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THE FLORISTIC AND PHYTOSOCIOLOGIC DIVERSITY OF THE UPPER BASIN OF IARA VALLEY, BETWEEN IARA VALLEY AND MUNTELE MARE PEAK (GILĂU-MUNTELE MARE MASSIF)

SUMMARY OF PHD THESIS

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CLUJ-NAPOCA
2011

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Keywords: biodiversity, floristic studies, phytosociology, Muntele Mare, Valea Ierii, diversity indices

FOREWORD

Writing a PhD thesis about the phyto-diversity of a mountainous area in Romania proved to be a challenge, not only due to the rough terrain, but also due to the fact that *biodiversity* is difficult to define. As data was collected, the thesis continued to grow outside the biological field of study. In the beginning, the only purpose of the study was to describe the flora and vegetation of a relatively unknown area in the Apuseni Mountains. Later in the study, thanks to the suggestions made by prof. dr. V. Cristea, the thesis came to include an analysis of biodiversity indices. As biodiversity information was being centralized and plotted on the map, questions appeared relating to why is the diversity of certain areas higher and that of other areas lower. Ordination and regression methods were used to answer those questions, thanks to the guidance of dr. Gafta and dr. Cristea.

The thesis achieved its 5 objectives, as described in the original plan from 2006, namely:

1. to create an inventory of superior plant species from the upper basin of Iara Valley, and to analyze the vascular flora of the study area;
2. to create an inventory of phytocoenosis from the study area;
3. to highlight floristic and phytocoenotic diversity by habitat type (forests, grasslands, wetlands, areas with human impact);
4. to interpret and analyse these results;
5. to analyze the areas protected by environmental laws within the study area.

Chapter 1. Physico-geographical characterization of the study area

Location. The study area (fig. 1) is part of the Apuseni Mountains, which are characterized by lower altitudes compared to the rest of the Carpathian range, having only 3 peaks above 1.800 m.s.m.: 1.849 m.s.m. Cucurbăta Mare, 1.836 m.s.m. Vlădeasa and 1.826 m.s.m. Muntele Mare.

The study area occupies about 60 km^2, on both sides of Iara Valley, for about 14 km from its springs. Approximated geographical coordinates: $46^0$14' – $46^0$29' N latitude şi $23^0$11' – $23^0$17' E longitude. Of the 60 km^2, a large part (about 70-80%) is covered by forests. Grasslands from lower altitudes are not found within the borders of the study area.

Geological substrate. The substrate is represented by volcanic rocks and crystalline schists, both acid rock types.

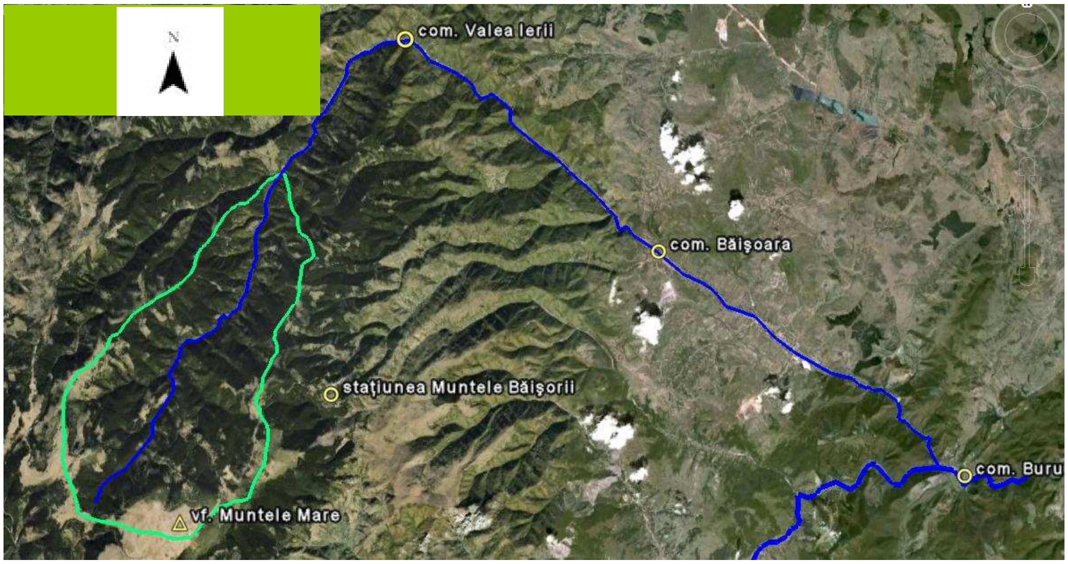

Fig. 1 – Iara (in blue), from the springs (near the Muntele Mare peak) to its flow in the Arieş river, near the commune of Buru; in green, the limit of the study area (1:2.300).

Geomorphology. According to Pop (1970) and Kovács (2000), the Gilău – Muntele Mare mountains (characterized by a massif, monolithic structure and an asymmetrical relief) have **three major types of relief**. At the highest altitudes, most common are the ***round hill and mountain tops***, with smooth shapes, in sharp contrast with the depth of the valleys below and the steepness of the slopes. The round hill and mountain tops gradually make way in certain locations to **mountain passes**, ("tarniţe"), but they usually continue along the valleys with positive geographical forms, making up large hills, with smooth tops in the reception basin, and wide shoulders in the upper segments of the slopes. A third type of relief is represented by **deep valleys**, carved in the crystalline substrate, with steep slopes and a relatively uniform morphology.

Fragmentation is quite high, especially on the ridge between the Şoimu and the Iara Valley – about 2-2,5 km/km^2 (Pop 1970).

Soils. Bunescu et al. (2000) considers that in the Gilău – Muntele Mare massif the most widespread are *districambosoils*, followed by *prepodzoic soils*, and the more rare *humisoils* and *alluvial soils*.

Hydrographical network. Iara is a tributary of the river Arieş. It springs from the northern slope of the Muntele Mare peak. The three spring valleys of Iara are, from west to east: Galbena Valley, Vânăta Valley (also called Iara Valley) and Negrului Valley. The first confluence is between Vânăta and Galbena; a few hundred meters downstream there is the confluence with Neagra, close to the Bondureasa lake (which was built to increase the hydro-energetical power of the neighboring Someşul Rece Valley). Downstream from Bondureasa, Iara receives multiple tributaries from both slopes, and the most important are: a) tributaries from the left slope: Plopeni Valley, Hancea Mare Valley, b) tributaries from the right slope: Leii Valley, Bondureasa Valley, Bădiea cel Mare Valley, Strâmba Valley.

Climate. The study area is located in the continental moderate climate. Regarding ***precipitations***, according to the diagramme presented by Coldea (1991), and to the analysis made by Bunescu et al. (2000), for the Băişoara weather station (1.364 m.s.m.), the yearly average is around 890l/m^2. It is important to note that the Băişoara weather station is subject to the foehn effect, manifested on the eastern slope of Apuseni Mountains, which is translated into smaller quantities of precipitation at lower altitudes.

As far as the ***temperatures*** are concerned, Bunescu et al. (2000) recorded a 4,6^{0}C yearly average temperature for Băişoara weather station (1.364 m.s.m.), compared to a 4,1^{0}C average at Stâna de Vale (1.102 m.s.m.) and 0,9^{0}C at Vlădeasa (1.836 m.s.m.). We observe here also the consequences of the foehn effect from the Băişoara weather station, where the average temperature is higher compared to that from Stâna de Vale, even if there is a 250 m difference of altitude between the two, and the situation should be opposite, with higher temperatures at Stâna de Vale.

According to Kovács (2000), a consistent ***snow cover*** appears in the Gilău – Muntele Mare massif as soon as the first week of November, lasting on average until the third decade of April. This translates into over 170 days of snow cover on average.

Bunescu et al. (2000) consider that ***winds*** are complicated in the Apuseni Mountains, due to the complexity and fragmentation of the relief. Average yearly speed of wind at the weather station from Băişoara was 2,3 m/s, compared to the weather station from Vlădeasa, much more exposed, where there was an average of 8,0 m/s. Also, in Băişoara the most frequent are the calm periods, 33,9%, followed in frequency by periods when wind blows from the West – 12,8%, or North-West – 13%.

Chapter 2. Material and method

The definition of biodiversity. According to the definition from the Convention on Biological Diversity (1992, art. 2), biodiversity is „*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*".

Biodiversity types and indices. In order to help measure biodiversity, a series of ***α-biodiversity indices*** were developed (tab. 1)**.** These indices differ mostly by the importance given to one of the two determining factors: species richness or equitability (abundance).

Opinions regarding the use of biodiversity indices. The existence of a high number of diversity indices made some authors (Hurlbert 1971) draw the conclusion that the concept of diversity has no meaning. According to Jost (2006) however, what we have to understand when we look at the „plethora" of indices, is that a diversity index is not diversity itself, just a representation, according to a specific purpose.

Tabel 1 The characteristics and performances of biodiversity indices

Diversity index	Capacity to discri-minate	Sensitivity to sample size	Factors considered	Complexity of calculus	Spread of use
α – diversity	Good	Low	Sp. richness	Simple	Wide
λ – diversity	Good	Average	Sp. richness	Complex	Restricted
Q Index	Good	Low	Sp. richness	Complex	Restricted
Species richness	Good	High	Sp. richness	Simple	Wide
Margalef Index	Good	High	Sp. richness	Simple	Restricted
Shannon Index	Average	Average	Sp. richness	Moderate	Wide
Brillouin Index	Average	Average	Sp. richness	Complex	Restricted
U McIntosh Index	Good	Average	Sp. richness	Moderate	Restricted
Simpson Index	Average	Low	Dominance	Moderate	Wide
Berger-Parker Index	Poor	Low	Dominance	Simple	Restricted
Shannon Index	Poor	Average	Equitability	Simple	Restricted
Brillouin Index	Poor	Average	Equitability	Complex	Restricted
D McIntosh Index	Poor	Average	Dominance	Simple	Restricted

Diversity indices can be organized in classes, creating a connection between the various indices used (by bringing them to a common class). These classes were summarized by Hill (1973). Hill's mathematical model demonstrates the fact that diversity indices measure different aspects of diversity, and that the results are not comparable between different classes. The most useful formula, according to both Hill (1973) and Jost (2006) is that of diversity of the first order, derived from the Shannon index. : $D = e^{\Sigma pi*\ln pi} = e^{H}$. Jost called this index „equivalent number of species".

Biodiversity – environment correlations. Once we have data related to the biodiversity of certain plots, we can go further and search for the reason of high or low values. Biodiversity varies as a consequence of environmental variation, and some of these environmental factors can be quantified. Methods of data ordination can then be deployed. How much of a given diversity is caused by soil pH, how much by exposition, altitude, humidity, human impact? The answer can be found either by ***data ordination*** methods or by ***multiple regression*** methods. Among the data ordination methods, most used are PCA („Principal Component Analysis") and CCA („Canonic Correspondence Analysis"), and we chose the latter in order to interpret the diversity data gathered for this thesis. Multiple linear regression will also be used, optimized using "step-by-step" regression.

Material and method. The taxonomical system used to describe the flora was based on Cronquist, Takhtajan et Zimmermann (1966), adapted by Ciocârlan (2009).

Floristic data (**chapter 3**) was gathered in the field using mainly phytosociological methods. This insured the identification of plant associations, presented in **chapter 4**. The method for phytosociological data collection was the one described by Braun-Blanquet, with A. Borza's adjustments.

In order to draw conclusions regarding the diversity of flora in the study area, we considered several types of analysis. In chapter 3, the floristic data was interpreted by means of: a) taxonomic analysis, b) life form analysis, c) species distribution analysis, d) analysis of ecological categories (UTR analysis), e) analysis of rare and endemic species.

In order to quantify biodiversity in a mathematical manner, in **chapters 4 and 5**, a first indicator used was species richness. Basically, for each relevée we calculated the so called diversity of “0” order (Jost 2006).

Next, for each phytosociological relevée the Shannon index of diversity was calculated. In parallel with the Shannon index, we used the equivalent number of species, calculated following the instructions given by Jost (2006).

For the statistical interpretations, we selected only the relevées which have an equal surface (400 m^2 in forest relevées, respectively 25 m^2 in grasslands or shrubs). The analysis is descriptive in nature, limited to the dataset which was investigated. Their deductive power is limited not only by the low number of repetitions and by the method data was collected (using phytosociological relevées, which are not random), but also as a consequence of the fact that they are limited to an area of approximately 60 km^2 in the Apuseni Mountain range.

A first analysis made in **chapter 5** is targeting the spatial distribution of diversity, in a graphic manner, by means of distribution maps, using the software Google Earth (Google Inc., 2009) and the plug-in GE-Graph 2.2 (2010).

A second analysis placed the relevées in a multi-dimensional space, using CCA (Canonic Correspondence Analysis). The software used to perform the analysis is R (R Development Core Team, 2005), namely the vegan package (Oksanen et al. 2010).

A third and last analysis is focused on explaining diversity, by means of linear regression using environmental variables as descriptors.

Chapter 3. The floristic diversity of the upper basin of Iara Valley

Short history of botanical research. The upper basin of Iara Valley has not been investigated from a floristic point of view. Some vegetation aspects were described nearby, in locations around the Muntele Mare peak and the Buscat peak. Resmeriţă (1985) researched pastures with *Nardus* from the Muntele Mare massif, while Csűrös M. et Csűrös Ş. (1968) investigated the area surrounding the chalet from Băişoara. Csűrös has also described from a botanic and phytosociologic point of view several areas near the Muntele Mare massif (Csűrös M. et Csűrös Ş., 1968) and near Scăriţa Belioara (Csűrös Ș., 1958). Another neighboring region, that of Gilău Mountains, has been investigated by Hodişan şi Pop (1970). These relevées are found also in the monograph of the vegetation from Cluj county, realized by Pop, Cristea et Hodişan (2002).

The history of botanical research is completed by the two papers published as a consequence of research for the current thesis. In 2008 we published an article, describing a new association (*Bruckenthalio - Vaccinietum*) in the study area (Coldea, Filipaş et Stoica 2008). Then, in 2011, we published a paper focused on the diversity of woody vegetation from the study area (Stoica 2011).

Taxonomic analysis. The floristic inventory comprises 405 plant taxa, of which 388 sp., 15 subsp., 1 var. and 1 hybrid. The 405 taxa are organized in 64 families, and 40 orders. The most important families are: *Asteraceae* (63), *Poaceae* (38), *Lamiaceae* (22), *Rosaceae* (22), *Cyperaceae* (19), *Scrophulariaceae* (17), *Caryophyllaceae* (16), *Ranunculaceae* (15), *Fabaceae* (14), *Juncaceae* (12), *Boraginaceae* (10), *Onagraceae* (9), *Polygonaceae* (8), *Apiaceae* (8). These 14 families have in total 284 sp., respectively 69,77% of the total number of registered taxa. (tab. 2).

Bibliography resources for floristic data. The thirteen volumes of the Romanian Flora (Săvulescu T. et al. 1952-1976) are one of the few sources that mention various plant species in the study area which have not been identified in the field studies for the thesis. By studying this bibliographical resource, we have found no less than 66 sp. of cormophytes. These species have been located in the Mt. Mare massif (62 sp.), or in the upper part of Iara Valley (4 sp.).

Table 2. – Families and no. of species in the study area

No.	Family	Sp.	Ssp.	Var.	x
1	Aceraceae	1			
2	Alliaceae	1			
3	Amaryllidaceae	1			
4	Apiaceae	8			
5	Aspleniaceae	11			
6	Asteraceae	60	2		
7	Balsaminaceae	1			
8	Betulaceae	2			
9	Blechnaceae	1			
10	Boraginaceae	10			
11	Brassicaceae	6			
12	Campanulaceae	5	2		
13	Caprifoliaceae	4			
14	Caryophyllaceae	15	1		
15	Chenopodiaceae	1			
16	Cistaceae	1			
17	Corylaceae	1			
18	Crassulaceae	2			
19	Cupresaceae	1		1	
20	Cyperaceae	19			
21	Dennstaedtiaceae	1			
22	Dipsacaceae	5			
23	Equisetaceae	7			
24	Ericaceae	5	1		
25	Euphorbiaceae	4			
26	Fabaceae	14			
27	Fagaceae	1			
28	Fumariaceae	1			
29	Gentianaceae	1	1		
30	Geraniaceae	4			
31	Grossulariaceae	2			
32	Hypericaceae	3			
33	Iridaceae	1			
34	Juncaceae	10	2		
35	Lamiaceae	22			
36	Liliaceae	4	2		
37	Lycopodiaceae	3			
38	Lythraceae	1			
39	Menyanthaceae	1			
40	Monotropaceae	1			
41	Onagraceae	8			1
42	Orchidaceae	5			
43	Oxalidaceae	1			
44	Papaveraceae	1			
45	Parnassiaceae	1			
46	Pinaceae	3			
47	Plantaginaceae	2			
48	Poaceae	38			
49	Polygonaceae	8			
50	Polypodiaceae	1			
51	Primulaceae	4			
52	Pyrolaceae	1			
53	Ranunculaceae	13	2		
54	Rosaceae	22			
55	Rubiaceae	6	1		
56	Salicaceae	5			
57	Saxifragaceae	1			
58	Scrophulariaceae	16	1		
59	Solanaceae	1			
60	Thymelaeaceae	1			
61	Trilliaceae	1			
62	Urticaceae	2			
63	Valerianaceae	2			
64	Violaceae	3			
	Total	**388**	**15**	**1**	**1**

Species richness analysis. We can easily note the low floristic diversity of the research area (405 taxa), a somewhat unexpected result if we consider the total surface of about 60 km^2, or the difference in altitude – 976 m (between the maximum altitude, Mt. Mare – 1.826 m.s.m., and the minimum altitude, near the confluence with Şoimu Valley – 850 m.s.m.).

We consider that there are multiple causes for this low value. A first cause is represented by the large area occupied by spruce (*Picea abies*) forests in the study area (about 70-80%).

A second cause is represented by the geomorphological particularities described in Chapter 1. The valleys gain depth rapidly, reaching 3-400 m in just a few km from the springs, a common phenomenon to Iara's springs and also to its tributaries. This is translated in a humid and cold climate, accentuated by the north-eastern exposition of the basin and the large areas covered by forests.

A third cause for the low species richness is represented by the fact that the part of the territory not covered by forests (about 20-30%) is composed by *Nardus stricta* grasslands (poor in plant species, grazed by cattle and horses), *Juniperus* and *Vaccinium* shrubs and oligotrophic marshes (poor in species by definition).

A fourth cause is the poorly defined subalpine belt. The plateau near the Mt. Mare peak has uniform vegetation, with oligotrophic and mesotrophic marshes on the eastern slope, and degraded *Nardus stricta* grasslands on the western slope.

A fifth and last cause for the low number of plant species is the monotony of substrate in the study area, which is completely acid, reflected in the absence of calciphilous plant species.

In these conditions, **species richness of various plant formation types** is as follows:

- forests: 185 sp. (coniferous forests 146 sp., mixed forests and alder forests 137 sp.);
- grasslands and subalpine shrubs: 113 sp. (grasslands 93 sp., shrubs 63 sp.);
- wetlands: 141 sp. (marshes and bogs: 64 sp., riversides: 102 sp.);
- forest cuts and areas with human impact: 149 sp. (forest clearings: 101 sp., areas with human impact: 91 sp.);

Rare and endemic species: The red lists considered for this analysis (tab. 3) are: LR1 – Boșcaiu, Coldea et Horeanu (1994), LR2 – Dihoru et Dihoru (1994), LR3 – Moldovan et al. (1984), LR4 – Oltean et al. (1994). We have also considered the red book: LR5 – Dihoru et Negrean 2009. Endemic taxa are considered according to Ciocârlan (2009).

Table 3 – Rare and endemic taxa from the upper basin of Iara Valley

No.	Taxa	Red list	Status	Endemic	Relict
1	*Menyanthes trifoliata*	LR 2/4	R/R		
2	*Pseudorchis albida*	LR 4	R		
3	*Valeriana simplicifolia*	LR 4	R		
4	*Pedicularis limnogena*	LR 2/3/4/5	R/R/VU/LR		

Table 3 (part 2)

No.	Taxa	Red list	Status	Endemic	Relict
5	*Listera cordata*	LR 1/4	R/R		
6	*Oxycoccus microcarpum*	LR 2/4	R/R		
7	*Carex limosa*	LR 2/4	R/R		R.boreal
8	*Lysimachia nemorum*	LR 4/5	R/CR		
9	*Arnica montana*	LR 4	VU		
10	*Campanula rotundifolia* subsp. *polymorpha*			End. carp.	
11	*Dentaria glandulosa*			End. carp.	
12	*Heracleum palmatum*			End. carp. Ro	
13	*Symphytum cordatum*			End. carp.	

Notă: LR = low risk species **VU =** vulnerable sp., **R =** rare sp., **CR** = critically threatened sp.; **End.carp.** = endemic sp. in the Carpathic chain; **End. carp. Ro** = endemic sp. in the Romanian Carpathians; **R. boreal** = boreal relict;

Table 4 – Taxa with Carpathic-Balkan distribution identified in the study area (Ciocârlan 2009, Tutin et al. 1964-1980)

No.	Taxa	Ciocârlan 2009	Tutin et al. 1964-1980	Considered in the thesis
1	*Aconitum toxicum*	Carp. balc.	Ju Rm	Carp. balc.
2	*Anthemis macrantha*	Carp. balc.	Bu Rm	Carp. balc.
3	*Actaea spicata*	Carp. balc. pan.	Al Au Be Br Bu Cz Da Fe Ga Ge Gr He Ho Hs Hu It Ju No Po Rm Rs(N,B,C,W,K,E) Su	-
4	*Bruckenthalia spiculifolia*	Carp. balc.	?Al Bu Gr Ju Rm	Carp. balc.
5	*Campanula abietina*	Carp. balc.	E. & S. Carpathians, and Mts. from Transylvania and N. of the Balkan pen.	Carp. balc.
6	*Crocus vernus*	Carp. balc.	East of It; naturalized in Br	-
7	*Hieracium transsylvanicum*	Carp. balc.	Al Au Bu Cz Ju ?Po Rm Rs (W)	Carp. balc.
8	*Leucanthemum waldsteinii*	Carp. Jug. centr.	Cz Ju Po Rm Rs (W)	End. carp.
9	*Pedicularis limnogena*	Carp. balc.	Ju Rm	Carp. balc.
10	*Petasites kablikianus*	Carp. balc. sudet.	Al Bu Cz Ju Po Rm Rs (W)	Carp. balc.
11	*Phleum montanum*	Carp. balc. cauc. anat.	Al Bu Gr Ju Rm Rs (W,K)	-
12	*Potentilla ternata*	Carp. balc.	Balkan Pen., S. & E. Carpathians	Carp. balc.
13	*Pulmonaria rubra*	Carp. balc.	Al Bu Ju Rm Rs (W)	Carp. balc.
14	*Salix silesiaca*	Carp. balc. sudetic	Sudet Mts., Carpathians, Balkan Peninsula	-
15	*Silene heuffelii*	Carp. balc.	Rm and the N. half of the Balkan pen.	Carp. balc.
16	*Telekia speciosa*	Carp. balc. cauc. anat.	Al Bu Cz Hu Ju Po Rm Rs(W); introduced in [Au Be Br Ga Ge Rs (C)]	Carp. balc.
17	*Viola declinata*	Carp. balc.	Cz Rm Rs (W)	End. carp.

* Al – Albania, Au – Austria, Be – Belgium, Br – Great Britain, Bu – Bulgaria, Cz – Czech Republic, Slovakia, Da – Denmark, Fe – Finland, Ga – France, Ge – Germany, Gr – Greece, He – Switzerland, Ho – Holland, Hs – Spain, Hu – Hungary, It – Italy, Ju – Jugoslavia, No – Norway, Po – Poland, Rm – Romania, Rs (N) – northern Russia, Rs (B) –Baltic Russia, Rs (C) – Central Russia, Rs (W) – Western Russia, Rs (K) – Crimeea, Rs (E) – Eastern Russia, Su – Sweden; End. carp –endemic sp. in the Carpathic range

According to the two tables (tab. 3, tab. 4), in the study area we have identified 9 taxa considered to be rare at least in one of the red lists, 6 endemic taxa and 11 carpathic-balkan taxa.

Protected areas. The study area overlaps partially with two protected areas in the Natura 2000 network, namely *ROSCI0119 – Muntele Mare* and *ROSCI0263 – Valea Ierii*. Both protected areas have been declared by Order no. 1964 from the 13th of December 2007, regarding the instauration of natural protected areas of community interest, as part of the ecological network Natura 2000 in Romania. Within ROSCI0119 there is one priority habitat type, namely **7110* – *Active raised bogs,*** found inside the study area of our thesis, occupying several hectares on the plateau near the Muntele Mare peak. The habitat was described within the thesis in the vegetation chapter (chapter 4), at the corresponding plant association (*Eriophoro vaginati – Sphagnetum recurvi* Hueck 1925).

Chapter 4. The diversity and structure of vegetation in the upper basin of Iara Valley

The inventory of plant associations in the study area. 163 relevées were collected in the field, and a total number of of 339 plant taxa was found. The relevées were grouped in 25 plant associations, and classified according to the system described by Coldea (1991) in 17 phytocoenological communities (alliances).

NARDO-CALLUNETEA Prsg. 1949
- NARDETALIA Oberd. 1949
  - **Potentillo – Nardion** Simon 1957
    1. *Violo declinatae-Nardetum* Simon 1966
- VACCINIO-GENISTETALIA Schubert ex. Passarge 1964
  - **Genistion pilosae** Duv. 1942 em. Schubert 1960
    2. *Bruckenthalio-Vaccinietum* Coldea et al. 2008

MONTIO-CARDAMINETEA Br.-Bl. et. Tx. 1943
- MONTIO – CARDAMINETALIA Pawl. 1928
  - **Cardamino-Montion** Br.-Bl. 1925
    3. *Chrysosplenio-Cardaminetum amarae* Mass. 1959
    4. *Philonotido-Calthetum laetae* (Krajina 1933) Coldea 1991

SCHEUCHZERIO-CARICETEA NIGRAE (Nordh. 1937) Tx. 1937
- CARICETALIA NIGRAE Koch 1926 em. Nordh. 1937
  - **Caricion nigrae** Koch 1926 em. Klika 1934
    5. *Sphagno-Caricetum rostratae* Steffen 1931
- TOFIELDIETALIA Prsg. ap. Oberd. 1949
  - **Caricion davallianae** Lika 1934
    6. *Carici flavae-Eriophoretum latifolii* Soó 1944

OXYCOCCO-SPHAGNETEA Br.-Bl. et Tx. 1943

SPHAGNETALIA MAGELLANICI (Pawl. 1928) Moore (1964) 1968

Sphagnion magellanici Kästner et Flössner 1933

7. *Eriophoro vaginati-Sphagnetum recurvi* Hueck 1925

BETULO-ADENOSTYLETEA Br.-Bl. et. Tx. 1943

ADENOSTYLETALIA Br.-Bl. 1931

Calamagrostion villosae Pawl. 1928

8. *Phleo alpini-Deschampsietum caespitosae* (Krajina 1933) Coldea 1983

ARTEMISETEA VULGARIS Loh., Prsg. et Tx. 1950

GLECHOMETALIA HEDERACEAE Tx. in Tx. et Brun-Hool 1975

Aegopodion podagraria Tx. 1967

9. *Telekio-Petasitetum hybridi* (Morariu 1967) Resm. et Raţiu 1974

10. *Rumici obtusifoliae-Urticetum dioicae* Kornas 1968

Rumicion alpinii Rübel 1933

11. *Senecioni-Rumicetum alpinii* Horv. 1949 em. Coldea 1986

MOLINIO-ARRHENATHERETEA Tx. 1937

MOLINIETALIA CAERULEAE W. Koch 1926

Filipendulion ulmariae Segal 1966

12. *Filipendulo-Geranietum palustris* W. Koch 1926

Calthion palustris Tx. 1937

13. *Scirpetum sylvatici* Maloch 1935 em. Schwich. 1944

14. *Epilobio-Juncetum effusi* Oberd. 1957

EPILOBIETEA ANGUSTIFOLII Tx. et Prsg. in Tx. 1950

ATROPETALIA Vlieg. 1937

Epilobion angustifolii (Rübel 1933) Soó 1933

15. *Senecio sylvatici-Epilobietum angustifolii* (Heck 1931) Tx. 1950

16. *Calamagrostio arundinaceae-Digitalietum grandiflorae* (Silling 1933) Oberd. 1957

Sambuco-Salicion Tx. 1950

17. *Rubetum idaei* Pfeiff. 1936 em. Oberd. 1973

18. *Sorbo-Betuletum pendulae* Dihoru 1975

QUERCO-FAGETEA Br.-Bl. et Vlieg. 1937

FAGETALIA Pawl. 1928

Alno-Ulmion Br.-Bl. et. Tx. 1943 em. Müll. et Görs 1958

19. *Telekio speciosae-Alnetum incanae* Coldea (1986) 1990

Symphyto-Fagion Vida 1959

20. *Pulmonario rubrae-Fagetum* (Soó 1964) Täuber 1987

21. *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987

VACCINIO-PICETEA Br.-Bl. 1939

VACCINIO-PICEETALIA Br.-Bl. 1939

Piceion abietis Pawl. in Pawl. et al. 1928

22. *Hieracio rotundati-Piceetum* Pawl. et Br.-Bl. 1939

23. *Leucanthemo waldsteinii-Piceetum* Krajina 1933

24. *Soldanello-Piceetum* Coldea et Wagner 1998

Pinion mugi Pawl. 1928

25. *Campanulo abietinae-Juniperetum* Simon 1966

Chapter 5. Analysis of diversity by types of surfaces

The diversity of 400 m^2 surfaces (forest associations).

In the study area we identified 6 forest associations, analyzed for phytodiversity:

1. *Soldanello-Piceetum* are pure spruce forests from high altitudes, located on the large shoulders of the study area, characterized by low number of species and low diversity (fig. 2). The average no. equivalent of species is just 5,10 (tab. 6).

2. The same reduced diversity is found in *Hieracio rotundati-Piceetum* spruce forests, the most widespread plant association in the study area. Phytocoenosis from this association have an average equivalent no. of species of 5,08 (tab. 6).

3. *Leucanthemo waldsteinii – Piceetum* spruce forests have above average diversity (fig. 2), with about 32 sp. per relevée, and 7,02 equivalent no. of species (tab. 6), values which can be explained by the high number and frequency of species from the order *Adenostyletalia* (e.g.: *Chaerophyllum hirsutum, Doronicum austriacum, Stellaria nemorum, Veratrum album*).

4. *Pulmonario rubrae – Fagetum* mixed forests have an average no. of 27,35 sp. / relevée, whith a quite high 7,15 equivalent no. of sp. (tab. 6). In these forests we found no less than 92 plant sp., these phytocoenosis being among the richest forest communities.

5. *Leucanthemo waldsteinii – Fagetum* forests have been identified in the lower part of the study area. The three phytocoenosis analyzed had in total 73 plant sp. (tab. 6), of which the highest numbers are for species from the order *Fagetalia*, and species from the order *Adenostyletalia*. The high number of species in this association is reflected in the high diversity of these forests, with 9,41, 9,33, respectively 6,73. equivalent no. of species, averaging 8,49 equivalent no. of species.

6. *Telekio speciosae – Alnetum incanae* are white alder forests, located only in two points within the study area. The equivalent no. of species of the two phytocoenosis (tab. 6) is 6,49, respectively 11,01. These high values are explained by the presence of deep, moist, soils, rich in humus, which are able to support a high number of species, but also by their position on the border between several types of vegetation.

In conclusion, we can state that *Telekio-Alnetum* relevées are the most diverse, although the low number of phytocoenosis from this association in the study area made an in-depth investigation of diversity differences difficult and also it made it impossible to compare its values against those from spruce and mixed forests.

According to Jost (2006), the equivalent no. of species can be used to derive a comparison even in such a case, so we can say that the alder forests that were investigated in the upper basin of Iara Valley are on average about 1,7 times more diverse than spruce forests from the association *Hieracio rotundatii – Piceetum* and *Soldanello – Piceetum* (characterized by 5,08 equivalent number of species).

From the perspective of rare and endemic taxa, there are no important differences between forest types, as they are poorly distributed in almost all coenosis that were investigated.

Regarding the spatial distribution of diversity (fig. 3), the most diverse forests are located in general on the valleys and at lower altitudes. These results are supported also by the Canonic Correspondence Analysis (CCA). In fig. 4, we can see that *Soldanello-Piceetum* spruce forests are grouped by CCA at higher altitudes. The *Telekio-Alnetum* forests are grouped at higher humidity and diversity. Spruce forests from the association *Hieracio rotundati-Piceetum* are grouped in the region of the plot which is characterized by high values for slope, while *Leucanthemo waldsteinii-Piceetum* forests group towards increased humidity. Mixed forests are not differentiated by the CCA analysis, both being grouped toward the upper part of the temperature and soil reaction gradients. Forests from the association *Leucanthemo waldsteinii-Fagetum* are located lower, towards the upper part of the humidity gradient.

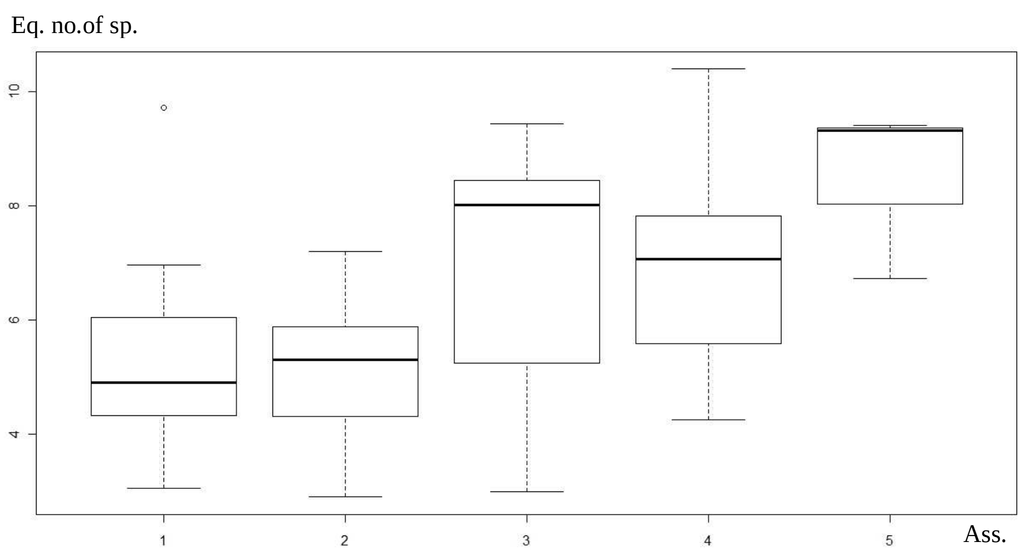

Fig. 2 – Comparison between the diversity of forest associations in the upper basin of Iara Valley, using **the equivalent number of species**; 1 - *Soldanello–Piceetum,* 2 – *Hieracio rotundati–Piceetum* 3 – *Pulmonario rubrae–Fagetum*, 4 – *Leucanthemo waldsteinii-Piceetum*, 5 – *Leucanthemo waldsteinii–Fagetum*

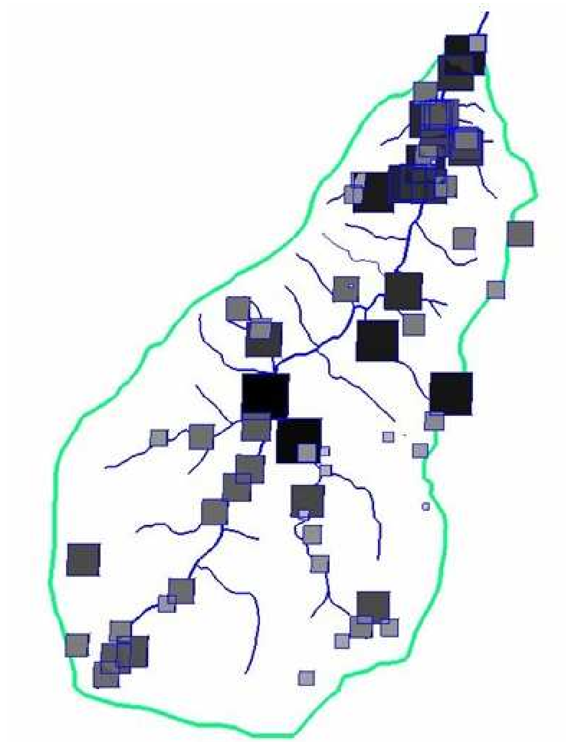

Fig. 3 – Spatial distribution of forest diversity (equivalent number of species) in the upper basin of Iara Valley, (scara 1:1000)
Note: the most diverse relevées are those represented with larger, darker squares, while the least diverse relevées have smaller, whiter squares

In order to explain the variability of the diversity index used, we have used a multiple regression model. The explicative power of the model is $r^2_{adj} = 0,48$ – the model explains about 48% of the variance in the diversity index. Among the variables, slope, humidity, and soil reaction are considered by the model to be the most significant in explaining the variance of diversity. This observation can be used to explain the differences between the diversity of mixed forests and that of spruce forests, as we know that mixed forests have soils richer in humus (especially mull type), with high values of soil reaction (neutrophilic-slightly basic).

We can conclude by stating that in the upper basin of Iara, spruce forests, which have a more acidic substrate have smaller diversity compared to mixed forests, which have poor acidic-neutrophilic substrate. An exception are spruce forests located in humid areas, characterized by the species *Leucanthemum waldsteinii*, which have a somewhat higher diversity, especially due to their position on the valley, where soils are deeper, but also due to the humidity, and the presence of hygrophilous species from the order *Adenostyletalia*.

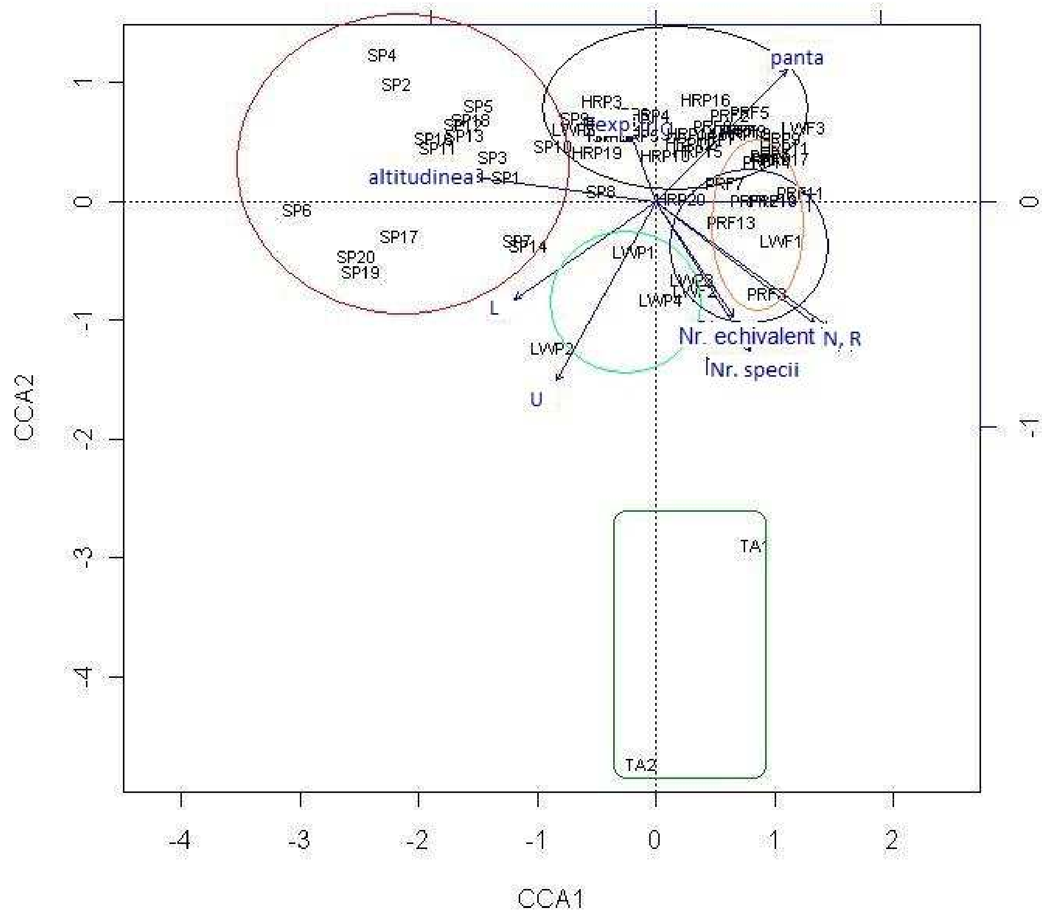

Fig. 4 – CCA plot with 65 forest relevées, in the space determined by the first two CCA axis, according to the variables considered (average values per relevée of Ellenberg indicators for light, humidity, temperature, soil reaction, preference to nitrogen in the soil, as well as exposition, altitude, no. of species, slope and the number of equivalent species)

Note:

SP – *Soldanello–Piceetum*, HRP – *Hieracio rotundati-Piceetum*, PRF – *Pulmonario rubrae-Fagetum*, LWP – *Leucanthemo waldsteinii-Piceetum*, LWF – *Leucanthemo waldsteinii-Fagetum*, TA – *Telekio-Alnetum*

Nr. echivalent = number of equivalent species, **Nr. Specii** = number of species, **panta** = slope of the relevées (degrees), **Exp** = trigonometric exposition, **altitudinea** = m.s.m., **L** = average of each relevée for the Ellenberg index of light, **T** = average of each relevée for the Ellenberg index of temperature, **U** = average of each relevée for the Ellenberg index of humidity, **R** = average of each relevée for the Ellenberg index of soil reaction, **N** = average of each relevée for the Ellenberg index of soil nitrogen preference.

Tabel 5 - Eigen-values & proportion of variance explained by the CCA axis

Axis	1	2	3	4	5	6	7
Eigenvalue	0.40	0.34	0.16	0.13	0.12	0.10	0.08
%	0.26	0.23	0.11	0.09	0.08	0.06	0.06
Total explained	0.26	0.49	0.59	0.68	0.76	0.82	0.88

Table 6 – Main characteristics of the woody plant associations from Iara Valley; for the associations with less than 5 relevées, averages were not calculated;

PLANT ASSOCIATION	No. of rel.	Average alt. (m.s.m.)	Average slope (deg)	Total no. of species*	Average species / relevée	Average Shannon Index	Equivalent no. of species (average)	No. of rare species	No. of endemic species	No. of Carpathic Balkan species
Soldanello-Piceetum	20	1540 (±98,8)	14,25 (± 6,74)	78	17,9 (±5,22)	1,58 (±0,3)	5,10 (±1,63)	1	2	5
Hieracio rotundatii-Piceetum	20	1168 (±136)	28,16 (± 7,3)	88	22,57 (±5,28)	1,58 (±0,24)	5,08 (±1,13)	1	1	4
Leucanthemo waldsteinii-Piceetum	6	1288 (±169,3)	17,50 (± 5,24)	70	32 (±9,19)	1,90 (±0,33)	7,02 (±2,33)	0	2	5
Pulmonario rubrae-Fagetum	14	1011 (±93,84)	30 (±6,79)	92	27,35 (±5,71)	1,92 (±0,34)	7,15 (±2,00)	0	3	4
Leucanthemo waldsteinii-Fagetum	3	-	-	70	-	-	-	0	3	4
Telekio-Alnetum	2	-	-	61	-	-	-	0	4	3
TOTAL	**65**	**-**	**-**	**183**	**-**	**-**	**-**	**2**	**5**	**8**
AVERAGE **	**-**	**1245**	**23,05**	**-**	**24,20**	**1,72**	**5,96**	**-**	**-**	

* note: we calculated the no. of cormophytes; bryophtes were excluded
** average of relevées from all 6 forest associations

The diversity of 25 m² plots (grasslands, wetlands, shrubs and forest cuts).

In the 60 km² of the study area we investigated 47 plots with an area of 25 m² belonging to 15 plant and woody associations (of the total 19 found in the study area).

In table 6 we made a comparison of their characteristics, according to their taxonomy (a comparison of the 15 associations). Statistical comparisons between the associations is however impossible to do, as the number of relevées is different for each association, and their ecological requirements are quite diverse.

As far as the rare and endemic taxa are concerned, the most interesting associations are those from the bogs near Muntele Mare peak, *Carici flavae-Eriophoretum latifolii* and *Eriophoro vaginati-Sphagnetum recurvi*. They each have 4 rare plant species in their composition. Again, we underline the need for floristic studies aside from diversity indices interpretations, as the most diverse associations *Senecio sylvatici-Epilobietum angustifolii*, *Rubetum idaei* – have a limited number of rare and endemic species (1, respectively 4).

Studying the spatial distribution of diversity for the 25 m² plots, we notice that in general the equivalent number of species is highest at low altitudes. It has average values at high altitudes and is small on the slopes.

Canonic correspondence analysis (CCA, fig. 6), gives us further information regarding the distribution of the plots in the study area. We can notice that the associations *Violo declinatae-Nardetum*, *Bruckenthalio-Vaccinietum*, *Phleo alpini-Deschampsietum caespitosae* are found at high altitudes, on acid soils. It is worth mentioning that *Phleo alpini-Deschampsietum caespitosae* plots are positioned along the low diversity and species richness vector. Two of the plant associations from the order *Atropetalia*, *Senecio sylvatici-Epilobietum angustifolii* and *Calamagrostio arundinaceae-Digitalietum grandiflorae* are found on steep slopes. The third association of the order, *Rubetum idaei*, is grouped nearby, being characterized by the more neutrophilous soils and the higher number of species. Associations from the order *Glechometalia* (*Rumici obtusifoliae-Urticetum dioicae* and *Senecioni-Rumicetum alpinii*) are grouped along the soil reaction and humidity gradients. The position in the multidimensional space of the association *Rumici obtusifoliae-Urticetum dioicae* is best explained by soil reaction (the association is found on soils rich in nitrites, usually near old sheepfolds), while the association *Senecioni-Rumicetum alpinii* is best described by the humidity gradient, being found near running waters. Associations from the orders *Molinietalia* and *Montio-Cardaminetalia* are placed in the CCA graphic near the high humidity vector, as they are located in humid habitats, swamps, bogs and near the water. Vegetation of *Sphagnum* sp. bogs is located by the CCA analysis at high altitudes (especially *Eriophoro vaginati-Sphagnetum recurvi*), in conditions of increased humidity (plots from the class *Scheuchzerio-Caricetea nigrae*), having in their composition also the highest number of light loving species among the studied plant associations.

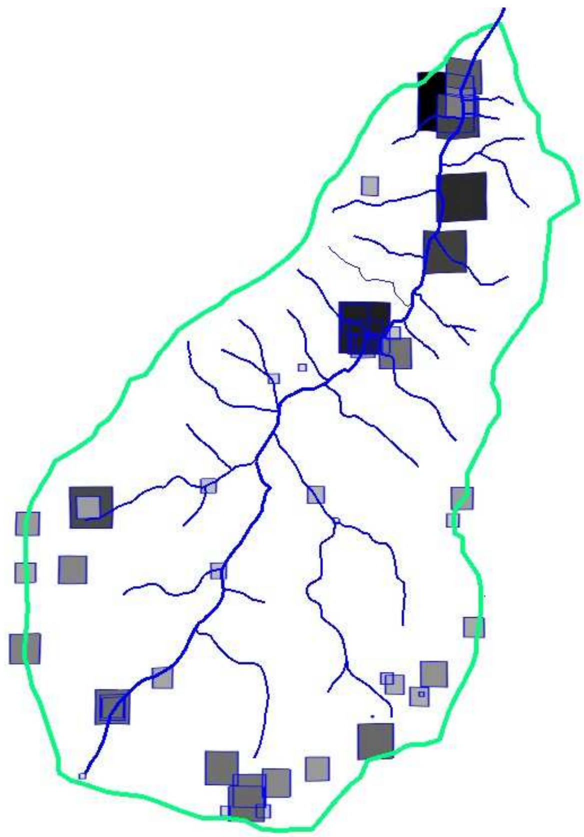

Fig. 5 – The diversity of 25 m^2 plots (grasslands, shrubs and wetlands) in the upper basin of Iara Valley; (1:1000)
Note: the most diverse plots are represented by bigger, darker squares, while the least diverse plots are represented by smaller, whiter squares.

In order to explain the variance of diversity (equivalent number of species), we used a multiple linear regression model, with the same variables as in the CCA analysis (average values per relevée of Ellenberg indicators for light, humidity, temperature, soil reaction, preference to nitrogen in the soil, as well as exposition, altitude, no. of species, slope and the number of equivalent species).

The explicative power of the model is - $r^2_{adj} = 0,33$ – which means that the model explains about 33% of the variance in the diversity data. Among the variables, slope and altitude are considered by the model as most significant in explaining the variance in the diversity of 25 m^2 plots. As far as the correlation between the equivalent number of species and the two variables is concerned, we can conclude that the highest diversity for 25 m^2 plots is found in localities with average-low values for slope and low altitudes.

Table 7 – The most important characteristics of grassland, shrub and wetland plant associations from the upper basin of Iara Valley; average values are calculated for the total number of relevées, only for the plant associations with at least 5 plots of 25 m^2 investigated.

No.	PLANT ASSOCIATION	Abbre-viated name	No. of 25 m^2 plots	Total no. of plots	Average alt. (m.s.m.)	No. of species	Average slope (deg.)	Average species/ plot	Average Shan. Index	Equivalent no. of species (average)	No. of rare sp.	No. of en-demic sp.	No. of Carp.-Balk. Sp.
1	***Bruckenthalio-Vaccinietum***	Vacc.	4	12	1471,42 (±231,81)	52	23,33 (±14,51	13,66 (±3,62)	1,32 (±0,27)	3,90 (±0,99)	1	0	4
2	***Calamagrostio arundinaceae-Digitalietum grandiflorae***	AtCalD	4	7	1088,57 (±75,03)	78	28,57 (±9,88)	24,66 (±8,43)	1,44 (±0,30)	4,38 (±1,26)	0	0	2
3	***Campanulo abietinae - Juniperetum***	-	0	8	1682 (±69,49)	40	10 (±3,77)	17,12 (±3,87)	1,47 (±0,30)	4,55 (±1,22)	1	0	3
4	***Carici flavae-Eriophoretum latifolii***	SphCfl	1	1	1800	15	0,00	15,00	1,57	-	4	0	0
5	***Chrysosplenio-Cardaminetum amarae***	MCCa.	3	7	1648,68 (±219,77)	30	6,14 (±3,97)	10 (±2,82)	1,10 (±0,39)	3,23 (±1,32)	1	1	1
6	***Epilobio-Juncetum effusi***	MoJuE	1	2	-	40	-	-	-	-	0	0	0
7	***Eriophoro vaginati-Sphagnetum recurvi***	SphErv	4	5	1648 (±122,59)	47	4,6 (±3,20)	16,6 (±5,17)	1,52 (±0,23)	4,71 (±1,14)	4	0	1
8	***Filipendulo-Geranietum palustris***	MoFil	1	2	-	46	-	-	-	-	0	0	2
9	***Philonotido-Calthetum laetae***	-	0	2	-	19	-	-	-	-	1	0	0
10	***Phleo alpini-Deschampsietum caespitosae***	Dsch	7	9	1639,1 (±111,69)	64	7,44 (±3,17)	16,55 (±2,74)	1,16 (±0,34)	3,40 (±1,29)	1	0	2
11	***Rubetum idaei***	Rub	4	12	1147,85 (±207,7)	104	19 (±12,20	23,66 (±7,77)	1,57 (±0,44)	5,27 (±2,25)	0	0	3

No.	PLANT ASSOCIATION	Abbre-viated name	No. of 25 m^2 plots	Total no. of plots	Average alt. (m.s.m.)	No. of species	Average slope (deg.)	Average species/ plot	Average Shan. Index	Equivalent no. of species (average)	No. of rare sp.	No. of en-demic sp.	No. of Carp.-Balk. Sp.
12	***Rumici obtusifoliae-Urticetum dioicae***	Rum	1	2	-	38	-	-	-	-	0	0	2
13	***Scirpetum sylvatici***	MoScr	3	3	-	31	-	-	-	-	0	0	1
14	***Senecio sylvatici-Epilobietum angustifolii***	AtSeE	1	2	-	28	-	-	-	-	0	0	1
15	***Senecioni-Rumicetum alpinii***	SeRum	3	3	-	35	-	-	-	-	0	0	1
16	***Sorbo - Betuletum pendulae***	-	0	2	-	39	-	-	-	-	0	0	2
17	***Sphagno-Caricetum rostratae***	SphCro	1	2	-	37	-	-	-	-	2	0	0
18	***Telekio - Petasitetum hybridi***	-	0	2	-	60	-	-	-	-	0	1	3
19	***Violo declinatae-Nardetum***	Nar.	9	13	1637,6 (±102,93)	62	9,92 (±8.88)	17,38 (±5,51)	1,50 (±0,40)	4,91 (±2,34)	2	2	3
	TOTAL	**-**	**47**	**96**	**-**	**266**	**-**	**-**	**-**	**-**	**7**	**4**	**7**
	AVERAGE	**-**	**-**	**-**	**1720**		**13,62**	**19,32**	**1,58**	**4,29**	**-**	**-**	**-**

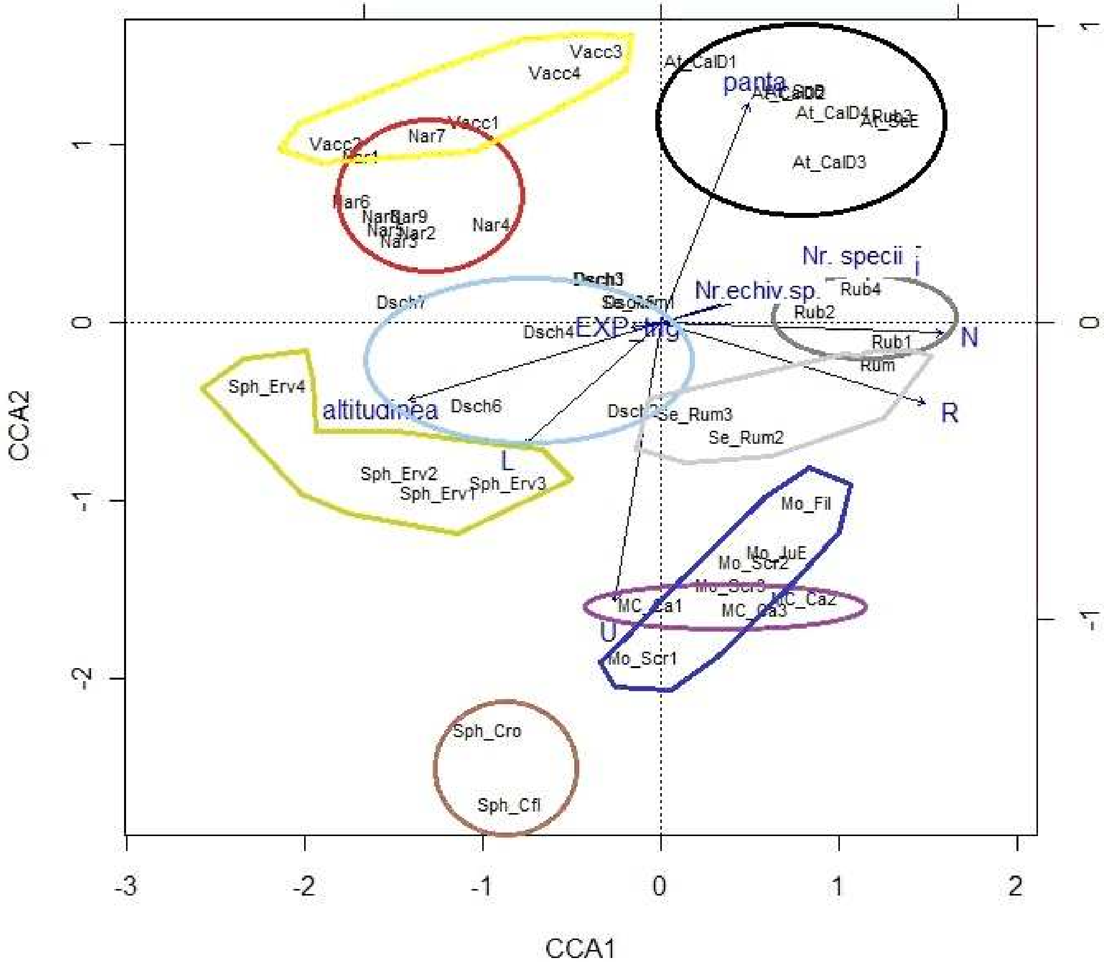

Fig. 6 – CCA plot for grassland, wetland and shrub plant associations in the space determined by the first two CCA axis, according to the variables taken into consideration (average values per relevée of Ellenberg indicators for light, humidity, temperature, soil reaction, preference to nitrogen in the soil, as well as exposition, altitude, no. of species, slope and the number of equivalent species). The abbreviated names are explained in tab. 37-38.

Table 8 - Eigen-values & the proportion of variance explained by the CCA axis

Axis	1	2	3	4	5	6	7	8	9	10	11	12
Eigenvalue	0.70	0.62	0.47	0.36	0.34	0.33	0.29	0.26	0.20	0.19	0.13	0.00
%	17.89	15.92	12.08	9.23	8.72	8.59	7.59	6.78	5.07	4.82	3.31	0.00
Total explained	17.89	33.81	45.89	55.12	63.84	72.43	80.02	86.80	91.86	96.68	100.00	100.00

CONCLUSIONS

1. The floristic inventory from the study area has found 405 cormophyte taxa, of which 388 sp., 15 subsp., 1 var. and 1 hybrid.
   - by cross-referencing our species list with the existing red lists, we identified 9 taxa considered to be rare or vulnerable, 6 endemic taxa and 11 Carpathic-Balkan taxa;
   - in the literature, we found 7 other rare taxa mentioned in locations which could be inside the study area, but which have not been identified during our field trips;
2. Using data from 163 relevées resulting from our field work, we have identified 25 plant associations, which were classified using the system described by Coldea (1991) in 19 phytocoenological communities (alliances)
   - of the 25 plant associations, 6 are forest associations, 4 are subalpine grasslands and shrubs, 8 are wetland associations and 7 are associations from forest cuts and areas with human impact;
   - the species richness of various plant formations is as follows: forests: 185 sp. (coniferous forests 146 sp., mixed and alder forests 137 sp.); grasslands and subalpine shrubs: 113 sp. (grasslands 93 sp., subalpine shrubs 63 sp.); wetlands: 141 sp. (swamps and bogs 64 sp., river sides 102 sp.); forest cuts and areas with human impact: 149 sp. (forest cuts 101 sp., other areas with human impact 91 sp.).
3. The **6 forest associations** analyzed for diversity belong to 3 alliances, respectively 2 classes;
   - according to the equivalent number of species (diversity index), alder and mixed beech forests with *Leucanthemum waldsteinii* are the most diverse, while spruce forests with *Soldanella major* and *Hieracium transsylvanicum* are the least diverse;
   - as far as rare and endemic plant species are concerned, there are no important differences between the forest types we investigated;
   - according to the distribution map of diversity, we observe that in general forests from humid areas, in the valleys, on soils richer in nutritive substances are more diverse;
   - the optimized linear regression model explains about 48% of the variance found in diversity. The factors which influence forest diversity most are soil reaction, slope and humidity;
4. The remaining **19 plant associations from grasslands, shrubs, wetlands and areas with human impact** are organized in 14 alliances, respectively 9 classes:
   - from the point of view of rare and endemic plant species, the bog plant associations *Carici flavae-Eriophoretum latifolii* and *Eriophoro vaginati-Sphagnetum recurvi* are of importance, with 4 rare species each;

- our study proves the need for floristic studies in diversity interpretations, as the most diverse associations - *Senecio sylvatici-Epilobietum angustifolii*, *Rubetum idaei* – have small numbers of rare and endemic species (1, respectively 4);
- according to the spatial distribution of grassland and shrub communities diversity, we notice that in general diversity is higher at lower altitudes, average at high altitudes and low on the slopes;
- the optimized linear correlation model reflects the influence of altitude and slope on the diversity of grassland and shrub formations (r^2_{adj} = 0,33); the highest diversity of the 25 m^2 plots is found in locations with average-low slope values, at low altitudes;

5. The evaluation of diversity using plant associations is worth investigating at a national scale, in order to allow the extrapolation of general rules for the distribution of diversity, and to create a national database, useful in monitoring its further evolution, and the correlation with environmental factors and spatial development of human activities.
6. Our study justifies, by means of floristic and phytosociological diversity, the constitution of Natura 2000 sites ROSCI0119 – Muntele Mare and ROSCI0263 – Valea Ierii and can represent a reference for management measures and future observations regarding vegetation and habitat dynamics.

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