 900 m), with remarkable phytogeographic and genetic value, are confronted with this successional process. They need to be protected, by proper management actions, otherwise they will be replaced by spruce forests (Witting 1936, Constantinescu & Clonaru 1954).

Conclusion

Stands with *Quercus petraea* and *Picea abies* are still present over a large area in the Întorsurii, Brețcu and Nemira Mountains. Such phytocenoses were found, on small areas, even in Giurgeu and Ciuc Mountains. Either wholly or at the stand level regarded, floristic composition of oak forests with spruce admixture in South-Eastern Transsylvania is not homogeneous, being a mixture of species with different ecological affinities. The vegetation is more similar with the units of acidophilous oak forests, but the spatial and dimensional structure of spruce and its abundant regeneration are characteristic.

The interest for oak-spruce forests is supported by naturalness the successional process, relict character of vegetation and peculiar composition of species. The human influence on stand structure should be not excluded, at least in the case of some stands. Because spruce shows a high competitive value in sessile oak habitat, we plead for a special attention through the forest management plan, in order to preserve some valuable stands of sessile oak in the region, like those on high altitude.

Acknowledgements

This study was partially supported by grants TD-74/2007 (CNCSIS) and 27/2005 (RNP Romsilva).

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Appendix. Species composition of the sessile oak-spruce forests

Relevé nr.:	7	5	1	4	14	6	9	13	18	8	12	21	16	17	3	23	22	11	19	24	20	2	25	15	10	K
Diagnostic species for Group 1																										
Luzula pilosa	+	+	+	.	.	+	.	+	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Maianthemum bifolium	1	+	.	.	+	+	1	+	+	+	+	.	+	+	+	.	.	.	.	.	.	.	+	+	.	III
Sorbus aucuparia (E1)	.	.	+	+	+	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Symphytum tuberosum	1	+	.	+	.	+	+	1	+	+	+	.	.	+	1	.	.	.	.	.	.	+	+	.	.	III
Vaccinium vitis-idaea	+	+	.	+	+	+	+	.	+	1	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	II
Potentilla erecta	+	.	.	+	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Orthilia secunda	.	.	.	.	.	+	+	+	+	+	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	II
Viola canina	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Festuca rubra	.	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	II
Atrichum undulatum	.	+	.	+	+	+	+	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	II
Polytrichum formosum	+	+	.	.	+	+	+	.	.	+	.	1	+	+	.	+	.	.	+	.	.	.	.	.	.	III
Tilia cordata (E1)	+	.	+	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	II
Veronica urticifolia	.	+	.	.	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hypnum cupressiforme	.	.	.	.	.	.	+	+	.	+	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Ranunculus auricomus	+	+	.	+	.	.	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	II
Eurhynchium striatum	.	.	.	.	.	.	.	+	3	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Carpinus betulus (E3)	.	.	+	.	.	.	1	.	.	.	1	.	1	.	+	.	.	.	.	.	.	.	.	.	.	I
Gentiana asclepiadea	.	+	.	.	.	.	+	+	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Neottia nidus-avis	+	.	.	+	+	+	.	+	.	+	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	II
Athyrium filix-femina	+	+	.	+	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	II
Platanthera bifolia	.	+	.	.	+	+	.	+	+	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	II
Polypodium vulgare	.	.	.	.	+	+	+	.	.	1	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Diagnostic species for Group 2																										
Sedum maximum	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	+	1	+	+	+	.	.	+	+	+	III
Achillea distans	1	+	.	+	+	+	.	.	.	.	.	.	.	.	.	+	1	+	+	+	.	+	+	1	+	III
Campanula persicifolia	+	.	+	+	.	.	+	.	.	+	.	.	.	.	.	+	+	.	+	+	+	+	+	+	+	III
Hypericum perforatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	+	.	+	I
Clinopodium vulgare	+	.	.	+	.	+	+	.	.	+	.	.	.	.	.	1	1	.	+	2	1	.	+	+	1	III
Dactylis polygama	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	+	.	.	I
Cornus sanguinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	1	.	.	.	.	.	I
Fagus sylvatica (E2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	1	.	.	.	.	+	.	I
E3 – tree layer																										
Quercus petraea	4	4	4	4	4	5	5	4	+	4	3	4	4	3	5	4	5	5	4	4	5	5	4	5	4	V
Picea abies	2	1	1	1	2	2	2	3	2	3	1	3	2	2	1	2	2	4	3	1	1	1	2	2	+	V
Fagus sylvatica	.	.	+	.	.	.	.	.	.	.	.	.	+	.	1	+	.	+	.	.	.	+	.	.	.	II
Abies alba	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	I
E2 – shrub layer																										
Picea abies	+	+	2	.	1	3	3	1	+	+	.	2	2	1	.	2	3	1	2	2	2	2	.	1	2	V
Corylus avellana	+	1	2	.	.	.	1	+	.	+	.	.	.	.	.	2	1	.	.	+	.	.	.	+	+	III
Juniperus communis	1	+	.	2	.	2	.	.	.	.	.	1	.	.	.	.	+	.	.	.	+	.	.	.	.	II
Abies alba	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	I
Carpinus betulus	+	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
E1 – herb layer (including seedlings)																										

Appendix (continuation)

Relevé nr.	7	5	1	4	14	6	9	13	18	8	12	21	16	17	3	23	22	11	19	24	20	2	25	15	10	K
Oligotrophic/Acidophilous species																										
Luzula luzuloides	2	1	1	+	1	1	1	+	+	2	1	2	+	1	1	1	2	3	1	2	+	2	1	2	1	V
Calamagrostis arundinacea	1	1	1	1	+	+	1	+	.	+	.	+	+	+	1	1	1	1	1	+	1	1	+	1	+	V
Picea abies	+	.	.	+	+	1	1	1	+	+	+	1	+	.	.	1	1	1	.	2	+	.	.	+	.	IV
Hieracium murorum	.	+	.	+	.	1	1	+	+	1	+	+	.	.	+	1	1	1	1	1	1	1	+	1	.	IV
Veronica officinalis	+	.	.	.	+	+	+	+	+	+	.	+	+	.	.	1	+	+	+	+	1	.	+	1	+	IV
Vaccinium myrtillus	3	2	.	.	4	2	1	+	1	2	2	2	1	.	.	.	1	+	2	.	.	1	.	.	.	III
Chamaecytisus hirsutus	1	+	.	.	.	+	.	.	+	+	.	.	.	+	.	+	+	+	.	.	.	.	+	+	+	III
Hieracium lachenalii	+	.	+	.	+	.	.	.	.	+	.	+	.	.	.	+	+	+	+	+	.	+	.	+	.	III
Pteridium aquilinum	+	.	.	.	+	.	+	+	.	+	.	.	1	.	.	.	.	.	.	+	.	.	.	1	.	II
Solidago virgaurea	.	+	.	+	+	+	.	+	.	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	+	II
Silene nutans ssp. dubia	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.	1	.	2	.	.	.	.	I
Hieracium sabaudum	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	I
Pyrola rotundifolia	.	+	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Juniperus communis	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	+	.	.	I
Hieracium transsylvanicum	.	.	.	.	+	.	.	.	1	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Xerophilous																										
Carex montana	1	1	.	2	.	1	+	+	+	1	1	+	.	+	+	1	+	.	+	1	2	.	1	1	+	IV
Festuca heterophylla	+	.	.	1	+	+	.	.	.	1	.	1	.	+	+	+	1	.	+	1	2	.	2	+	1	IV
Melittis melissophyllum	+	+	+	+	+	+	+	+	+	+	.	.	.	+	+	+	+	.	.	+	+	.	.	.	.	IV
Trifolium medium	+	+	+	+	+	1	+	.	.	.	.	.	.	.	.	+	1	+	.	.	+	1	+	+	+	III
Campanula rapunculoides	+	.	+	+	.	.	+	+	.	+	.	.	.	.	1	+	+	.	.	+	+	+	+	+	.	III
Lathyrus niger	.	.	+	.	.	+	.	+	.	+	.	.	.	.	+	+	1	1	+	.	+	+	+	.	.	III
Genista tinctoria	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	+	+	II
Tanacetum corymbosum	.	.	+	+	.	.	+	.	.	+	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	II
Polygonatum odoratum	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	I
Pulmonaria mollis	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	I
Melampyrum cristatum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	I
Poa angustifolia	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Potentilla alba	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Hierochloe australis	+	1	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Mesophilous/Mesotrophic																										
Carex pilosa	+	.	.	.	.	.	.	2	+	+	1	.	+	1	1	2	3	3	+	1	.	.	.	.	.	III
Carpinus betulus	.	.	.	.	.	.	2	1	.	+	2	+	.	+	.	.	+	.	.	+	+	+	+	+	.	III
Prunus avium	.	+	.	.	.	+	.	.	.	+	+	.	.	+	.	+	1	+	.	+	.	.	+	+	+	III
Galium schultesii	+	.	+	.	+	+	.	+	.	.	.	.	.	.	1	+	+	1	.	.	.	.	2	1	.	III
Dryopteris filix-mas	+	+	.	+	+	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	II
Euphorbia amygdaloides	.	.	.	.	.	.	+	+	.	.	+	.	.	.	+	+	1	.	+	.	.	.	+	.	.	II
Lamium galeobdolon	.	+	.	.	.	+	.	1	1	.	.	.	+	.	.	.	1	.	+	.	.	.	.	.	.	II
Rubus hirtus	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	1	2	.	.	+	+	.	+	.	.	II
Scrophularia nodosa	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	.	I
Pulmonaria officinalis	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Carex sylvatica	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	I
Festuca gigantea	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I

Appendix (continuation)

Relevé nr.	7	5	1	4	14	6	9	13	18	8	12	21	16	17	3	23	22	11	19	24	20	2	25	15	10	K
Melampyrum bihariense	.	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Galium odoratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	I
Epilobium montanum	.	.	.	+	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Dryopteris carthusiana	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Variae																										
Quercus petraea	2	+	+	1	1	2	+	+	+	1	1	1	1	1	.	+	+	+	+	1	1	+	1	2	1	V
Cruciata glabra	1	1	+	+	+	1	+	+	.	1	+	+	.	+	1	+	1	+	.	1	.	1	+	1	+	V
Fragaria vesca	1	.	+	1	+	+	+	+	.	1	+	+	.	+	+	1	1	+	.	1	+	+	+	1	+	V
Viola reichenbachiana	+	+	.	1	+	.	+	1	1	+	+	+	+	+	.	.	1	.	+	1	+	+	+	1	+	IV
Poa nemoralis	+	+	+	1	+	1	+	.	.	1	.	.	.	.	.	+	1	1	+	2	+	+	1	+	+	IV
Veronica chamaedrys	1	+	+	1	+	+	+	+	.	+	.	.	.	+	.	+	1	+	.	1	1	+	.	1	+	IV
Ajuga reptans	+	+	.	.	+	1	1	1	+	+	.	.	.	+	+	+	1	.	.	+	+	+	+	1	.	IV
Anemone nemorosa	1	2	.	.	+	+	.	+	+	+	2	.	+	+	1	.	.	+	.	.	+	1	1	+	.	IV
Mycelis muralis	+	.	+	+	+	.	+	+	+	.	.	.	+	.	.	+	+	.	+	1	+	.	.	+	+	III
Abies alba	.	+	.	.	.	.	+	+	1	+	.	+	.	+	.	1	+	+	.	+	+	+	.	.	.	III
Fagus sylvatica	.	.	.	.	+	.	+	+	+	.	.	+	+	.	+	+	.	+	.	+	.	+	.	.	.	III
Carex digitata	+	.	+	.	.	+	+	.	+	.	.	+	+	+	.	+	.	+	.	+	.	.	.	.	.	III
Corylus avellana	+	.	.	.	.	+	.	+	+	+	+	.	.	.	.	.	.	+	+	+	.	.	+	.	.	II
Rosa canina	+	.	.	+	.	+	.	.	+	.	.	.	.	.	.	+	1	+	.	+	.	.	+	+	.	II
Moehringia trinervia	+	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	+	+	.	+	+	.	.	+	.	II
Lathyrus vernus	.	.	.	.	.	.	+	+	+	+	.	.	.	.	1	+	1	+	.	.	.	1	+	.	.	II
Populus tremula	1	.	+	.	+	.	.	.	+	+	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	II
Vicia sepium	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	.	+	.	+	+	+	.	II
Hieracium umbellatum	+	.	.	.	.	1	.	.	.	+	.	+	.	.	.	.	.	.	+	+	.	.	.	+	+	II
Crataegus monogyna	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	+	+	.	.	+	.	.	+	.	.	II
Sanicula europaea	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	+	+	.	.	1	.	.	.	+	.	II
Frangula alnus	.	.	.	.	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	.	+	.	.	II
Iris ruthenica	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	II
Viburnum opulus	.	.	.	+	.	.	+	+	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Serratula tinctoria	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Rubus sp.	.	+	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Euonymus verrucosa	.	.	.	.	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Festuca drymeja	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	1	.	.	.	.	.	.	.	.	I
Acer campestre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	I
Melica nutans	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Convallaria majalis	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Astragalus glycyphyllos	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	I
Prunella vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	.	.	.	.	I
E0 – moss layer																										
Polytrichum juniperinum	.	.	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Dicranum scoparium	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	2	.	.	.	.	.	.	I

Other species in 1-2 relevés: E3 – *Sorbus aucuparia* 16: +; *Tilia cordata* 3: +; E2 – *Tilia cordata* 17: +; *Populus tremula* 5: +; *Lonicera xylosteum* 5: +, 3: +; *Crataegus monogyna* 12: +, 24: +; *Daphne mezereum* 3: +; *Malus sylvestris* 23: +; *Frangula alnus* 21: 1; E1 – *Acer pseudoplatanus* 25: +; *Asarum europaeum* 12: +, 13: +; *Stellaria holostea* 13: 2; *Carex michelii* 25: +, 5: +; *Primula veris* 7: +, 24: +; *Lychnis viscaria* 7: +, 10: +; *Brachypodium pinnatum* 24: 1, 10: +; *Viola hirta* 22: +; *Potentilla micrantha* 15: +; *Rosa pimpinellifolia* 9: +; *Trifolium pannonicum* 19: +; *Lathyrus venetus* 13: 1; *Digitalis grandiflora* 10: +, 1: +; *Galium pseudaristatum* 10: +; *Trifolium alpestre* 7: +, 4: +; *Vincetoxicum hirundinaria* 10: +; *Coronilla varia* 22: +, 4: +; *Lonicera xylosteum* 9: +, 2: +; *Astrantia major* 13: +, 9: 1; *Viola alba* 22: +, 23: 1; *Lathyrus laevigatus* 13: +, 3: +; *Cephalanthera rubra* 19: +, 23: +; *Cephalanthera longifolia* 22: +, 24: +; *Lilium martagon* 5: +, 7: +; *Hieracium bauhinii* 7: +, 19: +; *Hieracium cymosum* 14: +, 15: +; *Avenula adsurgens* 14: +, 7: +; *Peucedanum oreoselinum* 23: +, 10: +; *Polygonatum verticillatum* 18: +, 6: +; *Hordelymus europaeus* 7: +; *Senecio fuchsii* 2: +; *Phyteuma tetramerum* 5: +, 4: +; *Aegopodium podagraria* 9: 1; *Milium effusum* 13: +; *Galeopsis pubescens* 14: +; *Torilis japonica* 10: +; *Heracleum sphondylium* 3: +; *Arrhenatherum elatius* 25: +; *Vicia sylvatica* 11: 1; *Galium mollugo* 23: +; *Campanula trachelium* 11: +; *Juglans regia* 6: +; *Vicia tetrasperma* 25: +; *Oxalis acetosella* 16: 1; *Euphorbia carniolica* 13: +; *Carex depauperata* 21: +; *Cerastium holosteoides* 20: +; *Galeopsis speciosa* 25: +; *Bromus ramosus* 7: +; *Galium aparine* 9: +; *Rubus idaeus* 18: +; *Monotropa hypopitys* 3: +, 1: +; *Polygonatum multiflorum* 11: +; *Silene nutans* 24: 1; *Malus sylvestris* 7: +; *Hieracium laevigatum* 5: +; *Rosa gallica* 13: +; *Prenanthes purpurea* 13: +; *Hepatica transsilvanica* 13: 1; *Lotus corniculatus* 24: +, 4: +; *Succisa pratensis* 12: +; *Hieracium caespitosum* 25: +; *Daphne mezereum* 13: +; *Rosa pendulina* 3: +; *Ranunculus oreophilus* 5: +, 4: +; *Dactylis glomerata* 4: +; *Festuca amethystina* 4: +; *Geum urbanum* 4: +, 1: +; *Hypericum montanum* 4: +; *Lapsana communis* 4: +; *Laserpitium latifolium* 1: +; *Melampyrum pratense* 4: +; *Ranunculus polyanthemos* 4: +; E0 – *Plagiochila asplenioides* 8: +, 9: +; *Hylocomium splendens* 18: +, 8: +.