NEW INSIGHTS ON THE DYNAMICS OF THE FOREST VEGETATION FROM THE ROMANIAN CARPATHIAN MOUNTAINS

ANGHELUȚĂ VĂDINEANU [1], OVIDIU BADEA [2], IULIANA FLORENTINA GHEORGHE [3], ŞTEFAN NEAGU [2], DANIELA POSTELNICU [4]

[1] University of Bucharest, Department of System Ecology, Spl. Independentei 91-95, 050095, Bucharest, Romania; e- mail: anvadi@bio.bio.unibuc.ro
[2] Forest Research and Management Institute (ICAS), Sos. Stefanesti 128, 077190 Voluntari, jud. Ilfov, Romania; e-mail: biometrie@icas.ro
[3] University of Bucharest, Department of System Ecology, Spl. Independentei 91-95, 050095 Bucharest, Romania (current address: Ecological University of Bucharest, Ecological and Nature Science Faculty, Blvd. Vasile Milea, Nr. 1G, Bucharest, Romania; e-mail: iuliag65@yahoo.com
[4] Geosystems Romania, Roma 8, 011774, Bucharest, Romania; e-mail: dpostelnicu@esriro.ro

Abstract

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In the framework of the established long-term monitoring of the Carpathian forest ecosystems, the assessment of changes in the plant species richness, type of plant communities and biometric characteristics and health status of forest trees, for getting relevant insights regarding the effects of the type of management, pollution and climate changes upon forest biodiversity and health, is one of the major objectives. The joint monitoring activities in the Carpathians from the Romanian territory were launched in 1998 by including six study sites in the network of twenty- six sites established for monitoring and assessment changes in the Carpathian forests at the scale of the entire Carpathian Mountain range. The paper addresses the results gained by repeating field studies protocols in 2005, in the same study sites from the Romanian stretch of Carpathian Mts, and shows first findings of the attempt of comparative analysis of two sets of empirical results collected in 1998 and 2005. The biometric characteristics of the investigated forest stands have changed between the years 1998–2005, due to moderate (Retezat) or intensive (Fundata) silvicultural interventions, progressive improvement of the amount of precipitations and significant decrease of pressure exerted by air pollution (Badea et al, 2006). Except a relatively low volume increment (4.8 $m^3 yr^{-1} ha^{-1}$) estimated for Fundata forest stands, which is located at the upper altitudinal limit (1360 m asl), good (6.7–7.1 $m^3 yr^{-1} ha^{-1}$) and high (10–11 $m^3 yr^{-1} ha^{-1}$) volume increment were estimated for Magura Odobesti and Stana de Vale, respectively Obcina Mare and Retezat sites, according with the tree species composition and yield class. The data related to the share of damaged trees (defoliation classes 2–4) indicate that between 1998 and 2005 the health status of forests from the Romanian Carpathians has been slightly improved, as well as for all Romanian forests (Badea et al, 2006). The recorded data indicate also that the dominant plant species have not been changed, and thus, the type of plants associations. However, they indicate an increase with 5 species (SdV), 8 species (F; MO; R), 16 species (RA) and 19 species (OM) in the plant species richness between 1998 and 2005. In addition, the results of the comparative analysis based on Jaccard coefficient of similarity, show profound changes (78 percent) in species composition, in particular subordinate and transient species.

Key words: biodiversity, forest stand, ground vegetation, accumulation curve, Jaccard similarity, forest health, subordinate and transient species

Introduction

With an area of about 210,000 km^2, the Carpathian Mts represent one of the most significant natural regions in Europe. The Carpathian Mts are more than 1,500 km long and are located in five countries (the Czech Republic, Poland, Romania, Slovakia and Ukraine). They comprise the most representative forest ecosystems in Europe with about 300,000 ha of natural forests and 20,000 ha of primary beech forests still existing (WWF Report, 2001). Romania has about 55% of the entire Carpathian Mts, consisting in the Oriental, Meridional and Occidental Carpathian ranges. Romanian Carpathians are composed mainly of metamorphic eruptive and sedimentary rocks. The climate is continental with two sub-types: low and medium, and high mountains climates. In the Romanian Carpathian Mts there were distinguished five vegetation zones: (1) lower mountain zone with pure beech (*Fagus sylvatica* L.) stands; (2) middle mountains zone with mixture of spruce (*Picea abies* (L.) K a r s t e n), silver fir (*Abies alba* M i l l e r) and beech (*Fagus sylvatica* L.) stands; (3) upper mountain zone with pure spruce (*Picea abies* (L.) K a r s t e n) stands; (4) subalpine grassland zone; (5) alpine grassland zone. The dominant tree species in Romanian Carpathian forests are *Picea abies* ((L.) K a r s t e n), *Fagus sylvatica* (L.), *Abies alba* (M i l l e r), *Pinus* sp., *Larix europaea* ((D.C.) L.). About 65% from total area of Romanian forests are situated in the mountains and, in terms of contribution to the total coverage; the conifers contribute with 25%, broadleaves forests with 50% and mixed forests with 25% (Badea, 1998; Badea et al., 2004).

Due to the importance of forest ecosystems of the Carpathian Mts, a framework for joint and more integrated research and monitoring activities, covering the entire mountain range, has been designed and launched in the last decade (Grodzinska at al, 2004; Badea et al., 2004, Bytnerowicz et al., 2005).

The major objectives established for such activities were related to the needs for understanding and knowledge development regarding the spatial-temporal dynamics in the composition, structure and functioning of forest biodiversity (in particular vegetation diversity) under the impact of different pressures (level of forest management, air pollution, climate changes) of most active human and natural driving forces.

Within this frame, the first phase of field investigations upon the status of the Carpathian forests from the Romanian territory and its correlation with the pressure of air pollution, land use, and level of applied management has been carried out in 1998.

The results allowed the assessment of selected descriptors of the reference status of Carpathians forest ecosystems, comparative analysis at space scale and valuable references regarding the impact of major pressures (Badea et al., 2004; Grodzinska et al., 2004).

The second phase of program implementation has been carried out in 2005 and the aim was to allow for identification of changes and trends in the most sensible state variables – plant species richness and composition, type of plant associations, and biometrical characteristics and health status of forest stands from the established sites in the Romanian sector of Carpathian Mts.

The forest management applied, between 1998–2005, in the study sites, has been designed based on the narrow and very focused interpretation of the concept of forest biodiversity conservation. That consists in the maintenance of the mixed composition, vitality and productivity of tree stands. Thus, in order to prevent damages in wood quality which usually are produced by insects pest or other agents, the dead or fallen and broken trees were systematically extracted. There is an increasing evidence that, by doing this, the managers contributed to the change in the habitat, species composition and structure, and species richness of both flora and fauna (Hunter, 1999; Führer, 2000; Johnson, Kruys, 2001).

Material and methods

In 2005, a total of six study sites with 30 sample plots have been used for carrying out the field work regarding re-assessment the vegetation diversity and health of Carpathian forest ecosystems, from the Romanian territory. The study sites have had the same geographic position (longitude, latitude, altitude and exposition) and displayed the same slope gradient like those first established in 1998 (Table 1).

T a b l e 1. Characteristics of study sites in the Romanian Carpathian Mts.

No. of site	Locality	Latitude	Longitude	Altitude (m)	Exposition	Slope (°)	Main species
1	Obcina Mare	47° 44’ 17’’	25° 38’ 37’’	1100	NE	25	*Picea abies*
2	Rarau	47° 28’ 23’’	25° 32’ 33’’	980	N	10	*Picea abies* *Fagus sylvatica*
3	Magura Odobesti	45° 51’ 59’’	26° 56’ 44’’	960	SW	30	*Fagus sylvatica*
4	Fundata	45° 25’ 46’’	25° 16’ 14’’	1360	SE	35	*Fagus sylvatica*
5	Retezat	45° 18’ 38’’	22° 47’ 54’’	1250	E	5	*Picea abies*
6	Stana de Vale	46° 41’ 41’’	22° 38’ 21’’	1300	W	20	*Fagus sylvatica* *Picea abies*

Those study sites were established, in 1998, by taking into consideration the need for better reflecting the potential exposure towards air mass transported pollutants (Fig. 1). Although, that was the major aim, the site distribution (three in the eastern range, two in the southern and one in the western range of Carpathian Mts from the Romanian territory) has covered also in an acceptable extent the heterogeneity in dominant tree species of the Carpathian forests (Table 1).

Each of the six study sites has covered a surface of 0.7 ha and has contained five circular sample plots with a cluster configuration (Fig. 2). Further, in each circular plot of 500 m^2 size, the inventory of trees and phytosociological survey was carried out. The survey has distinguished among major vegetation strata: tree, shrubs, herbaceous and mosses.

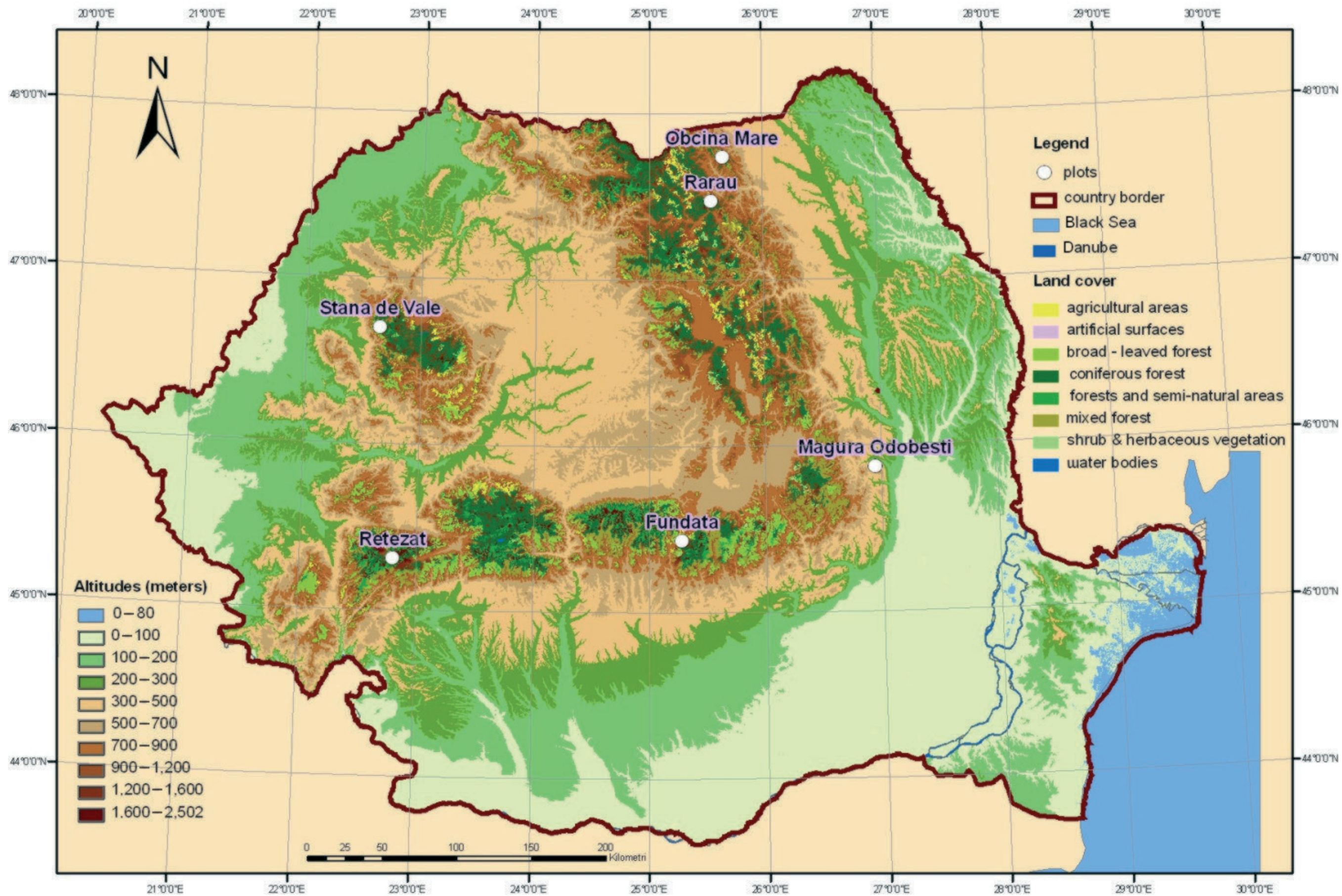

Fig. 1. Study sites location in the Romanian Carpathian forests. Land cover is superimposed only over the Carpathian Mts area.

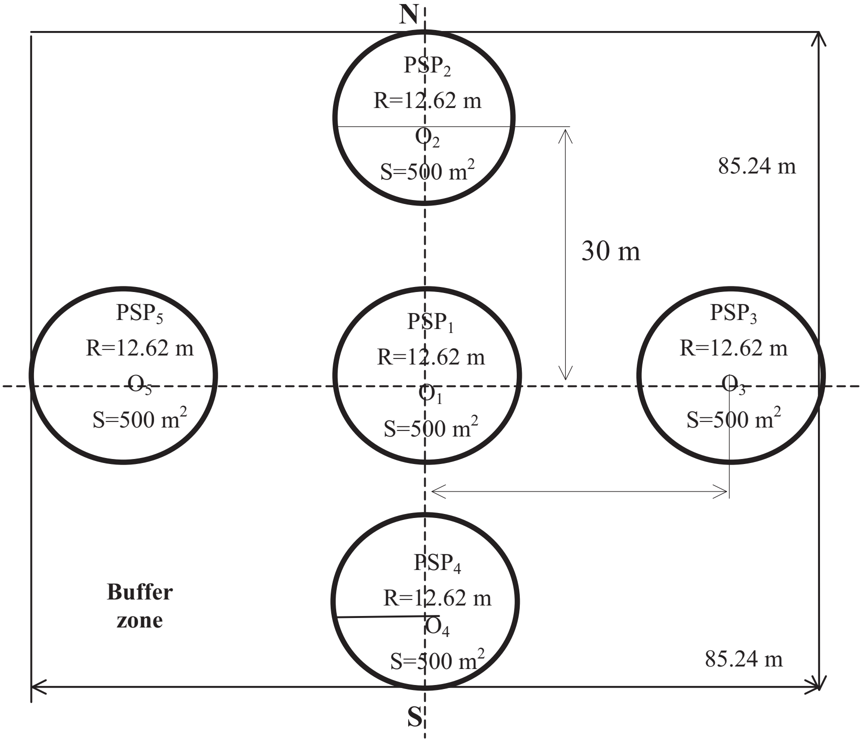

Fig. 2. Scheme of study site and spatial distribution of circular permanent sample plots (PSPs) for forest vegetation assessment.

All trees which exceed 7 cm of DBH (diameter at breast height) were labelled and measured for their height and DBH, and also health status was assessed by means of defoliation-discoloration parameters, according to ICP-Forests methodology (UN/ECE and ICP-Forests, 1998). Phytosociological records and description (abundance and dominance) were carried out by using the Braun Blanquet method (Braun-Blanquet, 1932).

For estimation of species cover from the trees, shrubs, herbs and mosses strata (Table 5), has been done according with the following ranking system: 5 – for coverage between 75–100% (dominant species); 4 – for coverage between 50–75% (co-dominant species); 3 – for coverage between 25–50%; 2 – for coverage between 5–25%; 1 – for coverage < 5% (abundant, but coverage low); + indicates few numerous, and r – rare species.

The empirical data concerning species composition and richness for herbaceous and mosses strata have been collected from 150 sample units, each consisting in a 100x100 cm quadrates. In that regard, from each plot of 500 m^2 size, 5 sample units have been randomly analyzed. Further, each sample unit has been divided in 100 microquadrates, of 10x10 cm each. The recorded frequency of all identified herbaceous and mosses species was established based on the number of microquadrates where they have occurred. The comparative analysis between the two study periods (1998 and 2005), between study sites and plots has been undertaken by using the calculated Jaccard's coefficient and cluster method (Jaccard, 1912). The accuracy of the sampling program has been also checked by building the species accumulation curves (SAC) for forest vegetation (Coleman et al., 1982).

The data used for analysis of ground vegetation, were those recorded in the end of summer sampling period (August). As the species composition of ground vegetation varies during the growing seasons, we are aware that typical vernal or earlier autumn species have not been recorded. However, for the purpose of this study, it was assumed that there are no significant implications. The preliminary analysis of data recorded in 2007, for the entire vegetation period, confirms most of findings reported in this paper (Andrei M., unpublished data).

Results and discussion

Tree vegetation in forest stands

Site locations for forest vegetation ecosystems in Romanian Carpathians were placed in representative forest stands of Norway spruce (*Picea abies* (L.) K a r s t e n), European beech (*Fagus sylvatica* L.) and mixed forest stands (Norway spruce, European beech and occasionally silver fir). At the moment of field investigations, the mean age of these forest stands was between 45 years (Obcina Mare) and 125 years (Fundata). The relative yield class was established at medium (class III) and medium to inferior (classes III–IV), and coverage of tree crowns was estimated between 70% and 80%.

During the 1998–2005 period, the biometric characteristics of the studied forest stands have changed due to silvicultural interventions according to the provisions established in the applied forest management and due to positive or negative effects of environmental and ecological factors (Table 2). Consequently, in most of the study sites, the mean trees height increased with 1 to 3 m (Rarău, Fundata and Obcina Mare, respectively), as for the maximum trees height, with 1 to 4 m (Măgura Odobeşti and Obcina Mare, Retezat, respectively). Similar values of the mean trees height were recorded, both in 1998 and 2005, in Măgura Odobeşti (17 m), Rarau (24 m) and for the maximum trees height in Fundata (31 m). At Stana de Vale site the tallest tree, recorded in 2005 was smaller with 3 m than in 1998, as a result of silvicultural interventions consisting in the removal of broken or fallen down trees, the events which affected, in particular, the tallest ones.

Concerning the mean trees diameter, it was recorded an increase between 2 cm (Rarau and Stana de Vale) and 4 cm (Obcina Mare). A decrease of the mean trees diameter was recorded in Fundata (6 cm) and in Retezat (2 cm). The largest diameter registered in these two years (1998 and 2005, respectively) of investigation, increased with 2 and 6 cm (Magura Odobesti and Rarau) and dropped with 5 and 15 cm (Retezat and Fundata, respectively). The relative homogeneous difference in the mean tree age, among the study sites, in spite of the recorded differences in the biometric parameters is not surprising as long as all sites consisted from even-aged forest stands.

In all study sites, in the year 2005, the number of inventoried trees were lower than those recorded in 1998, the difference ranged from 3 (Retezat) to 135 trees (Obcina Mare). In addition, the number of trees per ha decreased correspondingly, with 12 and 636 trees. Moreover, in the same time interval have not been recorded young trees which reached the threshold of 7 cm DBH.

By analyzing the values which describe the volume per ha in the investigated forest stands, it is possible to observe a growing trend during the investigation period (1998–2005), except from the sites where silvicultural interventions based on the stand volumes were highly intensive (Fundata) and moderately intensive (Retezat). The mean forest stands diameters decreased with 5 cm and respectively with 2 cm in the case of Fundata and Retezat study sites. Furthermore, the 15 cm and respectively 5 cm decrease of the largest diameter recorded in 1998 in the Fundata and Retezat forest stands, corroborates the fact that in the 1998–2005 period were mostly removed trees belonging to the large or largest categories. Thus it might be concluded that, compared to 1998, in the Fundata and Retezat forest stands, the diameter variability and individual tree volumes, respectively, considerably decreased.

The current average increment of the volume per year and ha fluctuated for every forest stand depending on species, relative yield class and forest stand age (Table 2). As a result, in the same relative yield class, the Norway spruce stands have a current average increment for stand volume greater than beech and mixed stands, as for the same species and relative yield class, the current average volume increment is also greater (Obcina Mare – 11.0 $m^3yr^{-1}ha^{-1}$ compared to Retezat – 10.3 $m^3yr^{-1}ha^{-1}$ and Stana de Vale – 7.1 $m^3yr^{-1}ha^{-1}$ compared to Magura Odobesti – 6.7 $m^3yr^{-1}ha^{-1}$). The mixed forest stands with beech and Norway spruce recorded a very good growth (9.0 $m^3yr^{-1}ha^{-1}$), therefore confirming a greater stability and higher quality of the mixed forest stands, which have a diversified composition and structure.

The lowest increment value was recorded in Fundata (4.8 $m^3yr^{-1}ha^{-1}$) stand site, being located at the upper altitudinal limit (1360 m) of the beech forest stand, where their growing conditions are limited.

T a b l e 2. Characteristics of forest stands used as permanent study sites in the Romanian Carpathian Mts (estimated values for 1998 and 2005).

No.	Locality	Main tree species*	Mean height (m)		Mean diameter (cm)		Maximum height (m)		Maximum diameter (cm)		Mean age of trees (yrs)		Coverage of trees crown (%)		No. of trees per site		No. of trees per ha		Yield class	Trees volume per site (m^3)		Trees volume per ha (m^3)		Growth (m^3 yr^{-1} ha^{-1})
			1998	2005	1998	2005	1998	2005	1998	2005	1998	2005	1998	2005	1998	2005	1998	2005		1998	2005	1998	2005	
1.	Obcina Mare	NS	17	20	19	23	23	27	41	46	45	52	80	80	379	245	1516	980	III	98	104	393	417	11.0
2.	Rarau	EB + NS	24	24	26	28	39	42	64	70	80	87	60	80	169	162	676	648	III	106	118	426	473	9.0
3.	Magura Odobesti	EB	17	17	24	27	24	25	67	69	85	92	80	70	134	115	536	460	III	50	58	200	233	6.7
4.	Fundata	EB	16	17	22	16	31	31	110	95	125	132	70	80	311	281	1244	1124	V	92	48	368	193	4.8
5.	Retezat	NS	22	24	33	31	33	37	92	87	80	87	80	80	146	143	584	572	III	126	123	505	490	10.3
6.	Stana de vale	EB + NS	20	22	18	20	37	34	80	84	75	82	80	80	201	195	804	780	IV	51	67	206	267	7.1

*NS – Norway spruce, EB – European beech

T a b l e 3. The level of defoliation (classes 2–4) for all main species in the Romanian Carpathian forests (1998 and 2005).

Species	Defoliation classes 2–4 (%)		Differences 1998–2005
	1998	2005	
All species	9.2	5.2	-4.0
Norway spruce	8.1	4.1	-4.0
Silver fir	10.0	7.4	-2.6
European beech	8.5	4.7	-3.8

Concerning the health status of the forests located in the Romanian Carpathians it could be concluded that in the 1998–2005 period it was recorded a slight improvement (Table 3). Therefore, for all species the share of damaged trees (defoliation classes 2 to 4) (ICP-Forests Manual, 1998) decreased with 4.0 percent points (from 9.2% to 5.2%), as for main species, with 4.0 percent points for Norway spruce (from 8.1% to 4.1%), 2.6 percent points for silver fir (from 10.0% to 7.4%) and with 3.8 percent points for European beech (from 8.5% to 4.7%). The results indicated that the Norway spruce was healthier than the beech, while the silver fir was slightly affected.

Based on the values showing the extent of damaged trees, both registered in the years 1998 and 2005 (Table 3), it might be said that the forests of the Romanian Carpathians were in a good health status at the beginning of the study interval and even improved the health during that interval.

The comparative assessment carried out in 1998, on the forests located in the entire Carpathian range, those from the Romanian Carpathians proved to be the least affected by the major pressures, in particular air-born pollutants. At that time, the share of the damaged trees (defoliation classes 2–4) was estimated at a level of 9.2% (Badea et al., 2004).

Taking into consideration that Romania comprises about 55% of the total area of the Carpathian Mts and that in 2005 the forest health status increased comparing to 1998, one can assume that the forest health status of the entire Carpathian Mts range correspondingly increased. This trend was registered and confirmed during the period 1997–2001 (Badea et al., 2004).

Ground vegetation in forest stands

In order to identify the potential changes in plant species composition and structure of Carpathians forest ecosystem's vegetation, during the time interval 1998–2005, additional assessment to the tree layer was carried out by including shrubs, herbs and mosses layers. In that regard, the empirical data derived from field investigations undertook during summer of 1998 and 2005 in the established study sites (Fig. 1) allowed for: i) estimation species

T a b l e 4. Number of shrubs, herbs and mosses species, recorded in August 1998 and 2005 and the type of plant communities from the long term study sites of forest stands.

Site / layer		Obcina Mare (OM)	Rarau (Ra)	Magura Odobesti (MO)	Fundata (F)	Retezat (R)	Stana de Vale (SdV)
No. shrubs species	1998	1	1	3	2	5	3
	2005	2	3	6	1	8	2
No. herbs species	1998	13	15	36	28	14	15
	2005	26	24	41	34	25	17
No. mosses species	1998	0	3	1	1	4	1
	2005	5	8	1	4	4	5
Total species	1998	14	19	40	31	23	19
	2005	33	35	48	39	37	24
Plant communities		*Picetalia excelsae*	*Betulo-pinetalia fagetalia*	*Fagetalia sylvaticae*	*Fagetalia sylvaticae*	*Picetalia excelsae*	*Betulo-pinetalia fagetalia*

composition, species richness and species abundance – dominance, and ii) comparative analysis based on Jaccard coefficient of similarity, type of phytocoenoses, species accumulation curve (SAC) and spatial distribution of average cover value of the investigated vegetation strata.

The data from two sampling periods (Table 4) indicate a significant increase in the ground plant species richness, in particular due to the increase of herbs and mosses species, in all sites and type of forests.

Thus an increase with 5 species in the mixed stand of European beach and Norway spruce (Stana de Vale), 8 species in European beach stands (Fundata, Magura Odobesti) and Norway spruce stand (Retezat), 16 species in the mixed stand of Norway spruce, European beach and occasionally silver fir (Rarau), and 19 species in Norway spruce stand (Obcina Mare), of the total number of recorded species in 2005 compared with that from 1998.

The data regarding the identified vegetation taxa (Table 5) and their related abundance – dominance allow for formulation the following observations on the occurred changes in the vegetation community: i) the total number of taxa (species level) which have been identified in the investigated Carpathian forests, from the Romanian territory, increased slightly from 110 species in 1998 to 117 species, in 2005; ii) the increasing number of herbal and mosses species in the forests stands from all study sites (Table 4) has been accompanied by very deep changes in the species composition, as clearly shows the calculated value of the Jaccard coefficient ; iii) although, the data indicate a deep change during 1998–2005 interval in the species composition of phytocoenoses described in all study sites, the major dominant species and type of plant communities did not change significantly.

The species composition and richness from herbaceous and mosses layers, described by different authors in 1980s and beginning of 1990s, in the same type of forests and plant

Table 5. Plant species composition of the four layers of vegetation in the forest stands from the long term study sites – Romanian Carpathian Mts.

Species / Study sites	OM_1	RA_1	MO_1	F_1	R_1	SdV_1	OM_2	RA_2	MO_2	F_2	R_2	SdV_2
Trees												
1. *Abies alba* Mill.		2			+	+		2				1
2. *Acer platanoides* L.			r									
3. *Acer pseudoplatanus* L.		+	+						1			
4. *Betula pendula* Roth			+		+				+			
5. *Fagus sylvatica* L.	2	3	4	5		3	2	3	4	5		4
6. *Fraxinus ornus* L.										r		
7. *Picea abies* (L.) Karsten	5	3			5	1	4	2		+	5	2
8. *Populus tremula* L.			r						+			
Shrubs												
9. *Crataegus monogyna* Jacq.									r			
10. *Lonicera xylosteum* L.					1						1	
11. *Ribes alpinium* L.					r							
12. *Rosa canina* L.				r					r			
13. *Rubus caesius* L.										r		
14. *Rubus hirtus* Waldst. et Kit.	r	r	r			1		r	+			
15. *Rubus idaeus* L.			r			1	1	+	1		+	2
16. *Salix caprea* L.					r						r	
17. *Sambucus nigra* L.					r				r			
18. *Spiraea chamaedryfolia* L.					r							
19. *Sorbus aucuparia* L.						+		r			1	+
20. *Sambucus racemosa* L.				r			+		2			
Herbs												
21. *Aegopodium podagraria* L.										+		
22. *Achillea millefolium* L.			r	r								
23. *Adoxa moschatellina* L.				r								
24. *Agrostis capillaris* L.									r			
25. *Alchemilla vulgaris* L. Emend Fröhner							r					
26. *Alliaria petiolata* (Bieb.) Cavara et Grande				r								
27. *Alopecurus pratensis* L.			+									
28. *Anemone nemorosa* L.				+								
29. *Aquilegia vulgaris* L.								r	r			
30. *Anemone ranunculoides* L.						2				r		
31. *Arabis hirsuta* (L.) Scop. s. str.										r		
32. *Asarum europaeum* L.							r				+	
33. *Aster alpinus* L.									r			
34. *Astragalus glycyphyllos* L.									r			
35. *Astrantia major* L.										r		
36. *Athyrium filix-femina* (L.) Roth			r			2						
37. *Ajuga genevensis* L.			+									
38. *Ballota nigra* L.									r			

T a b l e 5. (Continued)

39. *Calamagrostis arundinacea* (L.) Roth									+			
40. *Campanula abientina* Griseb	+		r		r		r			r	r	
41. *Campanula glomerata* L.				r								
42. *Campanula persicifolia* L.				r		r	r		+			
43. *Cardamine impatiens* L.			r						r			
44. *Carex spicata* Huds.			1									
45. *Carex digitata* L.							r	r				
46. *Carex sylvatica* Huds.							r	r	+			
47. *Camerion angustifolium* (L.) Holub.						+						
48. *Chelidonium majus* L.									r			
49. *Circaea lutetiana* L.							r		r	r	r	r
50. *Coeloglossum viride* (L.) Hartman									r			
51. *Coronilla varia* L.									+			
52. *Cystopteris fragilis* (L.) Bernh.			r					r				
53. *Chamaecytisus austriacus* (L.) Link			r									
54. *Dactylis glomerata* L.			r						+			
55. *Dentaria bulbifera* (L.)				r						r		
56. *Dentaria glandulosa* Waldst. et Kit.						r						
57. *Deschampsia cespitosa* (L.) P. Beauv.						1						
58. *Deschampsia flexuosa* (L.) Trin.						+						
59. *Digitalis grandiflora* Mill.									r			
60. *Dryopteris filix-mas* (L.) Schott	r				1			1		r	1	1
61. *Dryopteris carthusiana* (Vill.) H. P.Fuchs	+	1										
62. *Epilobium montanum* L.				+					r	+		
63. *Euphorbia amygdaloides* L.		r	1	r				r	r	r		
64. *Euphorbia cyparissias* L.			1						+	r		
65. *Festuca altissima* All.				r								
66. *Festuca drymeja* Mert. et Koch				1		1	r		1		+	r
67. *Fragaria vesca* L.		1	r	r			r	+	r	r	r	
68. *Galium glaucum* L.			2						1			
69. *Galium odoratum* (L.) Scop.	+			r	+		r			2		r
70. *Galium verum* L.			r	1								
71. *Galium schultesii* Vest.		r										
72. *Genista tinctoria* L.			r									
73. *Gentiana asclepiadea* L.					r							
74. *Geranium phaeum* L.								r		r		r
75. *Geranium robertianum* L.	r	r		r				r	r		r	
76. *Geum rivale* L.									r			
77. *Geum urbanum* L.				r					r	+		
78. *Glechoma hederacea* L.				r						+	r	
79. *Glechoma hirsuta* Waldst. et Kit.				r							r	2
80. *Gymnocarpium dryopteris* (L.) Newman		+										

Table 5. (Continued)

Species / Study sites	OM_1	RA_1	MO_1	F_1	R_1	SdV_1	OM_2	RA_2	MO_2	F_2	R_2	SdV_2
81. *Hieracium murorum* L.				r								
82. *Hieracium pilosella* L.			r									
83. *Homogyne alpina* (L.) Cass.					+						+	
84. *Hypericum perforatum* L.						+	r		r		r	
85. *Impatiens noli-tangere* L.									1			
86. *Isopyrum thalictroides* L.				r								r
87. *Lamium galeobdolon* (L.) L.		r				1	r	r	+	r		r
88. *Lamium maculatum* L.			1									
89. *Lathyrus venetus* (Mill) Wohlf.									+			
90. *Lithospermum officinale* L.									1	r	r	
91. *Luzula luzuloides* (Lam.) Dandy & Wilmott	+	+	+		r	1				r		
92. *Luzula pilosa* (L.) Willd.			r				r	r	2	+	+	
93. *Luzula sylvatica* (Hudson) Gaudin	r	+			r	r	r	r			r	r
94. *Lycopodium clavatum* L.		r									r	
95. *Lycopodium selago* L.					r							
96. *Lysimachia punctata* L.									r			
97. *Lithospermum purpureocaeruleum* (L.)	r											
98. *Maianthemum bifolium* (L.) F.W. Schmidt								r				
99. *Mercurialis perennis* L.			r	1			r	r	+	+		
100. *Milium effusum* L.			1									
101. *Moneses uniflora* (L.) A. Gray		r										
102. *Mycelis muralis* (L.) Dumort.			2	r		+	r	+	+	1	r	
103. *Myosotis sylvatica* Hoffm.							r					
104. *Oxalis acetosella* L.		2	1				3	2			3	2
105. *Paris quadrifolia* L.			r								r	
106. *Pedicularis exaltata* Besser										r		
107. *Pyrola minor* L.							r	r				
108. *Poa media* Schur										r	r	
109. *Poa nemoralis* L.				+							r	r
110. *Polygonatum multiflorum* (L.) All.			r									
111. *Polygonatum verticillatum* (L.) All.				r								
112. *Polypodium vulgare* L.										r		
113. *Primula acaulis* (L.) L.										r		
114. *Potentilla argentea* L.			r									
115. *Potentilla recta* L.			r									
116. *Prunella vulgaris* L.			r					r				
117. *Pulmonaria officinalis* L.			r									
118. *Pulmonaria rubra* Schott					r							
119. *Ranunculus carpaticus* Herbich	r	+										
120. *Ranunculus cassubicus* L.					r		r					r
121. *Ranunculus lanuginosus* L.											r	
122. *Ranunculus repens* L.			r									
123. *Rumex crispus* L.			r									

Table 5. (Continued)

124. *Rumex sanguineus* L.							r					r
125. *Salvia glutinosa* L.		r		+				r				
126. *Sambucus ebulus* L.					r			r				
127. *Sanicula europaea* L.							+	r	2	r		
128. *Scirpus sylvaticus* L.											1	r
129. *Scrophularia nodosa* L.			+									
130. *Senecio ovatus* (P. Gaertner, B. Meyer et. Scherb) Willd.		+		r								
131. *Senecio germanicus* Wall.										r		r
132. *Senecio sylvaticus* L.										r		
133. *Soldanella hungarica* Simonkai					r							
134. *Stellaria holostea* L.							+			r	+	1
135. *Stellaria media* (L.) Vill.	r					1						
136. *Stellaria nemorum* L.	r				r							
137. *Symphytum cordatum* Waldst. et Kit.										r	r	
138. *Symphytum tuberosum* L.	r			r						r		
139. *Tanacetum corymbosum* (L.) Schultz Bip.									r			
140. *Tanacetum vulgare* L.								+				
141. *Taraxacum officinale* Weber ex Wiggers							+					
142. *Telekia speciosa* (Schreber) Baumg.									r			
143. *Thymus serpyllum* L.			1									
144. *Trifolium medium* L.									+			
145. *Urtica dioica* L.	+		1	+			+		+	r		
146. *Vaccinium myrtillus* L.					+	r					r	r
147. *Veronica chamaedrys* L.			1									
148. *Veronica serpyllifolia* L.							r	+	r			
149. *Viola odorata* L.								1	r	r		
Mosses												
150. *Bryum capilare* L.								r		+		
151. *Dicranum scoparium* (L.) Hedw.					r		+	r		r	1	r
152. *Hylocomium splendens* Hedw.			r		2							
153. *Hypnum cupressiforme* L.							r	r			1	
154. *Mnium affine* Bl.								r			1	r
155. *Mnium spinosum* (Voit.) Schw.							r	+			2	r
156. *Plagiomnium undulatum* L.											1	
157. *Pleurozium schreberi* Mitt.		+			+		+	2	r	1	2	1
158. *Polytrichum commune* L.		1			+	2	r	1		r	2	+
159. *Ptilium crista-castrensis* (L.) De Not.								r			r	
160. *Rytidiadelphus triquetrus* (L) Warnst.		+										
161. *Sphagnum cymbifolium* Ehrh.				2								

Notes: OM – Obcina Mare; RA – Rarau; MO – Magura Odobesti; F – Fundata; R – Retezat; SdV – Stana de Vale; $_1$ & $_2$ designate the date of sampling, 1998 and respectively 2005

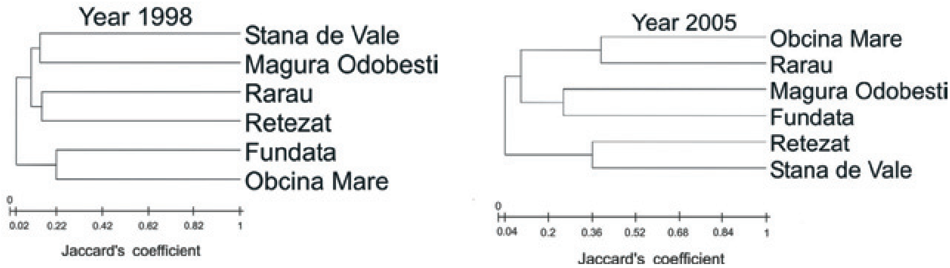

Fig. 3. The cluster diagram of study sites built on Jaccard coefficient of similarity (1998 and 2005).

communities, have a high similarity with that described for 2005 (Donita et al., 1992; Gergely, Ratiu, 1980). For example, for the plant association *Hieracio translivanicae-Piceetum oxalidentosum* has been reported (Coldea, 1991) a number of 29 species, of which 85% were found in 2005. In 1984, Chifu et al. (1984) described 21 plant species for Rarău, of which 80% have been recorded in 2005.

The cluster among study sites, built on the calculated values of the Jaccard coefficient of similarity, suggest for the year 1998 a weak similarity (Jaccard coefficient ~ 0.02) in species composition and a slight trend of clustering based on forest types. That suggests also, that the relative small number of study sites comparing with the large area of Carpathian forests on the Romanian territory, has covered quite well the spatial variability in environmental and ecological conditions. On the other hand, the cluster among study sites built for the year 2005, shows a clear trend of increasing similarity in species composition towards and above the threshold of 0.35 of the Jaccard coefficient, between sites which have a relative close space distribution (Fig. 3). It seems that the significant increase of the number of herbal species (Table 4) and the changes in ground vegetation cover (Table 6) have contributed to shift the way and strength of grouping the research sites, between 1998 and

T a b l e 6. Estimated vegetation cover (%) in the long term study sites from the Romanian Carpathian Mts (the area of records for each site – 2500 m^2)

Vegetation cover (%)	Date	Study sites					
		OM	RA	MO	F	R	SdV
tree layer	1998	70–80	60–70	70–95	70–85	75–90	40–60
shrub layer	2005	70–90	70–80	60–85	70–90	70–80	60–80
	1998	–	–	1–5	–	5–10	5–10
herb layer	2005	1–2	0–4	5–30	0–2	2–10	3–25
	1998	5–25	20–40	40–60	10–25	5–15	50–70
moss layer	2005	30–45	20–45	35–60	30–50	25–40	30–40
	1998	–	1–7	0–2	2–20	20–30	5–10
	2005	2–10	10–20	0–1	2–10	40–60	4–13

Legend: OM – Obcina Mare; RA – Rarau; MO – Magura Odobesti; F – Fundata; R – Retezat; SdV – Stana de Vale

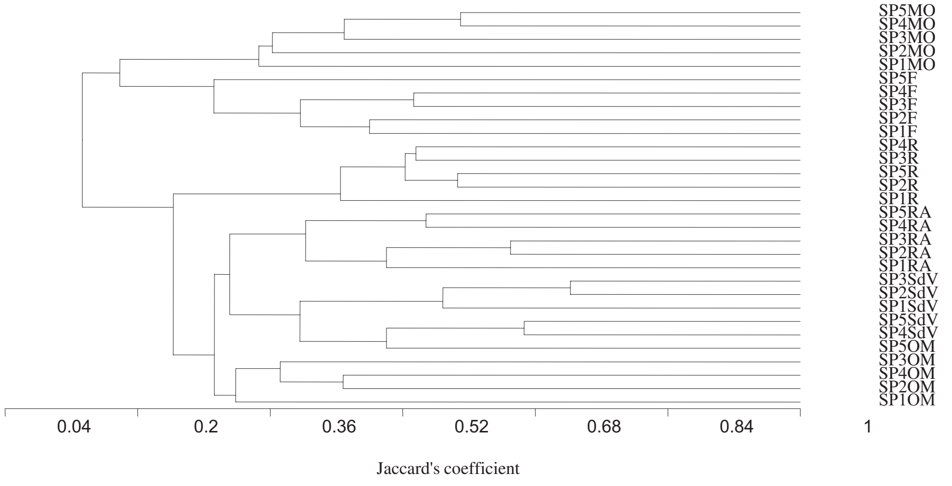

Fig. 4. The cluster diagram of permanent sampling plots built on Jaccard coefficient of similarity (2005).

2005 (Fig. 3). The same type of analysis was carried out by taking into account the results found in 2005 for the total number (30) of sampling plots. Although it is not surprising that a higher degree of similarity occurred among the sampling plots from the same study site (Fig. 4), the range of calculated values for Jaccard coefficients of similarity (0.36–0.7) suggest, on the one hand, that the plant community of each study site maintained a healthy degree of spatial complexity and, on the other hand, the fact that the sampling procedure allowed for full covering of it. The power of sampling procedure has been also proved by assessing the performance towards estimation of species composition of the investigated plant communities.

The construction of species accumulation or, species area curve (SAC) (Coleman et al., 1982; Topa et al., 2001), by taking into consideration the cumulated number of observed species against cumulated surface of sampling plots (Fig. 5), has been used in that regard. It is obvious that both curves built on data collected during sampling programme from 1998 and 2005, reached the plateau number of taxa within the range of cumulated surface of the 30 sampling plots.

Further, there is an attempt to use the average vegetation covers of trees, shrubs, herbs and mosses layers (Table 6) for showing the differences between sites and years of investigation. It can be easily distinguished a small difference (± 10 percent point) between 1998 and 2005, in the case of tree layer, and a more significant one, in the case of shrub, herb and mosses layers.

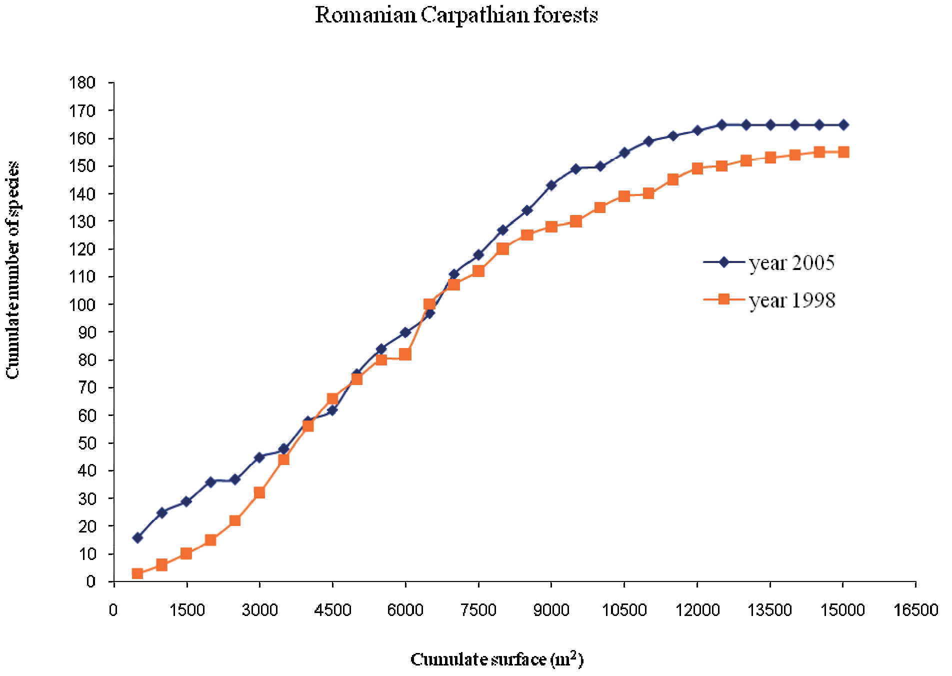

Fig. 5. The species accumulation curves for the Romanian Carpathian forests (1998 and 2005).

It is assumed that under changing environmental conditions (e.g. increase in the amount of precipitation from severe deficit in 1998 to normal or even excess of precipitation after 2003, light condition bellow canopy, soil humidity, litter formation and decomposition) (Geambasu, Danescu, 2005) in the Carpathian mountains, the occurred changes in species composition and species richness, have been supported by an active process of dispersion and colonization of herbaceous species from the surrounding plant communities, or by re-establishment (internal seed banks) of species which previously have occupied the site.

Many field studies and experiments have been carried out in the last few decades, trying to understand the dynamics of plant communities, in terms of species composition and structure, under the pressure of different driving factors (van der Maarel, 1988; van der Maarel, Sykes, 1993). A special attention was given to the ranking of plant species within a community, based on species abundance in order to construct the dominance diversity curve (Whittaker, 1965) and to the identification of the role of different species in the community.

In that regard, has been suggested (Grime, 1998, 2001) that the component species in a plant community might be divided in dominant (abundance ≥ 20%), subordinate (abundance < 20%) and transient species (abundance < 10%; high turnover rate). By taking these findings into consideration, we also assume that the dynamics of plant communities from our study sites has been supported mainly by subordinate and transient type of herbaceous and mosses species under the pressure of variable environmental and anthropogenic (e.g. type and intensity of forest management) drivers.

Indeed, the fact that the composition and species richness of plant communities recorded in 2005 are much closer to that described before 1998 in the same type of communities, might be explained by opportunities available to subordinate and mostly to transient species under particular environmental conditions recorded in 2005, which are in their turn much closer to that recorded in 1980s.

Conclusion

The relative good health status established in 1998 for the forest stands from the Romanian stretch of Carpathian Mts, proved to be maintained and even improved, as it was documented by the investigation carried out in 2005.

The favourable dynamics of biometric parameters and level of tree damages of the forest stands, as well the entire forest vegetation, during 1998–2005, has been driven by: i) the intensity and type of management; ii) the improvement of climate conditions (in particular precipitation and frequency and duration of extreme high temperature during vegetation season); and, iii) further reduction of pressure from air pollution. The identified changes and trends in species composition and richness of the ground vegetation indicate also, that the vegetation of the Carpathian forests has a strong adaptive potential, which make them resilient against changes in major drivers and pressures.

Translated by the authors

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