Babeş-Bolyai University of Cluj-Napoca
Faculty of Biology and Geology

Pavel Dan TURTUREANU

Plant species diversity and coenotic importance of nemoral forest gaps in Trascău Mountains

Summary of the PhD thesis

Scientific coordinator,
Prof. dr. Vasile CRISTEA

Cluj-Napoca
2012

Table of contents of the thesis

Keywords:

- Diversity
- Species richness
- Beta diversity
- Partitioning
- Phytosociological classification
- OptimClass
- Conservation
- Apuseni
- Trascău
- Romania

CHAPTER I

General consideration

1.1. Biodiversity: the spatiotemporal distribution of organisms

Plant species diversity (or phytodiversity – the main topic of this PhD thesis) could be considered at different levels, i.e. genetic, species, community, or landscape.

The research carried out in this particular field achieved great progress in methods of assessing diversity, as an efficient tool of determining the changes experienced by different vegetation assemblages (Tuomisto 2010). Many of the techniques that have been suggested were not accepted, or they had been limitedly used. Because vegetation structure of a given region is affected by local factors, such as topography, substrate type, hydrography, or precipitation regime, it is clear that general techniques are not always appropriate for particular conditions (Anderson *et al.* 2011).

1.2. Forest gaps (openings) as model ecosystems for the study of plant diversity

The formation of gaps (openings) in the forests represents natural events and/or artificial, which have a disturbance character. In the studied region, the gaps have originated due to human practices (i.e. forest exploitations), followed by the establishment and maintenance of a secondary vegetation (fig. 1.1). Therefore, the vegetation composition of gaps is distinct than the one of the adjacent forests.

Figure 1.1: The interior of two forest gaps from the Trascău Mountains, which are dominated by a secondary vegetation.

The forests and gaps studied here are located in the Trascău Mountains. The gaps have different sizes and isolation distances from the open fields, and they are mainly occupied by grassy formations. They are intermediate units in terms of structure, i.e. between forests and grasslands, and have been formed by extracting of a tree group, the surface being afterwards extensively grazed. This management usually prevented the regeneration of tree species.

1.1. Geographical description and vegetation of the Trascău Mountains

The Trascău Mountains (fig. 1.2) form a subdivision of the Apuseni Mountains group (South-Eastern Carpathians, Romania). They dominate the Mureş valley downstream of the confluence with the Arieş valley, and spread over a distance of about 75 km, from the north of Arieş valley towards the Ampoi valley, in a NNE to SSW direction.

The altitude of the valleys varies between 400 and 700 a.s.l., while most the teritory of the Trascău Mountains lies below 1000 m a.s.l. The relief which has been formed on crystalline schists is located on the northwestern part of Trascău, on both sides of the Arieş valley, providing a typical massif character (Oancea *et al.* 1987). The most noticeable mark is given by the presence of limestone. The rock types which are present in the area are crystalline schists, ophiolites, conglomerates, and sandstones, followed by clays and marls (Popescu-Argeşel 1977). A significant proportion is occupied by limestones.

The climate is temperate-continental. In the Trascău region, as in the whole Apuseni Mountains, mean annual temperature decreases with altitude, i.e. from about 7.5 °C in the Trascău Piedmont, to approximately 5 °C on the highest points. Mean annual precipitation gradually decreases from approximately 1000 mm at high altitudes to 700-800 mm on the eastern side.

Vegetation research carried out until now highlights the great diversity of plant communities in the Trascău Mountains. Overall, the works focused on major ecosystems (i.e. forests, secondary meadows, calcareous grasslands), providing a relevant picture of the vegetation of the area (Şuteu 1970b, Gergely 1964). The potential natural vegetation is represented by hornbeam forests from the southeastern Carpathians and beech forests. The secondary meadows are a major component of the landscape, while the grasslands on limestones are restricted on the upper calcareous cliffs. Various shrub communities appear as well.

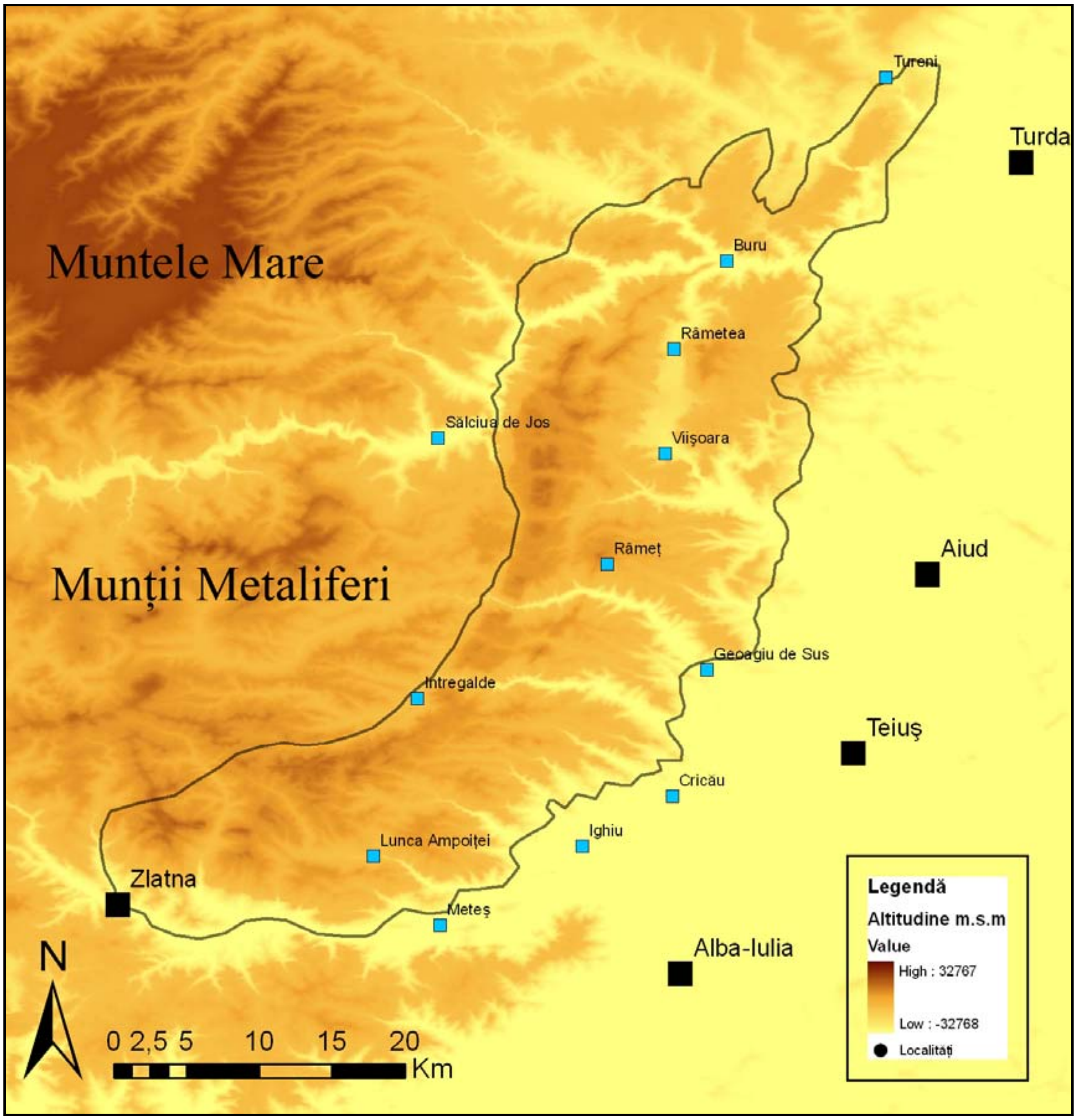

Figure 1.2: The altitudes of the Trascău Mountains compared to the neighbor mountainous regions within the Apuseni Mountains.

CHAPTER II

The forests of the Trascău Mountains: phytosociological classification using optimal partitioning

2.1. Introduction

Numerous studies have been done in Romania on forest classifications, and some of them were carried out at large, regional scales, such as the works of Beldie (1951), Boşcaiu *et al.* (1982), and Coldea (1991).

However, no forest classification exists in the Trascău Mountains (Apuseni) meant to consider their whole territory. The phytosicological descriptions have been focused only on sub-regions. Moreover, to our knowledge, there is no analytical study based on modern numerical methods dealing with forest classifications here.

Thus, we applied o recently proposed classification method on a database which represents the deciduous forests of the Trascău Mountains, and addressed the following questions: (i) which is the optimal number of clusters our database could be partitioned in, (ii) what ecological characteristics of the communities might be found from the cluster analysis, and (iii) are the obtained clusters similar with the existing phytosociological taxa, particularly those already described from the study area?

2.2. Materials and methods

The forests of the Trascău Mountains: general characterization

A considerable part of this mountainous unit is covered by decidous forests (*Querco-Fagetea* and *Quercetea pubescenti-petreae*), of which the mesic beech forests (*Fagetalia*) have the highest proportion, followed by the oak forests (*Quercetalia*) (Gergely 1962).

The main tree species which form the woodlands are, in order: *Fagus sylvatica, Quercus petraea, Carpinus betulus, Q. cerris, Q. pubescens,* and *Alnus* ssp. The other taxa which are less represented, such as *Acer* trees (including *A. pseudoplatanus, A. platanoides, A. campestre*) or *Fraxinus excelsior* are encountered as isolated individuals, or in patches, and they rarely form forests by themselves. *Quercus cerris* and *Q. pubescens* grow on calcareous substrates, and form xeric or xero-mesic forests.

Database

For the purposes of this study, we built a database comprising 161 relevés. Of these, 47 have been done by us between May and August 2010, across almost all the study area (fig. 2.1). The rest of them were taken from the literature published during 9 years (1962─1971), together with the data from the PhD thesis of Şuteu (1970).

The nomenclature follows the online version of the *European Flora* (Royal Botanic Garden Edinburgh 2011).

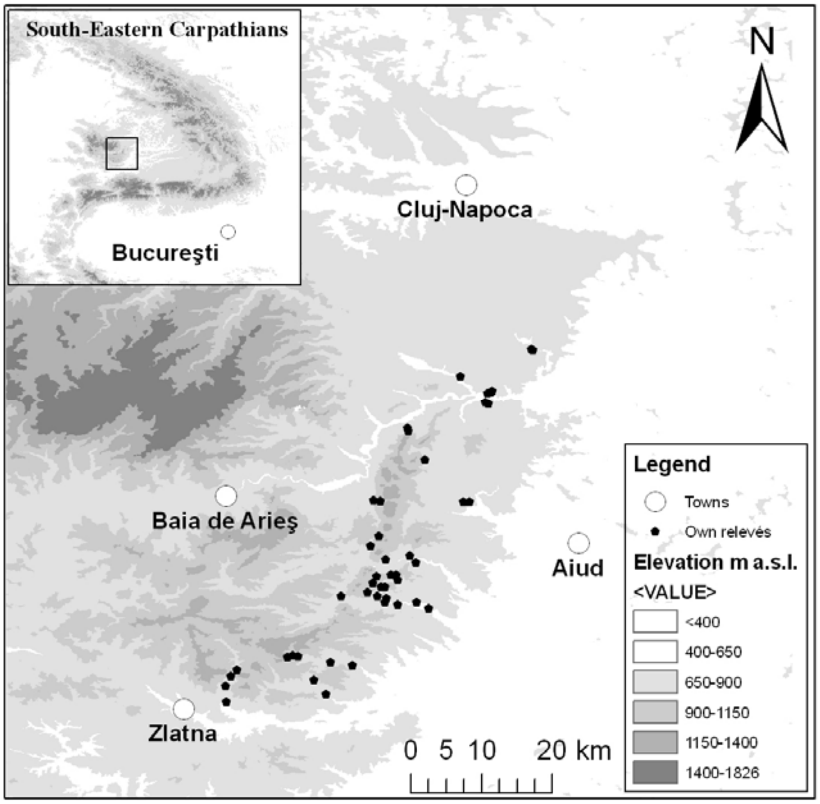

Figure 2.1: Location of the relevés made by us (n = 47) between May and August in the Trascău Mountains.

Database classification using OptimClass

Along with a synthesis of the works done on identifying the optimal number of clusters, Tichý *et al.* (2010) introduced a method called OptimClass. Its potential lies on the fact that the optimal partitioning is chosen so that it contains as numerous number of species with diagnostic value as possible.

In order to achieve our goals, starting with the classification of the deciduous forests of the Trascău Mountains, we applied the rules of the second variant of the OptimClass method (Tichý *et al.* 2010).

In the following, we provide the steps we followed in order to classify our database comprising the deciduous forests of the Trascău Mountains:

1. we calculated the distance matrix based on the Bray-Curtis index;
2. we used the distance matrix to build the dendrogram based on the average linkage method;
3. according to the OptimClass 2 method (Tichý *et al.* 2010), the dendrogram has been successively cut at different levels in order to achieve from 2 to 10 clusters;
4. at each cut, the indicator values of each species have been calculated for the established clusters. Then, validation criteria of a species to become diagnostic for a cluster have been that its indicator values to be higher than 0.2 for a single cluster, and the *p*-value of the Monte Carlo test with 1000 iterations to be less or equal to 0.05;
5. for each partition we selected the clusters which had at least 5 validated diagnostic species.

Numerical calculations have been one with the help of a script written in R programming language, vers. 2.15.0 (R Development Core Team 2012).

2.3. Results

The resulted diagram indicated two partitioning solutions. Of these, we chose the first one (fig. 2.2), which contains 7 clusters. The diagnostic species for each cluster are given in table 2.1., along with the number of relevés that form each cluster.

Cluster 1

The tree layer of these communities is composed mainly by *Quercus petraea*, often mixed with *Fagus sylvatica.* At some points, one of these two species prevails. The diagnostic species of the herbaceous layer (tab. 2.1) generally indicate oligotrophic or mesotrophic substrate, mostly acidic (Beldie *et* Chiriță 1968, Ciocârlan 2009).

Cluster 2

This cluster represents forests dominated by *Fagus sylvatica,* in some cases mixed with *Carpinus betulus*. The diagnostic species of the herbaceous layer indicate, in general, mesotrophic substrates, and some of them are indicators for soils with mull-type humus, such as *Mercurialis perennis* and *Cardamine bulbifera* (Beldie *et* Chiriță 1968, Ciocârlan 2009) (tab. 2.1).

Cluster 3

Forest assemblages are dominated by *Fagus sylvatica*. In contrast with the second cluster, *Carpinus betulus* is less frequent here. In general, the diagnostic species indicate mesotrophic substrates, including indicator species for soils with mull-type humus (*Asarum europaeum, Pulmonaria rubra*) (tab. 2.1). *Clematis alpina* and *Valeriana triperis* indicate shaded rocky and open rocky sites, respectively.

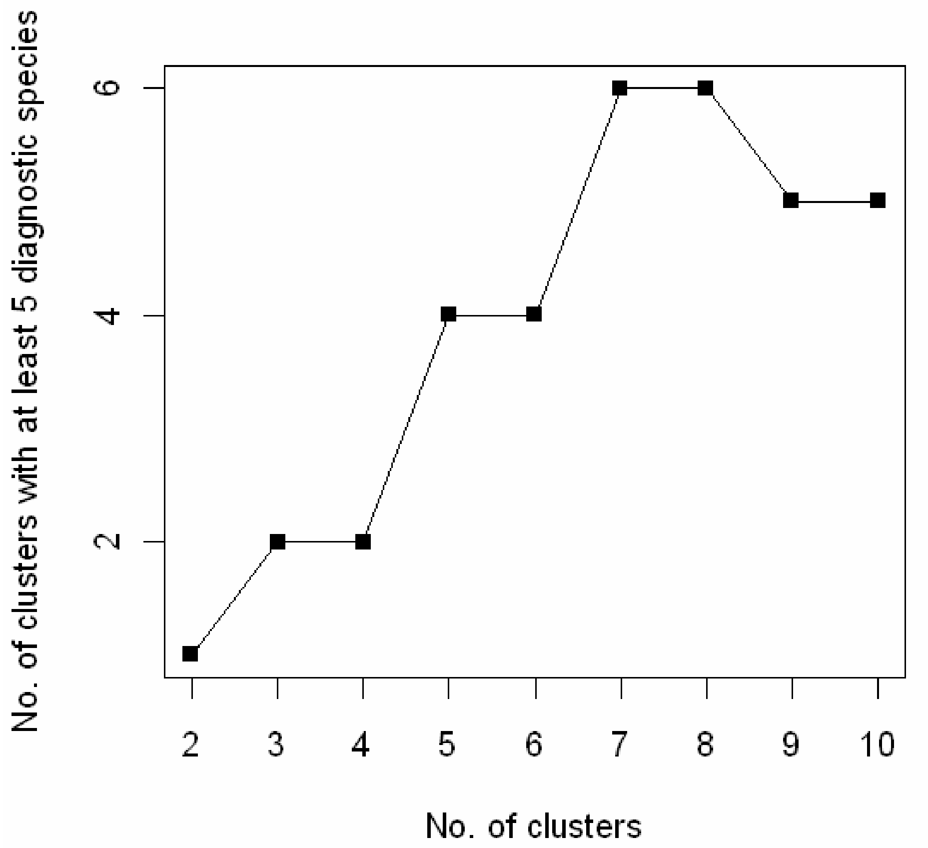

Figure 2.2: Results of the numerical analysis based on the OptimClass method applied on the database comprising the relevés made in the deciduous forests of the Trascău Mountains.

Cluster 4

This cluster represents forests dominated by *Carpinus betulus*, in some sites mixed with *Fagus sylvatica*. The diagnostic species generally indicate mesotrophic substrates.

Cluster 5

This cluster comprised few relevés in our database (tab. 2.1). However, we had many diagnostic species which indicate open thermophilous forests of *Quercus pubescens*, and to a lesser extent, *Q. cerris*. The diagnostic species of herbaceous layer are mostly xero-mesophilous.

Cluster 6

This cluster is similar to the first one, and corresponds to the *Quercus petraea* dominated forests. Many of the diagnostic species of this cluster are indicators of nutrient-poor soils or even acidic soils.

Cluster 7

This cluster represents alluvial *Alnus incana* forests. The majority of the diagnostic species, such as *Equisetum arvense, Matteuccia struthiopteris, Petasites hybridus, Poa trivialis, Ranunculus repens,* and *Mentha longifolia* are characteristic of substrates with high water content.

2.4. Discussion

The database originated from the Trascău Mountains (a relatively small region from the Carpathians) and therefore, the clusters obtained through our classification do not have a geographical significance as do most of the phytosociological syntaxa. Nevertheless, they indicated particular ecological conditions.

Cluster 1

Since *Luzula luzuloides* and *Quercus petraea* were listed among the diagnostic species of Cluster 1 (tab. 2.1), we assign this cluster to *Luzulo-Quercetum petreae* (Hilitzer 1932) Passarge 1953.

Cluster 2

Cluster 2 does not obviously correspond to any association. Based on the positive indicator values of the species diagnostic to Clusters 3 and 4, we could interpret this cluster as a transitional one between *Symphyto cordati-Fagetum* and *Melampyro bihariense-Carpinetum*.

Cluster 3

Of the diagnostic species of Cluster 3, *Pulmonaria rubra* and *Cardamine glanduligera* have been considered in the phytosociological literature as character species of the *Symphyto-Fagion* Vida 1959 alliance. *Symphytum cordatum* and *Fagus sylvatica* also had high indicator values. Therefore, we assign this cluster to *Symphyto cordati-Fagetum* Vida 1959.

Cluster 4

Since *Carpinus betulus* and *Melampyrum bihariense* are among the diagnostic species of Cluster 4, we assign this to *Melampyro bihariense-Carpinetum* Soó 1964.

Cluster 5

Because of the occurrence of *Quercus pubescens* and *Cornus mas* in the diagnostic species list of Cluster 5, we assign this to *Corno-Quercetum pubescentis* Jakucs *et* Zólyomi ex Máthé *et* Kovács 1962.

Cluster 6

Due to the presence of *Quercus petraea* and *Q. robur* among the diagnostic species of Cluster 6, we assign this cluster to *Quercetum robori-petraeae* Borza 1959. This is somewhat related to Cluster 1, as *Q. petraea* is a common diagnostic species for both clusters.

Cluster 7

Since *Alnus incana* and *Stellaria nemorum* are diagnostic for Cluster 7, we have assigned this to *Stellario nemori-Alnetum incanae* Oberdorfer 1953. Another possibility would be to assign Cluster 7 to *Telekio speciosae-Alnetum incanae* Coldea (1986) 1991 because this is the most widespread association of the *Alnus incana* forests in the Apuseni Mountains – even though our relevés do not include *Telekia speciosa*.

Table 2.1: Synoptic table of the seven clusters obtained through numerical classification. The validated diagnostic species (in dark-grey) and species with indicator values >= 0.15 (in light-grey) are ranked by their decreasing indicator value. The species with non-significant occurrence (Monte Carlo; $p<0.05$) were not included.

Cluster no. **No. of relevés**	**1** 18	**2** 39	**3** 25	**4** 28	**5** 6	**6** 36	**7** 9	***p-value***
1. *Luzulo-Quercetum petraeae*								
Heracium bifidum	**0.25**	-	-	-	-	-	-	0.002
Melampyrum nemorosum	**0.25**	-	-	-	-	-	-	0.004
Luzula luzuloides	**0.21**	0.02	0.13	0.02	-	0.12	-	0.033
Fallopia dumetorum	**0.19**	0.01	-	-	-	-	-	0.021
Hieracium praealtum subsp. bauhinii	**0.17**	-	-	-	-	-	-	0.019
2. Transitional type between *Symphyto cordati-Fagetum* and *Melampyro bihariense-Carpinetum*								
Lamiastrum galeobdolon	-	**0.32**	0.04	0.04	-	-	-	0.006
Mercurialis perennis	-	**0.32**	0.09	-	-	-	-	0.001
Cardamine bulbifera	0.02	**0.29**	0.11	0.01	-	-	-	0.003
Oxalis acetosella	-	**0.27**	0.06	-	-	-	-	0.009
Galium odoratum	0.02	**0.26**	0.12	0.05	-	-	-	0.013
Dryopteris filix-mas	0.01	**0.25**	0.06	0.03	-	0.04	0.05	0.002
Hordelymus europaeus	-	**0.18**	-	-	-	-	-	0.021
3. *Symphyto cordati-Fagetum*								
Fagus sylvatica	**0.18**	**0.30**	**0.40**	0.06	-	-	-	0.001
Asarum europaeum	-	0.06	**0.32**	**0.21**	-	0.02	0.01	0.002
Pulmonaria rubra	-	0.01	**0.32**	-	-	-	-	0.002
Clematis alpina	-	0.03	**0.27**	-	-	-	-	0.005
Gentiana asclepiadea	0.01	0.01	**0.26**	-	-	-	-	0.009
Veronica urticifolia	0.02	0.04	**0.24**	0.01	-	-	-	0.009
Cardamine glanduligera	-	0.04	**0.23**	-	-	-	-	0.019
Valeriana tripteris	-	-	**0.22**	-	-	-	-	0.013
Sorbus aucuparia	-	0.06	**0.20**	-	-	-	-	0.024
Hieracium rotundatum	-	-	**0.18**	-	-	-	-	0.026
Hepatica nobilis	-	0.08	**0.17**	0.09	-	0.01	-	0.050
Symphytum cordatum	-	0.03	**0.17**	-	-	-	-	0.050
4. *Melampyro bihariense-Carpinetum*								
Carpinus betulus	0.02	0.11	-	**0.62**	-	0.01	-	0.001
Glechoma hirsuta	-	0.03	0.06	**0.28**	-	-	-	0.004
Rosa pendulina	-	0.04	0.01	**0.25**	-	-	-	0.005
Euphorbia amygdaloides	-	0.14	0.03	**0.24**	-	-	0.01	0.006
Pulmonaria officinalis	0.01	0.13	0.01	**0.23**	-	0.01	-	0.008
Melampyrum bihariense	-	0.01	0.05	**0.22**	0.02	0.12	-	0.010
Carex sylvatica	-	0.06	-	**0.19**	-	-	-	0.029
Epipactis atrorubens	-	-	0.01	**0.18**	-	-	-	0.022
5. *Corno-Quercetum pubescentis*								
Quercus pubescens	-	-	-	-	**0.83**	-	-	0.001
Carex muricata subsp. lamprocarpa	0.01	-	-	-	**0.74**	0.02	-	0.001
Clematis vitalba	-	-	-	-	**0.67**	-	-	0.001
Carex humilis	-	-	-	-	**0.50**	-	-	0.001
Stachys recta	-	-	-	-	**0.50**	-	-	0.001
Crataegus monogyna	0.05	0.03	-	**0.17**	**0.34**	0.08	-	0.001
Euphorbia polychroma	-	-	-	-	**0.33**	-	-	0.002
Teucrium chamaedrys	-	-	-	-	**0.31**	-	-	0.004
Quercus cerris	-	-	-	-	**0.30**	0.01	-	0.004
Cornus mas	0.02	0.01	-	0.09	**0.27**	0.03	-	0.005
Coronilla varia	-	0.01	-	-	**0.25**	0.01	-	0.004
Erysimum odoratum	-	-	-	0.03	**0.25**	-	-	0.005
Euphorbia cyparissias	0.03	-	-	-	**0.24**	-	0.11	0.007
Rhamnus catharticus	0.01	-	-	-	**0.23**	0.01	-	0.010

Cluster no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	***p-value***
Cruciata glabra	0.10	0.02	-	0.09	**0.23**	**0.23**	-	0.013
Astragalus glycyphyllos	-	-	-	0.03	**0.23**	0.09	-	0.005
Hedera helix	-	0.02	-	0.01	**0.22**	-	-	0.004
Vincetoxicum hirundinaria	0.04	-	0.01	0.04	**0.22**	0.01	-	0.015
Poa angustifolia	0.01	-	-	-	**0.21**	0.04	-	0.013
Galium album subsp. album	-	-	0.05	-	**0.20**	0.01	-	0.019
Cephalanthera rubra	-	-	-	0.13	**0.18**	-	-	0.033
Brachypodium sylvaticum	0.03	-	-	**0.15**	**0.17**	0.02	-	0.031
Melica ciliata	-	-	-	-	**0.17**	-	-	0.040
Campanula sibirica	-	-	-	-	**0.17**	-	-	0.035
Inula ensifolia	-	-	-	-	**0.17**	-	-	0.030
Viola jooi	-	-	-	-	**0.17**	-	-	0.045
Medicago minima	-	-	-	-	**0.17**	-	-	0.031
Leontodon hispidus	-	-	-	-	**0.17**	-	-	0.030
Teucrium montanum	-	-	-	-	**0.17**	-	-	0.039
Verbascum phlomoides	-	-	-	-	**0.17**	-	-	0.033
Anthericum ramosum	-	-	-	-	**0.17**	-	-	0.039
Pyrus pyraster	-	0.01	-	-	**0.17**	0.07	-	0.016
6. *Quercetum robori-petraeae*								
Quercus petraea	**0.28**	-	-	0.01	0.03	**0.57**	-	0.001
Sedum telephium subsp. maximum	-	-	-	-	0.03	**0.51**	-	0.001
Veronica chamaedrys	0.08	-	-	-	0.02	**0.50**	-	0.001
Hieracium umbellatum	-	-	-	0.01	0.03	**0.39**	-	0.001
Lathyrus niger	0.13	-	-	0.02	-	**0.37**	-	0.001
Genista tinctoria	0.07	-	-	-	0.02	**0.35**	-	0.001
Carex montana	-	-	-	-	-	**0.33**	-	0.002
Galium pseudoaristatum	-	-	-	-	-	**0.31**	-	0.002
Quercus robur	-	-	-	-	-	**0.30**	-	0.007
Malus sylvestris	0.01	-	-	-	-	**0.29**	-	0.004
Potentilla alba	-	-	-	-	-	**0.28**	-	0.002
Festuca heterophylla	0.02	-	-	-	0.04	**0.27**	-	0.005
Trifolium medium	0.07	-	-	0.08	0.02	**0.25**	-	0.007
Hypericum perforatum	0.01	-	-	0.01	-	**0.24**	-	0.009
Hieracium racemosum	-	-	-	-	-	**0.22**	-	0.006
Veronica officinalis	**0.17**	-	-	0.01	-	**0.22**	-	0.010
Origanum vulgare	-	-	0.01	-	-	**0.21**	0.02	0.010
Stachys officinalis	0.03	-	-	-	-	**0.21**	-	0.018
Clinopodium vulgare	0.07	-	-	0.01	0.17	**0.21**	-	0.021
Poa nemoralis	**0.17**	0.06	0.01	0.09	0.08	**0.21**	-	0.029
Campanula persicifolia	0.11	0.01	0.02	0.03	-	**0.20**	-	0.046
Iris graminea	-	-	-	-	-	**0.19**	-	0.021
Sorbus torminalis	0.04	-	-	0.03	-	**0.19**	-	0.032
Chamaecytisus hirsutus	0.14	-	0.04	-	-	**0.18**	-	0.022
Hieracium bifidum	0.01	-	-	-	-	**0.15**	-	0.031
7. *Stellario nemori-Alnetum incanae*								
Alnus incana	-	-	-	-	-	-	**1.00**	0.001
Salix purpurea	-	-	-	-	-	-	**0.67**	0.001
Poa trivialis	-	-	-	-	-	-	**0.67**	0.001
Prunella vulgaris	-	-	-	0.01	-	0.01	**0.59**	0.001
Petasites hybridus	-	-	-	-	-	-	**0.56**	0.001
Ranunculus repens	-	-	-	-	-	-	**0.56**	0.001
Lysimachia nummularia	-	-	-	-	-	-	**0.56**	0.001
Urtica dioica	-	0.03	-	0.01	-	-	**0.55**	0.001
Impatiens noli-tangere	-	-	-	0.01	-	-	**0.54**	0.001
Stellaria nemorum	-	-	-	-	-	-	**0.53**	0.001
Matteuccia struthiopteris	-	-	-	-	-	-	**0.44**	0.001
Equisetum arvense	-	-	-	-	-	-	**0.44**	0.001
Polygonum lapathifolium	-	-	-	-	-	-	**0.44**	0.001
Mentha longifolia	-	-	-	-	-	-	**0.44**	0.001

Cluster no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	***p-value***
Mentha aquatica	-	-	-	-	-	-	**0.44**	0.001
Anthriscus sylvestris	-	-	-	-	-	-	**0.44**	0.001
Scrophularia nodosa	-	0.01	-	-	-	-	**0.43**	0.001
Chaerophyllum aromaticum	-	-	-	-	-	-	**0.41**	0.001
Salix triandra	-	-	-	-	-	-	**0.33**	0.001
Arctium nemorosum	-	-	-	-	-	-	**0.33**	0.002
Glyceria plicata	-	-	-	-	-	-	**0.33**	0.001
Potentilla anserina	-	-	-	-	-	-	**0.33**	0.001
Cardamine amara	-	-	-	-	-	-	**0.33**	0.001
Solanum dulcamara	-	-	-	-	-	-	**0.33**	0.001
Lamium album	-	-	-	-	-	-	**0.33**	0.002
Geum urbanum	0.01	0.02	-	0.02	0.02	0.01	**0.33**	0.002
Galium aparine	0.04	-	-	-	-	-	**0.28**	0.002
Glechoma hederacea	-	-	-	-	-	-	**0.26**	0.003
Geranium robertianum	-	0.11	-	0.04	-	-	**0.24**	0.011
Equisetum palustre	-	-	-	-	-	-	**0.22**	0.005
Poa pratensis	-	-	-	-	-	-	**0.22**	0.010
Poa annua	-	-	-	-	-	-	**0.22**	0.010
Lycopus europaeus	-	-	-	-	-	-	**0.22**	0.004
Chrysosplenium alternifolium	-	-	-	-	-	-	**0.22**	0.004
Ranunculus acer	-	-	-	-	-	-	**0.22**	0.004
Geranium sylvaticum	-	-	-	-	-	-	**0.22**	0.006
Myosotis sylvatica	0.01	-	-	-	-	0.01	**0.21**	0.005
Stachys sylvatica	-	-	-	0.06	-	-	**0.20**	0.012
Galeopsis speciosa	0.05	-	-	-	-	-	**0.18**	0.027
Plantago media	-	-	-	0.02	-	-	**0.17**	0.017

Sources of relevés, ordered by clusters: **1.** 15 – original, 1 - Gergely (1962), 2 - Gergely (1968); **2.** 16 –original, 4 - Gergely (1962), 8 - Gergely (1968), 4 - Ghişa *et al*. (1965), 1 - Şuteu (1971), 6 – Şuteu (1970); **3.** 4 – original, 10 – Gergely (1968), 11 – Şuteu (1970); **4.** 9 – original, 4 – Gergely (1962), 3 – Gergely (1968), 6 – Şuteu (1971), 6 – Şuteu (1970); **5.** 2 – original, 3 – Gergely (1962), 1 – Gergely (1968); **6.** 1 – original, 15 – Gergely (1962), 20 – Gergely (1968); **7.** 9 - rel. Şuteu (1970).

CHAPTER III

The flora and vegetation of the forest gaps in the Trascău Mountains: general characterization

3.1. Introduction

The flora of the forest gaps in the Trascău Mountains is made of: (i) grassland species with high conservation value (described by Brinkmann *et al.* (2009) from the Apuseni Mountains), (ii) forest edge species, and (iii) forest species. Therefore, we expect that these forest gaps to play an important role in maintaining these species categories into the future and more particularly, in our opinion, by nesting the two major units: forests and grasslands.

In this study, we aimed at (i) making an assessment and description of the flora of forest gaps, and (ii) describing their vegetation based on coenotaxa.

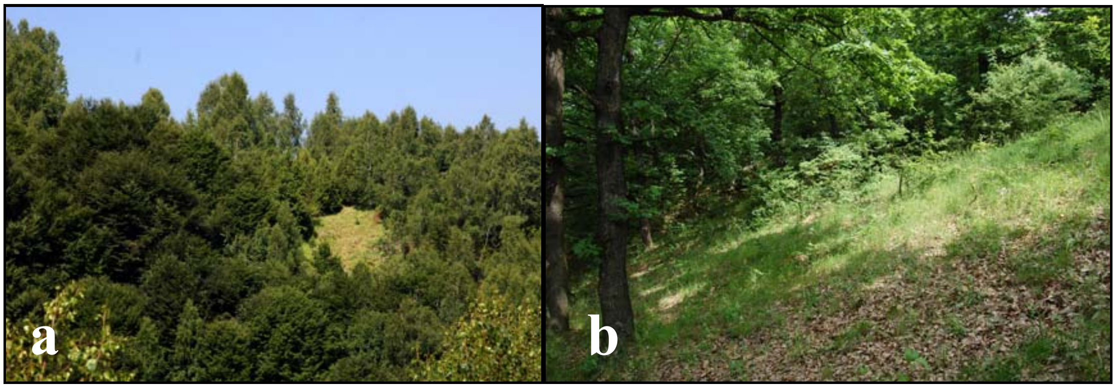

Figure 3.1. General view (a) and the interior (b) of two forest gaps located in the northern part of the Trascău Mountains.

3.2. Materials and methods

The flora

The study of flora first comprises a list of taxa which were identified during two vegetation periods: May–September 2012 and June–August 2011. The nomenclature follows the *European Flora* – online version (Royal Botanic Garden Edinburg 2011).

The vegetation

In order to study the vegetation of the forest gaps, we carried out:

1. the analysis based on phytosociological classes by considering all the taxa from the total list, in order to show the general character of the vegetation;
2. the detailed analysis at the level of phytosociological association (Cristea *et al.* 2004), by taking into account the information gathered along the transects made of 4 plots. To make the phytosociological tables, we pulled together all the species identified within each transect. The phytosociological affinities of the species followed Sanda *et al.* (1983).

3.3. Results

The flora

During our field research, we identified a total of 431 plant taxa, of which 409 species and 22 subspecies. They belong to 69 families and 238 genera.

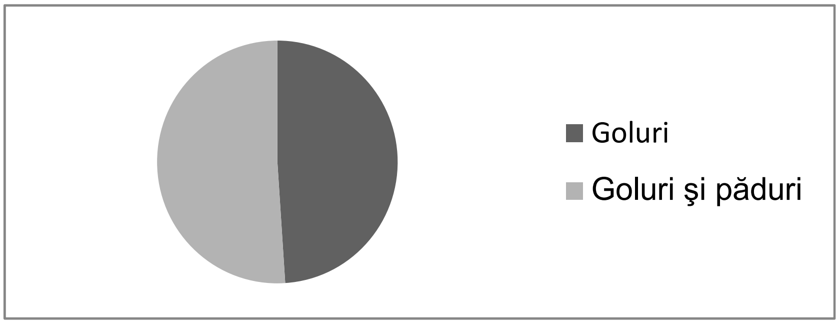

Figure 3.2: The number of species confined to gaps and those which occur also in forests.

In order to select the taxa that occur also in forests, we considered the literature from the region (Gergely 1962, 1968; Turtureanu *et al.* 2011), together with more general sources (Hermy *et al.* 1999, Ciocârlan 2009). The selected taxa were 220 (51%) in total. The rest of the taxa were considered as restricted to forest gaps. These were 211 (49%) in total, therefore having almost the same number as the first ones (fig. 3.2)! The distribution of the taxa within the families is shown in figure 3.4. for the first 9 families (58.2%).

Life forms are dominated by hemicryptophytes and terophytes. The geographic elements are dominated by the Eurasian and Europeans, of which the Mediterraneans are well represented.

From the point of view of humidity, the mesophilous species dominate, while the rest of the categories are evenly distributed. However, the xeromesophilous have a slightly higher contribution. The majority of the species are between acidophilous and neutrophilous, while those between neutrophilous and basiphilous are rather numerous. Moreover, in the study area, forest gaps have a high number of species which are not sensitive to the soil chemical reaction. When considering the Ellenberg index for light, species having a value of 7 prevail, i.e. those which occur generally in well lit places, but also occurring in partial shade.

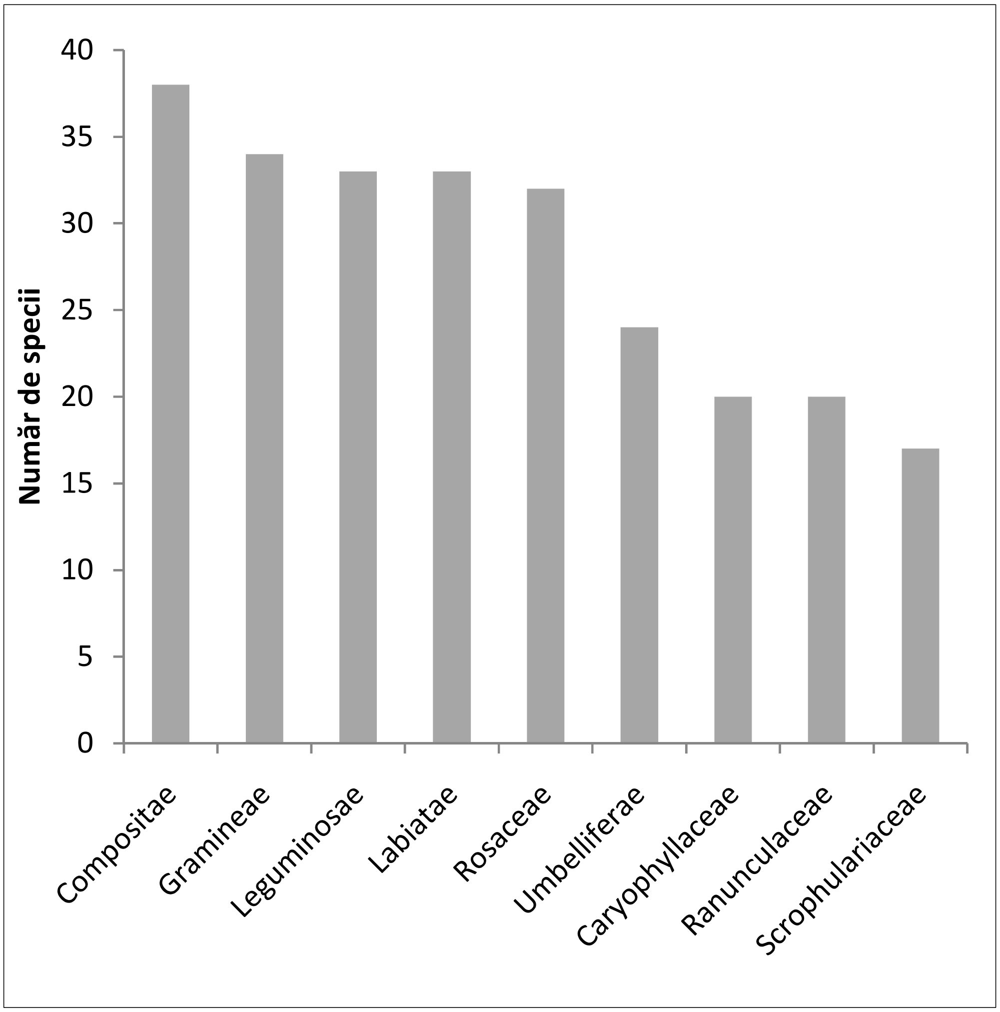

Figure 3.3: The number of species in each of the first 9 families.

The vegetation

The majority of the taxa belong to **Querco-Fagetea** phytosociological class (i.e. deciduous forests), while the rest are included in **Festuco-Brometea** and **Molinio-Arrhenatheretea** (i.e. grasslands), **Trifolio-Geranietea sanguinei** (i.e. forest edges), and **Epilobietea** (i.e. recent forest clearings).

Of the 40 forest gaps sampled, 39 have been included in two phytosociological associtations: ***Festuco rubrae-Agrostietum capillaris*** Horvat 1951 (i.e. 13 gaps) and ***Festucetum rupicolae*** Burduja *et al.* 1956 (i.e. 26 gaps). One forest gap was not included in any association since it was a transitional one, dominated by forest species. The two associations belong to the following coenotaxnomical system (Sanda 2002):

MOLINIO-ARRHENATHERETEA Tx. 1937

Arrhenatheretalia Pawl. 1928

Cynosurion R. Tx. 1947

1. ***Festuco rubrae-Agrostietum capillaris*** Horvat 1951

FESTUCO-BROMETEA Br.-Bl. *et* Tx. 1943

Festucetalia valesiacae Br.-Bl. et Tx. 1943

Festucion valesiacae Klika 1931

2. ***Festucetum rupicolae*** Burduja *et al*. 1956

3.4. Discussion

The flora

Since the flora of the forest gaps comprises many species occurring also in forests, there is a clear evidence of the influence of ***forest matrix*** on the gaps environment. Moreover, the high percent of species confined to gaps (49%), in other words grasslands, show that the forest gaps could be considered as ***habitat islands***.

The vegetation

The ecological and phytosociological characteristics or the two associations identified in forest gaps are discussed in the following:

1. ***Festuco rubrae-Agrostetum capillaris*** Horvat 1951

This association represents secondary assemblages with a mesophilous character. According to our expectations, this type of association occurs only on acidic substrates. We explain its presence on calcareous soils by the high altitudes (range 1015-1095 m a.s.l.), while at lower altitudes (range 634-899 m a.s.l.) it occurs on acidic soils.

2. ***Festucetum rupicolae*** Burduja *et al*. 1956

This association has a xeromesophilous character. The average elevation where this association was found was in accordance with our expectations, being lower than in the case of *Festuco rubrae-Agrostetum capillaries,* i.e. 655 m a.s.l. The highest altitudes where it was found were above 1050 m a.s.l. This might be explained by the presence of calcareous substrate, which causes thermophilisation.

CHAPTER IV

The structural and ecological relevance of several diversity measures within forest gaps of the Trascău Mountains

4.1. Introduction

Analysing α-diversity alone neglects the relevance of β-diversity on the regional diversity (γ-diversity; Tuomisto 2010). Therefore, along with species richness, we chose two types of classical measures largely used in the literature, which are the additive (β_{Add}; Lande 1996) and multiplicative β-diversity (β_{Mult}; Whittaker 1960). In order to take into consideration also the species composition, we used three multivariate β-diversity measures. The first one calculates β-diversity as the slope of the floristic dissimilarity and spatial distance, i.e. slope of the distance decay relationship (Nekola *et* White 1999). These types of measures have been criticized for their lack of independence between the sample pairs (since they used more than one pair of samples; Diserud *et* Ødegaard 2007), and therefore we additionally computed the Sørensen-based multiple-site dissimilarity (β_{SOR}; Baselga 2010b). This is a broad sense β-diversity because it provides information both for nestedness and turnover of the species (Baselga 2010b). Therefore, we employed the Simpson-based multiple-site dissimilarity (β_{SIM}; Baselga *et al.* 2007), which informs about the pure turnover of the species between the plots.

Using forest gaps in the Trascău Mountains, we addressed the following questions: (i) which environmental variables drive α-diversity at a fine scale (1 m^2)? (ii) how are different measures of β-diversity influenced by environmental factors? (iii) could the different observed patterns of the diversity measures that we compared be explained by ecological processes and/or mathematical constraints?

4.2. Materials and methods

We sampled the vegetation within 40 forest gaps ranging from approximately 15 m to 50 m width. We made a transect of four 1 m^2 plots in each gap, from the top edge towards the center.

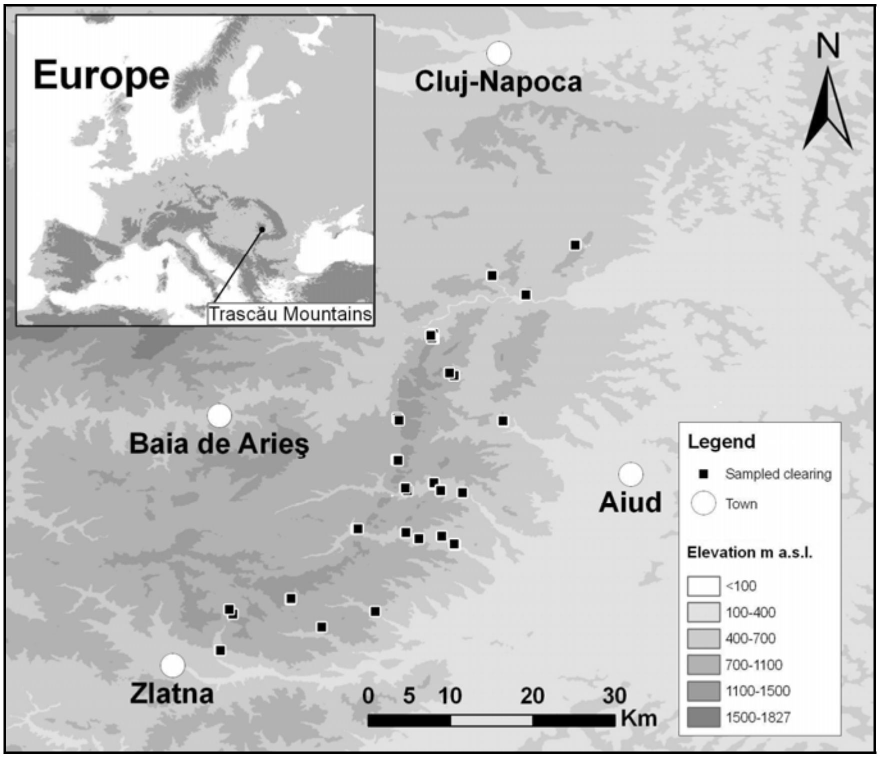

Figure 4.1: Location of the sampled forest gaps in the Trascău Mountains (Romanian Carpathians)

Each transect consisted of four square meter plots of 1 m^2, arranged at 3-m interval. At the transect level, we recorded three environmental variables: *altitude*, *bedrock type*, and *aspect*. For each 1 m^2, we measured four environmental variables: *slope*, *head load index*, and *litter cover*. Canopy openness was assessed using hemispherical photos.

Data analysis

We classified the species into three categories: (1) grassland, (2) forest edge, and (3) forest species. As a measure for α-diversity, we considered the species richness at 1 m^2 scale, both for the total species and for each category separately. In order to model α-diversity, we included the environmental variables measures in each plot as predictors.

As the plots were nested within transects, spatial autocorrelation potentially existed. Thus, we employed generalized linear mixed models (GLMMs), as they are able to account for nested samples (Zuur *et al.* 2009).

In order to compute the β-diversity as the slope of the distance decay relationship (Nekola *et* White 1999) in linear representation, we used pairwise Bray–Curtis dissimilarities and distances between plots.

Finally, we modelled the relationships between the β-diversity measures and the means and ranges of the environmental variables at the transect level, through simple and multiple linear regressions. To obtain the final models for both α- and β-diversity, a backward selection procedure was used.

The statistical computations were done in R (R Development Core Team 2011).

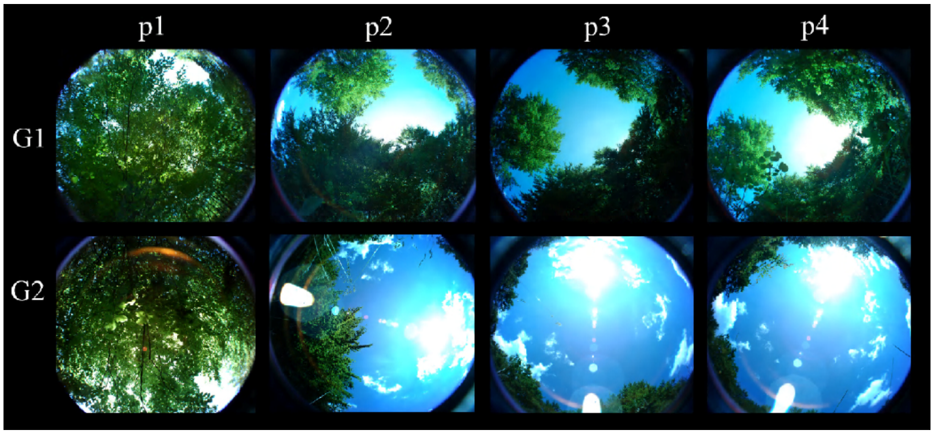

Figure 4.2: Hemispherical images taken towards the sky from each single plot (p1-p4) in two forest gaps named G1 and G2. The higher openness of the canopy in the second transect suggests the higher size of its corresponding gap.

4.3. Results

The total number of vascular plants recorded was 258, of which 113 were classified as grassland, 58 as forest, and 58 as edge species, whilst 29 species remained unclassified.

The α-diversity of total species richness was positively related to canopy openness and negatively to tree litter cover. Grassland species richness was also positively associated with canopy openness, but had a negative relationship with tree litter cover and slope. The forest species richness was negatively related to canopy openness and heat load index. For the richness of edge species, no environmental variables had significant influence.

The parameter β_{Add} for total and grassland species was positively associated with canopy openness range. For forest species, it had a positive relationship with altitude.

β_{Mult} for total species was positively related to altitude, and it had a weak positive relationship with canopy openness range. For grassland species, it was associated positively with tree litter cover mean and negatively with heat load index mean. When calculated for forest species, β_{Mult} was positively associated with canopy openness range and negatively with tree litter cover range.

None of the predictors explained $\beta_{\text{distance decay}}$, except for grassland species, where it had a positive relationship with heat load index. β_{SOR} yielded similar results with β_{Mult}, except for total species, where it was significantly and positively influenced only by canopy openness range. β_{SIM} was positively related with tree litter cover, but only when calculated for forest species. From the parameters of the full model, slope mean and bedrock type were not included in the minimum adequate models for any of the β-diversity parameters.

4.4. Discussion

The detected positive effect of canopy openness on the total α-diversity at the 1-m^2 scale indicates that species richness was higher towards the centre of the gaps, probably due to a positive effect of increasing light intensity. The negative relationship between the total α-diversity and tree litter cover can be explained by inhibitory influences of litter on plant regeneration. The positive relationship between canopy openness and the grassland species diversity reveals how the vegetation resembles grasslands towards the centre the study site. Albeit less evidently, the richness in grassland species was negatively related to slope, probably due to a more suitable water regime for the species on gentle slopes. The lack of relationships between the edge species richness and the environmental variables considered here suggests that—unlike for grassland and forest species—either they are within the gaps not restricted by any of the environmental factors or two opposing factors levelled each other out. On the contrary, the forest species richness increased in plots with low canopy openness. Interestingly, the heat load index had a stronger negative influence on the number of forest species than the canopy openness. This may be attributed to the lower tolerance of forest species in the open areas located on southern slopes.

In our study, a clear distinction first occured between β_{Add} and β_{Mult}, presumably due to the inclusion / exclusion of joint absences in their calculation. Thus, the information provided by β_{Mult} was more meaningful here, especially as β_{Add} has been criticized for its dependence on species richness (Jost 2007; Zeleny 2009; Baselga 2010a; Veech *et* Crist 2010).

The incorporation of distance in the $\beta_{\text{distance decay}}$ calculation provided an explanation for its different behaviour in comparison with β_{SOR}; they had been expected to give similar results because both are based on essentially the same dissimilarity measure (Sørensen is equivalent to Bray–Curtis for presence–absence data). Since many of our transects crossed small gaps, having similar values of environmental variables at the edges, the weak response of $\beta_{\text{distance decay}}$ to the predictors was not surprising.

β_{SOR} indicated the existence of a combination of nestedness and turnover in the data. Furthermore, as none of the predictors explained the narrow-sense β_{SIM}, except tree litter cover range in the case of forest species, we might conclude that pure spatial turnover is likely to be weak in the forest gap communities that we studied.

CHAPTER V

Plant diversity patterns in a complex of forest gaps from the Ugerului Massif (northwestern Trascău Mountains)

5.1. Introduction

Diversity patterns and application of some measures of floristic variation have not been studied enough in habitat islands.

In our study, we focus on a network composed of gaps located within the deciduous forests of the Trascău Mountains. Using presence data of plant taxa in 1 m^2 plots, along with the species pool of each gap, we addressed the following questions: (i) which differences exist between the species-area relationship including all species and that considering the grassland species?, (iii) do the number of species at gap level influences the richness at 1 m^2 scale?, (iii) are the nestedness and turnover components of β-diversity higher between than within the gaps? (iv) how these measures are influenced by the number of species (α-diversity), both at 1-m^2 and gap scale?

5.2. Materials and methods

Study area

The studied gaps are located in the proximity of Vidolm locality, in the northwestern part of the Trascău Mountains (46°28′38″N şi 23°30′39″E; fig. 5.1).

Data sampling

We sampled data within 17 forest gaps. Their area was measured using polygons drawn on an aerial photo of the area, raning from 32 to 3412 m^2.

Within each of the selected gap, we sampled the species from 1 m^2 plots. Beside the species recorded within the plots, we also noted the species observed while visiting the rest of the gap surfaces, therefore a complete species list was available at the gap level. They were classified into grassland and forest species.

Data analysis

We considered α-diversity at the forest gap level as being the total number of species resulted from the species recorded within the plots and those found in the rest of their area. In order to find the best function describing the relationship between the number of species (S_{gap}) and area (A), we made use of the mmSAR package (Guilhaumon 2010).

In order to assess β-diversity, we used the recent methods proposed by Baselga (2010b), where the total β-diversity is partitioned in nestedness and turnover components. Then, to examine how these two phenomena could be highlighted in the spatial structure of the communities within and between the forest gaps, we calculated the Sørensen pairwise (β_{sor}), Simpson pairwise (β_{sim}) and Nestedness-resultant dissimilarity (β_{nes}) based on pairs of plots (Baselga 2010b). For the first case, we used only pairs of plots located within the same plot, while for the second case, only plots located in different gaps. Using a selection procedure, 1000 pairs of plots were selected for each case. Therefore, in order to examine whether the means of β_{sor}, β_{sim} and β_{nes} are equal both within and between gaps, we used the Student's *t* test.

In order to examine the dependence of β-diversity to α-diversity, we simultaneously calculated the β-diversity using four plots, i.e. multiple-site dissimilarity. The selection of four random plots from each gap was made by 100 times. Finally, we considered the β-diversity of each gap as the mean of β_{SOR}, β_{SIM} and β_{NES} as calculated using multiple sites.

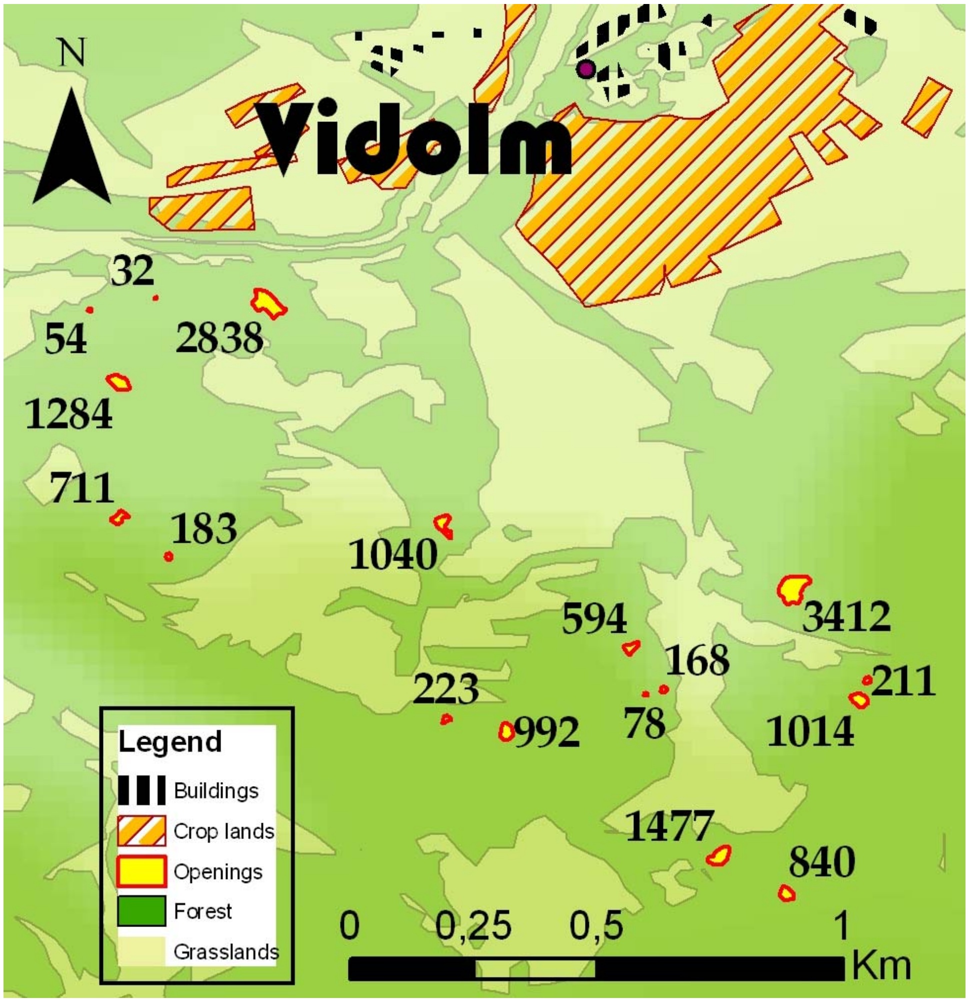

Figure 5.1: The spatial distributin of the studied forest gaps in the landscape of forests and secondary grasslands from the vicinity of Vidolm locality. The values represent the area of the gaps (m^2).

5.3. Results

The total number of species identified in the forest gaps (γ-diversity) was 209. The total number of species at gap level was dependent of the gap area, and the power function was the best model to describe this relationship (fig. 5.2). The optimal function which described the relationship between the number of grassland species and gap area was the logistic one.

The mean number of species at the plot level was dependent of the total number of species at the gap level. When considering only the number of grassland species, this relationship was stronger.

The means of β_{sor} and β_{sim}, as calculated for pairs of plots located in the same gap and for pairs of plots located in different gaps, were higher when we considered the pairs of plots located in different gaps. In contrast, the mean of the nestedness component (β_{nes}) was not significantly different.

The three β-diversity measures used were not explained by the total number of species at the gap level. On the contrary, when we calculated β_{NES} with grassland species only, it was negatively influenced by the number of grassland species at the gap level.

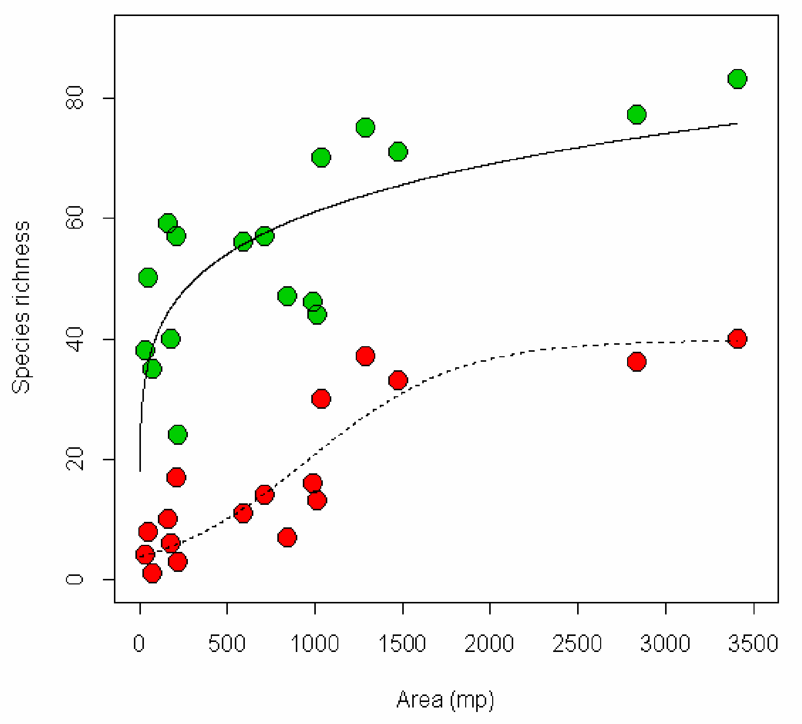

Figure 5.2: The power function applied in order to describe the relationship between the total number of species (green symbols) (S_{tot}) and area (A) ($S_{\mathrm{tot}} = 18.21 \times A^{0.18}$; AIC$_c$ = 89.35; BIC = 90.00). The relationship between the number of grassland species and area (red symbols) is adjusted through the logistic function ($S_{\mathrm{tot}} = 39.79 / (1 + \exp(-0.002 \times A + 2.24)$; AIC$_c$ = 89.35; BIC = 90.00).

5.4. Discussion

The optimal description of the relationship between the total number of species and area through the power function is in accordance with the results of other recent studies (e.g. Triantis *et al.* 2012). The dominant shape of this relationship is theoretically convex, without asymptote. In case of the logistic function, which describes the relationship between the number of grassland species and gaps area, one could find that the flattening is possible to be a result of a saturation in grassland species within very large gaps.

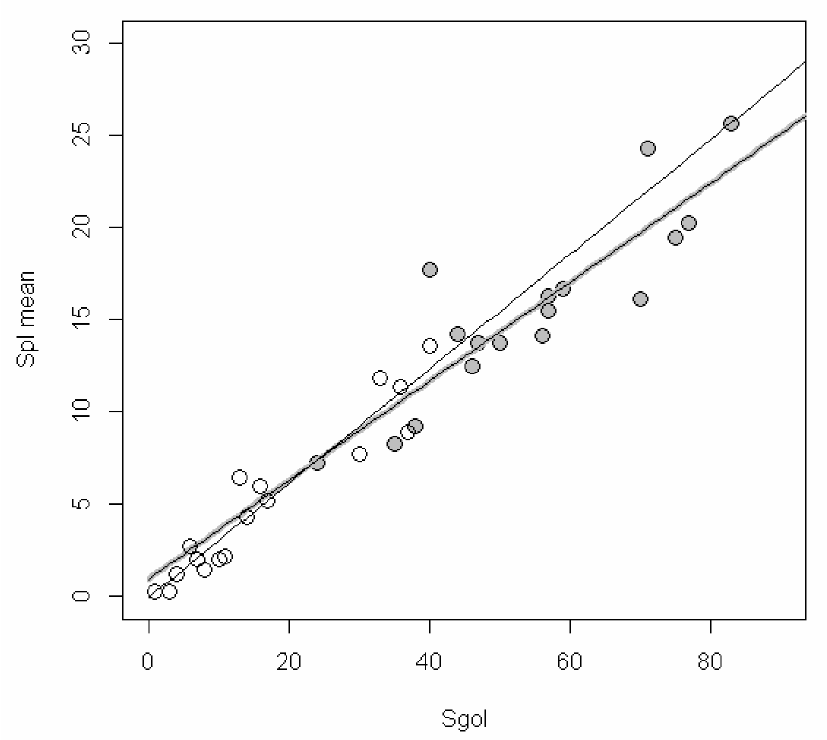

Figure 5.3: The linear relationship between the mean number of species at the plot level ($S_{\mathrm{pl\ mean}}$) and the total number of species at the gap level. For the total species, filled symbols were used, while open symbols were used for the grassland species. The colors of the regression lines are in accordance with the symbols they correspond to.

The relationship between the mean number of species at the plot level and the total number of species at the gap level might be explained by the fact that the existing species pool influences the floristic assemblage processes at fine scales.

As expected, the mean of total β-diversity (β_{sor}), as calculated for pairs of plots, was higher between the gaps than within them. Although the species composition within the gaps of this area is a response of some environmental variables (Turtureanu *et* Dengler 2012), β-diversity between gaps has a higher contribution on the complex made of these gaps.

β_{sim}, which represents the turnover of the species between plots, also had a higher mean between the gaps, and its values were much higher than those of the nestedness component β_{nes}, suggesting that the most part of the total β-diversity is made of β_{sim}. Although the forest gaps (i.e. small openings) harbor a low number of species according to the species-area relationship, the high turnover between these and the larger ones shows their important contribution to the γ-diversity.

Floristic nestedness was not significantly different between and within the gaps, which indicates that the ecological processes which lead to the species loss between the plant assemblages are the same regardless of the levels. However, we could notice that β_{nes} has relatively low values.

For the total species, no β-diversity measure has been dependent on the two α-diversities (the total number of species at the gap level and the mean number of species per plot), except β_{NES} when calculated using grassland species only. Therefore, it is obvious that the disaggregation process is exhibited as the number of grassland species is growing (from the small to large gaps). For the total number of species, this relationship was not significant since of the highest proportion of the total β-diversity (β_{SOR}), β_{NES} had a low contribution compared to β_{SIM}. The mean β_{NES} for all species was only 8.4% of the mean β_{SOR}. In contrast, for the grassland species, the mean β_{NES} contributed with 27.0% of the mean of β_{SOR}, therefore resulting in a significant relationship between the two α-diversities.

General conclusions

In particular, we can draw the following conclusions for each of the four chapters:

- The phytosociological research carried out on the deciduous forests used the optimal partitioning method called OptimClass. This suggested that the database (161 phytosociological relevés) should be partitioned into 7 groups. By cutting the dendrogram, we obtained 7 clusters, which were attributed to 6 associations: *Luzulo-Quercetum petraeae*, *Symphyto cordati-Fagetum*, *Melampyro bihariense-Carpinetum*, *Corno-Quercetum pubescentis*, *Quercetum robori-petraeae,* and *Stellario nemori-Alnetum incanae/ Telekio speciosae-Alnetum.*
- The floristic examination of the gaps resulted in the identification of 431 taxa. Of these, 52% occur also in forests, showing a transitional coenotic character of the gaps, i.e. between forests and grasslands. Taxa beonging to *Compositae*, *Gramineae*, *Leguminosae*, and *Labiatae* prevail. The majority of the species are hemicryptophytes and Eurasian. The mesophilous, meso-thermophilous, and acidiphilous-neutrophilous prevail, while many neutrophilous and basiphilous species indicate the presence of limestones. Plants growing generally in well lit places, but also occurring in partial shade prevail. Two phytosociological associations were identified in the studied gaps: *Festuco rubrae-Agrostetum capillaris* and *Festucetum rupicolae*. The first one stands for mesophilous, while the second for xeromesophilous communities.
- The analysis carried out in the 40 gaps in the Trascău Mountains showed that the environmental variables influenced both α- and β-diversity. α-diversity at 1 m^2 was mainly

explained by canopy openness and tree litter cover. β_{Add} and β_{Mult} were different in terms of their behaviour against the variables. The lack of any relationship between β_{SIM} and the environmental variables suggests that pure turnover is likely to be weakly influenced by these. The resulted measures reflect particular ecological processes, diversity assessment using a set of methodologically different measures being therefore recommended. Our results provide support for the conservation measures in the region.

- The species-area relationship at the level of the 17 gaps analysed on the Ugerului Massif was expressed by the power function, and in the case of grassland species, by a sigmoid curve. The positive relationship between the mean number of species at the plot scale and the total number of species at the gap level show that the existing species pool at the level of gaps influences the assemblages at fine scales. The total β-diversity (β_{sor}) was higher between the gaps that within. β_{sim} was also higher between the gaps. β_{nes} did not show any significant difference between and within the gaps. None of the β-diversity measures were dependent on α-diversity (measured both at the level of gaps and plots), except β_{NES} calculated with grassland species.

The importance of the forest gaps lies in their capacity of maintaining a high number of species not only dependent on their surface, but promoting a high turnover rate. Therefore, we highlight that management interventions must focus on maintaining more gaps varying in surface.

Selected references

1. Anderson, M.J., Crist, T.O., Chase, J.M., Vellend, M., Inouye, D., Freestone, A.L., Sanders, N.J., Cornell, H.V., Comita, L.S., Davies, K.F., Harrison, S.P., Kraft, N.J.B., Stegen, J.C., Swenson, N.G., 2011, Navigating the multiple meanings of β diversity: a roadmap for the practicing ecologist, *Ecology Letters*, **14**: 19–28.
2. Anderson, K.L., Leopold, D.J., 2002, The role of canopy gaps in maintaining vascular plant diversity at a forested wetland in New York State, *Journal of the Torrey Botanical Society*, **129**: 238–250.
3. Anderson, M.J., Ellingsen, K.E., Mcardle, B.H., 2006, Multivariate dispersion as a measure of beta diversity, *Ecology Letters*, **9**: 683–693.
4. Antrop, M., 2005, Why landscapes of the past are important for the future, *Landscape and Urban Planning*, **70**: 21–34.
5. Barik, S.K., Pandey, H.N., Tripathi, R.S., Rao, P.M., 1992, Microenvironmental variability and species diversity in treefall gaps in a sub-tropical broadleaved forest, *Vegetatio*, **103**: 31–40.
6. Baselga, A., 2010a, Multiplicative partition of true diversity yields independent alpha and beta components; additive partition does not, *Ecology*, **91**: 1974–1981.
7. Baselga, A., 2010b, Partitioning the turnover and nestedness components of beta diversity, *Global Ecology and Biogeography*, **19**: 134–143.
8. Baselga, A., Jiménez-Valverde, A., Niccolini, G., 2007, A multiple-site similarity measure independent of richness, *Biology Letters*, **3**: 642–645.
9. Başnou, C., Pino, J., Šmilauer, P., 2009, Effect of grazing on grasslands in the Western Romanian Carpathians depends on the bedrock type, *Preslia*, **81**: 91–104.
10. Beldie, A., Chiriță, C., 1968, *Flora indicatoare din pădurile noastre*, Ed. Agro-Silvică, Bucureşti.
11. Boşcaiu, N., Boşcaiu, V., Coldea, G., Tauber, F., 1982, Sintaxonomia făgetelor carpatine. In: Preda, V., Boşcaiu, N. (*eds*.), *Făgetele carpatine. Semnificația lor bioistorică şi ecoprotectivă*, Ed. Acad., Cluj-Napoca: 228–303.
12. Brinkmann, K., Păcurar, F., Rotar, I., Rusdea, E., Auch, E., Reif, A., 2009, The grasslands of the Apuseni Mountains, Romania. In: Veen, P., Jefferson ,R., de Smidt, J., van der Straaten, J. (*eds*.), *Grasslands in Europe of high nature value*, KNNV Publishing Zeist, Zeist: 226–237.
13. Caley, M.J., Schluter, D., 1997, The relationship between local and regional diversity, *Ecology*, **78**: 70–80.
14. Coldea, G., 1991, Prodrome des associations végétales des Carpates du Sud-Est (Carpates Roumanies), In: Gehu, J.-M., Pedrotti, F. (*eds*.), *Documents phytosociologiques*, Università degli Studi, Camerino, **13**: 317–540.
15. Cremene, C., Groza, G., Rakosy, L., Rakosy, L., Schileyko, A.A., Baur, A., Erhardt, A., Baur, B., 2005, Alterations of steppe-like grasslands in Eastern Europe: a threat to regional biodiversity hotspots, *Conservation Biology*, **19**: 1606–1618.
16. Crist, T.O., Veech, J.A., 2006, Additive partitioning of rarefaction curves and species-area relationships: Unifying alpha-, beta- and gamma-diversity with sample size and habitat area, *Ecology Letters*, **9**: 923–932.
17. Cristea, V., Gafta, D., Pedrotti, F., 2004, *Fitosociologie*, Ed. Presa Universitară Clujeană, Cluj-Napoca.
18. Dengler, J., 2009, Which function describes the species-relationship best? A review and empirical evaluation, *Journal of Biogeography*, **36**: 728–744.

19. Dengler, J., 2010, Robust methods for detecting a small island effect, *Diversity and Distributions*, **16**: 256–266.
20. Diserud, O.H., Ødegaard, F., 2007, A multiple-site similarity measure, *Biology Letters*, **3**: 20–22.
21. Dufrêne, M., Legendre, P., 1997, Species assemblages and indicator species: The need for a flexible asymmetrical approach, *Ecological Monographs*, **67**: 345–366.
22. Eysenrode, D.S.V., Kockelbergh, F., Bogaert, J., Impens, I., Hecke, P.V., 2002, Canopy gap edge determination and the importance of gap edges for plant diversity, *Web Ecology*, **3**: 1–5.
23. Frink, J.P., 2010, *Pajiştile de pe valea Arieşului între Turda şi Lupşa: Structură, ecologie, folosinţă durabilă*, Ed. Presa Universitară Clujeană, Cluj-Napoca.
24. Gafta, D., 2002, Influenţa antropo-zoogenă asupra pădurilor periurbane, In: Cristea, V., Baciu, C., Gafta, D. (*eds.*), *Municipiul Cluj-Napoca şi zona periurbană. Studii ambientale*, Accent, Cluj-Napoca: 241–274.
25. Gergely, I., 1964, *Flora şi vegetaţia regiunii cuprinse între Mureş şi masivul Bedeleu*, Teză de doctorat, Universitatea din Bucureşti.
26. Gergely, I., 1962, Contribuţii la studiul fitocenologic al pădurilor din partea nordică a Munţilor Trascăului, *Contribuţii Botanice*: 263–298.
27. Guilhaumon, G., 2010, mmSAR: An R-package for multimodel species-area relationship inference, *Ecography*, **33**: 420–424.
28. Hodişan, I., 1965, Pădurile de fag de pe Valea Feneşului, *Contribuţii Botanice*: 189–196.
29. Jost, L., 2007, Partitioning diversity into independent alpha and beta components, *Ecology*, **88**: 2427–2439.
30. Jurasinski, G., Retzer, V., Beierkuhnlein, C., 2009, Inventory, differentiation, and proportional diversity: a consistent terminology for quantifying species diversity, *Oecologia*, **159**: 15–26.
31. Koleff, P., Gaston, K.J., Lennon, J.J., 2003, Measuring beta diversity for presence-absence data, *Journal of Animal Ecology*, **72**: 367–382.
32. Ladislav, M., 1997, Classification of vegetation: Past, present and future, *Journal of Vegetation Science*, **8**: 751–760.
33. Lomolino, M.V., 2000, Ecology's most general, yet protean pattern: The species-area relationship, *Journal of Biogeography*, **27**: 17–26.
34. Măhăra, G., Popescu-Argeşel, I., 1993, *Munţii Trascău. Ghid turistic*, Ed. Imprimeriei Universităţii de Vest, Oradea.
35. Nekola, J.C., White, P.S., 1999, The distance decay of similarity in biogeography and ecology, *Journal of Biogeography*, **26**: 867–878.
36. Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Wagner, H., 2011, *Vegan. Community Ecology Package*, http://cran.r-project.org/web/packages/vegan/index.html.
37. Popescu-Argeşel, A., 1977, *Studiu morfologic, Munţii Trascău*, Ed. Acad., Bucureşti.
38. Purvis, A., Hector, A., 2000, Getting the measure of biodiversity, *Nature*, **405**: 212–219.
39. Sanda, V., 2002, *Vademecum ceno-structural privind covorul vegetal din România*, Ed. Vergiliu, Bucureşti.
40. Schnitzer, S.A., Carson, W.P., 2001, Treefall gaps and the maintenance of species diversity in a tropical forest, *Ecology*, **82**: 913–919.
41. Sfenthouraki, S., Panitsa, M. (*in press*), From plots to islands: Species diversity at different scales, *Journal of Biogeography*.
42. Şuteu, Ş., 1970, *Flora şi vegetaţia bazinului superior al Văii Râmeţului*, Teză de doctorat, Universitatea Babeş-Bolyai, Cluj-Napoca.

43. Tichý, L., Chytrý, M., Hájek, M., Talbot, S.S., Botta-Dukát, Z., 2010, Optimclass: Using species-to-cluster fidelity to determine the optimal partition in classification of ecological communities, *Journal of Vegetation Science*, **21**: 287–299.
44. Triantis, K.A., Guilhaumon, G. et Whittaker, R.J., 2012, The island species-area relationship: Biology and statistics, *Journal of Biogeography*, **39**: 215–231.
45. Tuomisto, H., 2010, A diversity of beta diversities: straightening up a concept gone awry. Part 1. Defining beta diversity as a function of alpha and gamma diversity, *Ecography*, **33**: 2–22.
46. Turtureanu, P.D., Dengler, J., 2012, Different aspects of plant diversity show contrasting patterns in carpathian forest gaps, *Plant Ecology*, **213**: 67–76.
47. Turtureanu, P.D., Coldea, G., Cristea, V., 2011, Classification of broad-leaved forests of the Trascău Mountains (Carpathians, Romania) through optimal classification, *Contribuții Botanice*, **XLVI**: 33–41.
48. Veech, J.A., Crist, T.O., 2010, Diversity partitioning without statistical independence of alpha and beta, *Ecology*, **91**: 1964–1969.
49. Veech, J.A., Summerville, K.S., Crist, T.O., Gering, J.C., 2002, The additive partitioning of species diversity: Recent revival of an old idea, *Oikos*, **99**: 3–9.
50. Whittaker, R.H., 1956, Vegetation of the Great Smoky Mountains, *Ecological Monographs*, **26**: 1–80.