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PATTERNS OF PLANT ENDEMISM IN THE ROMANIAN CARPATHIANS (SOUTH-EASTERN CARPATHIANS)

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Abstract: The study of endemism, both a biogeographical and evolutionary phenomenon, can reveal valuable historical and ecological aspects of a region's flora. Nevertheless, due to taxonomic inconsistencies and insufficient availability of distribution data, previous studies have shown differing results for the Romanian Carpathians. To reduce these shortfalls, we compiled a database using a vast coverage of existent literature and herbarium collections, complemented by field sampling. As a result, we considered 132 Pan-Carpathian and South-Eastern Carpathian endemic taxa as valid for the Romanian Carpathians. We present the general distribution of all taxa discussed, by covering the main literature from the other Carpathian countries. Then, in order to investigate the endemic plants richness distribution patterns in the study area, we used the framework of the morphological Carpathian units as natural, operational geographic units (OGU's). For spatial interpolation and visualization purposes, we then used an artificial, grid data registering system. Through the use of GIS and spatial analyses, we have identified three main regions of endemism, five major and three minor centres of endemism. We also discuss the possible floristic barriers from the Romanian Carpathians and explore the relationship between endemic taxa richness and several important topographic variables (mean altitude, maximum altitude and altitudinal range). Finally, we highlight the biogeographical importance of the revealed centres of endemism.

Keywords: centres of endemism, species richness, weighted endemism, Carpathians, kriging, Geographic Information System (GIS), Operational Geographic Unit (OGU), Operational Geographic Set (OGS).

Introduction

Pawłowski (1970) considered endemism to be one of the most striking of biogeographical phenomena. Endemics, although not necessarily comprising rare, spatially restricted taxa, are often referred to as '*narrow endemics*' [28], defined by their limited geographical range, restricted to one or a few biogeographical units.

Endemic plant taxa reinforce the floristic identity of geographical units, holding strong imprints of natural phenomena such as speciation, local extinction or areal dynamics. These biogeographical phenomena are often linked both to orogenesis and paleoclimatic events. Although it has been shown that there is not a complete congruence between diversity hotspots and either centres of endemism or threat hotspots [38], the value of using endemics as a tool for conservation purposes has been reiterated in many studies, both globally [30], but especially at a regional or local scale [6, 17, 45, 48]. These arguments might be considered enough to underline the major importance of identifying the centres of endemism in the Romanian Carpathians.

Using a comprehensive dataset of endemic plant taxa occurrences in the Romanian Carpathians, we aimed to: (i) offer the general distribution for all Carpathian endemic taxa present in Romania, except the polymorphic genera *Hieracium*, *Alchemilla* and *Rubus*; (ii) analyze the patterns of richness; and (iii) reveal the centres of endemism of the Romanian Carpathians.

Materials and Methods

Study area

The Carpathian Mountain Range is part of the European Alpine System (EAS) and includes two major subunits: the Western Carpathians and the South-Eastern Carpathians. The limit between these subunits was long discussed by geographers, geologists and biogeographers, resulting in several interpretations. Herein, we accept the opinion of Pawłowski (1970), who placed the limit at the Łupków Pass, on the border between Poland and Slovakia.

Stretching for nearly 1600 km, the Carpathian Mountain Range crosses six countries, namely Slovakia, Poland, Hungary, Ukraine, Romania and Serbia. We focused our study on the South-Eastern subunit of the mountain range, mainly the Romanian part.

The main characteristics of the South-Eastern (and subsequently the Romanian) Carpathians differentiate them from the Alps and other mountain ranges of the EAS. The relief is highly fragmented, with deep transverse valleys (e.g. the Olt, Mureș and Jiu valleys). Altitude does not exceed 2544 m a.s.l. (Moldoveanu Peak in the Făgăraș Mountains, Southern Carpathians) and the distribution of the alpine belt is fragmented, generating habitat insularity [41, 44]. The bedrock generally consists of flysches, crystalline schists, volcanic rocks and limestones [9].

Climatic conditions are mainly defined by an altitudinal gradient, with annual precipitation ranging from 900 mm to 1350 mm [10]. Mean annual temperature varies from negative values (-2^{o} C) in the alpine belt to 7^{o} C in the lower mountain belt or even 10^{o} C in the Danube Gorges [41].

Distribution data

By Carpathian endemic we understand three types of distribution: taxa that are restricted to the Western Carpathians, those which grow exclusively in the South-Eastern unit of the mountain range and those distributed along both of this units, termed *Pan-Carpathian*. In our analyses we have included only those taxa growing in the Romanian Carpathians, either South-Eastern Carpathian or *Pan-Carpathian* endemics.

We compiled the distribution database from literature sources, herbarium data and field surveys, using 132 endemic taxa. The database as well as the critical evaluation of the taxa considered valid was presented by Hurdu *et al.* (2012). The high accuracy of spatial references appended to every cited locality enabled us to use two different systems for analyzing the distribution: an artificial grid system and a natural system of orographic units.

Operational Geographic Units (OGUs) were defined by Crovello (1981) as any one of the set of geographic units to be analyzed in a study, while Operational Geographic Sets (OGS) comprise all OGUs in the study [12]. In order to register the endemic plants distribution and richness in the Romanian Carpathians, we used two OGSs. To facilitate the biogeographical interpretation, we first used a natural system consisting of morphological Carpathian units [34, 40] as OGU's. Moreover, we constructed an artificial, grid-based data registering system for spatial analyses and visualization purposes. The grid cell was similar to that used in the *IntraBioDiv* project [18], having a grid cell size of 12' lat. × 20' long (~ 22,3 × 25 km). One sensitive subject in spatial analysis of endemism is the grain size, in that it is known that scale influences the patterns of richness and the detail of discrimination between different areas [11, 29]. Therefore, choosing a smaller cell size would probably refine the results, but would also increase the risk of generating numerous 'artificially' empty grid units, which would bias the results. Thus, we considered the use of both natural and artificial OGS to be the best solution for increasing biogeographically informative results.

Data analysis

First, we excluded from the analysis the polymorphic taxonomic groups *Hieracium*, *Alchemilla* and *Rubus*. We also did not consider several critical taxa that lacked taxonomic consensus or had unknown distributions. Nomenclature was validated via several works [8, 51, 53].

In order to have an overview of the endemic-rich areas, we summarized the different occurrences in each natural OGU. We then used the functions in package 'doBy' [22] from the open-source statistical software R [43] to remove any accidental duplicates. Furthermore, in order to better visualize the general patterns and the hotspots of endemism, we used the artificial OGSs for spatial interpolation.

The simplest measure of endemism is the grid cell species richness [11]. This measure, however, can be misleading, as it does not provide information about species range. Consequently, we applied an additional measure, '*weighted endemism*'. This is considered a more appropriate measure of endemism because it offers weight to each taxon by using the inverse of its range. Although this measure was shown to correlate highly with species richness [11], it might reveal areas with range-restricted endemics, a reason for its frequent application in studies of endemism [2, 32, 50]. *Weighted endemism* is calculated by weighing each taxa by its inverse of its range. For example, a single cell endemic will then have a value of 1, one occurring in 2 cells would receive the value 0.5 and one present in 10 grid cells will have a weighted value of 0.1. Finally, we summed the new values for each grid cell. We carried out a *kriging* interpolation in ArcGIS 9.3.1 Spatial Analyst [16]. This method was employed for generating a surface of continuous richness or weighted endemism values and has been shown to be more appropriate for spatially auto-correlated data [7].

We also analyzed the relationship between endemic taxa richness and different topographic variables (mean altitude, maximum altitude and altitudinal range/grid cell). The response of species richness to the elevation gradient was analyzed by fitting a logistic curve selected automatically from a range of functions based on the lowest Akaike's Information Criterion (AIC) in the software CurveExpert Professional ver. 1.5 [24].

Centres of endemism are defined as areas where the ranges of restricted-range species overlap [19] or where there is a high occurrence of endemics, and are potential areas of special evolutionary history and biological diversification [26]. Moreover, such areas are of high conservative value. Based on the above spatial analyses, we have identified the centres of endemism from the Romanian part of the South-Eastern Carpathians.

Results and Discussion

Of the 132 taxa taxonomical and chorological validated, 27 are Pan-Carpathian and 105 are restricted in their range to the South-Eastern Carpathians. Pawłowski (1970) mentioned 25 endemics common to both Carpathian subunits and 100 South-Eastern Carpathian taxa. The total number of Carpathian endemics from Romania varied among different authors, e.g. 97 (Beldie, 1967), 149 (Heltmann, 1985), 128 (Negrean & Oltean, 1989). Their distribution *by country*, excluding Romania (which hosts all the taxa analyzed) shows Ukraine to have the largest number (60). These endemic taxa are mostly concentrated in the high massifs north of the Maramureș Mountains (i.e. Chornohora, Svydovets, Chyvchyn), all exhibiting close floristic connections. In the South-Western part of the South-Eastern Carpathians, the lower altitude Trans-Danubian unit from Serbia hosts several thermophilous endemic taxa common to the Romanian Carpathians. These are mostly restricted to a few lower mountains such as Mehedinți (Cerna Valley) or Almăjului (especially the Danube Gorge area): *Primula auricula* ssp. *serratifolia, Tulipa hungarica, Dianthus giganteus* subsp. *banaticus*, *Campanula crassipes* and

Centaurea triniifolia. The northern range margins of several Balkan sub-endemic taxa are also known from this area – *Hypericum rumeliacum*, *Ferula heuffelii* and *Knautia macedonica*, as well as many thermophilous non-endemic taxa. For these reasons, some biogeographers have following Adamović (1909) in considering that the Danube Gorge area actually belongs to the Western Moesian floristic district or Carpatho-Balcanic Serbia. Since the splitting of a compact unit such as the Porţile de Fier (Iron Gate) gorge is not the best solution, the transient nature of this area should be clarified in the future. The general distribution of these taxa is shown *per country* in Table 2.

Endemism patterns describe an uneven distribution of endemic taxa richness throughout the Romanian Carpathians (Table 1). This can be observed by analyzing the richness levels of endemic taxa in the main natural OGU's. High mountains supporting alpine environments (e.g. Rodna, Bucegi, Făgăraș or Retezat) have a high degree of endemism. Limestone massifs such as Piatra Craiului, Hăsmaș - Cheile Bicazului or Ceahlău also have a rich endemic flora, noticeable for its locally restricted distribution. In contrast, the lower mountains do not hold such a great level of endemism, except for several limestone units (Mehedinți, Trascău).

Table 1: Endemic taxa richness for the main OGU's from the Romanian South-Eastern Carpathians

OGU	No. end.	OGU	No. end.	OGU	No. end.	OGU	No. end.
Rodna	73	Țarcu-Godeanu-Cernei	39	Vrancei	19	Oaș	7
Bucegi	72	Cindrel (Cibin)	35	Almăjului	18	Tarcău	7
Făgăraș	70	Stânișoarei	34	Metaliferi	18	Penteleu	6
Piatra Craiului	65	Nemira	31	Pădurea Craiului	17	Semenic	6
Retezat	63	Gilău - Muntele Mare	29	Gutâi	16	Codru-Moma	5
Hăsmaș-Cheile Bicazului	62	Bihor-Vlădeasa	28	Harghita	16	Poiana Ruscă	5
Ceahlău	59	Iezer-Păpușa	28	Perşani	16	Meseș	6
Bârsei	57	Leaota	28	Șureanu	16	Bârgău	3
Parâng	55	Trascău	28	Latorița	15	Locvei	3
Ciucaş	51	Obcinele Bucovinene	26	Baiului	14	Buzăului	2
Căpățânii	50	Țibleș	26	Aninei	13	Ciucului	2
Rarău	50	Bistriței	24	Gurghiu	13	Culmea Codrului	2
Maramureș	47	Siriu	22	Suhard	12	Dognecea	2
Mehedinți	44	Cozia	20	Bodoc	10	Plopiș	2
Călimani	41	Lotrului	20	Zarand	8		

Based on both natural and artificial OGS richness (Fig. 1) and weighted endemism (Fig. 2) analysis and on floristic affinities between different areas, we have distinguished three main regions of high endemism, with five major and three minor centres. These, however, should not be confused with areas of endemism *sensu* Linder (2001), but interpreted rather as 'hotspots' of endemism with evolutionary and conservation implications. The major centres are characterized by both a rich endemic flora and, occasionally, by the presence of local endemics, indicating their high conservation value.

The three main *regions of endemism* are discriminated through differential endemic taxa and highlighted by their floristic richness:

(1) Central Eastern Carpathians (with Svydovets, Chornohora, Chyvchyn, Maramureș, Rodna, Țibleș, Călimani, Rarău, Ceahlău and Hășmaș-Cheile Bicazului Mountains);

(2) Southern Carpathians East of the Olt river (with Ciucaș, Bârsei, Bucegi, Piatra Craiului, Iezer-Păpușa and Făgăraș Mountains);

(3) South-Western Carpathians extending to the Danube Gorge (with Retezat, Țarcu – Godeanu-Cernei, Mehedinți-Oslea, Almăjului and Trans-Danubian Mountains).

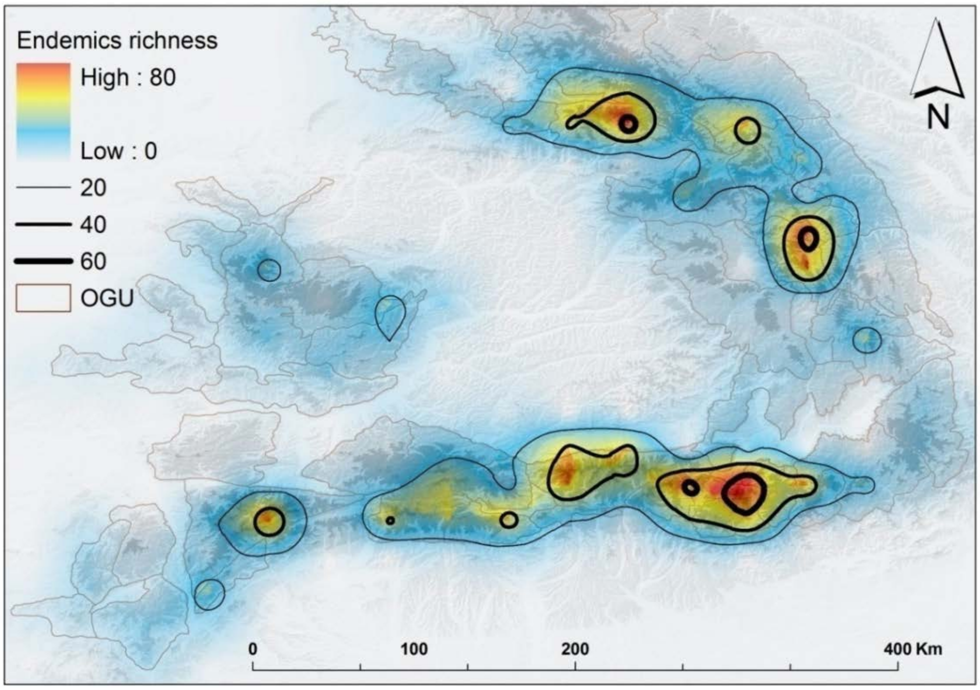

Fig. 1: Endemism patterns in the Romanian South-Eastern Carpathians obtained through Kriging Interpolation technique

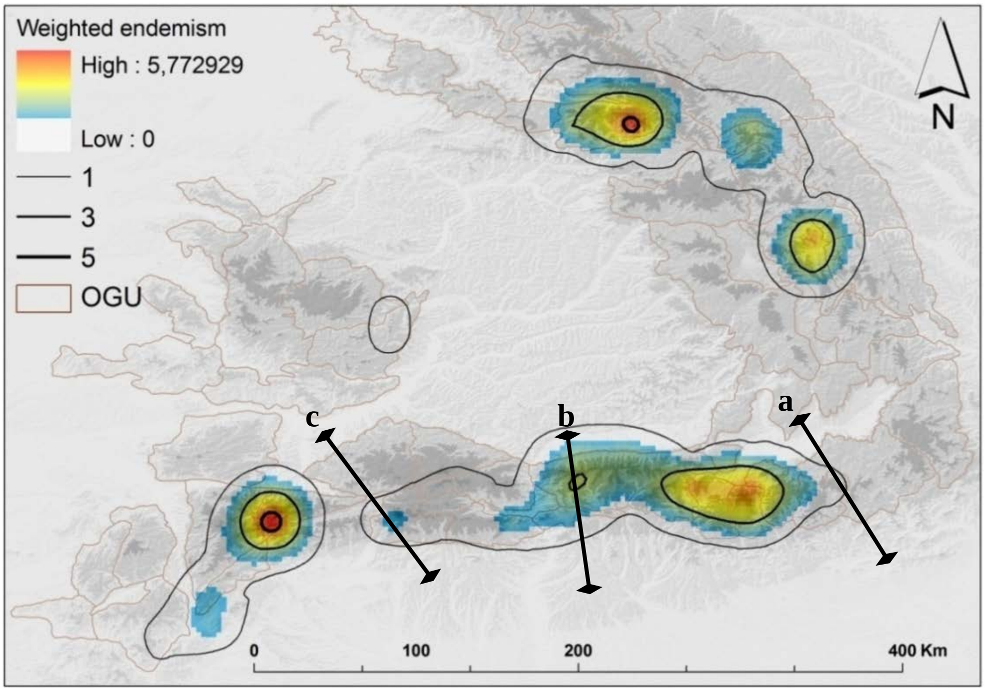

Fig. 2: Weighted endemism in the Romanian South-Eastern Carpathians obtained through Kriging Interpolation technique (a, b, c: floristic barriers; for explanation, see text above)

When discussing patterns of endemism and areal dynamics of species, we are taking into account two important aspects: a Pleistocene refugial effect and biogeographical barriers that prevented further expansion of some endemics. In our studied territory, range limits of several taxa (provided in brackets) may highlight such floristic barriers, as well as indicate possible refugial areas (Fig. 2):

(1) The Curvature Carpathians, which are lower mountains that link the Eastern Carpathians with the Southern Carpathians (*Athamanta turbith* subsp. *hungarica* and *Dianthus henteri* are limited to the west of this barrier, while *Festuca bucegiensis, Poa rehmannii* and *Primula elatior* subsp. *leucophylla* extend eastwards);

(2) the Olt Valley, a deep transverse valley which sets the range limit for several endemic taxa (*Draba kotschyi*, *Erigeron nanus, Gentiana cruciata* subsp. *phlogifolia, Heracleum carpaticum, Leontodon repens* and *Melampyrum saxosum* are distributed to the east of the barrier, while *Galium baillonii* and *Micromeria pulegium* are limited to the west);

(3) the Jiu-Strei corridor in the Western part of the South-Eastern Carpathians, delimiting the Retezat from the Parâng Mountains (*Cardaminopsis neglecta, Ranunculus carpaticus* and *Festuca bucegiensis* grow to the east of this limit, while *Primula auricula* subsp. *serratifolia* and *Dianthus giganteus* subsp. *banaticus* stop at the western side of the barrier).

Based on our analyses, we have identified the following *major centres of endemism* for the Romanian Carpathians:

(1) Rodna – Maramureş - Svydovets – Chornohora – Chyvchyn center of endemism has seven differential taxa: *Armeria pocutica, Cochlearia borzaeana, Euphorbia carpatica, Festuca versicolor* subsp. *dominii*, *Lychnis nivalis*, *Saussurea porcii, Soldanella rugosa*, and a total of 77 taxa (58%). The altitudinal maximum is in the Rodnei Mountains (Pietrosul Rodnei Peak: 2303 m a.s.l.), which also harbours three local endemics and the highest number of endemics of the South-Eastern Carpathians. These suggest a possible alpine refugium here;

(2) Hăşmaş-Cheile Bicazului – Ceahlău – Rarău mountain group form a centre of endemism with high floristic diversity and two restricted endemics, but without range congruency: *Astragalus roemeri*, *A. pseudopurpureus*, and several other rare endemics (*Asperula carpatica*, which grows also in the Stânişoarei Mountains). These limestone massifs might be characterized by the phenomenon of habitat insularity, which has presumably acted on their floristic isolation. The total richness of this centre of endemism is 77 taxa (58%);

(3) Bucegi-Bârsei – Piatra Craiului – Ciucaş centre of endemism possesses the highest diversity in the South-Eastern Carpathians, comprising 87 endemic taxa (66%). Moreover, it has several non-congruent local endemics: *Dianthus callizonus*, *Ornithogalum orthophyllum* subsp. *acuminatum*, *Primula wulfeniana* subsp. *baumgarteniana* and *Saxifraga mutata* subsp. *demissa*;

(4) Făgăraş Mountains have the most extensive compact alpine environment, together with the Retezat Mountains. With a total of 70 endemic taxa, mostly alpine, it is the third most diverse unit in the whole South-Eastern Carpathians. Remarkably, *Silene dinarica* is endemic solely to this massif and the neighboring Southern Cozia Massif (the species was cited also from the Godeanu Mountains by Heuffel in 1858, but not confirmed for the last 150 years);

(5) Retezat-Ţarcu-Godeanu Mountains represents one of the most diverse units in the South-Eastern Carpathians. It has a total of four local endemic taxa (*Barbarea lepuznica*, *Carduus kerneri* subsp. *lobulatiformis*, *Centaurea phrygia* subsp. *ratezatensis* and *Festuca pachyphylla*).

We also identified three minor centres of endemism, characterized by local endemics, but having lower species richness compared to the major centres:

(1) Cozia **–** Buila-Vânturariţa centre of endemism is formed of two limestone massifs separated by the Olt Valley. These two calcareous units have high floristic affinities, with taxa

restricted to this area (*Rosa villosa* subsp. *coziae*). *Stipa crassiculmis* P. Smirnov subsp. *heterotricha* Dihoru & Roman, another endemic taxon, was cited as being restricted to the Cozia Mountains. Despite this, we did not consider it for our analyses, as it has critical taxonomic status, being placed in synonymy under subsp. *euroanatolica* by Ciocârlan in his last edition of the Romanian Flora [8];

(2) Mehedinţi – Almăjului – Transdanubian Carpathians centre of endemism possesses several locally restricted taxa (*Minuartia hirsuta* subsp. *cataractarum*, *Prangos carinata*, *Stipa danubialis* and *Tulipa hungarica*) and several species that extended into a few mountains further north (*Campanula crassipes, Centaurea triniifolia, Dianthus giganteus* subsp. *banaticus, Primula auricula* subsp. *serratifolia* and *Sorbus borbasii*);

(3) Trascău-Scărița Belioara massifs constitute another minor centre of endemism, characterized by lower altitude limestone cliffs, and have two local endemics: *Sorbus dacica* and *Centaurea reichenbachii*.

At a coarser spatial resolution, Pawłowski (1970) identified four main centres of endemism in the South-Eastern Carpathians, with the main difference being that he considered the Southern Carpathians as a single floristic unit. We stress that, due to affinities of endemic floras, the mountains located eastwards from the Olt Valley are more closely related to the Eastern Carpathians. Similar findings have been presented by Negrean & Oltean (1989). Nevertheless, differences occurred as they separated Rarău Mountains and Cheile Bicazului from the Ceahlău and Hășmas Mountains, describing two different centres of endemism. Taxa such as *Asperula carpatica*, *Centaurea phrygia* subsp. *carpatica*, *Heracleum carpaticum*, *Hesperis moniliformis*, *Leontodon repens*, *Primula elatior* subsp. *leucophylla*, *Silene zawadzkii*, *Thesium kernerianum* and *Trisetum macrotrichum*, occurring in the Rarău, Ceahlău and Hășmaș Mountains, do not justify the existence of a floristic barrier between the above-mentioned centres of endemism.

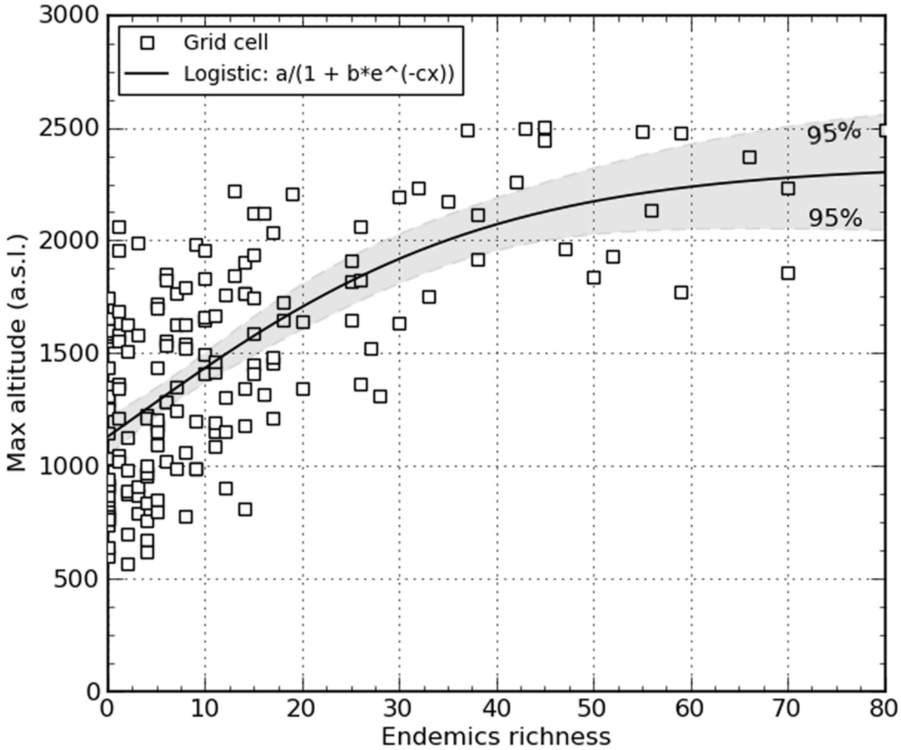

Fig. 3: The relationship between richness of endemic taxa and maximum altitude *per* grid cell (AIC: 1900.95, Standard error: 352.09, *r*: 0.69)

By analyzing the relationship between the richness of endemic taxa and different topographic variables (mean altitude, maximum altitude and altitudinal range *per* grid cell), we observed the strongest relationship to be between the maximum altitude and the richness of endemics (Fig. 3). It has been observed that there is a general tendency of richness to increase with altitude, especially between lower montane and alpine levels (up to ~2200 m a.s.l.). The distribution of endemics throughout the Romanian Carpathians is tightly linked to the extent of the alpine belt, which is characterized by insularity. This is known for certain, as the alpine system acted through isolation mechanisms as both a speciation environment and refugial area. Nevertheless, saturation is reached at a value of 50 and the curvature at about 40 for species richness, meaning that grid cells having similar maximum altitude vary largely in number of endemic taxa (50–80). This could be caused by several different factors, mainly the variation in climatic conditions, bedrock type and different historical backgrounds. To a lesser extent, human impact on the habitat or a difference in sampling intensity might play a role.

Conclusions

There are 132 Carpathian endemics in the Romanian Carpathians, of which 27 are *Pan-Carpathian* distributed and 105 have their range restricted to the South-Eastern Carpathians. Based on their distribution, we have distinguished *three* main regions of endemism, separated by possible floristic barriers.

Analysing the endemism patterns through spatial interpolation using species richness and weighted endemism as measures, we have identified *five major* and *three minor centres of endemism*. These are characterized by high values of endemism and weighted endemism, indicating the local character of the flora. Our findings are largely congruent with the analyses of Pawłowski (1970) and Negrean & Oltean (1989), suggesting that the differences in richness could be the result of different taxonomic interpretations and available knowledge of their distribution.

Many spatially restricted endemic taxa are confined to mountainous areas characterized by an extensive alpine environment or limestone bedrock. The relationship between richness and maximum altitude *per* grid cell was best fitted by a logistic function with saturation at a value of 50 taxa and a curvature at about 40. Richness of endemics varies along the alpine belt, with factors such as bedrock type, human influence or sampling intensity being possibly behind this phenomenon. The influence of these factors on endemism should be further analyzed, the study of these relationships being beyond the scope of this paper.

The majority of endemism hotspots are already included within legally protected areas. Nevertheless, they are still highly susceptible to anthropogenic influences such as logging, livestock grazing or irresponsible tourism. Areas such as the Maramureșului, Făgăraș or Bucegi Mountains are known to be more prone to such disturbances, thus requiring more strict protection measures.

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Table 2: The complete list of Pan-Carpathian and South-Eastern Carpathian endemic taxa and their distribution by country along the Carpathian Mountain Range.

No.	Pan-Carpathian Taxa	Family	Carp. distribution					
			Ro	Ukr	Srb	Pol	Sk	Hu
1	*Centaurea phrygia* L ssp. *melanocalathia* (Borbás) Dostál	*Asteraceae*	+	+		+	+	
2	*Erigeron nanus* Schur	-„-	+			+	+	
3	*Leontodon montanus* Lam. ssp. *pseudotaraxaci* (Schur) Finch & P.D.Sell	-„-	+	+		+	+	
4	*Leucanthemum waldsteinii* (Sch.Bip.) Pouzar	-„-	+	+		+	+	
5	*Symphytum cordatum* Waldst. & Kit. ex Willd.	*Boraginaceae*	+	+		+	+	
6	*Cardamine glanduligera* O.Schwarz	*Brassicaceae*	+	+		+	+	+
7	*Cardaminopsis neglecta* (Schult.) Hayek	-„-	+	+		+	+	
8	*Erysimum witmanni* Zaw. ssp. *witmanni*	-„-	+			+	+	
9	*Hesperis nivea* Baumg.	-„-	+	+		+	+	
10	*Campanula carpatica* Jacq.	*Campanulaceae*	+	+			+	
11	*Campanula rotundifolia* L. ssp. *polymorpha* (Witašek) Tacik	-„-	+	+		+	+	
12	*Campanula serrata* Hendrych	-„-	+	+		+	+	
13	*Silene nutans* L. ssp. *dubia* (Herbich) Zapal.	*Caryophyllaceae*	+	+		+	+	
14	*Sempervivum montanum* L. ssp. *carpaticum* Wettst. ex Hayek	*Crassulaceae*	+	+		+	+	
15	*Oxytropis carpatica* R.Uechtr.	*Fabaceae*	+	+		+	+	
16	*Trifolium medium* L. ssp. *sarosiense* (Hazsl.) Simonk.	-„-	+				+	+
17	*Luzula alpinopilosa* (Chaix) Breistr. ssp. *obscura* Frohner	*Juncaceae*	+	+		+	+	
18	*Thymus pulcherrimus* Schur	*Lamiaceae*	+	+		+	+	
19	*Dactylorhiza maculata* (L) Soo ssp. *schurii* (Klinge) Soó	*Orchidaceae*	+				+	
20	*Plantago atrata* Hoppe ssp. *carpatica* (Pilg.) Soó	*Plantaginaceae*	+	+		+	+	
21	*Festuca carpatica* F. G. Dietr.	*Poaceae*	+	+		+	+	
22	*Festuca rupicola* Heuffel. ssp. *saxatilis* (Schur) Rauschert	-„-	+	+			+	
23	*Festuca versicolor* Tausch. ssp.*versicolor*	-„-	+	+		+	+	
24	*Trisetum fuscum* Schultes	-„-	+	+		+	+	
25	*Aconitum lycoctonum* L ssp. *moldavicum* (Hacq.) Jalas	*Ranunculaceae*	+	+		+	+	+
26	*Ranunculus carpaticus* Herbich	-„-	+	+			+	
27	*Salix kitaibeliana* Willd.	*Salicaceae*	+	+		+	+	
No.	**South-Eastern Carpathian Taxa**	**Family**	**Ro**	**Ucr**	**Srb**	**Pol**	**Sk**	**Hu**
1	*Athamanta turbith* (L.) Brot. ssp. *hungarica* (Borbás) Tutin	*Apiaceae*	+		+			
2	*Heracleum carpaticum* Porcius	-„-	+	+				
3	*Heracleum sphondylium* L. ssp. *transsilvanicum* (Schur) Brummitt	-„-	+	+				
4	*Prangos carinata* Griseb. ex Degen	-„-	+					
5	*Achillea oxyloba* (DC.) Sch.Bip. ssp. *schurii* (Sch.Bip.) Heimerl	*Asteraceae*	+	+				
6	*Andryala laevitomentosa* (Sennikov) Greuter	-„-	+					
7	*Anthemis carpatica* Willd. ssp. *pyrethriformis* (Schur) Beldie	-„-	+					
8	*Anthemis kitaibelii* Spreng.	-„-	+					
9	*Carduus kerneri* Simk. ssp. *Kerneri*	-„-	+	+				
10	*Carduus kerneri* Simk. ssp. *lobulatiformis* (Csürös & Nyár.) Soó	-„-	+					
11	*Centaurea phrygia* L. ssp. *carpatica* (Porcius) Dostál	-„-	+	+				
12	*Centaurea phrygia* L. ssp. *rarauensis* (Prodan) Dostál	-„-	+					
13	*Centaurea phrygia* L. ssp. *ratezatensis* (Prodan) Dostál	-„-	+					
14	*Centaurea pinnatifida* Schur	-„-	+					
15	*Centaurea reichenbachii* DC.	-„-	+					
16	*Centaurea trichocephala* Bieb. ssp. *simonkaiana* (Hayek) Dostál	-„-	+					
17	*Centaurea triniifolia* Heuffel	-„-	+		+			
18	*Doronicum carpaticum* (Griseb. & Schenk) Nyman	-„-	+	+				
19	*Leontodon repens* Schur	-„-	+	+				
20	*Saussurea porcii* Degen.	-„-	+	+				
21	*Eritrichium nanum* Schrader ssp. *jankae* (Simonk.) Jáv.	*Boraginaceae*	+					

22	*Pulmonaria filarszkyana* Jav.	-,,-	+	+			
23	*Barbarea lepuznica* Nyár.	*Brassicaceae*	+				
24	*Cochlearia borzaeana* (Coman & Nyár.) Pobed.	-,,-	+				
25	*Draba dorneri* Heuff.	-,,-	+				
26	*Draba haynaldii* Stur	-,,-	+				
27	*Draba kotschyi* Stur	-,,-	+				
28	*Draba simonkaiana* Jav.	-,,-	+				
29	*Erysimum witmanni* Zaw. ssp. *transsilvanicum* (Schur) P.W.Ball	-,,-	+	+			
30	*Hesperis moniliformis* Schur	-,,-	+				
31	*Hesperis oblongifolia* Schur	-,,-	+				
32	*Thlaspi dacicum* Heuff. ssp. *banaticum* (R.Uechtr.) Jáv.	-,,-	+				
33	*Thlaspi dacicum* Heuff. ssp. *Dacicum*	-,,-	+	+			
34	*Campanula crassipes* Heuffel	*Campanulaceae*	+		+		
35	*Campanula rotundifolia* L ssp. *kladniana* (Schur) Witasek	-,,-	+	+		+	
36	*Phyteuma tetramerum* Schur	-,,-	+	+			
37	*Phyteuma vagneri* Kerner	-,,-	+	+			
38	*Cerastium arvense* L. ssp. *lerchenfeldianum* (Schur) Asch. & Graebn.	*Caryophyllaceae*	+				
39	*Cerastium transsilvanicum* Schur	-,,-	+				
40	*Dianthus callizonus* Schott & Kotschy	-,,-	+				
41	*Dianthus giganteus* d'Urv. ssp. *banaticus* (Heuff.) Tutin	-,,-	+		+		
42	*Dianthus glacialis* Haenke. ssp. *geldius* (Schott, Nyman & Kotschy) Tutin	-,,-	+				
43	*Dianthus henteri* Heuff. ex Griseb. & Schenk	-,,-	+				
44	*Dianthus spiculifolius* Schur. ssp. *spiculifolius*	-,,-	+	+			
45	*Dianthus tenuifolius* Schur	-,,-	+	+			
46	*Gypsophila petraea* (Baumg.) Rchb.	-,,-	+				
47	*Lychnis nivalis* Kit.	-,,-	+				
48	*Minuartia hirsuta* (M.Bieb.) Hand.-Mazz. ssp. *cataractarum* (Janka) Soó	-,,-	+				
49	*Minuartia verna* L. ssp. *oxypetala* (Woloszczak) G.Halliday	-,,-	+	+			
50	*Silene dinarica* Sprengel	-,,-	+				
51	*Silene zawadzkii* Herbich	-,,-	+	+			
52	*Scabiosa columbaria* L. ssp. *banatica* (Waldst. & Kit.) Diklić	*Dipsacaceae*	+		+		
53	*Scabiosa columbaria* L. ssp. *pseudobanatica* (Schur) Jáv. & Csapody	-,,-	+	+			+
54	*Scabiosa lucida* Vill. ssp. *barbata* Nyár.	-,,-	+	+			
55	*Euphorbia carpatica* Woloszczak	*Euphorbiaceae*	+	+			
56	*Astragalus pseudopurpureus* Gusul.	*Fabaceae*	+				
57	*Astragalus roemeri* Simonk.	-,,-	+				
58	*Genista tinctoria* L. ssp. *oligosperma* (Andrae) Borza	-,,-	+	+			
59	*Gentiana cruciata* L. ssp. *phlogifolia* (Schott & Kotschy) Tutin	*Gentianaceae*	+				
60	*Crocus banaticus* Gay	*Iridaceae*	+	+	+		
61	*Micromeria pulegium* (Rochel) Bentham	*Lamiaceae*	+		+		
62	*Thymus bihoriensis* Jalas	-,,-	+				
63	*Thymus comosus* Heuff. ex Griseb.	-,,-	+				
64	*Ornithogalum orthophyllum* Ten. ssp. *acuminatum* (Schur) Zahar.	*Liliaceae*	+				
65	*Tulipa hungarica* Borbas	-,,-	+		+		
66	*Linum uninerve* (Rochel) Jáv.	-,,-	+				
67	*Syringa josikaea* J.Jacq. ex Rchb.	*Oleaceae*	+	+			
68	*Dactylorhiza cordigera* (Fries) Soó ssp. *siculorum* (Soó) Soó	*Orchidaceae*	+				
69	*Papaver alpinum* L. ssp. *corona-sancti-stephani* (Zapal.) Borza	*Papaveraceae*	+				
70	*Armeria pocutica* Pawł.	*Plumbaginaceae*	+	+			
71	*Alopecurus pratensis* L. ssp. *laguriformis* (Schur) Tzvelev	*Poaceae*	+	+			
72	*Festuca bucegiensis* Mark. - Dan.	-,,-	+				

73	*Festuca nitida* Kit. ssp. *flaccida* (Schur) Markgr.-Dann.	-„-	+					
74	*Festuca pachyphylla* Degen ex Nyár.	-„-	+					
75	*Festuca porcii* Hackel	-„-	+	+				
76	*Festuca versicolor* Tausch. ssp. *dominii* Krajina	-„-	+					
77	*Helictotrichon decorum* (Janka) Henrard	-„-	+					
78	*Koeleria macrantha* (Ledeb.) Schult. ssp. *transsilvanica* (Schur) A. Nyár.	-„-	+	+				
79	*Poa granitica* Braun-Blanq. ssp. *disparilis* (Nyár.) Nyár.	-„-	+	+				
80	*Poa rehmannii* (Asch. & Graebn.) Woloszczak	-„-	+	+				
81	*Sesleria heuflerana* Schur ssp. *heuflerana*	-„-	+	+				+
82	*Stipa danubialis* Dihoru & Roman	-„-	+					
83	*Trisetum macrotrichum* Hackel.	-„-	+					
84	*Primula auricula* L. ssp. *serratifolia* (Rochel) Jáv.	*Primulaceae*	+		+			
85	*Primula elatior* L. ssp. *leucophylla* (Pax) Hesl.-Harr.f. ex W.W.Sm. & H.R.Fletcher	-„-	+					
86	*Primula wulfeniana* Schott ssp.*baumgarteniana* (Degen & Moesz) Lüdi	-„-	+					
87	*Soldanella rugosa* L.B.Zhang	-„-	+					
88	*Aconitum tauricum* Wulf. ssp. *hunyadense* (Degen) Ciocârlan	*Ranunculaceae*	+					
89	*Aquilegia nigricans* Baumg ssp. *subscaposa* (Borbás) Soó	-„-	+					
90	*Aquilegia transsilvanica* Schur	-„-	+	+				
91	*Delphinium simonkaianum* Pawł.	-„-	+					
92	*Hepatica transsilvanica* Fuss	-„-	+					
93	*Rosa villosa* L. ssp. *coziae* (Nyár.) Ciocârlan	*Rosaceae*	+					
94	*Sorbus borbasii* Jav.	-„-	+					
95	*Sorbus dacica* Borbas	-„-	+					
96	*Asperula carpatica* Morariu	*Rubiaceae*	+					
97	*Galium baillonii* D.Brândza	-„-	+					
98	*Galium kitaibelianum* Schult. & Schult.f.	-„-	+					
99	*Thesium kernerianum* Simonk.	*Santalaceae*	+					
100	*Chrysosplenium alpinum* Schur	*Saxifragaceae*	+	+				
101	*Saxifraga mutata* L. ssp. *demissa* (Schott & Kotschy) D.A.Webb	-„-	+					
102	*Melampyrum saxosum* Baumg.	*Scrophulariaceae*	+	+				
103	*Pedicularis baumgarteni* Simonk.	-„-	+					
104	*Viola declinata* Waldst. & Kit.	*Violaceae*	+	+				
105	*Viola jooi* Janka	-„-	+	+				
	TOTAL	**30**	**132**	**60**	**9**	**23**	**27**	**5**

List of abbreviations and main sources for distribution of endemics along the Carpathian range:
Ro: Romania (*Flora R.P.R.-R.S.R.*, 1952–1976; Beldie, 1977–1979; Morariu & Beldie, 1976; Dihoru & Pârvu, 1976; Negrean & Oltean, 1989; Ciocârlan, 2009; Dihoru & Negrean, 2009**); Ukr: Ukraine** (Tasenkevich, 1998; Antosiak *et al.*, 2009; Didukha, 2009**); Srb: Serbia (**Josifović, 1970–1977, Sarić & Diklić 1986, Sarić 1992**); Pol: Poland** (Mirek *et al.*, 2002; Piekos-Mirkowa & Mirek, 2003**); Sk: Slovakia (**Marhold & Hindák, 1998**); Hu: Hungary (**Király, 2007**); Carp: Carpathian (**Pawłowski, 1970; Tutin *et al.* (eds.), 1964–1980; Witkowski *et al.*, 2003**).**

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PATTERN-URI DE ENDEMISM ALE PLANTELOR DIN CARPAȚII ROMÂNEȘTI (CARPAȚII SUD-ESTICI)

(Rezumat)

Studiul endemismului, un fenomen atât biogeografic cât și evolutiv, poate evidenția aspecte istorice și ecologice importante ale florei unei regiuni. Totuși, datorită inadvertențelor taxonomice și a corologiei incomplet cunoscute, studiile anterioare au oferit rezultate și interpretări variabile pentru Carpații Românești.

Pentru a reduce aceste neajunsuri, am alcătuit o bază de date amplă, utilizând atât surse din literatură, cât și colecțiile de herbar existente sau date eșantionate recent. Ca rezultat, am considerat 132 de taxoni Pancarpatici și Sud-Est Carpatici ca fiind valizi din punct de vedere taxonomic sau corologic.

Am prezentat distribuția generală a acestor taxoni utilizând principalele surse bibliografice din ţările Carpatice. În afara României, care deține toți taxonii analizați, printre ţările cu o floră a endemitelor Carpatice bogată se află Ucraina (60 endemite), Slovacia (27 endemite Pancarpatice) sau Polonia (23 endemite).

Ulterior, pentru a investiga distribuția bogăției specifice din Carpații Românești, am utilizat unitățile morfologice muntoase drept unități geografice operaționale naturale. S-a observat o concentrare a endemitelor în

aria masivelor montane înalte din Carpați, flora cea mai bogată deținând-o Munții Rodnei (cu 73 de taxoni), urmată de Munții Bucegi (72) și Munții Făgăraş (70). De asemenea, masivele calcaroase din cuprinsul Carpaților Românești au prezentat o valoare conservativă mare, adăpostind taxoni locali.

Pentru a realiza interpolarea spațială a datelor am utilizat un sistem artifical de tip grid. Utilizând mediul GIS și analize spațiale, am identificat trei mari *regiuni de endemism* (Carpații Estici Centrali, Carpații Sudici la Est de Valea Oltului și Carpații Sudici la Vest de Valea Oltului), cinci *centre de endemism majore* (Munții Rodnei – Maramureș – Svydovets – Chornohora – Chyvchyn, Munții Hășmaș – Cheile Bicazului – Ceahlău – Rarău, Munții Bucegi – Bârsei – Piatra Craiului – Ciucaș, Munții Făgăraș și Munții Retezat – Țarcu – Godeanu) și trei *minore* (Munții Cozia – Masivul Buila-Vânturarița, Munții Mehedinti – Almăjului – Carpații Transdanubieni și Munții Trascău – Masivul Scărița Belioara).

Am discutat apoi asupra unor posibile bariere floristice din cadrul Carpaților Românești și am analizat relațiile dintre bogăția specifică a endemitelor și trei variabile topografice importante (altitudinea medie, altitudinea maximă și energia de relief din fiecare celulă a gridului). S-a observat o concentrare a endemitelor în etajul subalpin-alpin al Carpaților, bogăția specifică fiind corelată cel mai mult cu altitudinea maximă. În final am discutat asupra importanței biogeografice a centrelor de endemism prezentate.

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