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80 YEARS OF RADOSLAV RIZOVSKI'S BIRTH

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PREFACE

Dear Colleagues and Readers,

It is a great pleasure to announce the online publication of the 46th volume of Forest Review.

As we mentioned in our past 46th volume, this 2015 is a special year because we celebrate one great jubilee: 80 years of Prof. Dr. Radoslav Rizovski's birth (1935-2015).

We are especially interested in your submitted articles concerning vegetation, flora and dendrology, particularly because these scientific disciplines were one of the favourable and most investigated fields of Prof. Dr. Rizovski's professional life (1935-2008). You make us proud for your interest to participate, and we are sincerely grateful for the respect you have shown. Thank you!

So far, we had an excellent collaboration, with the faculties of forestry from the Balkan and South-Eastern European countries. Next year we plan to double the efforts and start to publish both online and in hardcopy two issues per year. We really hope that you will continue with your hard work and our Review will find again a place for your research articles.

Special thanks to all authors and members of the Forest Review, as well as to all peer – reviewers for the participation in this dedicated volume.

On behalf of the Editorial Board,

Asst. Prof. Bojan Simovski PhD, Editor-in-Chief

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Eighty years of Prof. Dr. Radoslav Rizovski's birth (1935-2015)...

... Many years memories of his scientific research and academic teaching

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THE LIFE AND WORK OF PROF. DR. RADOSLAV RIZOVSKI (16.IX 1935 – 20.VII 2008) 80 YEARS SINCE THE BIRTH OF AND OVER 40 YEARS OF EDUCATIONAL AND SCIENTIFIC ACTIVITY

MANDžUKOVSKI D.
Public enterprise Makedonski šumi, Skopje, Macedonia
Corresponding author e-mail address: d_mandzukovski@yahoo.com

ABSTRACT: Professor Radoslav Rizovski is one of the remarkable figures who made a mark in vegetation science in Macedonia. As a tireless researcher, he created invaluable tuition that will represent basis for future generations to learn from it but also to upgrade it. He has been active in nature conservation on the ground of the former Yugoslavia, especially in Macedonia. He has published 50 scientific papers, several working papers relating to vegetation mapping of part of Macedonia, and several monographs. This year marks 80 years since his birth and 40 years of teaching and research, and for that purpose this paper is dedicated to.
Keywords: Radoslav Rizovski, vegetation science, nature protection.

1 PROFESSIONAL PORTRAIT OF PROF. DR. RADOSLAV RIZOVSKI

Professor Radoslav Rizovski was born on 16.IX 1935, in the village Rozden in Mariovo, part of a broader area of Municipality of Kavadarci. His father's roots are from Kavadarci, and from the mother’s side, from Veles. His father finished studies in theology in Bitola and as highly valued man; he was a priest in three villages.

On his mother’s side there were also scholars, among them teachers and clergymen.

At a young age (seven years old), he is left without a parent. After the death of his father, Rizovski with his closest family moves to Skopje, where he forms his primary and secondary education.

Persuaded by the forestry engineer Strashimir Lazarov (his first cousin), he enrolled at the Agricultural - Forestry Faculty in Skopje, on the Department of Forestry, where he undergraduated in 1958, and graduated in 1959.

Figure 1: Radoslav Rizovski (Rožden, 16.IX 1935 - 20.VII 2008, Bitola)

During this period and after graduation, he worked at the Institute for Forest Management - Skopje, where participates in the execution of the field works for the current year at Tuinska forest - Kicevo and field work at the Shar mountain until late autumn, where he was witnessing a difficult situation of major snow drifts at the end of field work, and complex withdrawal from the mountain.

For this short stay, the young, industrious engineer Rade, as the older colleagues from the Institute of Forest Management, proudly and respectfully called him. A short time period, Prof. Rizovski works at Forest management officec Karadzica in Skopje.

His postgraduate studies continued at the Faculty of Forestry in Zagreb, Republic of Croatia, which were realized under inter-Republic cooperation in the former Yugoslavia, for additional education of the young staff of the newly established Faculties of Forestry.

For this occasion, he stays in Zagreb for about 4 years, and under the leadership of Professor Milan Anic, prepares his master's thesis. His Master thesis was in 1969, on the topic titled: *Cenoze hrasta kitnjaka s običnim grabom i hrasta kitnjaka u Centralnoj Makedoniji i Centralnoj Hrvatskoj*- in English *“Communities of sessile oak with hornbeam and sessile oak in Central Macedonia and Central Croatia”*.

The Doctoral dissertation entitled: *Шумите на дабот плоскач (Quercus farnetto* Ten*) во јужните краишта на СР Македонија*- in English *“The forests of Hungarian oak (Quercus farnetto* Ten*) in the southern parts of the SR of Macedonia”,* he successfully defended 1973 in Skopje before the commission consisting of: Em, H., Fukarek, P. and Dzekov, S.

Professor Rizovski was a recognized expert in the field of floristry and phytocoenology in our state and abroad, in the broader area of the Balkan Peninsula. Published about fifty scientific and professional papers in the field of which he worked, from which several are international.

He participated in scientific committees of international congresses, editorials of scientific - professional journals and reviews of high school and university textbooks. He was also a member of Committees for several doctoral and master thesis papers of candidates, who are now leading experts in the field of phytocoenology on the territory of the former Yugoslavia.

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Figure 2: Prof. Dr. Radoslav Rizovski with part of his family

2 EDUCATIONAL ACTIVITIES

During his studies, because of his interest in common names of plants and general plant affinity he was spotted by Professor Hans Em.

After the work at the Institute for Forest Manaagement and forest economy office Karadzica, he is drafted for military service.

During his military service period, the Forestry department of then Agricultural-Forestry Faculty in Skopje opens admission for an assistant in the Department of Sylviculture on the subject of Phytocoenology. In his absence, the request for admission and other documentation, according to Professor Rizovski, was filled out and personally applied by Professor Em.

From 13.X 1961, becomes assistant of the course Phytocoenology. After his doctorate in 1973, becomes an assistant professor. From 1978, he is associate professor of the course Ecology and typology of the forests and pastures, pretty later from Phytocoenology, while for full professor was elected in 1983.

For the purposes of education in the subjects which he held on the Faculty of Forestry in Skopje, regularly visited with his students, several mountain ranges, among them focus was given to the western part of Macedonia, with emphasis on the Shar and Bistra mountains, because of the rich diversity that these mountains have.

Part of the field activities were undertaken in Katlanovo near Skopje, due to an introduction of the sub Mediterranean vegetation. These were his basic field - teaching facilities, and occasionally field trips were made to Golak - Delcevo, Jakupica and other parts of Macedonia.

Besides the courses of Phytocoenology, Professor Rizovski short period lectured Petrographics, and from the early nineties of the last century to retirement, held lectures on the course Parks with protection of the environment.

His approach towards students was genuine and uncommon. His lectures were good representation of his background knowledge from multiple fields of natural sciences, filled with evoking memories of former field works, of course, associated with the current theme that he lectured. As such, the lectures remain in the memories of a large number of students.

He was always accessible for consultation or for a general chat.

3 SCIENTIFIC RESEARCH ACTIVITY

The main area of science research for Professor Rizovski was the forest vegetation of Republic of Macedonia; however, he gives his contribution in research of the pastures, as well as the typology of the forests.

With the research made in the doctoral dissertation, Professor Rizovski determined that in the southern edges of Macedonia, on the move of from Demir Kapija canyon to the south, which is known as Dolno Povardarie, are developing two forest communities of Hungarian oak (*Q. farneto*), but without the presence of Turkey oak (*Q. cerris*): *Carici cuspidatae-Quercetum farneto* Rizovski and *Carpino orientalis - Quercetum farneto* Rizovski.

An important moment of his career is the research of the wild fruit dendroflora, where in cooperation with several authors worked on the genera such as: *Rubus*, *Cornus*, *Vitis*, *Prunus*, *Corylus* etc.

Important is the contribution of Professor Rizovski in the typology of the forests. From the example of the typological schools from the former Yugoslavia and Austria in 1978, built a concept that is most suited to the natural conditions in our country and the level of exploration of the vegetation. For this purpose, he made several researches and mapping of the parts of the mountains Platchkovitza and Kozuf at the site called Duditza, gathering satisfactory results.

Professor Rizovski in middle of the seventies of the last century to the beginnings of the eighties (1981) with Lj. Micevski, works on the phytosociological and ecological regionalization and typization of bare lands in order to define and classify the sites within the limits of previously established areas for afforestation. Parts of these results are published at a later date (1990).

During this period, he publishes two new communities for science. The first, on the beech (*F. moesiaca*) and small-leafed lime (*T. cordata*) and the second is community of Hop Hornbeam (*O. carpinifolia*) that develops on silicate substrate at the gorges in Macedonia.

How big was the love of the professor Rizovski towards floristic and vegetation conveys the information that he with his own personal funding purchased professional literature, herbarium materials and equipment for the research of vegetation.

An important period from the scientific work of Professor Rizovski is his work in the project called "Vegetation map of Yugoslavia, in the region of the Republic of Macedonia". This project was undertaken on the initiative of Forestry Institute from Zagreb - the Republic of Croatia, upon the before held international symposium in Stolzenau 1959, for the preparation of vegetation map of Europe. The same project on the territory of the former Yugoslavia started to be realized in 1963.

In the period of 1963 - 1987, Professor Rizovski was included as associate in the teams for mapping the vegetation of Macedonia in favor of preparing the vegetation map of Yugoslavia in scale 1: 200 000 while in the period from 1989 to 1991, he was leader of the project for the Republic of Macedonia.

Figure 3: Field trip with students in second year of studies at the Faculty of Forestry in the early 90's, site Kozarica - Shar Mountain (Prof. Dr. Radoslav Rizovski first from left)

The team was made up of well-known phytocoenologists in Macedonia on the front with Em and his associates: Dzekov, Nikolovski, Rizovski, Andonoski, later they are joined by Matveyeva, Lj. Micevski, Mirčevski, Batkoski, Gudeski, Dimovski, Manevski and others. From this study, Prof. Rizovski in cooperation with Professor Em in 1974, draft a *Prodromus of plant communities of SR Macedonia* (manuscript).

In 1985, Professor Rizovski participates at the colloquium held in Bribir-Ilok, which actually was a gathering of eminent phytocoenologists from the former Yugoslavia organized as Scientific Council of the Vegetation map of Yugoslavia, in order to settle the some problems in Phytocoenolgy, and progress the making of the vegetation map of Yugoslavia.

From this gathering comes out *Prodromus phytocoenosum Jugoslaviae ad mappam vegetationis m 1: 200 000*, which with certain adjustments for the newly described communities is still used today.

In accordance with the determined objective of the project "Vegetation map of Yugoslavia" undertaken were obligations to be developed 2 types of the map:

- Map of the natural potential climatic vegetation zones with scale of R 1: 500 000, which for the territory of the Republic of Macedonia was created by Professor Rizovski, and the same was been printed as appendix in the book "Climate vegetation soil zones (regions) in the Republic of Macedonia", published by the Macedonian Academy of Sciences and Arts, 1996
- Map of recent (real) vegetation in the measurement scale of 1: 200 000

The Project "Vegetation Map of Macedonia" continues to early nineties of the last century but it is still not finished.

Although this project remains unfinished, under the guidelines of Professor Em, Professor Rizovski and Professor Dzekov have been working on the refugium vegetation of Macedonia. From this project arised several described communities, as that of the Macedonian oak (*Q.macedonica*), the narrow-leafed ash (*F. angustifolia*) and several communities from the gorges of the major rivers.

Professor Rizovski due to prolonged sickness passed away on July 20th 2008.

Figure 4: Prof. Dr. Radoslav Rizovski on a field research

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Figure 5: Prof. Dr. Radoslav Rizovski as a member of PhD thesis defence commission (Photo: J. Vukelić)

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A PHYTOCOENOLOGICAL STUDY OF FORESTS OF HUNGARIAN OAK AND TURKEY OAK (*QUERCETUM FRAINETTO-CERRIDIS* /RUDSKI 1949/ TRINAJSTIĆ ET AL. 1996) ON THE NORTHWEST BORDER OF ARRIVAL (NATURE PARK PAPUK, CROATIA)

[1]BARIČEVIĆ D., [1]VUKELIĆ J., [2]PUAČA M., [1]ŠAPIĆ I.
[1]*University of Zagreb, Faculty of Forestry, Zagreb, Croatia*
[2]*Hrvatske šume, limited liability company, Zagreb, Croatia*
Corresponding author e-mail address: dario.baricevic@zg.htnet.hr

ABSTRACT: The paper presents phytocoenological research of forests of Hungarian and Turkey oak in the locality of Otmanov Vis within Papuk Nature Park. These specific and very interesting areas has not so far been included in research of a broader distribution range of the community of Hungarian and Turkey oak and represents a unique feature because of very rare soil type (eutric ranker on trachyandesite). Phytocoenological sampling based on the principles of the Zürich-Montpellier School was performed on five plots. Our own relevés were compared with those from a broader Kutjevo area, Bosnia and Herzegovina and northwestern Serbia. Statistical analysis was accomplished using Syn-tax 2000 software. According to the results, the studied stands belong to the association *Quercetum frainetto-cerridis* (Rudski 1949) Trinajstić et al. 1996, or more precisely to its subassociation *ruscetosum* Jovanović et Dunjić 1951. Syntaxonomically, they belong to the alliance *Quercion frainetto*, order *Quercetalia pubescentis*, and class *Querco-Fagetea*. In addition to the characteristic species of the association, the subassociation in the study area is well defined by the following differential species of the subassociation: *Cornus mas, Helleborus odorus, Melica uniflora, Teucrium chamaedrys, Ruscus aculeatus, Physospermum cornubiense* and *Campanula persicifolia*. In terms of synecology, it is characterized by its occurrence in the colline belt, at elevations from 260 to 400 m and inclinations from 5 - 40°. As Otmanov Vis is the only area in Croatia where this subassociation is occurs this work also presents the first description of this subassociation in Croatia. The site should be placed under special protection due to exceptional biological diversity and beauty of the landscape.
Keywords: phytocoenological study, *Quercetum frainetto-cerridis*, Croatia, *ruscetosum*, first description.

1 INTRODUCTION

The forest of Hungarian oak and Turkey oak (*Quercetum frainetto-cerridis* Rudski /1949/ Trinajstić et al. 1996) is a climatogenic phytocoenosis occurring over a large part of the Balkan Peninsula. In Croatia, it has been studied in more detail by Trinajstić et al. [23] in the Slavonian uplands, which also form the north-western boundary of its occurrence. Otherwise, the Hungarian oak is a rare forest species in Croatia. It is distributed in Slavonia and in several places in Dalmatia, but it covers more extensive areas only on the southern slopes of Mt. Krndija. It appears in smaller enclaves surrounded by stands of sessile oak and common hornbeam, where it forms stable stands of high commercial and scientific value. Trinajstić et al. [23] define it as a mesophilic subassociation *carpinetosum betuli*, whereas the conclusion of the latest research [19] urges for a clear definition of plant community in the locality of Otmanov Vis, since it was observed that floristically, it differs fundamentally from the neighbouring, mesophilic subassociation studied by Trinajstić et al. [23]. This was corroborated by Vukelić [24] in his general description of the forest of Hungarian and Turkey oaks in Croatia.

The forest stands in the locality of Otmanov Vis, covering an area of 24.76 ha, occur under specific synecological conditions and differ significantly from the neighbouring stands in terms of flora and management. The specific synecological conditions have also enabled the growth of a large number of rare and protected species, making them a valuable object of research. In general, stands of Hungarian and Turkey oaks in the area of the Slavonian uplands cover 894 ha. It is interesting that Hungarian oak in this area was first recorded by the botanist P. Kitaibel as far back as 1808, which was also the first record of this species on the Balkan Peninsula [4]. Hungarian oak stands in the Slavonian uplands were also discussed by Fukarek [4, 5], Fukarek et al. [7], Cestar et al. [3], and Zelić [26, 27].

All the above prompted us to carry out a phytocoenological study of these stands in the subject area, make a detailed analysis of the floristic composition, compare the new relevés with those from a few previously published studies, and thus provide their clear definition, nomination and description. This paper aims to present the undertaken studies.

2 RESEARCH AREA

The research area encompasses the locality of Otmanov Vis (45.43° N, 17.95° E) on the southern slopes of Mt Krndija within Papuk Nature Park (Fig. 1). Mt Krndija, together with Psunj and Papuk in the west, and Požeška Gora and Dilj in the south, builds a mountain chain that surrounds the Požega Valley and forms the mountains of Slavonia. The mentioned mountains are isle mountains that stretch between the Podravina and Posavina lowlands in the south-western boundary part of the Pannonian Plain.

The research area is characterized by hilly-colline features. Diverse microrelief, microclimatic, geological and edaphic conditions alternate over a relatively small area. Elevations range between 260 and 400 m a.s.l.

The basic hills of Krndija are made up of diverse metamorphic rocks from the Paleozoic era, which are transgressively followed by the lower Miocene marine sediments with the effusion of trachyandesite, while Quaternary sediments are developed in the lower parts of the terrain. Igneous rocks are covered with Quaternary layers of loess that erodes gradually [22].

According to research Puača et al [19], eutric ranker on trachyandesite is developed on the complex and multilayered lithological bedrock as the dominant soil type. The multi-component composition of pedocartographic units includes eutric ranker, regolithic and browned, eutric brown soil and eutric colluvium

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(70:15:15). Pedological data analysis shows that this soil has very high humus content (according to Gračanin) of weak acidic reaction. The soil is very rich in nitrogen and potassium and rich in physiologically active phosphorus. In terms of mechanical composition, the analyzed soil is texturally marked as clayey loam. The limiting factors of soil productivity are its small depth and skeletal nature, which are conditioned by the properties of lithological bedrock, terrain inclination and constant erosion.

Figure 1: View at the site Otmanov Vis - spring aspect

According to the data for Požega meteorological station, the mean annual air temperature is about 11 ºC, and the mean annual precipitation is between 750 and 800 mm. In the Köppen classification, the climate type is Cfwb“x”. According to the Thornthwaite's classification system, the study area extends in the area of humid climate.

3 MATERIAL AND RESEARCH METHODS

Phytocoenological research into the community of Hungarian oak in the study area was performed in two stages. The first stage consisted of collecting phytocoenological relevés. Vegetation in the plots was sampled according to the principles of the Zürich-Montpellier Phytocoenological School [2]. Five phytocoenological plots were established in the locality of Otmanov Vis. Phytocoenological relevés were combined with the collection of individual synecological data in the field, such as the elevation, exposition, inclination and coordinate position of each relevé using a GPS device (Garmin Montana 650). The size of the relevés (plots) was 20m x 20m.

The second stage consisted of processing the data acquired in the field. The relevés were entered into the Turboveg database [10] together with 9 relevés from a wider surroundings of Kutjevo [23], 10 relevés from Bosnia and Herzegovina - including 3 relevés from the area of Croatia [7], and 10 relevés from north-western Serbia [13]. Statistical processing was performed using Syn-tax 2000 software [18]. Two methods of numerical analysis were applied: cluster analysis (Single linkage, Complete linkage, Average linkage method and Increment sum of squares method) and multidimensional scaling (Principal coordinates analysis). The Similarity ratio was used for both methods.

The species in the phytocoenological table were classified according to the social affiliation of the species [24], while plant nomenclature was adjusted according to the Flora Croatica database [17].

4 RESEARCH RESULTS AND DISCUSSION

The results of classical analysis of 34 phytocoenological relevés and the applied cluster methods (Fig. 2) and the analysis obtained by multidimensional scaling (Fig. 3) showed that the relevés were placed in four groups. Our phytocoenological relevés were grouped into a separate set. In order to clearly define the differences and similarities between individual sets of relevés, the floral composition was analyzed and compared in detail. The results of these analyses clearly show that the relevés in the study area of Otmanov Vis systematically belong to the association *Quercetum frainetto-cerridis* (Rudski 1949) Trinajstić et al. 1996 (Table 1).

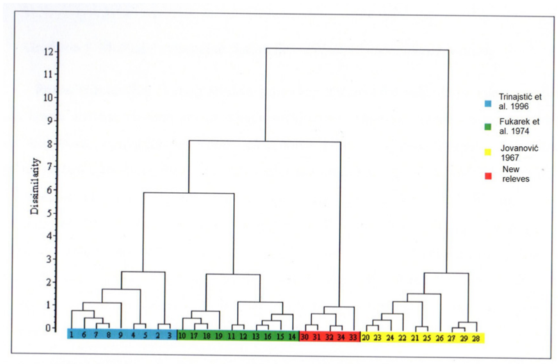

Figure 2: Dendrogram produced by cluster analysis – *Incremental sum of squares*

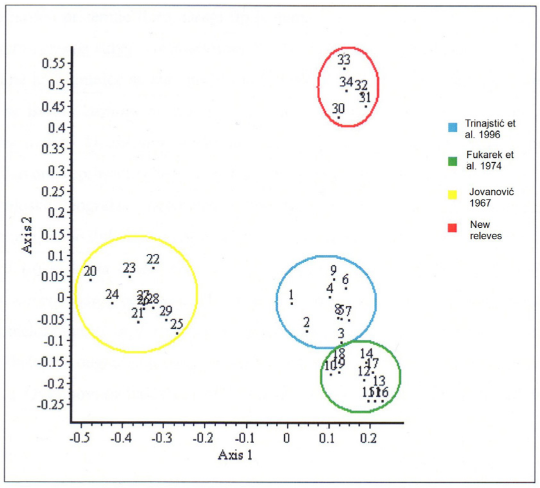

Figure 3: Multidimensional scaling - *Principal coordinates analysis*

Syntaxonomic affiliation to the association *Quercetum frainetto-cerridis* was confirmed by the species recorded there, including *Quercus frainetto, Quercus cerris, Pyrus pyraster, Carpinus betulus, Acer campestre, Fraxinus ornus, Crataegus monogyna, Ligustrum vulgare, Potentilla micrantha, Glechoma hirsuta, Brachypodium sylvaticum, Hieracium sabaudum, Carex flacca, Moehringia trinervia* and others, which are characteristic for this association (Table I). Furthermore, differences in the floristic composition suggest that the association should be affiliated to a lower syntaxonomic unit. To define lower systematic units, we should refer to the already defined subassociations which would possibly correspond to the studied stands. Thus, the association *Quercetum frainetto-ceridis* is divided into several different types that are described as different subassociations. This is the result of diverse variations in the synecological conditions of this association, as already discussed by Glišić [8]. The basic type is the typical forest of Hungarian oak and Turkey oak (*Quercetum frainetto-cerridis* subas. *typicum*). In terms of soil humidity and acidity it is almost identical to the forest of sessile oak and common hornbeam. It is characterized by the relatively rich, luscious and diverse herb layer The second type is the forest of Hungarian oak and Turkey oak with common hornbeam (*Quercetum frainetto-cerridis* subas. *carpinetosum betuli*). The first was described by Rudski [20], and it encompasses areas that border with the forest of sessile oak and common hornbeam. Their principal differential species are *Carpinus betulus* and some other species of the alliance *Fagion,* then *Acer campestre, Prunus avium, Moehringia trinervia* and others. The third type is the forest of Hungarian oak and Turkey oak with butcher's broom (*Quercetum frainetto-cerridis* subas. *ruscetosum*) which was described by Jovanović et Dunjić [11]. Ecologically and geographically, it is a separate phytocoenosis that occurs in the southern part of the Pannonian Plane and grows in thermophilic habitats [25]. Its principal differental species is butcher's broom (*Ruscus aculeatus*). The fourth type is the forest of Hungarian oak and Turkey oak with oriental hornbeam (*Quercetum frainetto-cerridis* subas. *carpinetosum orientale*). This is a phytocoenosis with xerophilic species with oriental hornbeam (*Carpinus orientalis*) featuring as the main discriminating species. It should be pointed out that owing to frequent degradation of these forests, their floral composition undergoes changes. The degraded stages include the subassociations *Quercetum frainetto-cerridis* subas. *nudum* and subas. *hieracietosum* [13]. Apart from these subassociations, the Habitat Handbook of Serbia [1] also lists the subassociations *comandretosum* B. Jovanović 1968, *fagetosum* E. Vukićević 1959, *juglandetosum* E. Vukićević 1974, *paeonietosum* M. Janković et Nikolić 1967, *physospermetosum* Rudski 1940, *pubescentosum* Jovanović, *petraeae* Z. Tomić 1989, *roboris* B. Jovanović et Z. Tomić 1978, *virgilianae* B. Jovanović et Vukičević 1977, and *scardicum* Krasniqi (1968) 1972 in Kosovo. In Macedonia, such forests are among the other described in Galičica National Park under the name of *Quercetum frainetto-cerris* Horvat 1954 [14] or *Quercetum frainetto-cerris macedonicum* Oberdorfer 1948 emend Horvat 1959 [15, 16]. Examples of geographic adjectives in the names of the subassociations are found in some other authors, e.g. *thracicum* = *bulgaricum* [9], *moesiacum* = *serbicum* [12]. In the latest analysis of the forest of Hungarian oak and Turkey oak in Bosnia and Herzegovina are described as *Quercetum frainetto-cerridis* (Rudski 1949) Trinajstić et al. 1996 because Trinajstić et al. [23] corrected its original illegitimate name "*Quercetum confertae-cerris serbicum*" [21]. They also conclude that in the southern B&H described association *Quercetum frainetto hercegovinum* [6] could not be separate from other *Quercetum frainetto-cerridis* forests.

The floristic composition of Hungarian oak-Turkey oak forests in the proximity of the study area (the surroundings of Kutjevo) was described and investigated by Trinajstić et al. [23]. These stands are discriminated from the typically composed stands of the association from the centre of its range in Serbia by the absence of the species *Tilia tomentosa*, *Sorbus domestica*, *Rosa gallica*, *Danna cornubiensis*, *Lychnis coronaria*, *Silene viridiflora*, *Tanacetum corymbosum*, *Trifolium alpestre* and many others. Based on the analysis, they affiliate these stands to the subassociation *carpinetosum betuli*.

However, the association described by Trinajstić et al. [23] also differs fundamentally from the studied stands in the locality of Otmanov Vis in terms of its floral composition and habitat conditions. The analysis of the floristic composition in the study area clearly shows independence at the level of subassociation (Table I). Because of the specific habitat conditions in the study area, there are species that are absent from the previously described subassociation, such as *Tilia tomentosa, Danna cornubiensis, Tanacetum corymbosum, Euphorbia cyparissias, Melica uniflora, Helleborus odorus, Dryopteris filix-mas, Physospermum cornubiense, Teucrium chamaedrys, Asplenium adiantum-nigrum, Calamintha nepeta, Poa nemoralis, Dictamnus albus, Spiraea chamaedryfolia, Ruscus aculeatus* and others. In terms of floral composition and the presence of characteristic and differential species, the community in the study area best corresponds to the forest of Hungarian oak and Turkey oak with butcher's broom *Quercetum frainetto-cerridis* subassociation *ruscetosum,* which was described in the work by Jovanović et Dunjić [11]. According to this description, the subassociation is developed over flat and mildly sloping terrains, of weak acid soil reaction. There is occurrence of thermophilic, Mediterranean floral elements, which were preserved during the ice age owing to the warm climate on the shores of the former Pannonian Sea. The described community contains species which were found in the study area, thus determining its affiliation to the subassociation of the forest of Hungarian oak with Turkey oak and butcher's broom. Differential species of this subassociation include *Cornus mas, Helleborus odorus, Melica uniflora, Teucrium chamaedrys, Ruscus aculeatus, Physospermum cornubiense* and *Campanula persicifolia*.

The study locality is specifically characterized by a very high abundance of the species *Digitalis grandiflora, Carex divulsa, Alliaria petiolata, Fallopia convolvulus, Dictamnus albus* and *Spiraea chamaedryfolia,* which will be the subject of further vegetation and floristic research. Of additional interest are the beautiful seasonal aspects that begin with the awakening of the vegetation in early March, as well as the dominance of hellebore (*Helleborus odorus*), dogwood (*Cornus mas*) and spring flowers. April is characterized by the dominance of the facies *Alliaria officinalis*. The end of April is marked by the abundant appearance of leopard's bane (*Doronicum columnae*). The beginning of May is characterized by luscious ground vegetation, when the main ridge is covered with nationaly protected species (*Dictamnus albus*)*,* early purple orchid (*Orchis mascula*)*,* martagon lily (*Lilium martagon*) and others. Manna ash (*Fraxinus ornus*)*,* germander meadowsweet (*Spiraea chamaedryfolia*) and dog rose (*Rosa canina*) are in full bloom. Large yellow foxglove (*Digitalis grandiflora*) appears in abundance at the beginning of June.

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Table I: Comparison of the relevés from the study area with the relevés of other types of forests of Hungarian oak and Turkey oak

Nr. of releve		30	31	32	33	34	Presence degree	Presence degree	Presence degree	Presence degree
Date (year/month)		2014/6	2014/6	2014/6	2014/6	2014/6				
Coordinate x		6496766	6496759	6496487	6496407	6496234				
Coordinate y		5031094	5031061	5031006	5031022	5030898				
Releve area (m²)		400	400	400	400	400				
Elevation (m)		375	395	380	375	340				
Exposition (degrees)		0	0	300	0	180				
Inclination (degrees)		35	0	25	40	10				
Cover layer of trees (%)		70	50	90	60	70				
Cover layer of shrubs (%)		40	20	5	15	10				
Cover layer of ground vegetation (%)		60	80	30	60	70				
Source							New releves	Trinajstić	Fukarek	Jovanović
							Otmanov Vis	et al. 1996	et al. 1974	1967
Floral composition:										
Characteristic species of association:										
Quercus frainetto	A	4	1	3	1	3	V	V	V	V
Fraxinus ornus		2	2	2	4	3	V	I		III
Quercus cerris		+	3	.	.	1	III	III	V	V
Tilia tomentosa		.	.	3	.	.	I		III	
Ligustrum vulgare	B	.	+	+	.	+	III	V	V	II
Fraxinus ornus		.	.	.	1	1	III	IV	V	III
Acer campestre		+	+	.	.	.	II	V	V	II
Crataegus monogyna		.	+	.	+	.	II	V	V	III
Rosa arvensis		.	.	.	+	+	II	III	IV	
Quercus frainetto		.	.	.	.	+	I	IV		V
Chamaecytisus supinus		.	.	.	.	.		IV		
Quercus cerris		.	.	.	.	.		I		V
Potentilla micrantha	C	1	1	1	1	+	V	V	V	IV
Hypericum perforatum		+	+	+	+	+	V	II		IV
Brachypodium sylvaticum		1	1	1	.	+	IV	III		II
Calamintha nepeta agg.		1	2	1	.	1	IV			II
Fraxinus ornus		+	.	.	.	.	I	II		IV
Quercus frainetto		1	.	.	.	.	I	III	IV	V
Veronica chamaedrys		+	.	.	.	.	I	V		IV
Clinopodium vulgare		.	+	.	.	.	I		V	II
Rosa arvensis		.	+	.	.	.	I			
Trifolium medium		.	.	.	.	+	I	II		
Tilia tomentosa		.	.	.	.	.		I		II
Quercus cerris		.	.	.	.	.		I	III	IV
Differential species of subassociation *carpinetosum betuli* :										
Prunus avium	A	+	.	.	.	.	I	I	III	
Carpinus betulus		.	.	.	.	.		III		
Acer campestre		.	.	.	.	.		III		
Carpinus betulus	B	.	+	.	.	.	I	V	V	V
Prunus avium		.	.	.	.	.		III		
Moehringia trinervia	C	+	.	+	.	.	II	III	I	
Helleborus croaticus		.	.	.	.	.		V		
Prunus avium		.	.	.	.	.		III		II
Carpinus betulus		.	.	.	.	.		II	III	II
Acer campestre		.	.	.	.	.				II
Differential species of subassociation *ruscetosum* :										
Cornus mas	B	3	2	.	1	+	IV	II	I	
Ruscus aculeatus		+	.	.	.	1	II			
Helleborus odorus	C	2	1	2	+	1	V		IV	
Melica uniflora		1	3	1	3	1	V		I	I
Teucrium chamaedrys		.	+	+	+	+	IV		II	
Physospermum cornubiense		+	.	+	.	.	II		III	IV
Campanula persicifolia		+	+	.	.	.	II	I	I	III
Quercetalia pubescentis :										
Sorbus torminalis	B	+	+	.	.	.	II	II	III	I
Acer tataricum		.	.	.	.	.		III	V	II
Sorbus domestica		.	.	.	.	.		II		I
Viola alba	C	+	+	+	.	.	III	III		
Tanacetum corymbosum		+	.	+	+	.	III	I	I	
Lathyrus venetus		+	.	.	.	.	I	II	III	
Tamus communis		.	+	.	.	.	I	I	II	III

continued

continuation of Table I

Lathyrus niger		.	.	.	.	.		I	V	IV
Acer tataricum		.	.	.	.	.		I		III
Convallaria majalis		.	.	.	.	.		I		
Polygonatum odoratum		.	.	.	.	.		I		
Sorbus torminalis		.	.	.	.	.				III
Oenanthe pimpinelloides		.	.	.	.	.		I		
Fagetalia :										
Fagus sylvatica	A	.	.	.	.	.		I		
Fagus sylvatica	B	.	.	.	.	.		III		
Mycelis muralis	C	.	+	+	2	+	IV	III		I
Stellaria holostea		+	+	+	1	.	IV	I	III	
Glechoma hirsuta		+	1	.	.	.	II	V	II	
Lilium martagon		+	.	.	.	.	I	I		
Symphytum tuberosum agg.		.	.	.	.	.		III	I	
Viola reichenbachiana		.	.	.	.	.		III		I
Primula vulgaris		.	.	.	.	.		III	IV	
Carex sylvatica		.	.	.	.	.		III	I	
Pulmonaria officinalis		.	.	.	.	.		III	II	
Galium odoratum		.	.	.	.	.		II		
Polygonatum multiflorum		.	.	.	.	.		I		
Sanicula europaea		.	.	.	.	.		I	I	
Neottia nidus-avis		.	.	.	.	.		I		
Scrophularia nodosa		.	.	.	.	.		I		
Geranium robertianum		.	.	.	.	.		II	I	
Dentaria bulbifera		.	.	.	.	.		I		
Melica nutans		.	.	.	.	.		I		
Calamintha grandiflora		.	.	.	.	.		I		
Epimedium alpinum		.	.	.	.	.		I	II	II
Stachys sylvatica		.	.	.	.	.		I		
Circaea lutetiana		.	.	.	.	.		I		
Asarum europaeum		.	.	.	.	.		I	I	
Salvia glutinosa		.	.	.	.	.		I		
Quercetalia robori-petraeae :										
Castanea sativa	A	.	.	.	.	.				I
Castanea sativa	B	.	.	.	.	.		I		I
Festuca heterophylla	C	2	.	1	1	1	IV	I	III	III
Hieracium sabaudum		+	.	.	.	.	I	III		IV
Veronica officinalis		+	.	.	.	.	I	III	II	V
Luzula forsteri		+	.	.	.	.	I	III	II	III
Melampyrum sylvaticum		.	.	.	.	.		III	III	
Serratula tinctoria		.	.	.	.	.		I	I	
Castanea sativa		.	.	.	.	.				I
Querco-Fagetea :										
Quercus petraea	A	+	.	.	.	.	I	IV	IV	IV
Quercus robur		.	.	.	.	.		I	I	
Pyrus pyraster	B	.	+	.	.	+	II	IV	V	
Quercus petraea		.	.	.	.	.		I		III
Rubus hirtus s.lat.		.	.	.	.	.		I		
Corylus avellana		.	.	.	.	.		I	I	I
Euonymus europaeus		.	.	.	.	.		I	II	
Cruciata glabra	C	.	+	.	.	.	I	III		III
Quercus petraea		.	.	.	.	.		III	III	III
Pyrus pyraster		.	.	.	.	.				III
Corylus avellana		.	.	.	.	.				I
Galium sylvaticum		.	.	.	.	.		III		
Fragaria vesca		.	.	.	.	.		I		II
Cephalanthera longifolia		.	.	.	.	.		I		
Galium schultesii		.	.	.	.	.		I		
Hedera helix		.	.	.	.	.		I		I
Rhamno-Prunetea :										
Cornus sanguinea ssp. hungarica	B	.	.	.	.	.		IV		
Clematis vitalba		.	.	.	.	.		III	III	
Cornus sanguinea		.	.	.	.	.		II	III	
Crataegus nigra		.	.	.	.	.		II		
Prunus spinosa		.	.	.	.	.		II	II	
Euonymus europaeus	C	.	+	.	.	.	I	I		
Prunus spinosa		.	.	.	.	.		I		
Crataegus monogyna		.	.	.	.	.				II

continued

continuation of Table I

Ligustrum vulgare		.	.	.	.	.				II
Other species:										
Genista tinctoria	B	1	.	.	.	.	I	III	IV	
Rubus ulmifolius		.	.	.	.	.		IV		
Juniperus communis		.	.	.	.	.		II		III
Dactylis glomerata	C	2	2	1	.	+	IV	V	V	
Geum urbanum		.	+	.	.	.	I	III		
Carex flacca		.	.	.	.	+	I	III		
Galium lucidum		+	.	.	.	.	I	II		
Vicia species		+	.	.	.	.	I	II		
Silene nutans s.lat.		.	.	.	+	.	I	I		
Vincetoxicum hirundinaria		.	+	.	.	.	I	I		
Ajuga reptans		.	.	.	.	.		V	IV	I
Ranunculus ficaria		.	.	.	.	.		I	I	
Prunella grandiflora		.	.	.	.	.		IV		
Galeopsis pubescens		.	.	.	.	.		III		
Astragalus glycyphyllos		.	.	.	.	.		III	I	
Lysimachia nummularia		.	.	.	.	.		III		
Urtica dioica		.	.	.	.	.		I		
Galium species		.	.	.	.	.		I		
Galium mollugo		.	.	.	.	.		I	IV	I
Symphytum officinale		.	.	.	.	.		I		
Myosotis ramosissima		.	.	.	.	.		I		
Erigeron annuus		.	.	.	.	.		I		
Limodorum abortivum		.	.	.	.	.		I		
Lysimachia nemorum		.	.	.	.	.		I		
Aremonia agrimonoides		.	.	.	.	.		I		
Viola mirabilis		.	.	.	.	.		I		
Lysimachia vulgaris		.	.	.	.	.		I		
Galium aparine		.	.	.	.	.		I		
Hieracium murorum		.	.	.	.	.		I		II
Hieracium species		.	.	.	.	.		I	V	
Origanum vulgare		.	.	.	.	.		I	I	
Juniperus communis		.	.	.	.	.			II	III
Genista tinctoria		.	.	.	.	.				II
Other specific species the study area:										
Spiraea chamaedryfolia	B	.	.	+	1	.	II			
Rubus canescens		.	+	.	.	.	I		III	
Malus sylvestris		+	.	.	.	.	I		I	
Alliaria petiolata	C	3	2	2	3	3	V	I		
Digitalis grandiflora		3	1	+	.	+	IV	I		
Fallopia convolvulus		+	1	+	1	+	V	I		
Dictamnus albus		.	2	1	.	2	III			
Carex divulsa		+	.	.	+	+	III	I		
Euphorbia cyparissias		.	.	+	.	+	II		II	
Dryopteris filix-mas		+	.	.	+	.	II		I	
Asplenium adiantum-nigrum		+	.	.	+	.	II			
Poa nemoralis		1	.	+	.	.	II			
Achillea millefolium		.	+	.	.	.	I		I	
Thymus pulegioides ssp. montanus		.	.	.	+	.	I			II
Rubus canescens		+	.	.	.	.	I			I
Prenanthes purpurea		.	+	.	.	.	I			
Trifolium repens		.	+	.	.	.	I			
Allium species		.	.	.	+	.	I			
Asplenium trichomanes		.	.	.	1	.	I			
Ranunculus bulbosus		.	.	.	+	.	I			
Sedum maximum		.	.	.	+	.	I			
Doronicum columnae		.	.	.	.	+	I			
Veronica montana		.	.	+	.	.	I		II	

Apart from these species are accompanied the following species, with presence degree: Fukarek (*Galium aristatum* V, *Brachypodium pinnatum* V, *Carex pilosa* V, *Prunella vulgaris* IV, *Cytisus nigricans* IV, *Fragaria moschata* III, *Viola hirta* III, *Dorycnium germanicum* II, *Silene italica* II, *Agrimonia eupatoria* II, *Melittis melissophyllum* II, *Peucedanum cervaria* II, *Potentilla erecta* I, *Thymus serpyllum* I, *Aristolochia clematitis* I, *Buglossoides purpurocaerulea* I, *Anemone nemorosa* I, *Euphorbia amygdaloides* I, *Populus tremula* I, *Tilia cordata* I, *Digitalis species* I, *Solidago virgaurea* I, *Stachys species* I, *Ulmus minor* I, *Aposeris foetida* I, *Centaurea species* I, *Chamaecytisus hirsutus* I, *Orlaya species* I, *Galeobdolon luteum* I, *Quercus polycarpa* I, *Conyza canadensis* I, *Erigeron candidus* I, *Myosotis sylvatica* I, *Persicaria maculosa* I, *Plantago media* I, *Solanum dulcamara* I, *Galium verum* I) and Jovanović (*Campanula patula* V, *Hieracium bauhinii* V, *Genista ovata* IV, *Chamaecytisus hirsutus* IV, *Rumex acetosella* IV, *Chamaecytisus austriacus* III, *Pteridium aquilinum* III, *Rubus hirtus* III, *Sedum cepaea* III, *Fagus moesiaca* II, *Luzula campestris* II, *Silene viridiflora* II, *Melampyrum pratense* II, *Polygala vulgaris* I, *Centaurium erythraea* I, *Epilobium lanceolatum* I, *Luzula pilosa* I, *Anthoxanthum odoratum* I, *Festuca drymeia* I, *Hypericum montanum* I, *Carex caryophyllea* I, *Lathyrus vernus* I, *Poa angustifolia* I).

4 CONCLUSIONS

The conducted phytocoenological analysis of the forests of Hungarian oak and Turkey oak in the study area show that the studied stands belong to the association *Quercetum frainetto-cerridis* Rudski (1949) Trinajstić et al. 1996, or more precisely, to its subassociation with butcher's broom *ruscetosum* Jovanović et Dunjić 1951.

Syntaxonomically, this community belongs to the class *Querco-Fagetea* Braun-Blanquet et Vlieger 1937, order *Quercetalia pubescentis* Klika 1933 and alliance *Quercion frainetto* Horvat 1954.

Along with the characteristic species of the association, the subassociation in the study area is well defined by the differential species of the subassociation *ruscetosum*: *Cornus mas, Helleborus odorus, Melica uniflora, Teucrium chamaedrys, Ruscus aculeatus, Physospermum cornubiense* and *Campanula persicifolia*. Synecologically, it characteristically occurs in the colline belt, in the Central European vegetation zone of thermophilic forests. It grows at elevations between 260 and 400 m and inclinations of 5-40° and on the dominantly eutric ranker on a trachyandesite base. The limiting factors of soil productivity are its depth and skeletal nature, which are conditioned by the properties of the bedrock, terrain slope and constant erosion. As a consequence, the stands are of poorer quality and lower commercial value.

As Otmanov Vis is the only area in Croatia in which this subassociation was detected, we provide the first description of this subassociation in Croatia. It should be placed under special protection owing to exceptional biological diversity and beauty of the landscape.

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PLANT BIODIVERSITY OF *SPHAGNUM*-DOMINATED MIRES IN VITOSHA NATURE PARK

[1]DIMITROV M., [2]NATCHEVA R., [2]GANEVA A., [3]GYUROVA D.
[1]*Department of Dendrology, University of Forestry, Sofia, Bulgaria,*
[2]*Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Sofia, Bulgaria,*
[3]*Vitosha Nature Park Directorate, Sofia, Bulgaria*
Corresponding author e-mail address: mariusdimitrov@abv.bg

ABSTRACT: Eighty-four *Sphagnum*-dominated mire complexes on the territory of Vitosha Nature Park were studied. It included spatial inventory as well as full account of plant species and plant community diversity in each mire. The distribution of mires with respect to elevation and exposure was analyzed. We found 121 vascular plant species and 89 bryophytes. This is a substantial biodiversity considering the small total area of this type of habitats in the Park (0.4% of its territory) and their patchiness. We recorded 24 species of conservation importance. The registered phytocoenoses belong to three classes, three orders, five alliances, six plant associations, three subassociations and five plant communities. The major identified threats for Sphagnum-dominated mires were changes in the hydrological regime due to natural drainage and climate change, as well as anthropogenic drainage and water catchment. Other negative impacts are deposition of airborne pollutants, trampling by tourists, wastes, grazing and burning. Our work highlights the role of Vitosha Nature Park for the conservation of *Sphagnum*-dominated mires in Bulgaria and the importance of proper management for their protection.
Keywords: plant biodiversity, phytocoenoses, diagnostic species, bryophytes, conservation, Bulgaria.

1 INTRODUCTION

Sphagnum-dominated mires on Mt Vitosha are among the most representative and in the most intact state in Bulgaria [8]. The characteristic climatic conditions and historical development of the mountain determine the formation of various plant communities that are dominated or participated by *Sphagnum* and/or other peat-forming mosses. These communities harbor a large number of species, many of which are of conservation importance. The specific hydrological regime and their vulnerability to various biotic and abiotic factors highlight a number of problems related to adequate management and conservation of *Sphagnum*-dominated mires on the territory of Vitosha Nature Park.

The first mention of *Sphagnum*-dominated mires in Bulgaria, and on Mt Vitosha in particular, was made by Adamovič [1]. He gave a brief description of vegetation and a short list of typical plant species for this type of habitat. Adamovič divided high-mountain mires into two groups – subalpine and alpine. However, he did not treat the mires on Mt Vitosha in more details.

The first extensive treatment of the bryophyte flora of the mires on Mt Vitosha was made by Podpéra [25]. He listed 62 species. Plant communities were briefly mentioned in relation to their bryophyte flora.

Brief information about the flora and vegetation of some mire complexes was provided by [2, 7, 19, 22, 30, 32, 33, 34, 37]. Ruskov [28] studied the development of spruce forests in the *Sphagnum*-mires with respect to their forestry value. Petrov [23] treated in detail four mire complexes in the spruce forests of the mountain. He presented the first comprehensive study of floristic diversity (including bryophytes), hydrology, origin and development of these mires. Hájek et al. [39] made the recent treatment of the vegetation of Sphagnum-dominated mires in Mt Votisha. The authors studied the syntaxonomic diversity of 53 mires and reported 45 bryophyte and 102 vascular plant species. Information about the floristic diversity of Vitosha mires was provided also by Hájkova et al. [12], Hájkova & Hájek [11], and Hájek et al. [9, 10].

Vitosha mires are young formations [5, 6, 19, 23, 35]. They started to form in late Subboreal and developed intensively during the Subathlantic.

Despite the relatively large list of publications mentioning in various respects *Spahgnum*-dominated mires on Mt Vitosha, there is still missing a complete inventory of this habitat type. The aim of this study was to make a comprehensive inventory of the distribution, vegetation and flora of *Sphagnum*-dominated mires in Vitosha Nature Park, to evaluate their nature conservation state and to draw attention to the most important threats for this extremely vulnerable and important habitat type.

2 MATERIAL AND METHODS

2.1 Study site

Vitosha Nature Park occupies the larger part of Mt Vitosha (Fig. 1). This is the oldest designated national Park in Bulgaria. Mt Vitosha is situated in the south-western part of Bulgaria. The average elevation is 1317 m a.s.l., the highest peak is Cherni vrah (2290 m a.s.l). The average precipitation is ca 1115 mm (841 mm at 1300 m and 1175 mm at 2286 m a.s.l.), the average temperature is ca. 3°C (7°C at 1300 m and 0,3°C at 2286 m a.s.l.). Mt Vitosha is a relatively young dome-shaped mountain containing an older upper Cretaceous crystalline plutonic core, surrounded by volcanic and volcano-sedimentary rocks [36]. Characteristic for the mountain is the presence of large plateau morphostructures that were further modelled by denudation and cryogenic processes. These structures harbor the largest mire complexes in Mt Vitosha and are the major water source of the mountain.

2.2 Spatial inventory

For the initial spatial inventory we used published data as well as the information for the distribution of habitat type 7140 and 91D0 for Mt Vitosha from the project on the Natura 2000 network in Bulgaria “Mapping and assessment of the conservation status of habitats and species. Phase I”. A preliminary map was drawn which was used for the field trips. At each site the geographical coordinates and elevation of a central point were measured via GPS. This data coupled with current

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ortophoto images was used to draw polygons of the studied sites.

2.3 Inventory of plant diversity

At each visited polygon in area with typical mire vegetation was selected a relevé of 25 m^2 for description of plant communities. For communities along springs and brooks the size of relevés was 16 m^2. Additionally, floristic diversity was studied in transects along the entire site and the recorded additional species were assigned an abundancy score of “+”.

The nomenclature of vascular plants follows [4], of mosses [13], and of liverworts [27].

The classification of plant communities was done using the Braun-Blanquet`s approach [3, 38]. The abundance/ dominance of taxa was evaluated using an extended nine-grade Braun-Blanquet scale [14]. Cluster analysis was made using the software Syn-Tax [25]. We applied UPGMA, floristic similarity was calculated using the Penrose index. Some relevé were moved manually considering common diagnostic species. The identified clusters were compared with vegetation descriptions provide by Hájek et al. [9, 39]. If general floristic composition, diagnostic, constant and dominating species coincided, the vegetation clusters were assigned to the respective syntaxa and syntaxonomic categories.

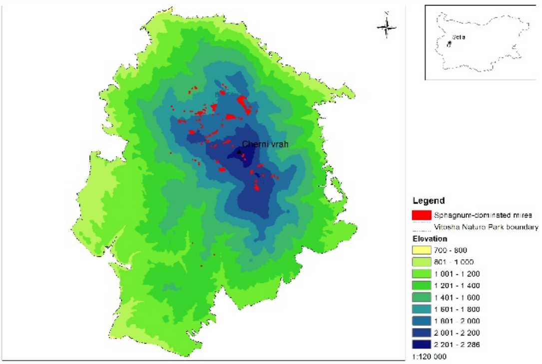

Figure 1: Map of the study area

3 RESULTS

3.1 Distribution of Sphagnum-dominated mires

We studied a total 84 mires on Mt Vitosha (Fig. 1, Annex I). All of them were situated within Vitosha Nature Park. They are distributed in the altitudinal range of 1230-2240 m. The largest number of mires is at 1700-1850 m and above 1900 m a.s.l. with a northern component of exposure (Fig. 2 and Fig. 3). Fewer peatlands are located on the southern slopes due to the prevalence of calcareous bedrock, higher insulation, and lower moisture. These conditions reflect on the vegetation composition and diversity. The total area of all studied mires is 73,3 ha. The average size is 0,9 ha (minimum 0,7 ha, maximum 17,8 ha).

3.2 Plant communities

Plant communities were described at 65 mire polygons. The syntaxonomic analysis revealed that the studied communities belong to three classes, three orders, five alliances, six plant associations, three subassociations and five plant communities (Annex I). Additionally were found plant groups belonging to the rangless category "community“. Two of these groups included five and three relevés, the remaining three were recorded at a single relevé.

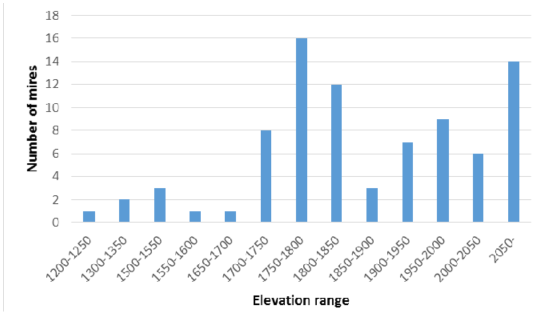

Figure 2: Distribution of Sphagnum-dominated mires in Vitosha Nature Park according to elevation

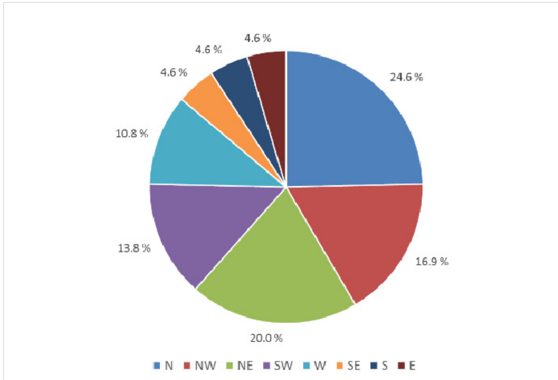

Figure 3: Distribution of Sphagnum-dominated mires in Vitosha Nature park according to exposure

Of the syntaxa described by Hajek at al. [39] only the *Drepanocladetum exannulati* Krajina 1933 was not recorded. The authors point that this association, documented from the Vitosha Mt only by one small relevé, represents the oligotrophic mires dominated by sedges and brown mosses indicating initial, albeit stable, and strongly waterlogged stages of mire formation.

Other communities represented by one locality in Vitosha Mt and distributed mainly in other mountains in Bulgaria [9], were also not identified: ass. *Carici echinatae-Sphagnetum* Soó 1944, ass. *Caricetum nigrae* Braun 1915 subass. typicum, var. *Sphagnum teres*, ass. *Dactylorhizo cordigerae-Eriophoretum latifolii* Hájek et al. 2008.

The association *Primulo exiguae-Caricetum echinatae* Roussakova 2000 was found at two relevés. Here are found the diagnostic for this association *Primula *exigua*, *Sphagnum platyphyllum*, *Pinguicula balcanica*, and *Pseudorchis frivaldii*. Bryophytes were represented mostly by the genera *Sphagnum*, *Warnstorfia*, and *Polytrichum*.

A large part of mire complexes in Mt Vitosha in the altitudinal range of 1750–1900 m a.s.l. belong to ass. *Cirsio heterotrichi-Caricetum nigrae* (Soo 1957) Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005 [39]. During the present study, this association was found at 18 localities. All of the diagnostic species of the association were registered. Among mosses the largest participation had *Sphagnum warnstorfii, Sphagnum capillifolium, Sphagnum flexuosum, Sphagnum contortum, Sphagnum palustre, Sphagnum teres, Aulacomnium palustre,* *Polytrichum commune, Warnstorfia exannulata, Warnstorfia sarmentosa*, etc. All known successional stages, described as subassociations were present. Subass. *sphagnetosum subsecundi* makes successional and syntaxonomic transition with ass. *Primulo exiguae-Caricetum echinatae*. It was found at 11 localities. The major diagnostic species *Sphagnum subsecundum* was well represented while the remaining diagnostic species *Carex echinata*, *Eriophorum angustifolium*, and *Gentianella bulgarica* had lower constancy and abundance as compared to the original diagnosis of the association. The typical subassociation was present at four relevés. Subass. *eriophoretosum vaginatae* was reported at four relevés and represents the most advanced successional stages within the association.

The largest number of relevés in the present study belonged to ass. *Bruckenthalio-Sphagnetum capillifolii* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005. It represents a more advanced successional stage characterized by shrub and semi-shrub species such as *Juniperus sibirica*, *Vaccinium vitis-idaea*, *Vaccinium myrtillus*, *Vaccinium uliginosum, Bruckenthalia spiculifolia*, as well as a number of species typical for wet meadows – *Deschampsia caespitosa*, *Agrostis capillaris*, *Alchemilla vulgaris* agg., *Geum coccineum*, *Allium sibiricum*, *Nardus stricta*, etc. This association was the optimum in the distribution of *Sphagnum capillifolium*. High constancy and abundancy had also *Sphagnum platyphyllum*, *Sphagnum subsecundum*, *Warnstorfia exannulata*, *Warnstorfia sarmentosa*, stc. This association was distributed mostly at 1900–2200 m a.s.l.

Association *Angelico pancicii-Calthetum laetae* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005 develops around springs and small water courses. Two relevés belonged to this association. Since the relevés were chosen in order to reveal bryophyte diversity, the abundancy of *Caltha palustris* and *Angelica pancicii* was relatively low. Besides the diagnostic *Brachythecium rivulare* and *Rhizomnium punctatum* were detected 10 bryophyte species albeit with lower abundancy.

To the spring vegetation belongs the association *Saxifragetum stellaris* Deyl 1940. It was represented at four relevés at 1775–1860 m a.s.l. Of the diagnostic species were found *Saxifraga alpigena*, *Philonotis seriata*, and *Soldanella montana*. Other differential species were *Scapania undulata* and *Oncophorus virens*.

Besides the typical mire and spring vegetation types, Sphagnum mosses develop in hygrophylic communities of order *Molinietalia*. Such were the phytocoenoses of ass. *Scirpetum sylvatici* Ralski 1931, which was found by Hajek et al. [39] as well as in the current study. Differential for this association are *Scirpus sylvaticus*, *Lysimachia vulgaris*, *Scutellaria alpina*, and *Sphagnum fimbriatum*. Other bryophytes are *Dicranella palustris*, *Sphagnum girgensohnii*, *Sphagnum squarrosum*, *Polytrichum commune*, and *Philonotis fontana*.

At some sites were observed phytocoenoses characteristic for advanced successional stages and indicating more mesic conditions – lesser representation of *Sphagnum* mosses, higher proportion of mesophilic grasses, shrubs and trees. The coenoses of comm. with *Holcus mollis* had relatively high abundance and constancy of species from *Caricetalia fuscae* (*Carex nigra*, *Carex echinata*, *Eriophorum vaginatum*, *Eriophorum latifolium*), as well as species from *Molinietalia* (*Deschampsia caespitosa*, *Angelica pancicii*, *Juncus effusus*, *Scirpus sylvaticus*, *Juncus conglomeratus*, *Potentilla erecta*, *Filipendula ulmaria*, etc.). At better-drained places were developed facies dominated by or with higher abundance of *Holcus mollis*, *Calamagrostis arundinacea*, *Rubus idaeus*, *Pinus sylvestris*, and *Alnus glutinosa*. These species indicate a succession towards formation of shrub and forest vegetation types. Differential species were *Holcus mollis* and *Calliergonella cuspidata*. Of bryophytes often occur *Sphagnum warnstorfii*, *Sphagnum subsecundum*, *Scapania undulata*, *Warnstorfia exannulata*, *Sphagnum flexuosum*, *Sphagnum contortum*, etc. Similar species composition had the coenoses of comm. of *Festuca rubra*, where high constancy and relatively high abundancy had *Festuca rubra* and *Agrostis capillaris*.

Community of *Carex rostrata* was found at one locality. It developed at a water saturated site at the edge of permanent water pool. Differential and dominant species were *Carex rostrata* and *Carex curta*. Bryophytes with highest abundancy were *Sphagnum teres*, *Sphagnum russowii*, *Sphagnum inundatum*, *Polytrichum commune*, *Warnstorfia exannulata*, *Aulacomnium palustre*, and *Philonotis fontana*.

Community of *Carex nigra* and *Luzula sudetica* is transitional between ass. *Primulo exiguae*-*Caricetum echinatae* and ass. *Saxifragetum stellaris*. Major dominants were *Carex nigra*, *Sphagnum capillifolium*, *Luzula sudetica*, *Carex echinata*, and *Sphagnum flexuosum*. Higher participation had also *Sphagnum contortum*, *Sphagnum inundatum*, *Scorpidium cossonii*, *Philonotis seriata*, *Rhizomnium punctatum*, etc.

Community of *Fissidens adianthoides* and *Hamatocaulis vernicosus* was described at one site with lower cover of vascular plants. A large number of bryophytes without a clear dominant also participated in this community. Differential species were *Fissidens adianthoides* and *Hamatocaulis vernicosus*. The optimum development of the latter species is where herbaceous vascular plants are absent or their abundancy is low [31].

3.3 Plant diversity and conservation species

In *Sphagnum*-dominated mires on the territory of Vitosha Natural Park were found a total of 210 plant species (Table I). Of them 121 were vascular plants and 89 were bryophytes. Nine vascular plants and 15 bryophytes are of conservation importance (Table I). Two species are Critically Endangered, three Endangered, 17 Vulnerable, one Near Threatened, and one Data Deficient [18, 24, 21]. Further three species are included in Annex II and 22 species are included in Annex 2a of Bulgarian Biodiversity Act. One species is included in Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

Further five species are Balkan endemics or sub-endemics (*Angelica pancici*, *Senecio pancici*, *Gentianella bulgarica*, *Crocus veluchensis*, and *Cirsium heterotrichum*). Ten bryophyte species (*Sphagnum auriculatum*, *Sphagnum compactum*, *Sphagnum subnitens*, *Calypogeia neesiana*, *Campylium polygamum*, *Plagiomnium ellipticum*, *Scorpidium cossonii*, *Scorpidium revolvens*, *Drepanocladus polygamum*, and *Dichelyma falcatum*) are new to the flora of Mt. Vitosha.

4 DISCUSSION

4.1 Importance of Vitosha Nature Park for the conservation of Sphagnum-dominated mires

Table I: Vascular plant and bryophyte species of conservation importance in *Sphagnum*-dominated mires on the territory of Vitosha Nature Park. Abbreviations: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient, RL – Red list, RDB – Red Data Book of Republic of Bulgaria, BA – Biodiversity Act of Bulgaria.

№	Species	Category	National conservation status	Other
	Vascular plants			
1.	*Angelica pancici*	VU	RL	Balkan endemic
2.	*Drosera rotundifolia*	VU	RL	
3.	*Potentilla palustris*	VU	RL	
4.	*Pseudorchis albida*	VU	RL, CITES	
5.	*Pseudorchis frivaldii*	VU	RL, CITES	
6.	*Salix pentandra*	CR	RL, RDB, BA	Glacial relict
7.	*Senecio pancici*	NT	RL	Balkan endemic
8.	*Swertia perennis*	EN	RL, RDB	Glacial relict
9.	*Utricularia minor*	EN	RL, RDB, BA	
	Bryophytes			
1.	*Bryum weigelii*	VU	RL	
2.	*Calypogeia sphagnicola*	VU	RL	
3.	*Drepanocladus polygamum*	VU	RL	
4.	*Cephalozia connivens*	VU	RL	
5.	*Cephalozia pleniceps*	DD	RL	
6.	*Cephaloziella hampeana*	CR	RL, RDB	
7.	*Hamatocaulis vernicosus*	VU	RL, RDB, BA, Directive 92/43	
8.	*Meesia uliginosa*	VU	RL	
9.	*Plagiothecium denticulatum var. undulatum*	VU	RL	
10.	*Riccardia incurvata*	VU	RL	
11.	*Riccardia multifida*	VU	RL	
12.	*Scorpidium revolvens*	VU	RL, RDB	
13.	*Sphagnum fallax*	VU	RL	
14.	*Sphagnum subnitens*	VU	RL, RDB	
15.	*Tomentypnum nitens*	EN	RL, RDB	

Vitosha Nature Park is an important area for the conservation of *Sphagnum*-dominated mires and their plant species and community diversity in Bulgaria. Mt Vitosha is the richest of *Sphagnum*-mosses phytogeographic region in Bulgaria with 23 species. Despite the restricted and scattered distribution and small size, this type of habitat is characterized by a considerable plant species and plant community diversity. For the first time Stefanoff [32] paid attention to the process of drying out of Vitosha mires. He suggested that measures must be undertaken for their restoration in the light of their importance for the water regime of the mountain. In addition to their role for biodiversity conservation, Vitosha mires provide a number of valuable ecosystem services. The most important of them are related to the water holding and water regulation capacity of *Sphagnum* cover and the peat layer. The rain and snowmelt water penetrate slowly in the peat and thus it supports the even river flow. Most rivers of Mt Vitosha have their sources in *Sphagnum*-dominated mires.

The most important threat to the mires in Mt Vitosha is drying. This is mostly a natural process due to two factors: climate change and lowering of water table due to water erosion of stream beds. The natural processes were enhanced by building of a number of water catchments for drinking water in the spring areas of many mires in the 1950-s and 1960-s. Drying has a twofold effect. On the one hand, it suppresses the development of the major habitat component – *Sphagnum* mosses. On the other hand drying stimulates the development of more competitive vascular plants. The overall effect is gradual displacement of the typical mire species with species of mesophilic meadows. The process of displacement is enhanced by increased nutrient input from air pollution with nitrogen and sulphur from the nearby urban areas (the city of Sofia and the industrial area of town Pernik) which was considerable during the middle of XIX by the end of XX century.

Proper management of *Sphagnum*-dominated mires on the territory of the Park is needed in order to protect this unique and rich type of habitat. This include mostly preventive measures: careful consideration when new water catchments or infrastructures are built in order to prevent disturbance of water regime, taking measures to avoid passing of tourists through mires, and last but not least raising awareness for the importance and vulnerability of *Sphagnum*-mires. Active restoration of some sites with disturbed water regime may also be undertaken. Such recommendation could be found also in the report for habitat 7140 Transition mires and quaking bogs (distribution and ecological status) as a result of above mentioned project on mapping habitats and species in Natura 2000 sites in Bulgaria (http://natura2000.moew.government.bg).

4.2 Comments on some species of conservation importance

Drosera rotundifolia. The species was reported for Mt. Vitosha in 1883 [20]. Since then there are occasional reports [e.g. 23] but the general view was that it is rare. Our study showed that *D. rotundifolia* is a relatively regular member of *Sphagnum*-dominated mires in Mt Vitosha having being found at 18 sites. All of them are situated in the altitudinal range of 1300-1886 m a.s.l. At most sites the populations are numerous and in very good state.

Potentilla palustris. In Mt. Vitosha it has been found for the first time in 1930 [37], and has not been reported since then for the flora of the mountain. We found it at three sites. The populations were represented by a small number of individuals with scattered shoots often barely to be seen above the *Sphagnum* cover. Only at one site the plants were observed with flowers.

Sphagnum subnitens. This is the first report of the species for Mt. Vitosha. The species is known only form Pirin [29] and Rila Mts [17]. On Mt. Vitosha *S. subnitens* was found at one site, represented by few small patches.

Drepanocladus polygamum. This is the first report of the species for Mt. Vitosha. The species is reported only form Pirin Mt [15] but it was not supported by herbarium specimen. The species has not been observed in Bulgaria since 1966.

Hamatocaulis vernicosus. The occurrence of *H. vernicosus* on Mt Votisha has been doubtful. It was reported by Podpéra [26] for loc. Dragalevsko blato, which is located around the springs of Dragalevska river at ca. 1800 m a.s.l. and is today called loc. Kapaklivets. The attempts of the authors to verify the occurrence of the species at this locality proved unsuccessful. Since the conditions at the site differ from the conditions, where *H. vernicosus* is found in Bulgaria at present and is not supported by herbarium specimen, this report was treated as probable misidentification. The location of *H. vernicosus* on the south-western slopes of Mt. Vitosha in the current study is the first confirmed occurrence of the species in Vitosha Nature Park.

Dichelyma falcatum. This species was recently added to the list of bryophytes in Bulgaria. It was found for the first time in Rila Mts at 2300 m a.s.l. [16]. This is the second location of *D. falcatum* in Bulgaria and the first report for Mt. Vitosha. The species had similar ecological requirements on Mt. Vitosha – high elevation (2230 m a.s.l.) growing on acidic rocks in streams that dry out in late summer flowing through *Sphagnum*-mires. The species is not Red-listed because it was found in Bulgaria after the publication of the most recent Red list [18]. However, since its discovery it proved to be rare and grows at extremely vulnerable sites. It will therefore be considered in the next evaluation of Bulgarian bryophytes and will be assigned to a threat category.

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Annex I: Area, elevation and geographic coordinates of the investigated mire in Vitosha Nature Park. Mire numbers correspond to Annex II.

Nr.	Area (ha)	Elevation (m a.s.l.)	Longitude	Latitude
1	0.05	1800	23.291063	42.58905
2	0.01	2240	23.282532	42.562478
3	0.06	2235	23.281997	42.562313
4	0.23	2225	23.28138	42.561382
5	0.16	2225	23.28331	42.559605
6	1.73	2150	23.289183	42.551828
7	0.56	2150	23.2935	42.546433
8	0.51	1957	23.279205	42.58437
9	0.28	2130	23.293127	42.544017
10	3.65	2130	23.293842	42.542563
11	0.02	2060	23.29362	42.55549
12	0.31	2060	23.294455	42.555632
13	6.1	1790	23.256981	42.59076
14	0.1	1824	23.232778	42.581372
15	0.01	1952	23.277223	42.5847
16	0.28	1822	23.234676	42.58076
17	1.59	1814	23.230481	42.581557
18	0.04	1727	23.233761	42.587235
19	0.99	1510	23.241319	42.602244
20	0.03	1833	23.246824	42.58457
21	0.25	1887	23.246224	42.58239
22	11.07	1926	23.268523	42.58455
23	0.04	1885	23.243607	42.58194
24	0.11	1787	23.249498	42.58665
25	0.03	1775	23.249945	42.58826
26	0.27	1774	23.249263	42.588952
27	0.02	1755	23.240201	42.58725
28	0.15	1725	23.238814	42.58735
29	0.14	1526	23.239467	42.60144
30	0.4	1545	23.237193	42.59924
31	0.11	1656	23.223465	42.58983
32	0.16	1700	23.224869	42.58817
33	0.33	1776	23.24276	42.58618
34	0.02	1787	23.24408	42.5863
35	0.57	1780	23.244945	42.58667
36	2.73	1793	23.246718	42.58666
37	0.01	1787	23.266442	42.60308
38	0.01	1786	23.266137	42.60312
39	0.01	1790	23.265989	42.60296
40	0.07	1794	23.265603	42.60301
41	0.01	1789	23.265068	42.60321
42	0.18	1785	23.263199	42.6045
43	3.86	1805	23.263971	42.59937
44	5.69	1830	23.284095	42.58901
45	0.52	1840	23.285689	42.59171
46	0.04	1818	23.283812	42.59409
47	0.08	1806	23.282432	42.59687
48	0.11	1815	23.281437	42.59702
49	17.08	1840	23.278615	42.59497
50	0.06	1815	23.296888	42.55645
51	0.04	2010	23.295881	42.55655
52	0.02	2030	23.295526	42.55583
53	0.02	1940	23.307565	42.55028
54	0.01	1950	23.307448	42.54984
55	0.09	1920	23.309799	42.54926
56	0.12	1920	23.310269	42.54851
57	0.22	2140	23.29859	42.549707
58	4.29	1970	23.265713	42.55256
59	0.96	1990	23.261705	42.55737
60	0.04	1573	23.224503	42.56128
61	0.03	1701	23.24201	42.5579
62	0.02	1705	23.2438	42.55762
63	0.03	1706	23.244265	42.55748
64	0.11	1711	23.247182	42.55536
65	0.08	1718	23.247104	42.55622
66	0.01	1230	23.245056	42.50663
67	0.06	1318	23.252863	42.49297
68	0.06	1348	23.262691	42.50016
69	0.04	1879	23.283993	42.58691
70	0.17	2117	23.273196	42.56725
71	0.1	2046	23.270814	42.57024
72	1.62	2040	23.268327	42.56941
73	0.02	2030	23.266009	42.56885
74	0.48	2052	23.259509	42.56709
75	0.02	2051	23.257008	42.56617
76	0.06	2038	23.256381	42.5665
77	0.22	1994	23.248799	42.56785
78	0.81	1996	23.253211	42.56966
79	0.26	1994	23.251895	42.57214
80	0.49	1976	23.25419	42.57277
81	1.62	1954	23.259068	42.57493
82	0.33	1910	23.26425	42.57935
83	0.04	1912	23.264295	42.58301
84	11.07	1926	23.268523	42.58455
85	0.7	1830	23.303	42.571

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Annex II: Synoptic table of the phytocoenoses from Vitosha Mts. Mire numbers correspond to Annex I. 1. Syntaxa: 1. ass. *Primulo exiguae-Caricetum echinatae* Roussakova 2000; 2. ass. *Cirsio heterotrichi-Caricetum nigrae* (Soo 1957) Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005 subass. *sphagnetosum subsecundi* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005; 3. ass. *Cirsio heterotrichi-Caricetum nigrae* (Soo 1957) Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005 subass. *typicum* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005; 4. ass. *Cirsio heterotrichi-Caricetum nigrae* (Soo 1957) Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005 subass. *eriophoretosum vaginatae* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005; 5. ass. *Bruckenthalio-Sphagnetum capillifolii* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005; 6. ass. *Angelico pancicii-Calthetum laetae* Hájek, Tzonev, Hájková, Ganeva and Apostolova 2005; 7. comm. with *Holcus mollis*; 8. ass. *Saxifragetum stellaris* Deyl 1940; 9. comm. of *Festuca rubra;* 10. comm. of *Carex rostrata*; 11. ass. *Scirpetum sylvatici* Ralski 1931; 12. comm. of *Carex nigra* and *Luzula sudetica*; 13. comm. of *Fissidens adianthoides* and *Hamatocaulis vernicosus.*

	Syntaxa	1	2	3	4	5	6	7	8	9	10	11	12	13
	Number of relevés	2	10	4	4	26	2	5	5	3	1	1	1	1
	Number of species	75	110	103	64	147	42	78	75	45	24	12	26	26
Taxa	Mire number	CONSTANCY/ABUNDANCE												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
*Primula *exigua*	1, 3-6, 10, 12, 16, 25, 27, 38, 39, 49, 57, 64, 65, 75, 82	**V^{+-1}**	II^{+}			III^{+}								
Sphagnum platyphyllum	2, 3, 9-11, 16, 25, 49, 50, 69-71, 74, 76, 78, 79	**V^{2m-2b}**	I^{2a}			III^{2b-3}								
Carex nigra	1, 2, 4, 6-8, 10-13, 15-17, 20, 21, 27-29, 32-35, 37, 43, 57, 61, 63-65, 69-71, 73-75, 78, 82	V^{+-1}	**V^{+-5}**	**V^{+-3}**	**V^{+-3}**	V^{+-4}	V^{2b-3}	III^{2a-2b}			+		4	
Molinia caerulea	1, 13, 14, 16, 17, 19-23, 25, 27, 28, 32, 36, 38, 39, 42-44, 49, 50, 60, 69, 71	V^{+}	**IV^{+-4}**	**V^{2m-3}**	**IV^{+-4}**	I^{+-3}								+
Succisa pratensis	1, 13, 14, 16-23, 25, 27, 29, 32, 33, 36, 38, 39, 42-44, 60, 63, 65, 69, 77, 81	III^{+}	**V^{+-2b}**	**V^{+-2b}**	**V+-3**	II^{+-2b}		I^{2a}			+			+
Cirsium heterotrichum	1, 3, 4, 6-8, 10, 13, 14-17, 20-22, 25, 27, 29, 32, 34, 35, 37, 42, 43, 49, 50, 57, 61, 64, 65, 69-71, 75, 77-79, 81, 82, 85	V^{+}	**IV^{+}**	**IV^{+-2a}**	**II^{+}**	IV^{+-3}	V^{+}	I^{2a}	I^{+}	IV^{+}	+			
Potentilla erecta	4, 6-10, 12-21, 23, 25, 27-29, 32-39, 42-44, 49, 50, 57, 60, 61, 64, 65, 67-71, 74-79, 81, 82, 85	V^{+}	**V^{+-2b}**	**V^{+-2b}**	**III^{2b-3}**	V^{+-3}	V^{+}	IV^{+-2a}	IV^{+}	V^{2a-3}	+			+
Dactylorhiza cordigera s.l.	1, 5, 10, 11, 13, 16, 17, 21, 23, 25, 27, 29, 32, 33, 37-39, 42, 43, 49, 60, 61, 62, 63, 65, 69, 75, 77, 82	V^{+}	**V^{+-1}**	**II^{1}**	**III^{+}**	II^{+-2a}		III^{+-1}			+			+
Sanguisorba officinalis	1, 7, 13, 14-18, 20, 23, 25, 27, 29, 62, 63, 69, 71, 74, 76, 81, 82, 78	III^{+}	**II^{+}**	**IV^{+-2b}**	**III^{+}**	III^{+-2a}		I^{+}						
Sphagnum warnstorfii	1, 2, 4, 9, 13, 14, 17, 19-21, 23, 27, 28, 33, 42, 43, 49, 50, 60, 61, 62, 70, 78, 81	III^{+}	**II^{2m-2a}**	**IV^{2m-2a}**	**III^{2-m}**	II^{2m-2b}		III^{2m-2a}	I^{2b}					1
Sphagnum subsecundum	2, 4-6, 10, 16-18, 25, 27-29, 34, 35, 38, 42, 50, 57, 57, 62, 64, 67-71, 73-75, 78, 79, 82, 85	III^{2m}	**V^{+-3}**		II^{2a}	III^{2a-2b}	V^{2b-3}	III^{2a-2b}	I^{2b}					
Carex echinata	1, 4, 6, 8-11, 13, 16-18, 20, 21, 25, 28, 34-36, 38, 39, 42, 50, 57, 61, 62, 66, 68, 71, 74, 76, 77, 81, 82, 85	III^{+}	**II^{+-1}**	III^{+}	V^{+-2a}	IV^{+-3}	V^{+-2b}	II^{+-2a}	I^{+}		+		2a	
Eriophorum angustifolium	11, 18, 28, 35, 64, 71, 74	III^{+}	**II^{+-2a}**	III^{+-2m}	II^{+}	I^{3}								
Gentianella bulgarica	1, 4, 8, 10, 13, 14, 17, 18, 21, 23, 25, 44, 49, 50, 69-71,	III^{+}	**II^{+}**	IV^{+}	II^{+}	II^{+}	III^{+}				+			

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	74-79, 81, 82													
Eriophorum vaginatum	2, 3, 5, 6, 8, 10, 12, 15, 19, 22, 23, 25, 35, 37-39, 43, 44, 49, 50, 57, 61, 63, 70, 71, 74, 78, 79, 81, 82	III^{+}	III^{+-2a}	II^{+}	**V^{2b-4}**	**III^{+-4}**	III^{+}	I^{1}	II^{+-1}	II^{+}				
Juniperus sibirica	1, 2, 4, 5, 7-10, 13, 14-16, 18-21, 23, 25, 27, 29, 37, 42, 44, 49, 57, 62-65, 69-71, 73-75, 79	V^{+}	III^{+-2a}	V^{+}	IV^{+}	**IV^{+-3}**	III^{3}	I^{2a}	II^{+}				+	
Bruckenthalia spiculifolia	4, 7, 9, 10, 12, 13, 16, 20, 21, 23, 25, 28, 29, 32, 37-39, 43, 44, 61, 65, 69, 70, 71, 74	III^{2m}	IV^{+-2a}	IV^{+-1}	II^{+}	**III^{+-2a}**		I^{+}	II^{+}					
Vaccinium myrtillus	4, 7-10, 13, 16, 17, 21, 25, 27, 29, 36, 42, 44, 50, 57, 65, 69-71, 74, 79, 82	III^{+}	II^{+}	III^{+-2m}		**III^{+-2b}**	III^{+}		I^{2a}					
Vaccinium vitis-idaea	2, 7, 10, 13, 14-17, 20, 23, 25, 29, 32, 38, 39, 43, 44, 50, 57, 65, 69, 71, 74	III^{+}	III^{+}	IV^{+-2m}	II^{+}	**II^{+}**			I^{2a}					
Sphagnum capillifolium	1-3, 6, 7, 10-13, 15-17, 19-23, 25, 29, 32, 33, 43, 44, 49, 50, 57, 62-65, 70, 71, 73-76, 78, 79, 81, 82	V^{2m-2b}	III^{2a-3}	IV^{2b-3}	V^{2b}	**V^{2m-3}**		II^{2b}	II^{2a-2b}				3	
Homogyne alpina	2-6, 9, 13, 16, 21, 27, 29, 44, 57, 70, 71, 73-76	III^{+}		II^{+}		**III^{+}**			III^{+}				+	
Caltha palustris agg.	4, 6, 13, 18, 21, 33, 37, 57, 60, 69, 77		I^{+}	II^{+}		I^{+}	**III^{2b}**	I^{+}	II^{+-2a}		+			+
Rhizomnium punctatum	12, 36, 73, 75, 85					I^{2m}	**III^{2a}**		II^{2m}	II^{2a}			2m	
Brachythecium rivulare	8, 11, 17, 37-39, 65, 85		II^{+-1}			I^{2m}	**V^{2a}**							
Angelica pancicii	1, 10-13, 16-18, 20, 32, 35, 44, 61-63, 65, 69, 75, 85	III^{+}	II^{+}	IV^{+-1}	II^{+}	II^{+}	**III^{+}**	II^{+}	I^{+}	II^{+}				
Holcus molis	13, 33, 60, 61, 62, 67, 68			II^{1}				**V^{+-2b}**						**+**
Calliergonella cuspidata	14, 16-18, 23, 25, 28, 33, 60-62, 64, 68, 69	III^{2a}	II^{2m-2a}	II^{2a}	II^{2a}	I^{2m-2a}		**IV^{2m-2b}**	I^{2a}					2m
Calamagrostis arundinacea	14, 62			II^{+}				**I^{3}**						
Rubus idaeus	17, 18, 44, 62		I^{+}	II^{+}				**I^{2a}**						
Pinus sylvestris	1, 13, 14, 16-18, 68	III^{+}	I^{+}	III^{+}		I^{+}		**I^{2b}**						
Alnus glutinosa	68							**I^{2a}**						
*Saxifraga *alpigena*	11, 16, 21, 28, 29, 57, 70, 73	III^{+}				I^{+}			**IV^{+-2b}**				+	
Philonotis seriata	5-7, 12, 16, 17, 21, 28, 29, 42, 44, 49, 57, 67, 73, 75, 85	V^{+-2m}	II^{2m-1}	II^{2m}		I^{2m-2b}	III^{2m}	I^{2a}	**IV^{2a}**				2a	
Soldanella montana	4, 7, 11, 13, 16, 28, 57, 64, 70, 75, 76	III^{+}		II^{+}		II^{+}			**III^{+-3}**					
Scapania undulata	1, 2, 11-13, 16, 17, 19-21, 25, 28, 44, 49, 57, 61, 62, 64, 69, 70, 75, 79	V^{2m}	II^{1-2m}	IV^{1-2m}	II^{1}	II^{2m-2a}		II^{1}	**V^{2m-2a}**					
Oncophorus virens	6, 12, 57					I^{2m}			**III^{2m-2a}**					
Festuca rubra agg.	2-4, 6, 13, 18-21, 27-29, 32, 34-37, 44, 62, 69, 70, 73 81		II^{+-2a}	IV^{+-2m}	II^{+}	II^{+-1}		I^{+}	II^{1}	**V^{+-3}**			+	
Juncus effusus	13, 17, 29, 33-35, 66, 68		I^{+}	II^{1}		I^{+}		II^{+-1}		**IV^{+-2a}**		1		
Carex rostrata	4										**4**			
Carex curta	29, 77					I^{+}					**2b**			
Scirpus sylvaticus	33-35, 66							I^{2b}		IV^{+-2a}		**4**		
Lysimachia vulgaris	14, 17, 66		I^{+}	II^{+}								**2a**		

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Scutellaria alpina	66											+		
Sphagnum fimbriatum	66											**2b**		
Luzula sudetica	2, 3, 6, 7, 11, 21, 32, 39, 42, 50, 57, 64, 65, 69-71, 73-78		II^{+}			III^{+-2a}			IV^{+-2a}		+		**2a**	
Fissidens adianthoides	60, 74					I^{r}								**1**
Hamatocaulis vernicosus	60													**1**
Other vascular plants														
Achillea millefolium	17, 18, 62		I^{+}					I^{+}						
Agrostis capillaris	1, 2, 4-9, 13, 14, 17-21, 23, 25, 27, 32-36, 44, 50, 57, 62, 64, 69, 70, 74, 75, 78, 79, 85		III^{+-3}	V^{+}	III^{+}	IV^{+-1}	V^{+}	$II+^{-2b}$	I^{+}	V^{+-3}				
Alchemilla vulgaris agg.	1, 5, 7, 11-13, 25, 27, 28, 33, 57, 65, 69-71, 82, 85		I^{+}	II^{+}		II^{+}	III^{+}	I^{+}	III^{+}					
Allium sibiricum	2, 3, 5-7, 10-14-17, 20, 22, 27, 28, 32, 37-39, 43, 44, 50, 57, 69, 70, 71, 74, 75, 78, 79, 82	III^{+}	III^{+-2b}	V^{+-2a}	II^{+}	IV^{+-3}			IV^{+-2b}					
Athyrium filix-femina	13, 16, 17, 66	III^{+}	I^{+}	II^{2m}								+		
Betula pendula	17, 32		I^{+}											
Bistorta major	2, 7, 13, 15-17, 19-21, 29, 43, 44, 49, 82	V^{+-2a}	II^{+}	IV^{+-2m}	II^{+}	I^{+-2a}								
Briza media	67							I^{+}						
Campanula abietina	32, 44		I^{+}	II^{+}										
Cardamine rivularis	1, 4, 11, 13, 17, 37, 57, 70		I^{+}	II^{2m}		I^{+}			I^{1}					
Carex ovalis	32		I^{+}											
Carex pallescens	2, 5, 13, 50, 70			II^{1}		I^{+}								
Cirsium appendiculatum	1, 4, 21, 28		I^{+}			I^{+}			II^{+}					
Crepis paludosa	1, 2, 8, 29					I^{+-2a}	III^{+}							
Crocus veluchensis	3-6, 18, 44, 81		I^{+}	II^{+}		I^{+}								
Cruciata glabra	1, 13, 18		I^{+}	II^{+}										
Deschampsia caespitosa	1-15, 17, 18, 20, 21, 23, 25, 28, 32, 34-37, 42-44, 49, 50, 57, 60, 62, 64, 68, 70, 71, 73-79, 81, 82	III^{+}	IV^{+-1}	V^{+-2a}	II^{+}	V^{+-2b}	III^{4}	II^{+-3}	IV^{+-1}	V^{1-3}	2b		+	+
Deschampsia flexuosa	8, 13, 15, 17, 21, 35, 37, 42, 44, 57, 69-71, 74		II^{+}	III^{+-2m}		I^{+-1}	III^{+}		I^{1}	II^{1}				
Dianthus superbus	1, 15, 60-64, 69, 79				II^{+}	I^{+-1}		II^{1-2a}						+
Doronicum austriacuam	4					I^{+}								
Drosera rotundifolia	13, 16, 17, 23-26, 28, 32, 43, 49, 61-65, 67, 68	V^{+}	II^{+}	II^{2m}	III^{+}	I^{+}		II^{+}						
Epilobium angustifolium	14, 17, 44, 49, 71	III^{+}	I^{+}	III^{+}										
Epilobium palustre	4, 11, 13, 18, 20, 22, 34, 36, 69, 74-76, 79		I^{+}	III^{+}	II^{+}	II^{+}				IV^{+}				
Equisetum hiemale	61, 63, 66				II^{+}			I^{+}				+		
Equisetum palustre	13, 17, 23, 33-35, 44, 50, 68, 77		I^{+}	III^{+-1}	II^{+}	I^{+}		II^{+}		IV^{+}	+			
Eriophorum latifolium	1, 2, 4, 7, 10-14, 16, 17, 27, 29, 37-39, 44, 49, 57, 61,	V^{+-2a}	II^{+-1}	IV^{+-2a}		IV^{+-3}	III^{4}	I^{3}	IV^{+-2b}				+	

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	64, 65, 69-71, 73-76, 79, 82, 85													
Euphrasia rostkoviana	6, 11, 16, 32, 64, 69, 71, 82	III^{+}	I^{+}											
Festuca valida	8						III^{+}							
Filipendula ulmaria	1, 17, 18, 33, 34		I^{+}			I^{+}		I^{2a}		II^{+}				
Galium palustre	1, 32-34		I^{+}			I^{+}		I^{1}		II^{+}				
Gentiana pneumonanthe	6, 10, 11, 16, 49, 57, 68, 75, 78, 82	V^{+}				II^{+}		I^{+}	I^{+}					
Geum coccineum	1-13, 16-18, 21, 23, 25, 28, 29, 32, 34-37, 42-44, 50, 57, 61, 64, 65, 69, 71, 73-77, 81, 82, 85	III^{+}	IV^{+}	III^{+-1}	II^{+}	IV^{+-2a}	V^{+}	I^{+}	V^{+}	V^{+}	+		+	
Geum montanum	4, 7					I^{+}								
Hieracium cymosum	21								I^{+}					
Hypericum maculatum	6-8, 17, 18, 20, 21, 32, 62, 69, 73		I^{+}	II^{+}		I^{+}	III^{+}	I^{+}	II^{+}				+	
Hypericum perforatum	17, 18, 67		I^{+}					I^{+}						
Juncus articulatus	1, 7, 8, 11, 12, 14-16, 29, 33, 49, 50, 61, 63, 65	V^{+-2m}		II^{+}	II^{+}	II^{+-1}	III^{+}	II^{+}	I^{+}					
Juncus conglomeratus agg.	1, 8, 11, 14, 16-18, 21, 25, 28, 35, 36, 61-64, 67, 69, 85	III^{+}	I^{+}	II^{+}	II^{+}	I^{+}	V^{+-2b}	III^{+}	II^{2a}	IV^{+}				
Juniperus communis	68							I^{+}						
Lathyrus pratensis	1, 8, 32-35, 61, 62		I^{+}			I^{+}	III^{+}	III^{+}		IV^{+}				
Leontodon autumnalis	3-5, 10-12, 18, 25, 27, 32, 33, 61, 62, 64, 65, 67, 69, 71, 75, 76, 78, 82		I^{+}			III^{+}		IV^{+}	I^{+}					
Luzula forsteri	43		I^{+}											
Luzula luzuloides	27					I^{+}								
Luzula sylvatica	13, 18, 27, 29		I^{+}	II^{1}		I^{+}								
Lysimachia nummularia	18, 35, 37		I^{+}							II				
Lythrum salicaria	13, 17, 18, 60, 67		I^{+-1}	II^{2m}				I^{+}						+
Matricaria caucasica	2, 4, 5, 9, 67					I^{+}		I^{+}						
Mentha arvensis	67							I^{+}						
Meum mutellina	2-7, 10-12, 17, 18, 33, 34, 62, 69, 74, 82		I^{+}			III^{+-2a}		II^{+}	I^{+}	II^{1}				
Myosotis scorpioides agg.	1, 11, 15, 21, 33, 34, 37, 57, 69		I^{+}			I^{+}		I^{+}	I^{+}	II^{+}				
Nardus stricta	1-5, 6, 8, 13, 18, 21, 29, 44, 62, 64, 68, 69-71, 73-76, 78, 79, 85		I^{+-1}	III^{+-1}		IV^{+-3}	V^{+}	II^{+}					1	
Parnassia palustris	1, 7, 8, 10, 12, 13, 16, 17, 25, 32, 57, 60, 63, 64, 77-79, 81, 82, 85	III^{+}	I^{+}	II^{2m}	II^{+}	II^{+}	V^{+}		II^{+}		+			+
Persicaria maculata	6, 10, 11					I^{+}								
Phleum alpinum	2, 23, 25, 28, 44, 49	III^{+}		II^{+}	II^{+}	I^{+}			I^{+}					
Phragmites australis	33							I^{+}						
Picea abies	8, 13, 14, 16-19, 23, 32, 42, 44, 49	V^{+}	II^{+}	IV^{+}	III^{+}	I^{+}	III^{+}							

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	65													
Pinguicula balcanica	3-5, 7-13, 16, 21, 29, 49, 57, 60, 62, 64, 69, 77, 78	V^{+}	I^{+}	II^{+}		III^{+}	III^{+}	I^{+}	II^{+}		+			+
Pinus peuce	42		I^{+}											
Plantago gentianoides	6, 35					I^{+}				II^{+}				
Potentilla palustris	15, 22, 43		I^{+}		II^{2b}	I^{+}								
Potentilla ternata	3, 4					I^{+}								
Pseudorchis albida	16, 39, 42, 44, 65	III^{+}	I^{+}	II^{+}		I^{+}								
Pseudorchis frivaldii	1, 4, 5, 8-11, 16, 23, 25, 29, 32, 37-39, 44, 49, 65, 70, 71, 79, 81	V^{+}	II^{+}	II^{+}	II^{+}	III^{+}	III^{+}							
Ranunculus sartorianus	2, 4-6, 9, 32-34, 69		I^{+}			II^{+}		I^{+}		II^{+}				
Rhynanthus angustifolius	13, 17, 32, 49	III^{+}	I^{+}	I^{+}										
Rumex acetosa	1, 4, 18, 73		I^{1}			I^{+}							+	
Salix caprea	17-19, 32, 36, 63, 65		I^{+}		III^{+}	I^{+}				II^{+}				
Salix lapponum	1, 6, 10, 12-17, 35-39, 42-44, 49, 57, 65, 67, 69, 71, 75, 76, 78, 81	V^{+-2m}	II^{+-2a}	IV^{+-1}		III^{+}		I^{2a}	II^{+-2a}	IV^{+}				
Salix waldsteiniana	12-14, 16, 17, 32, 44, 49, 57, 71	V^{+-2m}	I^{+-1}	IV^{+}		I^{+}			II^{+}					
Senecio nemorensis	3, 7, 10, 20, 23, 50, 70, 79			II^{+}	II^{+}	II^{+}								
Senecio pancicii	3, 5, 10, 13, 16, 17, 25, 28, 44, 49, 69-71, 79	V^{+}	I^{+}	III^{+}		II^{+}			I^{+}					
Sesleria comosa	2, 4, 6, 12, 22, 44, 50, 57, 70, 71, 75, 76, 78, 79, 81, 82			II^{+}	II^{+}	III^{+}			II^{+}					
Stellaria graminea	32		I^{+}											
Swertia perennis	6, 10, 63, 82				II^{+}	I^{+}								
Taraxacum appeninum	3, 4, 70					I^{+}								
Thalictrum aquilegifolium	8						III^{+}							
Thlaspi ptraecox	6, 44			II^{+}		I^{+}								
Trichophorum caespitosum	4, 7-10, 12, 13, 16, 20, 21, 23, 25, 29, 38, 42, 44, 49, 50, 70, 71, 74-76, 78, 79, 81, 82	V^{2a-2b}	II^{2a-4}	IV^{2m-2b}	II^{3}	III^{+-4}	III^{+}		I^{+}					
Trifolium michelii	10, 32, 69, 85		I^{+}			I^{+}	III^{+}							
Trifolium pratense	12, 28, 32, 69, 82		I^{+}			I^{+}			II^{+}					
Trifolium spadiceum	10, 12, 13, 18, 28, 32, 62-64, 77, 82		I^{+}	II^{+}	II^{+}	I^{+-2a}		I^{2a}	II^{+}		+			
Trisetum flavescens	35									II^{+}				
Trolius europaeus	1					I^{2a}								
Utricularia minor	13, 14, 25, 37			III^{+}										
Vaccinium uliginosum	1, 3, 4, 6, 7, 8, 10-13, 15-17, 23, 28, 29, 32, 37, 39, 42, 44, 50, 57, 69-71, 74-76, 79, 82, 85	III^{+}	II^{+-2a}	III^{+-1}	II^{+-2a}	IV^{+-2b}	V^{+}		III^{+-2b}					
Veratrum lobelianum	1, 8, 12, 13, 17, 19, 20, 21, 23, 25, 27, 32, 34, 35, 37,		II^{+}	IV^{+}	III^{r-+}	II^{+}	III^{+}		II^{+}	IV^{+}			+	

continued

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	42-44, 50, 64, 69, 71, 73, 74, 79, 81, 82													
Viola dacica	4					I^{+}								
Other mosses														
Aneura pinguis	13			II^{2m}										
Aulacomnium palustre	2, 3, 5, 6, 9, 12, 13, 15-19, 22, 32, 36, 42, 44, 49, 60, 63, 67-69, 73, 77, 78, 85	V^{2a}	II^{2m-2a}	III^{2m-2a}	III^{2m-2a}	II^{2m-2a}	III^{2m}	II^{2m}	II^{2m}	II^{2a}	2a		2m	1
Barbilophozia atlantica	12								I^{2m}					
Brachythecium mildeanum	19					I^{2m}								
Brachythecium reflexum	79					I^{1}								
Brachythecium sp.	36									II^{2m}				
Bryum pallens	3, 12, 61, 62					I^{1}		II^{1}	I^{1}					
Bryum pseudotriquetrum	1, 6, 7, 11-13, 16, 17, 21, 25, 36, 49, 57, 60, 64, 65, 70, 79	V^{2m}	II^{+-2m}	II^{2m}		II^{1-2m}			IV^{2m}	II^{1}				1
Bryum weigelii	11					I^{+}								
Calliergon cordifolium	33							I^{1}						
Calypogeia azurea	28, 71, 77, 79					I^{2m}			I^{2m}		2m			
Calypogeia muehleriana	13, 71, 76			II^{2m}		I^{2m}								
Calypogeia neesiana *	36									II^{2m}				
Calypogeia sphagnicola	28, 42, 71		I^{1}			I^{1}			I^{1}					
Campylium polygamum *	73												2m	
Cephalozia bicuspidata	12, 13, 28, 71, 75, 79			II^{2m}		I^{2m}			II^{2m}					
Cephalozia connivens	71					I^{2m}								
Cephalozia pleniceps	6, 35, 70					I^{+-2m}				II^{2m}				
Cephaloziella divaricata	3					I^{r}								
Cephaloziella hampeana	79					I^{2m}								
Chiloscyphus pallescens	10, 11, 13, 16, 19, 20, 35, 49, 61, 62, 69	V^{2m}		III^{1-2m}	II^{1}	I^{2m-2a}		II^{2m}		II^{2m}				
Chiloscyphus polyanthos	65, 69, 73					I^{1-2m}							2m	
Climacium dendroides	1, 6, 8, 15, 19, 20, 27, 33, 60, 64, 69, 73, 81, 82			II^{2m}	II^{2m}	II^{2m-2a}	III^{2m}	II^{2a}					2m	2m
Dichelyma falcatum	3	I^{2m}												
Dicranella palustris	13, 16, 25, 44, 64, 66, 70, 71, 75, 81	III^{2m}	II^{2m}	III^{2m-2a}		I^{2m-2a}						1		
Dicranum bonjeanii	2, 6, 7, 10, 21, 22, 43, 70, 75		I^{1}		II^{2a}	II^{1-2a}								
Dicranum scoparium	13, 70, 71, 75			II^{2a}		I^{2m-2a}								
Jungermannia leiantha	75					I^{2m}								
Kiaeria starkei	12, 25, 60, 70, 75					I^{2m}			I^{1}					+

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Lophocolea heterophylla	36									II^{2m}				
Lophozia obtusa	12								I^{2m}					
Lophozia ventricosa	70, 71, 75, 79					I^{2m-2a}								
Marchantia polymorpha	19					I^{2m}								
Meesia uliginosa	12								I^{1}					
Palustriella decipiens	6-8, 10, 11, 16, 17, 21, 57, 75	III^{2m}	I^{2m}			I^{2m-2a}	III^{2a}		II^{2m}					
Pellia epiphylla	16, 17, 35, 44, 69	III^{2m}	I^{2m}	II^{2m}		I^{2m}				II^{2m}				
Pellia neesiana	22, 25, 36		I^{2m}		II^{2m}					II^{2m}				
Philonotis fontana	6, 8, 21, 60-62, 66		I^{1}			I^{2m}	III^{2m}	II^{1}				1		1
Plagiochila porelloides	36									II^{2m}				
Plagiomnium affine	61, 62							II^{2m}						
Plagiomnium ellipticum	33, 36-39, 60		I^{1}					I^{2a}		II^{2a}				2m
Plagiomnium undulatum	36, 60									II^{2b}				2m
Plagiothecium denticulatum var. *undulatum*	35									II^{r}				
Pohlia nutans	61							I^{r}						
Polytrichum commune	2, 5, 8, 9, 12-17, 19, 20, 22, 32, 35, 37-39, 43, 44, 49, 50, 60-62, 66, 68, 69, 71, 77, 79, 85	V^{2a}	II^{2m-2a}	V^{2m-2a}	III^{2a}	II^{2m-2b}	V^{2a}	III^{2m-2a}	I^{2a}	II	2a	2a		2m
Polytrichum strictum	6, 15, 16, 43, 44, 49, 62, 70, 74, 79, 81	V^{2m-2a}	I^{2a}	II^{2m}		II^{2a-2b}		I^{2a}						
Rhizomnium magnifolium	8, 13			II^{2m}			III^{2m}							
Rhizomnium pseudopunctatum	19					I^{2m}								
Rhytidiadelphus squarrosus	73												2m	
Riccardia incurvata	13, 57			II^{2m}					II^{1}					
Riccardia multifida	13, 60-62			II^{2m}				II^{+}						1
Sanionia uncinata	75					I^{2m}								
Schistidium rivulare	21		I^{r}											
Scorpidium cossonii	6, 73, 76, 82					I^{2a}							2a	
Scorpidium revolvens	12, 13, 76			II^{2m}		I^{2m}			I^{2a}					
Sphagnum angustifolium	13, 16, 19-21, 23, 42, 43	III^{2a}	II^{1-2m}	III^{+-2m}	III^{+-2m}									
Sphagnum auriculatum	3, 9, 10, 12-14, 16, 17, 22, 37-39, 49, 57, 71, 74, 76, 82	V^{2m-2a}	II^{2m-2a}	III^{2a-2b}	II^{2a}	II^{2a-2b}			III^{2b}					
Sphagnum centrale	17, 21, 25, 32, 36, 68, 71		I^{2m-2a}			I^{2m}		I^{2b}		II^{2b}				
Sphagnum compactum	50					I^{2m}								
Sphagnum contortum	9, 10, 13, 14, 16, 17, 19, 20, 22, 23, 29, 33, 44, 49, 57, 61, 62, 73, 78, 81	V^{2a-2b}	I^{2b}	V^{2a-2b}	IV^{2b}	I^{2a-2b}		III^{2a-3}	III^{2a}				2a	

continued

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Sphagnum fallax	16, 21, 23, 32, 35, 42, 71	III^{2a}	II^{2m-2a}		II^{2a}	I^{2a}				II^{2m}				
Sphagnum flexuosum	13, 14, 16, 17, 21, 23, 25, 27, 28, 32, 33, 35, 36-39, 42-44, 49, 60, 62-65, 68, 73, 81, 82	V^{2a-2b}	III^{2a-3}	IV^{2b-3}	III^{2a-3}	I^{2a-2b}		III^{2b}	II^{3}	IV^{2b}			2b	1
Sphagnum fuscum	22, 44			II^{2b}	II^{2a}									
Sphagnum girgensohnii	8, 11, 13, 16, 17, 32, 35-39, 42-44, 49, 62, 66, 68, 70, 71, 85	V^{2m-2a}	III^{2m-2a}	III^{2a-2b}		I^{2a}	V^{2a}	II^{2m-3}		IV^{2a}		2a		
Sphagnum inundatum	1, 9, 60, 68, 69, 73, 77, 78					I^{2m-2a}		I^{2m}			2a		2a	2m
Sphagnum magellanicum	44, 49, 71	III^{3}		II^{2b}		I^{2a}								
Sphagnum palustre	13, 19-21, 23, 25, 35, 36, 43, 44, 49, 50, 65, 71, 79	III^{2b}	I^{2a-2b}	IV^{2a-2b}	III^{2a-2b}	I^{2a-2b}				IV^{2a}				
Sphagnum quinquefarium	1	III^{1}												
Sphagnum russowii	13-15, 17, 21, 25, 36, 43, 49, 71, 77, 85	III^{2a}	I^{1-2a}	III^{2m-2a}		I^{2m-2a}	III^{2a}			II^{2a}	2a			
Sphagnum squarrosum	8, 10, 19-21, 32, 34-39, 42, 49, 66, 82	III^{2m}	III^{2m-2a}	II^{2m}	II^{2m}	I^{2m-2a}	III^{2m}			V^{2a}		2m		
Sphagnum subnitens	75					I^{2m}								
Sphagnum teres	10, 13, 14, 16, 17, 19-22, 23, 25, 29, 32-39, 44, 62, 63, 70, 77, 82	III^{2a}	II^{2a-2b}	V^{2m-2b}	V^{2a-2b}	I^{2a-2b}		II^{2a}		V^{2b}	2b			
Straminergon stramineum	1, 6, 13, 16, 17, 19, 20, 22, 28, 36-39, 49, 50, 69-71, 74, 82	V^{2m}	II^{2m}	III^{2m-2a}	III^{2m-2a}	II^{2m-2a}			I^{2a}	II^{2a}				
Tomentypnum nitens	10, 44			II^{2m}		I^{2a}								
Warnstorfia exannulata	2, 4-6, 9, 10, 12-16, 21-23, 25, 28, 29, 32, 33, 37-39, 43, 44, 49, 50, 61-64, 67, 69-71, 74-78, 81, 82	V^{2m}	III^{2m-2a}	IV^{2m-2a}	IV^{2m-2a}	IV^{1-2a}		IV^{2m-2b}	II^{2m-2a}		2a			
Warnstorfia sarmentosa	4, 6, 9, 10, 12-14, 16, 19, 20, 23, 25, 28, 49, 50, 57, 61, 62, 70, 71, 75, 78, 79, 81	V^{2m-2a}	II^{2a}	IV^{2m-2a}	III^{2m-2a}	III^{2a-2b}		II^{1}	IV^{2a}					

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PLANT SPECIES DIVERSITY AND INVASIBILITY OF (PERI-)URBAN FORESTS OF LJUBLJANA, SLOVENIA

[1]KUTNAR L., [2]ELER K.
[1]*Slovenian Forestry Institute, Department of Forest Ecology, Ljubljana, Slovenia*
[2]*Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia & Slovenian Forestry Institute, Ljubljana, Slovenia*
Corresponding author e-mail address: lado.kutnar@gozdis.si

ABSTRACT: Vascular plant species were assessed in the (peri-)urban forests of the Ljubljana region. Among the forests investigated were alluvial and riparian forests with high levels of plant species diversity. However, due to the vicinity of urban areas, the human impact on these forests is intense, and they are also highly exposed to the invasion of alien species. Within three forest locations in urban and peri-urban forests in the Ljubljana region, the vascular plant species were recorded, and their cover and origin status were estimated. In total, 161 vascular plant species were recorded at three study sites. Among them, 13 alien species were recognized. The majority of them were declared to be invasive species in Slovenia, which adversely affect the forest habitats and outcompete native plant species, and consequently, decrease the provisioning of some important ecosystem services such as erosion protection, recreation usage, biodiversity hosting, etc. The most abundant invasive species in the studied sites were *Solidago gigantea* Ait. and *Fallopia japonica* (Houtt.) Ronse Decr. The (peri-)urban forests of Ljubljana are under the significant impact of invasive plant species. The dynamics of expansion of invasive species should be carefully monitored.
Keywords: plant species, diversity, invasive species, (peri-)urban forest, Ljubljana.

1 INTRODUCTION

In urban environments, the proportion of alien species is closely related to the disturbance level (Chytrý *et al.*, 2008; Kowarik, 2008). In many heavily disturbed habitats (brownfields, urban wastelands, railway corridors, and industrial sites), alien species may appear as dominant species. Late-successional habitats are expected to host smaller populations of aliens; however, woody vegetation on urban sites may also include a surprisingly high amount of aliens (Kowarik, 2008).

In Slovenia, there are roughly 50 invasive vascular plant species (Jogan *et al.*, 2012). Black locust (*Robinia pseudoacacia* L.) with 0.6% of the total forest growing stock is the most widespread alien (non-native or non-indigenous) tree species in Slovenian forests (Kutnar & Pisek, 2013). It is widely distributed in lowlands and hilly areas, and in some urban areas. Due to ongoing climate change, even higher share of black locust (Kutnar & Kobler, 2013) and some other invasive plant species can be expected in the future (Dakskobler *et al.*, 2016).

Habitats vary considerably in the level of invasion (number or proportion of alien plant species they contain), which depends on local habitat properties, propagule pressure, and climate (Chytrý *et al.*, 2008). Lowland forests in Slovenia, such as riverine and floodplain forests woods, are highly exposed to the invasion and sub-spontaneous spread of invasive alien species (Dakskobler *et al.*, 2013, 2016). Rivers may act as the dispersal corridors of invasive alien species (Säumel & Kowarik, 2010). These invasive species may adversely affect the forest habitats and outcompete native plant species. Many invasive taxa have transformed both the structures and functions of ecosystems (Rejmánek *et al.*, 2005).

Among the (peri-)urban forests of the Ljubljana region, there are also alluvial and riparian forest types with high level of plant species diversity. However, due to the vicinity of urban areas, the human impact on these forests is intense, and they are also exposed to the invasion of alien species. Therefore, the aim of this study is to address the plant species diversity and to determine the number of alien plant species in selected urban and peri-urban forests in the Ljubljana region. Within the same EMoNFUr Project as in the Ljubljana region, the vegetation and flora in urban forests of Lombardy, Italy were also studied (Digiovinazzo & Padoa-Schioppa, 2014).

2 STUDY AREA AND METHODS

2.1 Study plots and vegetation assessment

In the Ljubljana region, plots for the plant species assessment were set in three different forest sites: i) Gameljne site-1 (G1), ii) Gameljne site-2 (G2), and iii) Rožnik site (R) (Fig. 1).

Figure 1: Position of studied locations in Ljubljana region (Google Earth); G1 - Gameljne site-1; G2 - Gameljne site-2; R - Rožnik site

The Gameljne site-1 was selected on the upper terrace of the Sava River. It is a relatively dry site (gravel bedrock) without direct river influences (Fig 2). The second location, the Gameljne site-2 was selected in the flood area on the lower terrace of the Sava River (Fig 3). Both Gameljne sites are in the peri-urban area. The third

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location was the Rožnik site in an urban area, close to the city centre (Fig 4).

Figure 2: Forest stand on the Gameljne site-1 with *Pinus sylvestris* L. in the upper tree layer, and various broadleaves in the lower tree layer (Photo: L. Kutnar)

Figure 3: The Gameljne site-2 near Ljubljana in spring aspect; it is under direct impacts of the Sava River (Photo: L. Kutnar)

Figure 4: Forest stand at the Rožnik site is located in Ljubljana urban area (Photo: L. Kutnar)

The size of each study site (location) was 2,500 m² (50 meters × 50 meters). Within each site, two different plots were installed; the large plot (400 m²) was set in the centre; 10 small plots (4 m²) were randomly selected around the large plot (Fig. 5).

In April 2013, and between June and July 2013, the assessments of plants and vegetation were performed on large and small plots.

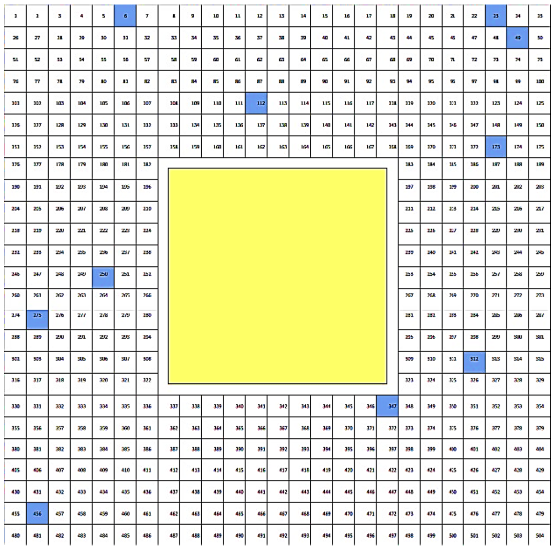

Figure 5: Sampling design; distribution of large plot (in the centre) and 10 randomly distributed small plots around the centre

The cover of all vertical vegetation-layers (moss, herb, shrub, and tree layer) was estimated. The vertical vegetation-layers were defined according to the ICP-Forests protocol (Canullo *et al*., 2011). The percentage cover of each of the above-mentioned layers, as well as the cover of bare soil and of surface rocks, were visually estimated.

All vascular plant species were recorded separately in each vertical layer (herb, shrub, and tree layer) (Canullo *et al*., 2011). On large plots, the plant species cover was estimated using the Barkman *et al*. (1964) method, and the modified Londo (1975) method for small plots. The sources of the plant species nomenclature were Flora Europaea (Tutin *et al*., 1964-1980; 1993) and national flora (Martinčič *et al*., 2007).

2.2. Data analysis

The field data (vegetation relevés) of two temporal repetitions (spring and summer 2013) were merged into one common dataset for each plot. For further vegetation analysis, the cover estimations, for example from r to 5 of the Barkman (1964) scale and from 0.1 to 10 of the Londo (1975) scale, have been transformed to cover estimations in percentage, for example from 0.01% to 87.5% of the Barkman scale, and from 0.5% to 97.5% of the Londo scale.

The following measures of diversity were investigated:

1) Species richness (N) refers to the number of all plant species within a given plot;

2) The Shannon diversity index (H´) is a measure that describes the structural composition of communities:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where p_i is a relative cover of species i in a record.

The plant species diversity, diversity index, and share of invasive alien species were analysed for all large and small plots. Based on the plant species composition in vertical vegetation layers, 30 small plots and main diversity gradients were plotted in non-metric multidimensional scaling (NMS ordination) (McCune & Mefford, 2011).

3 RESULTS AND DISCUSSION

3.1 Plant species composition and diversity

In the secondary pine forest of the Gameljne site-1, *Pinus sylvestris* L. was the dominant species in the upper tree layer, and *Carpinus betulus* L., *Tilia cordata* Mill., and *Corylus avellana* L. were recorded in the lower tree layer. In the forest stand of the Gameljne site-2 near the Sava River, *Alnus glutinosa* (L.) Gaertn., *Salix eleagnos* Scop., *Acer pseudoplatanus* L., and *Fraxinus excelsior* L. were among the most abundant tree species. Plots of the Rožnik site were overgrown by *Quercus petraea* (Matt.) Liebl., *Picea abies* (L.) Karst., *Castanea sativa* Mill., and *Robinia pseudacacia* L.

The most abundant shrub species on the Gameljne site-1 were *Ligustrum vulgare* L., *Lonicera caprifolium* L., and *Viburnum lantana* L.; *Rubus caesius* L. and *Cornus sanguine* L. on the Gameljne site-2; and *Rubus hirtus* W. & K. on the Rožnik site.

The most common herb-layer species on the Gameljnesite-1 were *Carex alba* Scop., *Calamagrostis varia* (Schrad.) Host, *Anemone trifolia* L., *Carex flacca* Schreb., *Galanthus nivalis* L., and *Melica nutans* L.. The dominant herb-layer species on the Gameljne site-2 were *Solidago gigantea* Ait., *Galanthus nivalis* L., *Allium ursinum* L., *Aegopodium podagraria* L., *Fallopia japonica* (Houtt.) Ronse Decr., *Lamium orvala* L., and *Ranunculus ficaria* L. The dominant herb-layer species on the Rožnik site were *Anemone nemorosa* L., *Erythronium dens-canis* L., *Pteridium aquilinum* (L.) Kuhn, *Crocus vernus* (L.) Hill subsp. *vernus*, and *Maianthemum bifolium* L.

On all large and small plots on three sites (Gameljne site-1 and Gameljne site-2, Rožnik site), 161 vascular plant species were recorded in total (Table I). The number of vascular species varied between 61 (Rožnik site) and 85 (Gameljne site-2) per site.

Table I: Species diversity at three sites in the (peri)-urban forest

	All sites	Gameljne site-1	Gameljne site-2	Rožnik site
All plots	n=33	n=11	n=11	n=11
N Vascular species	161	69	85	61
Tree species	36	21	14	22
Shrub species	21	14	15	7
Herb species	104	34	56	32
Invasive species	9	0	8	3
Large plot (400 m^2)	n=3	n=1	n=1	n=1
N species per plot	63.3	66	68	56
Shannon H'	3.39	3.17	3.51	3.48
Small plot (4 m^2)	N=30	N=10	N=10	N=10
N species per plot	19.3	17.7	22.1	18.1
Shannon H'	2.24	2.26	2.34	2.09

In total, in all vertical vegetation layers; herb, shrub, and tree layers, 36 tree species were identified. The number of all shrub species, including climbers, was 21. Altogether, 104 herb layer species (including only non-woody species) were documented.

On average, 63 plant species per large plot, and 19 plant species per small plot were documented.

3.2 Alien species

On the Gameljne site-2 near the Sava River, and on the Rožnik urban site, several alien plant species were found (Table I, Fig. 6). The majority of them have been declared to be invasive species in Slovenia. These invasive plant species, which represent 6% of the flora recorded (Fig. 7), probably come from different urban areas, e.g. gardens and parks. The majority of invasive species identified on studied sites are of North American or Asian origin.

Figure 6: In summer time, the forest floor of the Gameljne site-2 was covered by a dense layer of invasive alien species, *Solidago gigantea*, *Fallopia japonica*, *Rudbeckia laciniata* L. and others (Photo: L. Kutnar)

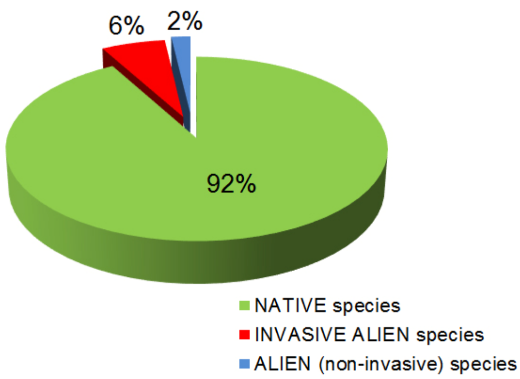

Figure 7: Alien and invasive species in the floristic spectrum of three (peri-)urban forests in the Ljubljana region

Among three sites in (peri-)urban forests in the Ljubljana region in Slovenia, the level of plant invasion was the highest at the Gameljne site-2 (9% or 8 species) (Table I). The most abundant invasive species on this site were *Solidago gigantea* and *Fallopia japonica* (including hybrid *F.* x *bohemica*) (Fig. 8 and Fig. 9). Other invasive species were *Rudbeckia laciniata* (Fig. 10), *Erigeron annuus* (L.) Pers., *Helianthus tuberosus* L., *Impatiens glandulifera* Royle, *Impatiens parviflora* DC., and *Physocarpus opulifolius* (L.) Maxim.

Besides the invasive species *Robinia pseudacacia*, *Berberis thunbergii* DC., and *Impatiens parviflora*, three alien but non-invasive species were also recorded on the Rožnik site, namely *Aesculus hippocastanum* L., *Prunus laurocerasus* L., and *Juglans mandshurica* Maxim.

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Figure 8: *Solidago gigantea*, and similar species *Solidago canadensis* L. are invasive alien species of riverine, floodplain and swamp forests in Slovenia (Photo: L. Kutnar)

Figure 9: *Fallopia japonica* and *F.* x *bohemica* are invasive species that colonize different riparian ecosystems, roadsides, and waste places. (Photo: L. Kutnar)

Figure 10: *Rudbeckia laciniata* is one of the most widespread species on the Gameljne site-2 and also in Slovenia (Photo: L. Kutnar)

3.2 Main ecological and diversity gradients

Distribution of plots in the NMS ordination space reflects the main ecological and diversity gradients (Fig. 11). Axis 2 correlates closely with the gradient of water availability. At the lower values of Axis 2, the Gameljne site-2 plots are placed, which are under significant river impact, including occasional flooding. The forest vegetation of this site belongs to a *Salici-Populetum* s. lat. association.

At the upper part of the ordination space (Fig. 11), plots on the Gameljne site-1 and Rožnik site, where direct water impacts are not pronounced, may be found. The forest vegetation of these two sites may be considered a *Querco-Carpinetum* s. lat. plant community. However, the forest community composition of both sites is rather different, mostly due to differences in soil and bedrock properties. Both sites were exposed to significant human impacts, such as the provision of timber and fuel wood, litter gathering for farm use, collecting of non-timber forest products, and urbanisation, industrialisation, recreation activities mostly in the last decades, and therefore these forest stands were modified or even converted to secondary forests.

Additionally, Figure 11 depicts the main diversity gradients. On average, plots at the bottom of the ordination space are characterized by higher plant species diversity (see also Table I). The abundance of invasive plant species was higher on the Gameljne site-2 than on the Rožnik site, and on the Gameljne site-1 where no invasive species were found. Values of the Shannon diversity index were slightly higher on the Gameljne site-2 (2.34) and the Gameljne site-1 (2.26) than on the Rožnik site (2.09) (Table I, Fig. 11).

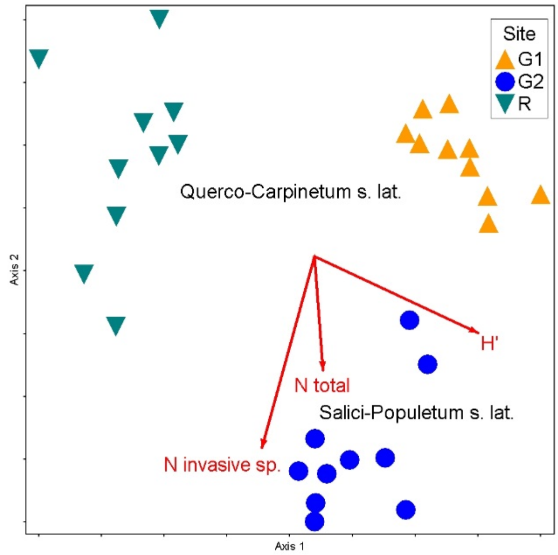

Figure 11: NMS ordination of small plots. Three test sites (locations) are represented by symbols as follows: G1 – Gameljne site-1; G2 – Gameljne site-2; R – Rožnik site. Scaling of plots was based on the plant species composition and species abundance in vertical vegetation layers. The main diversity gradients (the number of all vascular species (N total), the number of invasive alien species (N invasive sp.), and Shannon diversity index (Shannon H')) are plotted. The lengths of arrows depict the increase in species number or in theindex value.

4 CONCLUSIONS

In studied sites of the Ljubljana (peri-)urban forest area, high levels of vascular plant species diversity were determined. If the diversity of these forests is compared with the other main forest types of Slovenia (e.g. ICP

Forest Level II plots; Kutnar, 2006) the species diversity of (peri-)urban forests is, on average, higher.

The total number of plant species (161 species) recorded on three sites in Ljubljana region is also significantly higher than in the sites within different lowland forests, urban plantations, and parks in the Lombardy region, Italy (120 species on 14 sites; Digiovinazzo & Padoa-Schioppa, 2014). In both regions, the same harmonised method for evaluation of plant species diversity was applied.

However, the significant impact of invasive alien plant species was determined in the (peri-)urban forests of Ljubljana. Among all the plant species identified on studied sites 8% were alien and 6% of all were invasive. In comparison to the studied Ljubljana forests, the portion of alien species in Lombardy urban forests and parks was higher (15%; Digiovinazzo & Padoa-Schioppa, 2014). Kowarik (2008) reported an even higher amount of alien species number (33%) in urban stands dominated by *Robinia pseudoacacia*, but it is known that disturbed human-made habitats with herbaceous vegetation are the most invaded by aliens (Chytrý *et al.*, 2008).

It was suggested that there is not necessarily a relationship between the invasibility of a plant community and the number of species present in that community (Crawley *et al*., 1999; Davis *et al*., 2000). Other studies show that such a relationship exists: positive at the landscape scale (Stohlgren *et al*., 1999; Sax, 2002) and negative at scales of < 1 m² (Levine, 2000). Taking into account 30 small plots (4 m²) studied in (peri-)urban forests in the Ljubljana region, the weak positive correlation (Pearson r = 0.254) between total species number and the number of invasive species was established.

Invasive species may outcompete native plant species, may change forest habitats, and may disturb natural forest regeneration, ecosystem services, and functions (Rejmánek *et al*., 2005). Among forest services in urban areas, the recreation use is one of the most significant. Besides the considerable change of the plant species composition of forest vegetation in the Sava River, and partly also in the urban forest on the Rožnik site, we determined that the dense cover of invasive species may negatively affect the accessibility and use of paths along river and the forest alone, and invasive species may affect the whole physiognomy of the riparian forests.

Therefore, in Ljubljana (peri-)urban forests, the dynamics of expansion of invasive species should be carefully monitored, and appropriate measures for its limitation need to be established in the near future. More forest management and silvicultural activities should be engaged with regard to the invasive species that already disturb the forest development, structure, and functions of (peri-)urban forests.

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Original scientific article

FIRST RECORDS FOR SEVEN SPECIES AND ONE HYBRID FOR THE FLORA OF THE REPUBLIC OF MACEDONIA

MELOVSKI Lj., HRISTOVSKI S.
Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, Macedonia
Corresponding author e-mail address: melovski@pmf.ukim.mk

ABSTRACT: Contribution to the knowledge of distribution ranges of several plant species is presented in this article. The following plant species were recorded in course of the botanical research during last several years and they represent new findings for the flora of the Republic of Macedonia: *Polypodium interjectum, Polypodium* x *mantoniae*, *Clematis recta*, *Salix repens* subsp. *rosmarinifolia*, *Lathraea rhodopea*, *Cirsium grecescui*, *Eleocharis mamillata* subsp. *austriaca* and *Arabidopsis arenosa*.
Keywords: Macedonia, flora, new records.

1 INTRODUCTION

The flora of the Republic of Macedonia is extraordinary rich in comparison with the territory of the country and taking into account that it is a landlocked country. According to recent data, 210 families, 920 genera and 3700 species comprise the flora of higher plants, angiosperms being the richest group with about 3200 species [28]. This makes the flora of the Republic of Macedonia one of the richest floras in the context of the whole European continent [43]. Diverse geological, geomorphological and climatic factors, as well as historic circumstances have contributed for such richness and diversity of vascular plants [28, 37]. As a result, the current Macedonian flora represents a mosaic of various floral elements – Tertiary relicts, Mediterranean, Greek-Asia Minor, Caucasian, arcto-alpine, middle-European, Eurasian, Holarctic and cosmopolitan [28]. Endemic taxons (Illirian, Scardo-pindic, Balcan etc.) represent a special characteristic and value of the Macedonian flora. Among them, 114 flowering plant species are Macedonian endemics [28, 40, 41]. Due to these floral values, 42 Important Plant Areas were recently identified across Macedonian territory [37].

The flora of the Republic of Macedonia has been intensively studied for more than one and a half century. The most extensive data can be found in [3, 4, 5,6,17, 30, 39]. Floristic contributions with new species and/or findings for the flora of Macedonia are regularly published as well, like for example in [10, 11, 12, 13, 26, 27, 29, 31, 32, 33, 34, 35, 42, 43]. In addition, several new plant species were described in the last ten years from the territory of the Republic of Macedonia: *Helianthemum marmoreum* Stevan., Matevski & Kit Tan [41], *Jurinea micevskii* Stevan., Matevski & Kit Tan [42], *Festuca jakupicensis* Kostadinovski [21], *Viola pseudaetolica* Tomović, Melovski & Niketić [44].

This paper represents the continuation of the floristic studies of vascular flora of the Republic of Macedonia. Data on seven new species and one new hybrid for the flora of Macedonia, collected at different localities throughout the country are presented in this paper.

2 METHODS

The study was based on fieldwork in the territory of the Republic of Macedonia during the last two decades and collected and stored plant material in Herbarium Melovskiorum (MKMEL!) [47], as well as in the Biology Students Research Society herbarium of the Faculty of Natural Sciences and Mathematics in Skopje. Besides the field survey, relevant literature sources were used for supplementation of the distribution records.

The determination of species was done according to standard floras and related recent taxonomic articles. Identification of the two *Polypodium* taxa was performed with microscopic method by analysis of indurated cells per annulus and basal cells per sporangium as well as the proportion of sterile spores in sporangia [22].

We followed the nomenclature of the taxa used in Euro+Med Plant Base (http://ww2.bgbm.org/EuroPlusMed/query.asp). The quotation of the distribution locations and habitats for all records in this article follows the MAKMEL data base pattern.

The regional division of Melovski *et al.* [38] was used to present the general geographic position of the localities.

3 RESULTS AND DISCUSSION

***Polypodium interjectum* Shivas** in J. Linn. Soc., Bot. 58: 28 (1961)

First chorological records in Macedonia

Mt. Belasica: above v. Smolare – Smolarski Vodopad, on the rock in chestnut forest, 550 m a.s.l., 15.09.2009, leg. S. Hristovski, det. Lj. Melovski (MKMEL! 04335-04339); Bistra: Lopušnik – Dolen Lopušnik, on limestone rocks in narrow dale with horse chestnut and beech forest, 900-1000 m a.s.l., 10.08.2010, leg./det. Lj. Melovski (MKMEL! 04341); Bistra: above v. Janče – lower part of the valley of Galička Reka, silicate rocks in mixed broadleaf forest next to the river, 800-900 m a.s.l., 29.07.2010, leg./det. Lj. Melovski (MKMEL! 04343-04347); Plačkovica: Zrnovska Reka – between Orlov Kamen and Ploča peaks, mixed broadleaf forest with linden, beech, *Carpinus betulus* and other trees, 600-700 m a.s.l., 4.09.2014, leg./det. Lj. Melovski (MKMEL! 08189); Plačkovica: v. Laki – Selska Reka valley (between Strumički Rid and Kartal - below and above the inflow of Lomska Reka), eroded stony site next to the road in beech forest, 950-1000 m a.s.l., 24.10.2014, leg./det. Lj. Melovski (MKMEL! 08190); Drimkol: Drenočka Reka – just above the inflow into Crn Drim, limestone stony site in mixed broadleaf forest in mesophilous ravine, 735 m a.s.l., 16.11.2014, leg./det. Lj. Melovski (MKMEL! 08191 and 08192).

P. interjectum grows in deep and humid forested dales and ravines and was found in several localities in Macedonia) (Fig. 1). It is broadly distributed in Europe

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[51] but its distribution in Balkan Peninsula was not well studied until recently when it was recorded in several Balkan countries [7, 21, 22]. This species was not mentioned in the Flora of the Republic of Macedonia Micevski [39]. The ecology of this species and its closely related *P. vulgare* as well as the main taxonomic characteristics is described in Ivanova [22].

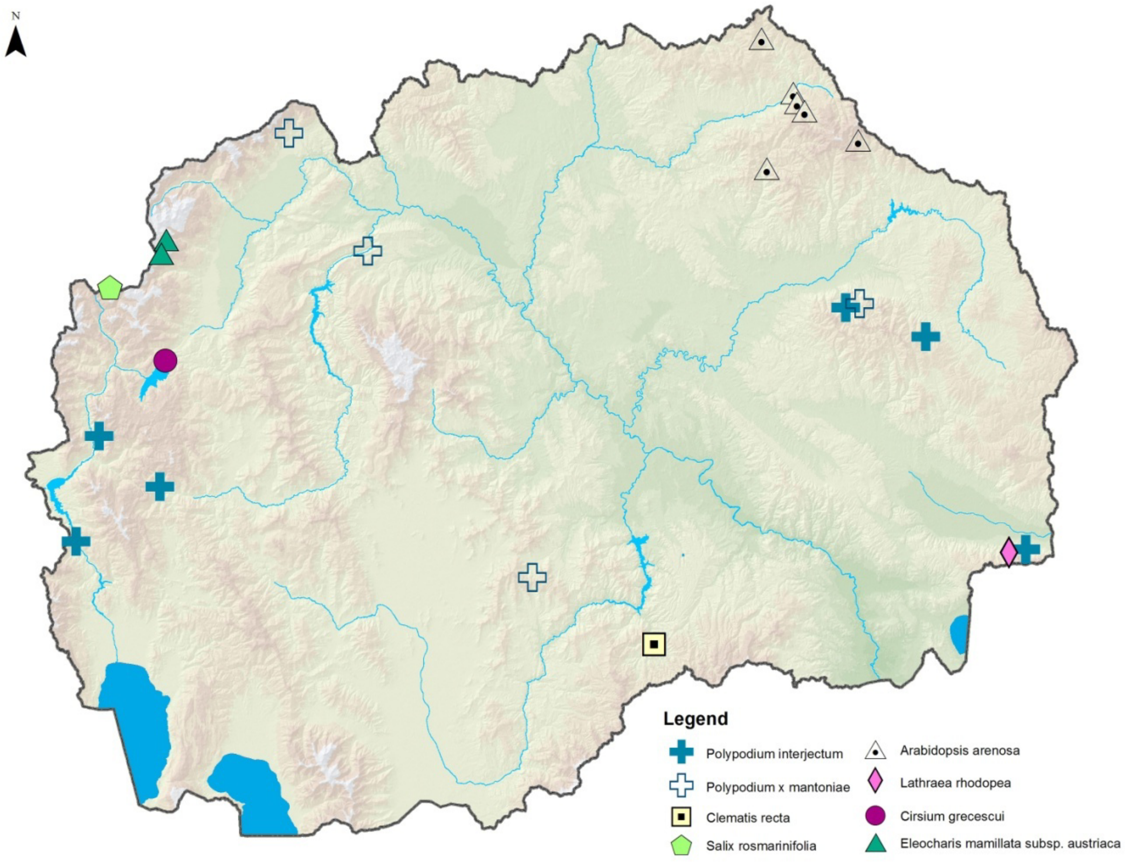

Figure 1: Distribution map of the first records of seven plant species and one hybrid in the Republic of Macedonia

***Polypodium* x *mantoniae* (Rothm.) Shivas** in Rothm. & U. Schneid., Kulturpflanze Beih. 3: 245 (1962) [*P. interjectum* Shivas x *P. vulgare* L.]

First chorological records in Macedonia

Treska canyon: Matka – near the cave "Krštalna", limestone stony ground, 320 m a.s.l., 04.09.2009, leg. S. Hristovski, det. Lj. Melovski (MKMEL! 04329-04333); Dren: below Ligurasa – toward Dlaboki Dol, on silicate rocks in shady and mesophilous dale, 950 m a.s.l., 28.04.2012, leg./det. Lj. Melovski (MKMEL! 04348); Šar Planina: Podgora – Petočko Vodiče (above v. Belovište), Silicate rocks next to the brook in beech forest, 920 m a.s.l., 12.09.2012, leg./det. Lj. Melovski (MKMEL! 04349-04351); Plačkovica: above v. Gradec – Next to Gradečka Reka (below Garvan), on silicate rocks in beech forest - mesophilous site, 870 m a.s.l., 30.11.2012, leg./det. Lj. Melovski (MKMEL! 04352).

This taxon was described in 1960-ties but its distribution is not well known. Only recently some papers appeared confirming its distribution in Balkan Peninsula [7, 19, 21, 22]. *P.* x *mantoniae* can be found together with the populations of its parent plant species but it also has well established populations in sites where one parent plant is absent (Fig. 1). This may be result of lack of complete distribution data for both parent plants. It is also evident that *P.* x *mantoniae* populations are vigorous and effectively spread vegetatively [22].

***Salix repens* subsp. *rosmarinifolia* (L.) Andersson** in Sp. Pl. 1020 (1753) [syn.: *Salix rosmarinifolia* L.]

First chorological records in Macedonia

Šar Planina: Dolno Lukovo Pole – upper part, peat-bog/mire, 1730 m a.s.l., 24.05.2010, leg. Lj. Melovski & S. Hristovski, det. Lj. Melovski (MKMEL! 04313-04315); Šar Planina: Dolno Lukovo Pole – upper part, peat-bog/mire, 1730 m a.s.l., 10.07.2011, leg./det. Lj. Melovski (MKMEL! 04311 and 04312).

Only one locality of this willow species in north-western Macedonia (in the southern part of Shar Planina Mt.) is known so far (Fig. 1). Only one cluster of *Salix repens* subsp. *rosmarinifolia* (Fig. 2) was discovered in Dolno Lukovo Pole peat land (Fig. 3). This cluster of shrubs was partially burnt at the end of 2011. In the south and central Balkans it is known from Bulgaria [18] and Serbia [24].

Figure 2: *Salix repens* subsp. *rosmarinifolia* – habitus; (a) the whole cluster, (b) branches with leaves, (c) young branch with female flowers (Photo: S. Hristovski)

Figure 3: Dolno Lukovo Pole mires – *Salix repens* subsp. *rosmarinifolia* habitat (Photo: Lj. Stefanov)

***Clematis recta* L.** in Sp. Pl. 554 (1753)

First chorological records in Macedonia

Rožden region (Mariovo): v. Mrežičko – below Glavite, mixed broadleaf forest in mesophilous ravine on limestone ground – next to the stream, 600 m a.s.l., 30.05.2010, leg. Lj. Melovski & S. Hristovski, det. Lj. Melovski (MKMEL! 02961).

Clematis recta was found only on one locality close to v. Mrezhichko in Mariovo region (Fig. 1). This species is common in Central, South and East Europe [50].

***Arabidopsis arenosa* (L.) Lawalrée** in Bull. Soc. Roy. Bot. Belg. 42: 242 (1969). 1969 [syn.: *Cardaminopsis arenosa* (L.) Hayek]

First chorological records in Macedonia

Bilina Planina: v. Podržikonj, Zli Dol – below Mišinci, beech forest, 1000 m a.s.l., 15.05.2005, leg./det. Lj. Melovski (MKMEL! 05154); Osogovski Planini: Kriva Palanka – Varoški Rid, hornbeam forest with sessile oak, 700-750 m a.s.l., 15.05.2011, leg./det. Lj. Melovski (MKMEL! 05155); Osogovski Planini: Emirica – above the inflow of Emirička Reka into Zletovska Reka, eroded sandy site next to the road, 850 m a.s.l., 03.05.2008, leg./det. Lj. Melovski (MKMEL! 05156);

Osogovski Planini: Ruen – above Toranica mine, beech forest – close to the road, 1430 m a.s.l., 23.05.2009, leg./det. Lj. Melovski (MKMEL! 05157); Osogovski Planini: v. Stanci – in the village, grassy site next to the road and houses, 850 m a.s.l., 13.05.2007, leg. IDSB '07, det. Lj. Melovski (MKMEL! 05158); Osogovski Planini: v. Duračka Reka – next to Stanečka Reka, next to the road and houses, 700-750 m a.s.l., 13.05.2007, leg. IDSB '07, det. Lj. Melovski (MKMEL! 05159).

Arabidopsis arenosa is widespread species in Europe and in the neighbouring countries [2, 23, 27]. The species was cited by Hayek [20] for Ma (=Mazedonien) but it was not included in the flora of Macedonia by Micevski [39]. The term "Mazedonien" in Hayek [20] does not coincide with the present administrative territory of the Republic of Macedonia.

All of the presented records from Macedonia are from the north-east part of the country (Fig. 1).

***Lathraea rhodopea* Dingler** in Bot. Zeitung (Berlin) 35: 74 (1877)

First chorological records in Macedonia

Belasica: above v. Smolare – below Šarena Češma, mixed broadleaf forest with beech, 800-1100 m a.s.l., 17.05.2010, leg. Lj. Melovski & S. Hristovski, det. S. Hristovski & Lj. Melovski (MKMEL! 04316).

Lathraea rhodopea (Fig. 4) was found on Belasica Mt. (Fig. 1), which actually represents a continuation of the Rhodope massif and Slavyanka Mt. toward Macedonia. Up to now, this species was known from south Bulgaria and north-east Greece [1, 14].12]. The new finding extends its distribution range toward west.

Figure 4:*Lathraea rhodopea* from Belasica Mt. (Photo: S. Hristovski)

***Cirsium grecescui* Rouy** in Bull. Soc. Bot. France 37: 164 (1890)

First chorological records in Macedonia

Bistra-Šar Planina: Children's resort "Bunec" – below the resort, marshy site next to a small stream, 1250 m a.s.l., 25.08.2004, leg. Lj. Melovski & N. Angelova, det. Lj. Melovski (MKMEL! 00180).

Cirsium grecescui (Fig. 5) was found on the border between Shara Mt. and Bistra next to the wetland at the Bunec resort (Fig. 1). This record was already announced in Melovski & Matevski [36]. It was known from south and east Romania and north-east Serbia [8] although in the Flora of Serbia it is quoted as common plant, but without exact distribution localities [15]. However, it was recently reported from Sokolovica [49] and Rogozna mountains [44] in central and southwest Serbia which is the closest finding to the locality from Macedonia.

Figure 5:*Cirsium grecescui* from Bunec wetland – habitus (a) and inflorescence (b) (Photo: Lj. Melovski)

***Eleocharis mamillata* subsp. *austriaca* (Hayek) Strandh.** in Opera Bot. 9(2): 9 (1965) [Basionym: *Eleocharis austriaca* Hayek]

First chorological records in Macedonia

Šar Planina: Borislovec-Mala Smreka – Bogovinsko Ezero, sandy-gravely place next to the lake, 1935 m a.s.l., 08.09.2006, leg./det. Lj. Melovski (MKMEL! 01588); Šar Planina: Rudoka – above Crno Ezero, small pond, 2250 m a.s.l., 30.07.2008, leg. Lj. Melovski & N. Angelova, det. Lj. Melovski (MKMEL! 01590).

Eleocharis mamillata subsp. *austriaca* grows on Shar Planina next to the alpine lake Bogovinsko Ezero and above Crno Ezero (Fig. 1). This subspecies is known from Europe and Asia. Most of the European records come from the Alps but it is also known from Pyrenees, Carpathians and Pirin mountain in Bulgaria [16] and Tara Mt. in Serbia [52].

4 CONCLUSIONS

Seven plant species and one hybrid were recorded for the first time in the flora of the Republic of Macedonia: *Polypodium interjectum* Shivas, *Clematis recta* L., *Salix repens* subsp. *rosmarinifolia* (L.) Andersson, *Lathraea rhodopea* Dingler, *Cirsium grecescui* Rouy, *Eleocharis mamillata* (H. Lindb) H. Lindb. subsp. *austriaca* (Hayek) Strandh., *Arabidopsis arenosa* (L.) Lawalrée and *Polypodium* x *mantoniae*. The discovery of these species was well expected, or not surprising for some of them, since they are known from neighbouring countries. The records of *Salix repens* subsp. *rosmarinifolia, Cirsium grecescui* and *Eleocharis mamillata* subsp. *austriaca* represent one of the southernmost localities in Europe. These three species were found in wetlands on the high mountains in west Macedonia. The Balkan endemic species *Lathraea rhodopea* was found in south-east Macedonia and this record extends its distribution range westwards.

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BOREO-MONTANE FOREST PHYTOCOENOSES IN CENTRAL STARA PLANINA MTS.

[1]NIKOLOV I., [2]DIMITROV M.
[1]*Central Balkan National Park Directorate, Gabrovo, Bulgaria*
[2]*University of Forestry, Department of Dendrology, Sofia, Bulgaria*
Correspondig author e-mail address: mariusdimitrov@abv.bg

ABSTRACT: This study deals with the subalpine conifers and related birch forests on the territory of National Park "Central Balkan"in Bulgaria. It is a part of a comprehensive study on the forest vegetation in the Park. 30 relevés were collected during the field research. JUICE, TWINSPAN and STATISTICA were applied for classification and statistical analysis. The studied forests are fragmented and do not form a continuous altitudinal belt within the park. The species composition, ecology and distribution determine their differentiation into four groups of phytocoenoses. Most widespread are the communities dominated by Norway spruce, which combine mesohygrophitic and eutrophic phytocoenoses, forming the timberline. Community of *Picea abies* and *Luzula sylvatica* includes woods, tied to acidophilous and relatively less humid and poor soil. Mesophytic and mesotrophic community of *Betula pendula* develops in areas where the timberline is composed of spruce forests, mostly southward from the main ridge of the mountain. The natural habitat of the Macedonian pine in the study area represents northernmost locality of its natural area of distribution and is the only one in Stara Planina Mts. Two associations were described: *Adenostylo alliariae-Pinetum peucis* and *Ranunculo carthusianae-Piceetum abietis*. They include hygromoesophytic and mesotrophic forests, forming some parts of the alpine timberline.
Keywords: subalpine forests, classification of vegetation, diagnostic species, environmental variables, *Pinus peuce*, phytocoenoses.

1 INTRODUCTION

Holarctic disjunctions are biogeographical phenomena formed after cooling of the climate during the Pliocene and are expressed in both distribution of plant species and communities in areas with different latitude and different altitude [1]. Boreal mountain disjunction includes coniferous forests growing north in the taiga and their vicariant phytocoenoses that develop in the high mountains in the central and southern parts of the continent. This is determined by the temperature gradient that changes analogously from south to north in the plains and from lower to higher altitudes in the mountains. According to the proposed altitudinal stratification of mountain systems depending on environmental, floristic and vegetation criteria, the coniferous forests grow in the lower subalpine belt [2]. According to the traditions concerning the zone differentiation of vegetation in Bulgaria [3, 4, 5] the boeral coniferous forests grow in the high mountain belt, which is equal to the lower subalpine belt, according to the traditional European stratification [2, 6].

Boreal forests include monodominant and polydominant coniferous and deciduous-coniferous forest phytocoenoses developing on diverse habitats. In southeastern Europe this vegetation is defined as a submediterranean and subcontinental mountain vegetation [7]. Besides typical boreal elements it is constituted of part european and endemic elements, which makes it somewhat different from the typical boreal vegetation. This research confines to the approach of boreal vegetation [8] and the visions for the hemiboreal vegetation in Southeast Europe [9, 10, 11, 12]. Similar mountain vegetation in Europe is found only on higher mountain ridges - the Pyrenees, the Alps, Jura, Black Forest, Hercynian hills, Thuringia, Carpathians, Dinaric Alps, Rhodope, Rila, Pirin, Stara Planina, and the Caucasus. Regional features are the main reason for the formation of a large number of regional plant associations.

Central Stara Planina is the northernmost mountain in Bulgaria with occurrence of vegetation types, common to the mountains in Central Europe [2] (between the boreal and mediterranean zone).

Forest communities in Central Stara Planina had been partly studied by different methodological approaches for collection, analysis and aggregation of phytocoenotic information [13, 14, 15, 16, 17, 18, 19, 20, 21, 22]. Currently there is not a comprehensive classification scheme providing an idea of the syntaxonomic diversity. The beech forests were relatively well studied out of the forest habitats and plant communities [23]. There is also some information about syntaxa in the forests in some of the reserves located within Central Stara Planina, differentiated using the Broun-Blanquet`s approach [17, 18, 22].

This research is part of a comprehensive study of the forest vegetation within the "Central Balkan" National Park, which covers the highest part of the Central Stara Planina. Main purpose is to study the boreo-montane forest phytocoenoses, which includes subalpine coniferous and related birch forests.

2 MATERIALS AND METHODS

Central Stara Planina is the highest part of the Stara planina Ridge, located between Zlatishki and Shipchenski passes (Fig. 1). Well shaped are Zlatishko-Tetevenski parts (Vejen peak – 2198 m.a.s.l., Troyanski (Kupena peak – 2169 m.a.s.l.) and Kaloferski (Botev peak – 2376 m.a.s.l.). The studied area falls within the Meridional zone, Submediterranean region, Balkan province [24]. The climatic conditions in this area are diverse and with dynamic changes in their values. This is due to the rough terrain, deep river valleys and hollows. The climate in the northern parts of the territory is temperate continental and

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in the southern parts is subcontinental. The thermal conditions are characterized by well-defined seasons, depending on the topography of the region [25]. This study covers the areas in the mountain belt (1500 - 2000 m.a.s.l.), characterized by a short vegetation period, an average annual temperature between 3,3°C and 5,1°C and annual rainfall sum from 860 to 1300 mm/m^2 [25]. Hydrographic system has a very high overall density – 3,03 km/km^2.

Figure 1: Location of Central Stara Planina Mts.

Soil variability is represented by zonal soils of the classes Cambisols – Dystric-Eutric Cambisols, Umbric Cambisols, Modic Cambisols [26].

Coniferous forests occupy a limited area primarily in the higher western and central parts of Central Stara Planina.

For purposes of this study in the period May 2011 – July 2013 30 relevés were established in the range of 1450-1850 m.a.s.l. The combined (cover-abundance) scale of Braun-Blanquet was used [27, 28].

When drawing up the environmental characteristics and while performing the gradient analysis the following factors and indicators were taken into account: exposition, slope, altitude, soil type, bedrock, stoniness, mechanical structure, morphological complexity, continentality, humidity, precipitation, light, and temperature. Environmental groups of plants were determined according Ellenberg [29].

The nomenclature of higher plants is according Delipavlov and Cheshmedjiev [30]. Floral elements were determined using the system of Walter [31].

Phytocoenological nomenclature is according ICPN [32] and the referenced literature. Sintaxa to alliance level are in accordance with the concepts of Rodwel et al. [33] and Mucina et al. [34]. Natural habitats are according Kavrakova et al. [35] and Biserkov et al. [36].

Phytocoenological analysis was conducted according to the Braun-Blanquet approach [27]. The classification analysis was perfomed by using the software product JUICE [37]. Cluster analysis was done using Modified TWINSPAN [38] and additional use of control clustering tools TWINSPAN 1979 and K-means [39]. Sorensen`s dissimilarity index was used.

Phi-coefficient (fidelity – association ratio between species and plant units) was used to determine the diagnostic species [40]. Preliminary thresholds for fidelityare Phi ≥20 Lower, ≥60 Higher [41, 42, 43]. The values of the constancy of species was taken into consideration [41]. The thresholds accepted for constant species are those with 'Frequency threshold' – ≥50 Lower, ≥60 Higher. Dominant species have cover higher than the upper limit provided in the methodology ≥ 20 Lower, ≥60 Higher. For the purpose of comprehensive treatment of the database the program STATISTICA [44] was used.

Classification of species was done using the scale of Ellenberg [29]. To assess the influence of several factors (variables) we used simultaneously the multidimensional variance analysis. Also, descriptive analysis of the environmental variables was performed (Descriptive statistics). 26 environmental variables were compared in the range of 30 relevés. A separate grouping of environmental factors equal to the grouping of the phyto-coenotic descriptions was achieved as a result. Principal Components Analysis (PCA) for ordinates of vegetation to environmental variables was put into practice [29].

3 RESULTS AND DISCUSSION

As a result of the implemented classification and coordination procedures 4 basic syntaxa were identified.

They are included in the following syntaxonomic scheme:

Class *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939
Order *Piceetalia excelsae* Pawłowski et al. 1928
Alliance *Piceion excelsae* Pawłowski et al. 1928
Eu-Vaccinio-Piceenion Oberdorfer 1957
Association *Ranunculo carthusianae-Piceetum abietis* ass. nova (holotypus hoc loco, Annex I, rel. 8)
Community of *Picea abies* and *Luzula sylvatica*
Community of *Betula pendula*
Alliance *Pinion peucis* Horvat 1950
Association *Adenostylo alliariae-Pinetum peucis* ass. nova (holotypus hoc loco, Annex I, rel. 28)

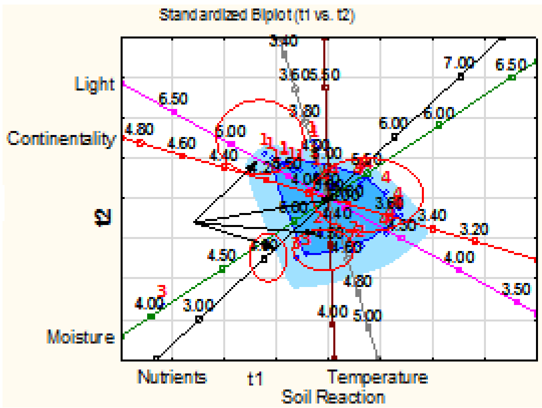

Figure 2: PCA of the boreal mountain forests on the territory of Central Stara Planina. 1 – Assoc. *Ranunculo carthusianae-Piceetum abietis*; 2 – Comm. of *Picea abies* and *Luzula sylvatica*; 3 – Comm. of *Betula pendula*; 4 – Assoc. *Adenostylo alliariae-Pinetum peucis*.

Fig. 2 illustrates the spatial arrangement of the isolated phytocoenoses in relation to the floristic similarity and the main environmental factors. Phytocoenoses from group № 1 develop on moderately moist acidic soils at low temperatures and sufficient light. Group № 2 prefers less acidic substrates and relatively higher temperatures. Plant communities of Group № 3 develop at relatively low humidity and on poorer soils. Group № 4 combines hydrophilic and eutrophic communities.

3.1 Forests of *Picea abies*

Total 18 phytocoenotic relevés were done in this type of forest. Group №1 includes monodominant spruce forests. Group №2 unites forests with domination or high participation of *Picea abies*, in some places dominated by *Pinus peuce* and rarely (one time each) by *Abies alba* and *Fagus sylvatica*. The phytocoenoses dominated by or with participation of *Betula pendula* - group № 3 – possess high floristic and ecological similarity with forests of *Picea abies*. Species composition and location of these forests show that they are part of the succession line, developing on the site where coniferous forests were destroyed in the past. That is why they are referred to the alliance *Piceion excelsae* and are considered simultaneously as related to climax spruce forests.

High-mountain forests of *Picea abies*, monodominant or involving other conifers, form associations related to suballiance *Eu-Vaccinio-Piceenion* Oberd. 1957 and alliance *Piceion excelsae* Pawłowski et al. 1928. In Central Europe these communities often include *Larix europea*, *Pinus cembra* and *Pinus uncinata*, which sometimes form also monodominant phytocenoses. The spruce forests in Southeastern Europe are distinctive and with regional characteristics derived from both their history and the zonal location of mountains where they develop. Some authors accept the differentiation of regional suballiances, while others describe the regional associations. Based on some floristic characteristics in Romania the suballiance *Soldanello majori-Piceenion* Coldea 1991 is described [45, 46] as synvicariant of *Eu-Vaccinio-Piceenion* Oberd. 1957. The following associations are related to it: *Hieracio rotundati-Piceetum* Pawl. et Br.-Bl. 1939, *Luzulo sylvaticae-Piceetum* Wraber 1953, *Bruckenthalio-Piceetum* Borhidi 1969, *Vaccinio-Piceetum* Brez. et Had. 1962, *Sphagno-Piceetum* Brez. et Had. 1962, *Soldanello majori-Piceetum* Coldea et Wagner 1998 [45, 46, 47, 48, 49, 50, 51].

Phytosociologists in Serbia [52, 53, 54, 55, 56, 57, 58] point out a series of associations related to *Eu-Vaccinio-Piceenion* – *Junipero sibiricae-Piceetum* (Rudski 1947) Mišić et Popović 1980, *Oxali acetosellae-Piceetum abietis* (Rudski 1947) Mišić et Popović 1980, *Arctostaphyllo-Piceetum* (Jov. 1953) Mišić et Popović 1954.

The association *Piceetum subalpinum scardicum* Em (1962) 1986 was described in Macedonia (Jovanović et al. 1986). In Slovenia Zupančić (1980, 1999) includes spruce phytocoenoses in *Luzulo sylvaticae-Piceetum* Wraber 1963 em. Zupančić 1999 and *Luzulo albidae-Piceetum* Zupančić 1980. For Western Balkans the following associations were reported: Bosnia and Herzegovina - *Sorbo-Piceetum* Fukarek 1964; Croatia – *Piceetum croaticum subalpinum* Ht. (1950) 1967, *Helleboro nigrae-Piceetum* (Ht. 1958) Trinajstič et Pelcer 2005; Montenegro - *Piceetum abietis bertisceum subalpinum* Blečić (1961) 1964 [54]. In Greece the spruce forests have limited distribution. Dafis [59] refers them to the association *Piceetum abietis* s.l. and alliance *Piceion excelsae.*

In Bulgaria the spruce phytocoenoses are not enough studied. Most frequently mentioned in the phytocoenotic is the association *Piceetum myrtillosum*, distinguished by using the dominant method of Russian-Scandinavian phytocoenological school [6, 60]. Michalik [18] mentions the association *Piceetum excelsae balcanicum* (nom. illeg. – ICPN Art. 2b, 5, 34a) for the territory of the reserve "Boatin" (Central Stara Planina) [32]. An attempt to clarify the syntaxonomical status of spruce phytocoenoses in Rila was done by Rusakova & Valchev [61]. They relate the studied communities to alliance *Piceion excelsae* without any associations. Later, some of their relevés were included in the diagnosis of association *Moehringio pendulae-Piceetum* Roussakova et Dimitrov 2005, described for the territory of Rila and Western Rhodopes [62]. Pine species like *Pinus peuce* (as ecological vicariant of *Pinus cembra*) and *Pinus sylvestris*, and sometimes (in Rila and Pirin) *Pinus mugo* as undergrowth element, are common in the alpine spruce forests in Bulgaria [63]. Spruce forests in the Central Stara Planina occupy separate areas – Dobrila, Vezhen, Bashitite, Cartula, Boatin, Cherni vruh, Rozinska ravna and others. Most of these forests are older than 200 years. *Picea abies* forms mixed communities with *Pinus peuce* near Vezhen massif and partly with *Pinus sylvestris* north of Vezhen peak.

3.1.1 Ass. *Ranunculo carthusianae-Piceetum abietis* ass. nova hoc loco (Group № 1)

Diagnostic species: *Picea abies, Ranunculus carthusianus, Ribes alpinum, Rumex alpinus, Juniperus sibirica, Potentilla haynaldiana.* **Constant species**: *Picea abies, Juniperus sibirica, Ajuga reptans, Dryopteris filix-mas, Fagus sylvatica* ssp. *sylvatica, Myosotis sylvatica, Rubus idaeus, Scila bifolia, Senecio nemorensis, Sorbus aucuparia, Vaccinium myrtillus, Vaccinium vitis-idaea.* **Dominant species**: *Picea abies, Juniperus sibirica, Vaccinium myrtillus.* **Nomenclature type (holotypus):** Reléve 8, Annex I. The specific composition of species and environmental conditions are the reason for diagnosing the new association *Ranunculo carthusianae-Piceetum abietis*, which unites 11 phytocoenotic relevés.

The communities of the association *Ranunculo carthusianae-Piceetum abietis* are distributed in the range of 1600 – 1800 m.a.s.l. on slopes an average 8-10 degrees. (Fig. 3). The expositions vary, but those with western and northern components dominate, and there are also some with southernt component (below Karatepe peak). The rocks are silicate – south Bulgarian granite, slate, and diorite. The soils are Umbric, rarely Dystric or Modic Cambisols – moderately rich, medium deep, sandy and clay soils. The average temperature is about 3 °C.

The tree layer covers about 60% in average. Dominant species is *Picea abies* (Annex I). The cover of shrub layer ranges from 0 to 60%. *Picea abies, Juniperus sibirica, Ribes alpinum, Sorbus aucuparia, Fagus sylvatica* ssp. *sylvatica, Rubus idaeus, Rumex alpinus* are

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the most common species. The herbaceous layer has a cover of an average 40%. *Picea abies, Juniperus sibirica, Ranunculus carthusianus, Rumex alpinus, Vaccinium vitis-idaea, Veronica alpina* and others are with high constancy. Typical physiognomic feature for these communities is the low species diversity. These are light, subalpine forests, in certain areas changing into sparse early stage of forests involving *Juniperus sibirica*.

Figure 3: Ass. *Ranunculo carthusianae-Piceetum abietis*

Given the location of the forests at higher parts of the mountain and the climatic conditions, the boreal elements dominate (50%) in the phytogeographic spectrum, followed by the european (17%), arctic-alpine (13%), balkan, eurasian, euro-mediterranean, pontic and cosmopolitans (4% each).

Such types of forest are common in the Bashitite area, Karatepe, Dobrila, Gerdeka, Kumanitsa, and Harmana.

The combination of diagnostic species *Ranunculus carthusiana, Ribes alpinum, Rumex alpinus, Juniperus sibirica, Potentilla haynaldiana* reflects the highland character of the communities. These species are differential compared to other known associations of ordinary spruce on the Balkan Peninsula. The communities of the association *Ranunculo carthusianae-Piceetum abietis* are isolated from the similar forests, located in the western part of Stara Planina where the association *Junipero sibiricae-Piceetum* was established (Rudski 1947) Mišić et Popović 1980. The latter is distinguished by its open nature and the constant participation of species such as *Poa violacea, Potentilla ternata, Bruckenthalia spiculifoilia, Nardus stricta, Polygonum bistorta, Hypericum alpigenum, Agrostis capillaris, Thymus glabrescens, Alchemilla pubescens, Polygala comosa*, etc. [52, 58]. Furthermore *Ranunculus carthusianus, Ribes alpinum* and *Potentilla haynaldiana* are missing.

Association *Ranunculo carthusianae-Piceetum abietis* differentiates from the spruce forests described in Rila and Rhodope Mountains in Bulgaria, where participate species with high constancy as *Moehringia pendula, Melampyrum sylvaticum, Campanula sparsa, Lerchenfeldia flexuosa, Dicranum scoparium, Calamagrostis arundinacea, Orthilia secunda, Valeriana tripteris* [62]. This research confirms the findings of Roussakova and Dimitrov [62] that the spruce forests in Bulgaria differ from those located in neighboring countries which, although close as physiognomy and species composition, are characterized by the presence of species related to the specific historical development of the flora and vegetation. For example, the spruce communities in the Carpathian Mts are differentiated by a number of carpathian elements such as *Hieracium rotundatum, Syphythum cordatum, Dentaria glandulosa, Euphorbia carniolica, Soldanella major, Leucanthemum waldsteinii, Aconitum moldavicum*, etc. [48, 64]. The presence of species unusual for Central Stara Planina is typical in western Balkans - *Astrantia carniolica, Homogyne sylvestris, Adenostyles glabra, Lonicera alpigena, Sorbus mougeotii,* and *Helleborus niger* [6, 58].

3.1.2 Community of *Picea abies* and *Luzula sylvatica* (group №2)

Diagnostic species: *Picea abies, Pinus peuce, Dryopteris expansa, Laserpitium krapfii, Galium rotundifolium, Cardamine pectinata, Fragaria vesca, Geranium pyrenaicum, Galium odoratum.* **Constant species**: *Picea abies, Dryopteris filix-mas, Luzula luzuloides, Luzula sylvatica, Senecio nemorensis, Vaccinium myrtillus.* **Dominant species**: *Picea abies, Pinus peuce.*

The communities of this group are mainly located in the area between Kositsa peak and Yumruka peak (Fig. 4). They are distributed in the range of 1400 – 1600 m.a.s.l. The slopes are about 20 degrees. The exposures vary, but are dominated by those with northern and eastern components. The rocks are south Bulgarian granites, crystalline schists and others. Almost everywhere the soils are Umbric Cambisols, but in the lower parts are Dystric-Eutric Cambisols, medium deep, sandy and stony. The average temperature is above 4 °C. The environmental analysis shows that these are alpine forests, growing in places rich with nitrogen and water, shady and dark.

Figure 4: Community of *Picea abies* and *Luzula sylvatica*

These forests accomplish the transition from the mixed coniferous-deciduous forests to macedonian pine forests. The cover of the tree layer is 60-90%. Dominant and subdominant species is *Picea abies*, in certain communities *Pinus peuce* dominates, while in others there is participation of *Fagus sylvatica* and *Abies alba*. In the shrub layer the coverage ranges from 0 to 20%, involving mainly undergrowth of *Picea abies* and *Fagus sylvatica*. The herbaceous layer has a cover an average of 30%. The most commonly found species are *Dryopteris filix-mas, Luzula luzuloides, Luzula sylvatica, Senecio nemorensis, Vaccinium myrtillus* (Annex I).

Boreal elements dominate in those communities too (40%) although their quantity is less compared to the monodominant spruce and macedonian pine forests that grow at high altitudes and in extreme ecological conditions. There is a relatively high participation of the sub-mediterranean elements (17%), followed by european (13%), mediterranean (9%) balkan (9%). Euro-mediterranean, euro-asian and cosmopolitan elements are involved with 4% each.

Typical physiognomic feature of these forests is the big cover of the tree layer, the lack of shrub layer at most places and poor grass layer with low coverage. The grass cover is formed only near small streams, bright open "windows" when the horizontal structure is disrupt, around springs. These phytocoenoses do not border the timberline zone, as the belt over them are common to the forests of *Pinus peuce*. The facies of *Luzula sylvatica* and *Senecio nemorensis* which develop in the lighter areas are typical.

3.1.3 Community of *Betula pendula* (group № 3)

Diagnostic species: *Betula pendula*. **Constant species**: *Fagus sylvatica* ssp. *sylvatica, Betula pendula, Luzula luzuloides, Vaccinium myrtillus.*

Dominant species: *Betula pendula, Juniperus sibirica, Vaccinium myrtillus.*

The communities of this group develop around the timberline in the areas where this line is composed of spruce forests, mostly south of the main ridge of the mountain. They are distributed in the range of 1400 – 1600 m.a.s.l. Sloppes are about 30-35 degrees. The expositions are diverse, but dominated by those with a southern component. The rocks are silicate – south Bulgarian granite, slate, diorite and some other less represented types. The soils are Umbric Cambisols, and in the lower parts Dystric Cambisols, moderately rich, medium deep, sandy, mostly stony. The average annual temperature is above 4 °C.

Figure 5: Community of *Betula pendula*

The cover of the tree layer is 50% on average. *Betula pendula* is the main dominant, but *Picea abies* dominates in some localities (Fig. 5). In the shrub layer *Fagus sylvatica* ssp. *sylvatica* and *Betula pendula* have sporadic occurrence. The grass layer has cover an average of 30%. Most commonly are found *Betula pendula, Luzula luzuloides* and *Vaccinium myrtillus* (Annex I).

The boreal floristic elements (36%) have the lowest relative participation in these forests. The higher temperatures and the open character of some of the communities are the major cause of strong presence of euro-mediterranean (25%) and mediterranean elements (7%), followed by euro-asian (14%), balkan (11%) and european (7%).

Characteristics of these forests are their fragmented distribution, their great lighting, the presence of *Betula pendula* in all layers, the acidophilous and oligotrophic character, and the low soil moisture. During the last 10–20 years there has been an expanding of their area and occupation of territories in the subalpine treeless zone in many places in the mountains, mainly in the high southern slopes – Ravnets massif over Vasil Levski, Karlovo and Sushitca villages, above Sopot, Anevo, Karnare, Iganovo and in several other places in the western part of the mountain.

3.2 Forests of *Pinus peuce*

12 relevés dominated by *Pinus peuce* which form a separate cluster of high floristic similarity were made during this research (group №4).

The forests of *Pinus peuce* in Europe belong in the mountainous and sub-alpine nemoral coniferous vegetation. These forests were much or less formed under the Mediterranean influence. Therefore, and due to historical reasons associated with the last icing, that vegetation can be considered endemic. The spread of the forests of macedonian pine is like insularity. They can be found in the highest mountain systems of Montenegro, Kosovo, Albania, Macedonia, and Bulgaria. The data on the natural habitat of macedonian pine in Bosnia and Herzegovina needs confirmation through genetic studies [65]. Vertically and environmentally the macedonian pine forests occupy mostly areas above beech and spruce forests and form the upper timberline, mainly on acid substrates, and less frequently on basic rocks.

The areal of macedonian pine forests include the Rila-Rhodope massif, Stara Planina, Voras, Shar Planina, Mokra gora and others. Their total area is about 96 000 ha [66], of which about 250 ha is territory of Central Stara Planina.

Various of authors have contributed in the sintaxonomy of the forests of *Pinus peuce* in the Balkans [6, 67, 68, 69, 70, 71, 72, 73, etc.]. The sintaxonomy of phytocoenoses of macedonian pine in Bulgaria is developed using only the dominant method of Russian-Scandinavian Phytocoenological School [14, 16, 74, 75]. The presence of the typical species *Gentiana lutea*, *Knautia midzorensis, Verbascum longifolium* ssp. *Pannosum* and the floristic composition of some phytocoenoses are a reason to assume their distribution in this country, at least partly in Rila and Pirin. The association *Gentiano luteae-Pinetum peucis* described by Pelister in Macedonia and the typical species of the endemic for the Balkan alliance *Pinion peucis* are found

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everywhere in phytocoenoses of *Pinus peuce* in Bulgaria [76].

Studies show that since 1970 there is a remarkable ascent of the macedonian pine in Rila and Stara Planina, which is mainly associated with climate changes and the increasing temperatures and weakened anthropogenic pressure [16, 77].

3.2.1 Ass. *Adenostylo alliariae-Pinetum peucis* ass. nova hoc loco (group № 4)

Diagnostic species: *Pinus peuce, Adenostyles alliariae, Calamagrostis arundinacea, Homogyne alpina.* **Constant species**: *Picea abies, Athyrium filix-femina, Dryopteris filix-mas, Hieracium murorum* gr., *Luzula luzuloides, Luzula sylvatica, Mycelis muralis, Prenanthes purpurea, Rubus idaeus, Senecio nemorensis, Sorbus aucuparia, Stellaria nemorum, Vaccinium myrtillus.* **Dominant species**: *Pinus peuce, Picea abies, Pinus sylvestris, Sorbus aucuparia, Festuca drymeja, Luzula sylvatica.* **Nomenclature type (holotypus)**: Relévе 28, Annex I.

The comparative analysis of the total species composition, of the diagnostic species and of the environmental conditions in relation to the previously described syntaxons allows us to describe a new association - *Adenostylo alliariae-Pinetum peucis*.

The distribution of its communities is in the range of 1600-1900 m.a.s.l., but mostly at about 1700 m.a.s.l. The slopes are an average 35 degrees. The exposures are varied, but dominated by those with westerly and northerly component. South of Vezhen peak exposures are with southern components (Fig. 6). The rocks are acidic – south bulgarian granite, diorite and others. The soils are mainly Umbric Cambisols, medium rich to rich, medium deep, sandy, stony, wet. Compared with other boreal mountain forests in Central Stara Planina, the communities of *Pinus peuce* grow in the most humid and rich soils (Group № 4, Fig.2). The average annual temperature is about 3 degrees.

Figure 6: Ass. *Adenostylo alliariae-Pinetum peucis*

The tree layer cover is an average 60%. Dominants in various ratios, mostly prevailed by *Pinus peuce* are *Pinus peuce, Picea abies, Pinus sylvestris* and *Abies alba*. The cover of the shrub layer is generally low (below 10%). *Sorbus aucuparia* and *Rubus idaeus* are most common. The grass layer has a cover of on average 40%. Dominant and constant species most often are *Athyrium filix-femina, Adenostyles alliariae, Diphyscium foliosum, Gentiana asclepiadea, Gymnocarpium dryopteris, Homogine alpina, Lamium garganicum, Calamagrostis arundinacea, Stellaria nemorum* (Annex I).

Typical physiognomic feature of these forests are dense facies of *Adenostyles alliariae* in the grass layer, especially on a wet places and near streams.

In phytogeographical spectrum the boreal elements dominate (56%), which is determined by the environmental conditions, especially by the acidic substrates and the altitude. Follow by european and balkan (12%), mediterranean (8%), arctic-alpine, euro-mediterranean and cosmopolitans (4% each).

The association *Adenostyles alliariae-Pinetum peucis* has a relatively hygrophylous character and species that are not found in other known associations are present here - *Adenostyles alliariae, Cirsium appendiculatum, Heracleum verticillatum, Veronica beccabunga, Stellaria nemorum, Gymnocarpium dryopteris, Dryopteris dilatata, Senecio nemorensis, Diphyscium foliosum*. Moreover, other species, described in other associations for different areas, cannot be found here: *Gentiana lutea, Lilium carniolicum, Doronicum columnae, Bruckenthalia spiculifolia* and *Knautia midzoensis* for association *Gentiano luteae-Pinetum peucis* Em 1960; *Alyssum bertolonii, Dactylorhiza saccifera, Daphne blagayana, Minuartia baldaccii* and *Thymus boissieri* for association *Pinetum peucis* Janković 1959; *Digitalis viridiflora, Vaccinium uliginosum, Helleborus cyclophyllos* and *Astragalus glyciphyllos* for association *Digitali viridiflorae-Pinetum peucis* Em 1960; *Wulfenia carinthiaca, Potentilla ternata, Geum montanum* for association *Wulfenio carinthiacae-Pinetum peucis* Blečić et Tatić 1957; *Ajuga pyramidalis, Galium rotundifolium, Briza media, Platanthera bifolia* for Association *Ajugo pyramidalis-Pinetum peucis* Janković et R. Bogojević 1962, etc. [6, 58, 78].

The monodominant and mixed communities of macedonian pine in Central Stara Planina are located in separate mountain localities – north of Vezhen peak and Kamenitza peak. Scattered small groups are developing around Yumruka peak. In the recent past they had been developing into lower altitudes on inaccessible steep terrains [16]. In the recent years the lower limite had risen, where the macedonian pine is replaced primarily by beech. The upper limite has been higher as well and it corresponds to the upper timberline of the forest.

3.3 Conservation

Boreal mountain forests in Central Stara Planina are located within the National Park "Central Balkan". This is the second largest national park in Bulgaria and one of the most valuable park and one of the largest protected areas in Europe – second category according to the International Union for Conservation of Nature (IUCN). The territory of the park overlaps with the territory of the Special Protection Area – BG 0000494 Central Balkan (NATURA 2000), and about 45 000 ha of forest habitats are preserved there. The studied boreo-mountain forest communities belong to three habitat types listed in Annex I of the Habitats Directive 92/43/EEC and to 3 types of habitats of the Red Book of Bulgaria – section 3 Natural habitats [36].

The spruce forests (ass. *Ranunculo carthusianae-Piceetum abietis*, comm. of *Picea abies* and *Luzula sylvatica*) are related to habitat 9410 Acidophillous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*) and habitat 34G3 Norway spruce (*Picea abies*) forests with conservation category Nearly threatened [63].

The forests dominated by common birch (comm. of *Betula pendula*) are related to habitat 25G1 Birch (*Betula pendula*) forests with conservation category Nearly threatened [79].

Macedonian forests (ass. *Adenostylo alliariae-Pinetum peucis*) are identified with habitat 95A0 High oro-Mediterranean pine forests and 38G3 Macedonian pine (*Pinus peuce*) forests – Endangered habitat [77].

4 CONCLUSION

The boreo-mountain forests on the territory of Central Stara Planina are fragmented, forming a separate belt only at the highest parts. The described new associations with specific species composition show their relict character, their geographical isolation and the specific environmental conditions.

Early stages of forest dominated by spruce, macedonian pine, silver birch and scots pine, which displace mainly heats and bushes of bilberries and siberian juniper are developing in the upper timberline. Particularly active in this process is the macedonian pine that is successfully spreading on mountain screes, rock landslips and steeper slopes, on places where spruce forests cannot grow.

The results obtained from this research will be a sound basis for making correct management decisions. They will be of great help at monitoring the forest succession in the highest part of the mountain.

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Annex I: Syntaxonomical table of boreo-montane forest phytocoenoses in Central Stara Planina Mts.

1 - Assoc. *Ranunculo carthusianae-Piceetum abietis* ass. nova, holotypus hoc loco, rel. 8; 2 - Comm. of *Picea abies* and *Luzula sylvatica*; 3 - Comm. of *Betula pendula*; 4 - Assoc. *Adenostylo alliariae-Pinetum peucis* ass. nova, holotypus hoc loco, rel. 28 (Fidelity >20)

Syntaxa	1												2					3				4												
Reléve number	1	2	3	4	5	6	7	8	9	10	11		12	13	14	15		16	17	18		19	20	21	22	23	24	25	26	27	28	29	30	
Altitude (m a.s.l.) (x 10)	169	169	178	172	170	167	169	170	168	168	169		147	160	159	161		151	145	144		162	173	164	168	175	161	170	181	183	183	179	168	
Exposition	W	W	SE	N	S	SW	W	W	S	W	SW		N	NE	NE	NE		N	SE	S		NW	NE	N	N	NE	W	N	N	N	N	NE	N	
Slope (degree)	1	10	2	15	20	10	1	3	8	1	15		50	20	20	10		2	35	40		20	35	45	35	45	35	10	30	50	45	50	10	
Sample size (m^2)	400	400	400	400	400	400	400	400	400	400	400		400	400	400	400		225	225	225		400	400	400	400	400	400	400	400	400	400	400	400	
Cover of trees (%)	45	40	45	60	60	70	90	80	60	65	70		60	90	90	90		40	75	50		55	55	70	70	60	65	65	50	40	55	70	65	
Cover of bushes (%)	60	60	4	2	3	4	20	15	10	20	4		10	0	20	5		1	0	40		10	1	2	2	3	5	10	3	3	3	1	40	
Cover of grass (%)	20	20	50	45	60	40	30	35	45	35	45		50	30	30	20		55	30	20		40	60	40	40	55	40	40	40	75	45	40	30	
Soil richness	7	7	7	5	5	5	5	5	5	5	5		5	7	7	7		5	5	3		5	7	5	7	7	5	7	5	5	5	7	7	
Soil depth	4	4	4	3	3	3	3	3	3	3	3		3	4	4	4		3	3	2		3	4	3	4	4	3	4	3	3	3	4	4	
Soil stoniness	2	2	2	2	2	2	3	2	2	3	2		3	2	3	2		3	3	4		2	3	2	3	3	2	3	3	3	3	3	3	
Soil composition	4	4	4	4	4	4	4	4	4	4	4		4	4	4	2		3	4	4		4	4	4	4	4	4	4	4	4	4	4	4	
Soil reaction	4.5	4.7	4.9	5.1	5.2	4.9	5.2	5.8	5.6	5.1	5.2		4.4	4.2	4.9	4.6		3.5	6.1	4.4		4.4	5	4.7	4.7	5.1	4.5	4.3	4.6	4.6	4.7	4.9	4.2	
Nutrients	4.7	4.6	5	5.2	5.5	5.4	5.3	5.2	5.2	5.2	5.2		5	5	4.7	5.2		2.2	4.7	4.6		5.1	5.3	5.2	5.2	5.3	4.8	5	5.1	5.3	5.2	5.4	5.2	
Moisture	5.2	5.2	5.2	5.2	5.2	5.3	5.6	4.9	4.9	5.7	4.9		5.1	5	5.1	4.9		4.2	5.1	5		5.3	5.5	5.4	5.4	5.6	5.3	5.4	5.5	5.6	5.5	5.6	5.3	
Accessibility Q	500	500	500	500	500	500	500	500	500	500	500		650	650	650	650		700	600	700		700	700	700	700	700	700	700	700	700	700	700	700	
Air humidity Vv	83	83	83	83	83	83	83	83	83	83	83		82	83	82	83		82	82	82		83	83	83	83	83	83	83	83	83	83	83	83	
Light	5.4	5.4	5.6	5.4	5.2	5.2	5.5	5.6	5.7	5.6	5.4		4.9	4.3	4.7	5.2		5.9	4.9	5.1		4.5	4.6	4.6	4.5	4.8	4.6	5.4	5.3	5.3	5.3	5.2	5.3	
Temperature	3.6	3.8	4.1	4.3	4.3	4.5	3.9	4.2	4.2	4	4		4.5	4.3	4.4	4.6		4.3	5.4	4.4		4.5	4.6	4.6	4.5	4.4	4.6	3.8	3.9	3.8	3.9	4	4	
Continentality	3.8	4.2	4.1	4	4	3.9	3.9	4.4	4.2	3.9	4.1	***Fidelity***	3.4	3.9	3.6	4.1	***Fidelity***	4.5	3.9	3.7	***Fidelity***	3.5	3.6	3.6	3.5	3.8	3.5	4.2	3.8	3.8	3.8	3.9	4.5	***Fidelity***
Ranunculus carthusianus	1	.	.	r	1	1	+	+	+	+	+	**88**	.	.	.	.	--*	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Rumex alpinus	.	.	+	+	1	1	+	+	1	+	1	**88**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Myosotis sylvatica	1	1	+	+	+	+	+	+	+	+	+	**86**	.	.	.	1	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Juniperus sibirica b	4	4	+	+	+	1	+	+	1	2	1	**82**	.	.	.	.	--	.	.	3	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Juniperus sibirica c	1	2	+	+	+	+	+	+	+	+	+	**82**	.	.	.	.	--	2	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Ribes alpinum b	.	.	+	+	1	.	+	1	1	+	+	**82**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Vaccinium vitis-idaea	1	.	2	1	2	1	1	2	2	1	1	**75**	.	.	.	.	--	2	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Fagus sylvatica c	1	1	+	+	+	+	.	+	+	+	1	**75**	.	.	.	.	--	.	.	1	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Potentilla haynaldiana	.	.	.	r	r	1	.	1	1	.	r	**69**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Scilla bifolia	.	1	2	+	+	+	+	2	+	1	.	**68**	.	.	.	.	--	.	2	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Veronica officinalis	.	.	1	+	+	+	+	.	1	+	+	**65**	.	.	.	.	--	.	.	.	--	1	.	.	+	.	+	.	.	.	.	.	.	--
Ajuga reptans	1	.	+	+	+	1	+	.	2	+	1	**48**	1	.	1	.	--	.	1	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Picea abies b	.	1	1	1	1	1	2	2	2	2	1	**48**	.	.	2	2	--	.	.	.	--	.	.	.	.	+	.	+	1	1	1	+	+	--

continued

continuation of Annex I

Acer pseudoplatanus b	.	.	.	.	+	1	+	.	.	.	.	**47**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Veronica alpina	1	.	.	.	.	.	+	.	.	+	.	**47**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Veronica beccabunga	.	.	.	.	.	.	2	.	.	2	.	**38**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Juncus effusus	.	.	.	.	.	.	.	.	.	1	.	**26**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Geum coccineum	.	1	.	.	.	.	.	.	.	.	.	**26**	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Dryopteris expansa	.	.	.	.	.	.	.	.	.	.	.	--	.	.	1	1	**66**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Laserpitium krapfii	.	.	.	.	.	.	.	.	.	.	.	--	.	.	1	.	**45**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Galium rotundifolium	.	.	.	.	.	.	.	.	.	.	.	--	.	.	1	.	**45**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Cardamine pectinata	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	1	**45**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Fragaria vesca	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	1	**45**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Geranium pyrenaicum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	1	**45**	.	.	.	--	.	.	.	.	.	.	.	.	.	.	.	.	--
Galium odoratum	.	1	.	.	.	.	.	.	.	.	.	--	.	2	.	1	**41**	.	.	.	--	.	+	.	1	+	.	.	.	.	.	.	.	--
*Abies alba*c	.	.	.	.	.	.	.	.	.	.	.	--	.	1	1	.	**23**	.	1	.	--	1	+	+	+	.	+	.	.	.	.	.	.	--
Betula pendula a	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	3	1	2	**78**	.	.	.	.	.	.	.	.	.	.	.	.	--
Betula pendula b	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	1	.	1	**78**	.	.	.	.	.	.	.	.	.	.	.	.	--
Chamaecytisus austriacus	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	1	1	.	**78**	.	.	.	.	.	.	.	.	.	.	.	.	--
Potentilla rupestris	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	2	.	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Poa nemoralis	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	1	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Crocus veluchensis	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	1	.	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Corylus avellana c	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	1	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Asarum europaeum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	1	.	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Acer pseudoplatanus a	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	+	.	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Acer pseudoplatanus c	1	.	.	+	+	+	.	.	.	+	.	--	.	.	.	.	--	.	1	1	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Acer heldreichii c	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	1	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Epilobium montanum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	1	.	**52**	.	.	.	.	.	.	.	.	.	.	.	.	--
Geranium macrorrhizum	.	.	.	.	.	.	.	.	.	.	.	--	2	.	.	.	--	.	1	.	**31**	.	.	.	.	.	.	.	.	.	.	.	.	--
Abies alba a	.	.	.	.	.	.	.	.	.	.	.	--	2	.	.	.	--	.	.	2	**21**	.	.	2	.	.	3	.	.	.	.	.	.	--
Luzula luzuloides	1	1	1	+	2	.	+	.	.	+	.	--	1	1	.	1	**1**	1	2	2	**52**	2	+	1	1	1	1	1	+	+	+	.	1	**23**
Calamagrostis arundinacea	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	1	--	.	.	.	--	1	+	r	+	+	+	+	+	r	+	r	1	**86**
Hieracium murorum gr.	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	1	--	+	+	1	+	+	+	+	+	+	+	+	1	**82**
Dryopteris dilatata	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	2	1	2	2	.	.	1	2	1	1	.	**78**
Gentiana asclepiadea	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	+	+	+	+	+	.	1	+	+	.	.	**78**
Adenostyles alliariae	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	2	.	2	+	.	1	1	2	2	2	.	**78**
Stellaria nemorum	.	.	.	2	+	2	+	.	.	+	.	--	.	.	.	.	--	.	.	.	--	1	+	+	+	+	+	1	+	1	+	2	1	**76**
Lamium garganicum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	1	+	+	+	r	+	.	.	.	.	r	.	**72**
Homogyne alpina	1	.	2	2	.	.	+	.	.	r	.	--	.	.	.	.	--	.	.	.	--	1	+	+	+	+	+	+	+	1	1	+	.	**70**
Pinus peuce a	.	.	.	.	.	.	.	.	.	.	.	--	.	5	.	3	--	.	.	.	--	2	3	2	2	4	2	2	2	3	3	3	2	**68**

continued

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continuation of Annex I

Festuca drymeja	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	1	+	1	+	+	3	.	.	.	.	.	.	**66**
*Abies alba*b	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	2	+	+	+	+	2	.	.	.	.	.	.	**66**
Pinus peuce b	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	+	.	.	1	1	1	+	.	**59**
*Pinus peuce*c	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	+	+	+	+	+	.	**59**
Gymnocarpium dryopteris	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	+	.	1	+	.	.	.	+	.	r	.	**59**
Mycelis muralis	.	.	+	+	+	1	+	.	.	+	.	--	.	.	1	1	--	.	.	.	--	1	+	+	+	+	+	+	+	+	+	+	1	**56**
Prenanthes purpurea	1	1	.	.	.	.	.	.	.	.	.	--	1	.	1	.	--	.	.	.	--	.	1	1	1	1	.	+	1	+	+	+	1	**54**
Lerchenfeldia flexuosa	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	r	+	r	.	1	.	.	.	.	.	.	**52**
Diphyscium foliosum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	+	.	.	+	.	.	.	.	.	+	.	**45**
Cirsium appendiculatum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	+	1	1	.	.	**45**
Geranium sylvaticum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	+	+	.	.	**36**
Dryopteris filix-mas	1	.	r	+	+	+	+	+	1	.	1	--	.	1	1	1	--	.	.	1	--	1	1	+	+	1	1	+	1	1	1	+	1	**36**
Pinus sylvestris a	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	3	.	.	.	.	3	**36**
Pinus sylvestris b	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	+	.	.	.	.	+	**36**
Pinus sylvestris c	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	+	.	.	.	.	1	**36**
*Lonicera xylosteum*b	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	+	.	.	.	.	.	.	.	**25**
Heracleum verticillatum	.	.	.	.	.	.	.	.	.	.	.	--	.	.	.	.	--	.	.	.	--	.	.	.	.	.	.	.	.	+	.	.	.	**25**
Luzula sylvatica	1	1	.	+	.	.	+	.	.	+	.	--	2	2	.	1	**23**	.	.	.	--	1	3	2	2	3	1	2	2	2	2	2	2	**52**
Senecio nemorensis	1	1	+	+	1	1	+	+	2	+	1	**35**	2	1	1	2	**35**	.	.	.	--	1	1	+	1	+	.	2	2	2	2	+	1	**24**
Picea abies a	3	3	3	4	4	4	5	5	4	4	4	**26**	3	2	5	3	**26**	.	4	+	--	4	2	3	3	2	+	2	2	2	2	2	2	**26**
Picea abies c	1	1	+	+	+	.	+	1	1	+	+	**50**	.	.	.	.	--	.	.	.	--	1	+	+	+	+	+	+	+	1	+	+	1	**60**
Rubus idaeus	1	1	1	1	1	1	+	+	+	r	1	**60**	.	.	.	.	--	.	.	1	--	.	+	+	+	1	+	+	+	+	+	+	1	**41**
Athyrium filix-femina	1	1	+	.	2	+	+	.	.	+	+	**40**	.	.	.	.	--	.	.	.	--	.	1	+	1	1	.	+	+	2	1	+	1	**52**
Sorbus aucupariac	1	1	+	+	1	+	+	.	.	+	1	**35**	.	.	.	1	--	.	.	.	--	+	+	+	+	+	+	2	+	+	+	+	1	**56**
Sorbus aucuparia b	.	.	+	+	+	+	.	.	.	+	1	**28**	2	.	.	.	--	.	.	.	--	1	+	+	1	+	+	2	.	.	.	+	3	**53**
Oxalis acetosella	.	.	.	r	r	+	.	.	.	.	1	**25**	.	.	.	.	--	.	.	.	--	1	+	+	+	.	+	.	.	.	.	.	.	**32**
Vaccinium myrtillus	2	1	2	2	3	2	2	2	2	2	3	--	2	2	2	1	--	3	.	1	--	2	2	1	+	2	+	+	1	1	1	1	1	--
Fagus sylvatica a	.	.	.	.	.	.	.	.	.	.	.	--	2	.	.	.	--	+	+	2	--	+	.	2	+	.	2	.	.	.	.	.	.	--
Fagus sylvatica b	.	.	.	.	+	1	.	1	+	.	1	--	2	.	.	.	--	.	.	1	--	1	+	1	1	+	+	.	.	.	.	.	.	--

Locality of releves: Boryanin grob - **1, 4, 11**; Gerdektepe - **2**; Karatepe - **3, 7–10**; Dobrila - **5**; Nezabravka - **6**; Peshova maka - **12, 17**; Chernata mogila - **13**; Hristova dolchina - **14**; Dutkova polyana - **15**; Kelkaya - **16**; Dermenakaya - **18**; Murov dol - **19, 20, 25**; Borov dol **– 21—24, 29, 30**; Kasadzhika **–26–28**.

Location: 1– 42º 42' 45.8964", 24º43' 48.6156"; **2** - 42º42' 58.0248", 24º42' 52.1100"; **3** - 42º42' 28.2960", 24º44' 22.6392"; **4** - 42º42' 47.3868", 24º43' 55.9704"; **5** - 42º42' 28.2960", 24º 44' 22.6392"; **6** - 42º42' 20.2932", 24º 44' 7.7856"; **7** - 42º42' 46.3320", 24º43' 53.2344"; **8** - 42º42' 46.1880", 24º43' 53.8608"; **9** - 42º42' 43.0308", 24º44' 0.4056"; **10** - 42º42' 46.5300", 24º43' 53.1876"; **11** - 42º 42' 38.7972", 24º 44' 4.0740"; **12** - 42º44' 3.7019", 24º39' 36.8192; **13** - 42º46' 29.4528", 24º23' 27.6432"; **14** - 42º46' 34.5072", 24º23' 25.0368"; **15** - 42º46' 34.5072", 24º23' 25.0368"; **16** - 42º43' 34.5108", 24º40' 28.0020"; **17** - 42º43' 56.2584", 24º39' 25.9992"; **18** - 42º43' 55.2828", 24º39' 42.2100"; **19** - 42º46' 15.3408", 24º23' 23.1036"; **20** - 42º45' 52.2036", 24º23' 17.0556"; **21** - 42º45' 59.0580", 24º23' 23.5176"; **22** - 42º45' 54.4716", 24º23' 19.5108"; **23** - 42º45' 52.4340", 42º45' 52.4340"; **24**- 42º46' 8.4432", 24º23' 25.4940"; **25** - 42º46' 12.4824", 24º23' 36.7368"; **26** - 42º45' 53.3196", 24º23' 37.2192"; **27** - 42º45' 46.4796", 24º23' 24.3276"; **28** - 42º45' 49.8672", 42º45' 49.8672"; **29** - 42º45' 46.0080", 24º23' 15.8496"; **30** - 42º 46' 13.3536", 24º23' 37.8708.

Date: 25.06.2013 **-1–11**; 12.06.2011 **-12**; 26.06.2012 - **17**; 09.07.2011 **-13–15**; 18.06.2013 - **16**; 07.06.2013 - **18**; 11.07.2013 **-19–30**.

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Original scientific article

ANALYSIS OF FLORISTIC COMPOSITION OF MOUNTAIN BEECH FOREST ON LIMESTONE AND SERPENTINE IN SERBIA

NOVAKOVIĆ-VUKOVIĆ M., MILOŠEVIĆ R.
University of Belgrade, Faculty of Forestry, Belgrade, Serbia
Corresponding author e-mail address: marijana.novakovic@sfb.bg.ac.rs

ABSTRACT: The paper is floristic composition comparative research of mountain beech forests on serpentine in southwestern Serbia, and beech forests on limestone in eastern Serbia. The analysis showed that there are significant differences in the floristic composition. On the serpentine bedrock a low count of plant species was recorded, Jacquard's similarity index of studied stands had a very low value. Within phytocoenological relevés made on limestone bedrock, the most typical species of beech forests appear as isolated, while in the beech forests on serpentine, xerophyl species characteristic to the order *Erico - Pinetalia* and *Quercetalia pubescentis* were observed, in addition to "fagetal" species. In the spectrum of life forms on both the geological substrate hemicryptophytes dominated, and phanerophytes and nanophanerophytes of serpentinite had the significant presence, as a result of warmer climate in southwestern Serbia. In geofloristic spectrum, a group of submediterranean floral elements, which are connected with Balkan floral elements, is as twice as numerous in the mountain beech forest on serpentine than on limestone, which is another indicator of southwestern Serbia's exposure to submediterranean influence.
Keywords: beech, serpentine, limestone, southwest Serbia, eastern Serbia.

1 INTRODUCTION

Beech is the most ubiquitous tree species in Serbia with the widest altitudinal distribution, arising from a broad ecological amplitude in regard to climatic factors (light and temperature), and edaphic factors (geological substrate and soil types), and slightly lower amplitude compared to the humidity of habitat [8]. It occurs in most parts of Serbia, except in the Pannonian Plain, with the exception of Fruška Gora and Vršac Mountains [2]. On the territory of Serbia beech forests cover 660,400 ha (29.3% of the total covered area), out of which is 64.7% is in government property [1]. Considering that the beech communities are widespread in almost all mountain massifs in Serbia, their soils were formed on different rocks which vary in textural characteristics, chemical and mineral composition, as well as in resistance and products created in their degradation process [5]. Within beech forests, several basic types of substrate can be defined, considering the importance of the parent substrate for the genesis and soil properties [6]: carbonate rocks, acidic and neutral silicate rocks and mafic silicate rocks. Beech forests have very diverse botanical composition, considering their prevalence and effect of orographic-edaphic factors, so they include a large number of phytocoenoses. One of them is a mountain beech forest *(Asperulo odoratae-Fagetum moesiacae* B. Jovanović in 1973., Syn. *Fagetum moesiacae montanum* B. Jovanović 1953.; *Fagetum montanum asperuletosum* B. Jovanović 1973), which represents a powerful climate-regional belt of vegetation on the territory of Serbia, as well as the most abundant and economically important type of beech forest and Serbian woodland in general [11]. Aim of the paper was to determine the extent of the differences in the floristic composition between mountainous beech forests on serpentine and limestones, which would contribute to a better knowledge of beech forests on different geological substrates, since these forests are of great importance for Serbia.

2 MATERIAL AND METHOD

The study of mountain beech forests floristic composition (*Asperulo odoratae-Fagetum moesiacae* B. Jovanović 1973) was based on 24 phytocoenological relevés that were obtained from literature. 14 phytocoenological relevés were sampled in the mountain beech forest on serpentine bedrock on Crni vrh near Priboj [12], another 10 were sampled in the mountain beech forest on Mount Ozren - Sokobanja, on a limestone substrate [3]. Syntaxonomic names follow [16]. CA vegetation data analysis was performed using the statistical software CANOCO 4.5 [9]. Indexes of diversity and equivalence (Shannon -Wiener diversity index and Evenness) were calculated in the program JUICE 7 .0 [15]. Jaccard's similarity index of investigated stands was also calculated [10]. The spectrum of floral elements was made according to the systematization of phytogeographical elements [4], and spectrum of life forms [7].

3 RESULTS AND DISCUSSION

64 species were recorded in mountain beech forest on serpentine and 77 species in beech forest on limestone. The conclusion is that the beech forest on limestone is floristically richer than on the serpentine, although the analysis included a smaller number of phytocoenological relevés on limestone than in the serpentine [14] compared the vegetation of limestone and serpentine in Bosnia and came to the conclusion that the serpentine, unlike limestone, sees great uniformity in terms of growing vegetation and poorness in the number of species. It should be noted that the serpentine bedrock is very unfavorable for the development of the plant world, on which only plants that have managed to adapt to life on this inhospitable bedrock can survive. The same conclusion is reached by analyzing the floristic composition of beech forests on serpentine and limestones in Serbia. Floristic composition analysis of mountain beech forests on Pešter, on limestone and silicate bedrock, also showed greater floristic richness of this forest on limestone, but this phenomenon is explained by higher degradation and more open set of studied stands, which enables settlement to a large number of species [13].

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Mountain beech forests on both serpentinite and limestone within studied stands occupy mainly same expositions - northern and northwestern. They are also located on similar inclinations - inclinations on serpentinite are in 5-40° range, while inclinations on limestone are in 0-30° range. Mountain beech forests on serpentinite are registered in 560-800 m elevation range, while stands on limestone are registered on elevations between 810-870 m. Based on all of the above-mentioned, it can be concluded that geological substrate is the primary factor that affects floristic composition in the studied stands of mountain beech forest on serpentinite and limestone. Jaccard's index of similarity of studied stands [10] is:

$$J = \frac{UV}{V + U - UV} = 0.24, \text{ where is}$$

UV- the number of common species,
U, V- the number of species in mountain beech forest on serpentinite and limestone, respectively.

Jacquard's similarity index shows that although this is the same community, floristic similarity among the studied stands is low.

Ordinate system (Fig. 1) shows that, although it is one plant community, phytocoenological relevés diverge depending of the geological basis. Within phytocoenological relevés made on limestone bedrock, in the negative part of the coordinate system, "fagetal" species appear as isolated: *Asperula odorata, Isopyrum thalictroides, Cardamine bulbifera, Anemone ranunculoides, Salvia glutinosa* and others. On the other hand, within the beech forests on serpentine, in addition to "fagetal" species, xerophyl species characteristicfor *EricoPinetalia* and *Quercetalia pubescentis* orders*: Fraxinus ornus, Campanula patula, Polygonatum odoratum,* appear on the graph.

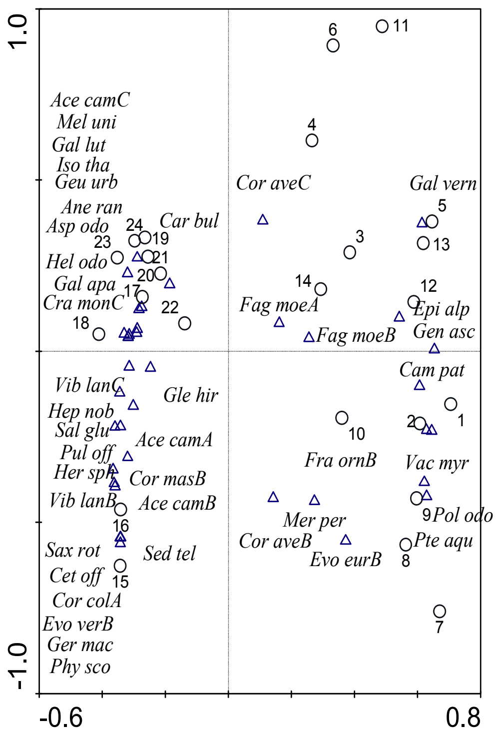

Figure 1: CA ordination biplot, fit range for the species 30-100%, 42 species (○-relevé representation, Δ-species representation; (1-14)- relevés on serpentine; (15-24)- relevés on limestone
Species abbreviations: *Ace cam-Acer campestre;Mel uni-Melica uniflora; Gal lut-Galeobdolon luteum; Iso tha-Isopyrum thalictroides;Geu urb-Geum urbanum; Cor ave-Corylus avellana; Gal vern-Galium vernum; Ane ran-Anemone ranunculoides; Asp odo-Asperula odorata; Car bul-Cardamine bulbifera; Hel odo-Helleborus odorus; Gal apa-Galium aparine; Cra mon-Crataegus monogyna; Fag moe-Fagus moesiaca; Epi alp-Epimedium alpinum; Gen asc-Gentiana asclepiadea; Vib lan-Viburnum lantana; Cam pat-Campanula patula; Gle hir-Glechoma hirsuta; Hep nob-Hepatica nobilis; Sal glu-Salvia glutinosa; Pul off-Pulmonaria officinalis; Her sph-Heracleum sphondilium; Cor mas-Cornus mas; Fra orn-Fraxinus ornus; Vac myr-Vaccinium myrtillus; Mer per-Mercurialis perennis; Pol odo-Polygonatum odoratum; Sax rot-Saxifraga rotundifolia; Sed tel-Sedum telephium; Pte aqu-Pteridium aquilinum; Evo eur-Evonymus europaeus; Cet off-Ceterach officinarum; Cor col-Corylus colurna; Evo ver-Evonymus verrucosa; Ger mac-Geranium machrorrhizum; Phy sco-Phyllitis scolopendrium* (the abbreviations following the species denotes A-tree layer,B –shrub layer, C-ground flora layer)

Shannon Wiener index (Table I) shows significant differences between the studied stands. This index has a much higher value in the mountain beech forest on limestone than on serpentinite, which is logical if we consider the number of recorded species, which is larger in the stands on limestone. On the other hand, Evenness index shows approximately equal value (Table I), provided that it's slightly higher in the mountain beech forest on limestone. Based on Evenness index it can be concluded that plant species do not have regular spatial distribution. As species that reduce the value of this index, we can mention the ones that are characterized by great number and coverage in a certain number of relevés: *Asperula odorata, Allium ursinum, Geranium machrorrhizum, Cardamine bulbifera etc.*

Table I: Indices of the diversity and evenness of mountain beech forest at the study sites

	Average Shannon-Wiener index	Average Evenness index
serpentinite	1.37	0.55
limestone	2.24	0.60

The life form spectrum (Fig. 2) reveals significant differences. Hemicryptophytes are dominant in mountain beech forest on limestone and serpentine, which is a common occurrence in temperate zone climatic conditions, with the fact that they are about 10% more numerous on limestone than on serpentine. On the other hand, phanerophytes have significant presence on serpentine, a lot larger than on limestone (37.5%: 27.3%). Considering that the analysis of the spectrum of life forms shows plant species relation to the climate of a region, we can conclude that this phenomenon is due to a warmer climate in southwestern Serbia. Geophytes also have strong presence both in the beech on the serpentinite and on limestone (20.41%: 19.47%), which was expected, considering very mesophilic nature of beech forests. Other life forms have approximately equal presence on both the geological substrata.

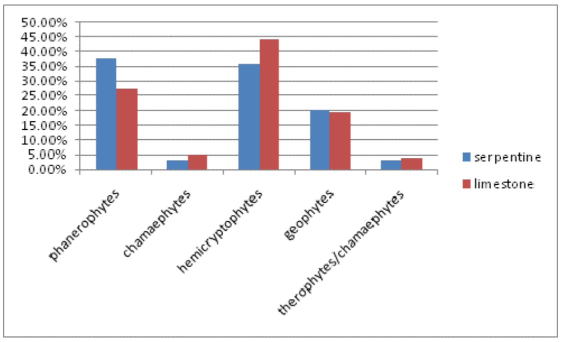

Figure 2: The spectrum of life forms for the community of mountain beech on limestone and serpentinite

Analysis of geofloristic spectrum (Fig. 3) also shows significant differences between the studied stands. In both cases, the most common as collective is Central European floral element. A group of species with wide ecological amplitude (Eurasian areal type) is the second most common on limestone. The biggest differences are reflected in the presence of a collective group of sub-Mediterranean floral elements, which are connected with Balkan floral elements. This group is as twice as numerous in the mountain forest of beech on serpentinite than on limestone, which is another proof that this community is more xerophyl on serpentine than on limestone. Larger presence of gropu of subatlantic floral elements on limestone than on the serpentine is indicator of more mesophilic conditions on limestone.

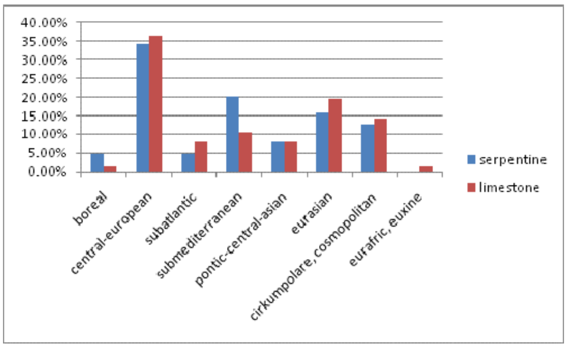

Figure 3: Spectrum of floral elements for the community of mountain beech on limestone and serpentinite

4 CONCLUSIONS

The paper is based on a comparison of the floristic composition of mountain beech forests *(Asperulo odoratae-Fagetum moesiacae* B. Jovanović 1973) on limestone and serpentinite, based on 14 phytosociological relevés made in the mountain beech forest on serpentine on Crni Vrh, close to Priboj, and 10 relevés made on limestone in Ozren-Sokobanja. The analysis showed significant differences. Jaccard's index of similarity on studied stands is 0.24, indicating a very low floristic similarity in studied stands. CA floristic data analysis showed relevés grouping into two groups, depending on the geological substrate. Within phytocoenological relevés made on limestone bedrock, typical species of beech forests appear as isolated: *Asperula odorata, Isopyrum th alictroides Cardamine bulbifera, Anemone ranunculoides, Salvia glutinosa* and others. On the other hand, within beech forests on serpentinite, in addition to "fagetal" type, xerophyl species characteristic to the order *Erico - Pinetalia* and *Quercetalia pubescentis: Fraxinus ornus, Campanula patula, Polygonatum odoratum* are also visualized on the graphics.

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Original scientific article

FLORISTIC AND VEGETATION DIVERSITY IN KONGURA RESERVE (SOUTH-WEST BULGARIA)

PEDASHENKO H., VASSILEV K., BANCHEVA S., DELCHEVA M., VLADIMIROV V.
Institute of Biodiversity and Ecosystem Research – Bulgarian Academy of Sciences, Sofia, Bulgaria
Corresponding author e-mail address: hristo_pedashenko@yahoo.com

ABSTRACT: Kongura reserve is situated in the Bulgarian part of Belasitsa mountain. It occupies an area of 1310.80 ha on slopes with northern, north-eastern and north-western exposition from 430 to 1740 m alt. The reserve was established in 1988 mainly to protect the well preserved *Castanea sativa* and *Fagus sylvatica* forests. A total of 300 vascular plant species were identified, more than a quarter of which belong to the families *Asteraceae*, *Rosaceae* and *Fabaceae*. Among the richest genera are *Galium*, *Campanula*, *Acer*, *Hieracium*, *Lathyrus*, *Trifolium* and *Viola*, which comprise more than 12% of the total flora of the study area. Five species are of conservation concern and are included in the *Red Data Book of the Republic of Bulgaria*. Three taxa of these are legally protected by the national Biodiversity Act. Endemism is relatively low (3.3%) since only 10 Balkan endemics have been recorded. Almost the entire territory of the reserve is covered by various forest types. The most widespread vegetation type belongs to *Querco-Fagetea* class, which is represented by alliance *Fagion sylvaticae*. The rest of the forest vegetation was classified to alliances *Quercion petraeo-cerridis* and *Carpinion orientalis* of *Quercetea pubescentis* class. Wet woodlands of *Salici purpureae-Populetea nigrae* class (alliance *Platanion orientalis*) have only limited distribution in the area. Areas covered by shrubs were classified to *Loiseleurio-Vaccinietea* and *Rhamno-Prunetea* classes. Although areas dominated by herbs or grasses cover only less than two percent of the reserve's territory their diversity was classified into four classes: *Festuco-Brometea*, *Juncetea trifidi*, *Mulgedio-Aconitetea* and *Galio-Urticetea*.
Keywords: Belasitsa Mt., endemics, flora, habitats, conservation.

1 INTRODUCTION

Kongura reserve was declared as a protected area in 1988, covering the area of the former "Skoshnik" reserve, established in 1954 to preserve the most characteristic for Belasitsa mountain primary sweet chestnut forests. Apart from them slopes of the mountain are covered by variety of mesic and xeric woodlands, creating a rich diversity of habitats and niches. The top of the main ridge of Belasitsa mountain consists of vast mountain pastures.

Despite the high number of researches from Belasitsa Mt. there was no complete study of the reserve's flora and vegetation until now. Studies on the vegetation and habitat diversity of Belasitsa Mt. are clearly unequal. On one hand, there are a considerable number of scientific publications that deal with syntaxonomy [73, 53, 58], ecology [79, 49, 33, 70, 55, 60, 52], resources [81, 72, 71, 47, 45, 46] and ecosystem health of sweet chestnut forests [48, 64, 59], whereas on the other hand, shrub and grassland vegetation and resources were highly neglected [54, 27].

Floristic data were provided by [54, 61, 5, 41], as well as in the above mentioned vegetation studies. However, these publications do not deal with the area of Kongura reserve.

The aim of this study is to reveal the floristic and syntaxonomic diversity of Kongura reserve and to assess their current condition.

2 MATERIAL AND METHODS

2.1 Study area

The study was conducted in Kongura reserve, situated in the northeast part of Belasitsa Mountain. It covers 1310.8 ha in the valley of Petrichka river at altitude from 430 m to 1740 m a.s.l. (Fig. 1). The average annual air temperature is 9-11°C with average gradient of decline 0.26°C/100m. The highest average monthly temperature is in July (18-23°C) and the lowest in January (0-2°C) [6]. The monthly maximum precipitation rates are in November – December, and the minimum in July – August [21]. Annual precipitation rates are between 600 and 1100 mm, depending on the altitude. The snow cover is shallow and short lasting (about 20–80 days/year) between November and April. The bedrock type is silicate [30]. Soils are Litosols up to 1000 m a.s.l. and Regosols above [67].

The potential natural vegetation is mostly comprised of south and east Balkan, as well as Crimean-west Caucasian colline Oriental hornbeam-downy oak forests (Mapping unit G57) and Species-rich, eutrophic and eu-mesotrophic beech and mixed beech forests with two subtypes 1. Colline-submontane, partly with hornbeam, sessile oak (Mapping unit F124) and 2. Montane-altimontane mostly with fir, partly with spruce and other mixed tree species (Mapping unit F154) [69].

The territory of the reserve is part of the Belasitsa Natural Park as well as Site of Community Importance (NATURA 2000 site BG0000167 Belasitsa). Recently, Belasitsa Mt. was declared as Important Plant Area [26].

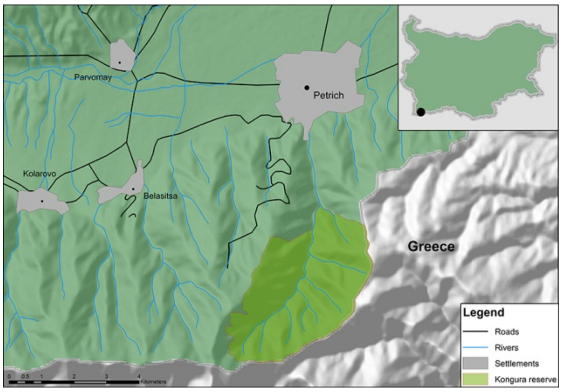

Figure 1: Map of the study area

2.2 Sampling of the flora

Field studies were conducted in summer and autumn of 2014 using transect sampling method. For compilation of the list of vascular plant species in the reserve phytosociological relevés from the syntaxonomic studies

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as well as some critical editions on the Bulgarian flora were used [18, 76, 77, 62, 19, 78]. The taxonomic scheme adopted follows mostly [13]. Biological types and life-forms are based on field observations and checked with relevant literature sources, e.g. [18, 77, 76, 62, 19, 50, 22]. Conservation significance of the species was determined according to [10] and [2]. Floristic elements follow [7].

2.3 Vegetation sampling

The field sampling was carried out during the period July – August 2014 following the Braun-Blanquet approach [35, 83]. We covered the whole range of different vegetation types as well as all grassland fragments on the territory of the reserve. We used 16 m^2, 64 m^2 and 100 m^2 plots (n = 28) square-shaped and placed in stands that were visually homogeneous in terms of topography, vegetation structure and floristic composition. All relevés were stored in TURBOVEG database [63] and in the Balkan Vegetation Database [38].

2.4 Data analysis of relevés

Numerical classification was performed by PC-ORD [9] incorporated in JUICE 7.0 software package [40]. Relative Sörensen was used as distance measure and species similarity was calculated using flexible betta (-0.25).

2.5 Habitat classification and mapping

Habitat types were determined according to the Interpretation Manual of European Union Habitats [34, 74]. Assignment of each vegetation unit at association level to a certain Habitat Directive Code (HDC) was given in the text. Mapping was done using ArcGIS 10.0 software [23]. Spatial data was collected in the field using GPS devise Juno BS by Trimble and was later overlaid over the most recent orthophoto images available. Outlining the polygons was done manually by using features collected in the field as well as the orthophoto images. Mapping was done in scale 1:5000.

3 RESULTS

3.1 Flora

The flora of Kongura reserve comprises 64 families, 184 genera and 300 species. The taxonomic structure of the flora is presented in table I. *Polypodiophyta* comprises 7.81% of the families, 3.80% of the genera and 2.67% of the species from the total flora, *Pinophyta* – 3.13% of families, 1.09% of genera, 0.67 of species, and *Magnoliophyta* – 89,06%, 95.11% and 96.67% respectively. The list of taxa is provided in Annex I.

Table I: Taxonomic structure of the flora

Taxon	no. of species	no. of genera	no. of families
Polypodiophyta	8	7	5
Pinophyta	2	2	2
Magnoliophyta	290	175	57
Magnoliopsida	*255*	*151*	*50*
Liliopsida	*35*	*24*	*7*
Total numbers	300	184	64

The richest in species 12 families are: *Asteraceae* – 29 species (9.67% of the total flora), *Rosaceae* – 25 (8.33%), *Fabaceae* – 25 (8.33%), *Lamiaceae* – 23 (7.67%), *Poaceae* – 18 (6.00%), *Caryophyllaceae* – 15 (5.00%), *Scrophulariaceae* – 13 (4.33%), *Rubiaceae* – 9 (3.00%), *Ranunculaceae* – 8 (2.72%), and *Apiaceae*, *Boraginaceae*, *Liliaceae* – each with 6 (2.33%). Altogether these families comprise 57.33% of the species and 52.72% of the genera in the total flora. The largest genera are *Galium* – 7 species, *Campanula* – 6, *Acer*, *Hieracium*, *Lathyrus*, *Trifolium*, *Viola* – each with 5 species, *Genista*, *Ranunculus*, *Rosa*, *Rubus*, *Veronica* – each with 4 species.

The biological spectrum of the flora of Kongura reserve is presented in table II.

Table II: Biological spectrum of the flora

Biological type	no. of species	Share (%)
Perennials	198	66.00
Shrubs, incl. semishrubs and lianes	31	10.33
Trees	23	7.67
Biennials and Annuals to Biennials	19	6.33
Annuals	12	4.00
Annuals to perennials and biennials to perennial	11	3.67
Shrub/Tree	6	2.00
total	**300**	100

The life-form spectrum of the flora of Kongura reserve is presented in table III.

Table III: Life-form spectrum of the flora

Life form	no. of species	Share (%)
Hemicryptophytes	172	57.33
Phanerophytes	43	14.33
Geophytes	33	11.00
Chamaephytes	19	6.33
Therophytes	13	4.33
Therophytes/ Hemicryptophytes	9	3.00
Chamaephytes/ Phanerophytes	7	2.33
Geophytes/ Hemicryptophytes	3	1.00
Chamaephytes/ Hemicryptophytes	1	0.33
total	300	100

The phytogeographic composition of the flora of Kongura reserve is presented in Table IV.

Table IV: Floristic elements in the flora of Kongura reserve

Floristic element	no. of species	Share (%)
subMed	38	12.67
Eur-As	37	12.33
Eur-Sib	34	11.33
Eur-Med	31	10.33
Eur	30	10.00
Boreal	27	9.00
subBoreal	22	7.33
Bal	10	3.33
Kos	9	3.00
Med	9	3.00

Eur-subMed	8	2.67
Bal-Anat	5	1.67
Carp-Bal	5	1.67
Eur-OT	4	1.33
Pont-Med	4	1.33
Alp-Carp	3	1.00
Spont	3	1.00
Ap-Bal	2	0.67
Other – each with 1 species (Adv (SAm), Alp-Carp-Bal, Arct-Alp, Bal-Carp, Bal-Dac, Bul-Dac, Eur-Med-CAs, Eur-Pont, Eur-WAs, Med-CAs, Med-OT, Med-subMed, Pann-Bal, Pont-OT, Pont-Sib, Pont-subMed, SSib, subMed-As, subMed-CAs)	19	6.34
total	**300**	**100**

The endemic taxa in the flora are 10 – *Acer heldreichii*, *Armeria rumelica*, *Chamaecytisus absinthioides*, *Digitalis viridiflora*, *Festuca hirtovaginata*, *F. valida*, *Peucedanum olygophyllum*, *Scabiosa triniifolia*, *Scrophularia aestivalis* and *Viola speciosa*, all Balkan endemics [3].

The species of conservation concern are five. With a national IUCN category are *Viola speciosa* (CR), *Castanea sativa* (EN), *Ilex aquifolium* (EN), *Medicago carstiensis* (EN), *Acer heldreichii* (VU), all included in the *Red Data Book of the Republic of Bulgaria* [15, 14, 12,11, 17, 16, 64, 65]. Legally protected by the national Biodiversity Act are three species – *Acer heldreichii*, *Ilex aquifolium* and *Viola speciosa*.

3.2 Vegetation

Classification of relevés showed a great diversity of communities on the territory of Kongura reserve. The list of established syntaxa consists of 10 classes, 10 orders, 12 alliances, 8 associations and 5 communities at association level. Beech forests are the most widespread vegetation type and cover more than 85% of the reserve's territory. Despite their prevalence they are relatively uniform and were classified into two associations of *Querco-Fagetea* class (clusters 1-12 Fig. 2).

3.2.1 Ass. *Asperulo odoratae-Fagetum sylvaticae* (HDC: 9130; 1101.0 ha)

This is the most widespread association on the territory of the reserve. Its communities occur at 700-1600 m a.s.l. on moderately steep slopes (20°-30°) with varying aspects. Soils are shallow to moderately deep regosols. The dominant species is *Fagus sylvatica* but at lower altitude other species like *Castanea sativa*, *Quercus dalechampii* and *Carpinus betulus* are found as subdominant with covers between 10% and 30%. The shrub layer is usually missing but undergrowth has cover between 0% and 40%, mainly by *Calamagrostis arundinacea*, *Luzula sylvatica*, *Melica uniflora*, *Euphorbia amygdaloides*, *Festuca heterophylla*, *Geranium robertianum*, *Lapsana communis*.

3.2.2 Ass. *Aremonio agrimonoidis-Fagetum sylvaticae* (HDC: 91W0; 28.4 ha)

This vegetation type was found at 900-1000 m a.s.l. on south facing slopes with inclination of 30°-35°. *Fagus sylvatica* subsp. *moesiaca* is dominant species and subdominants are *Castanea sativa* and *Quercus dalechampii*. Shrub layer is presented by young trees of above mentioned species as well as *Carpinus betulus*, *Tilia tomentosa*, *Fraxinus ornus*, *Acer platanoides* and *Crataegus monogyna*. Undergrowth is well developed mainly by *Dactylis glomerata*, *Melica uniflora*, *Poa nemoralis*, and *Festuca heterophylla*.

Quercetea pubescentis class covers only 11% of the study area but its communities were classified into three different alliances (clusters 13-17 and 24 Fig. 2).

3.2.3 Ass. *Tilio tomentosae-Castanetum sativae* (HDC: 9260; 113.7 ha)

Sweet chestnut forests are distributed from 550-800 m a.s.l. on north facing slopes with inclination of 25°-35°. Soils are moderately deep litosols. *Castanea sativa* is dominating in the tree layer (50%-70%) together with *Fagus sylvatica* subsp. *moesiaca* (20%-40%). Participation of *Quercus dalechampii* and *Carpinus orientalis* is low (up to 10%). Accept for the species from the tree layer the shrub layer is also formed by *Chamaecytisus austriacus*, *Corylus avellana*, *Rubus caesius*, *Rosa* sp. *Brachypodium sylvaticum*, *Melica uniflora*, *Galium pseudoaristatum* and *Festuca heterophylla* are forming the undergrowth.

3.2.4 *Quercus dalechampii* communities (HDC: 9170; 20.5 ha)

Communities of *Quercus dalechampii* have a limited distribution on the territory of the reserve. They cover areas between 750 and 800 m a.s.l. on north facing slopes with inclination between 25°-35°. Soils are moderately deep litosols. Balkan durmast oak is covering between 50%-60% whereas its subdominants (*Castanea sativa* and *Fagus sylvatica*) between 10%-20%. Single trees of *Carpinus orientalis* and *Ostrya carpinifolia* are also typical for the communities. The shrub layer is formed by *Corylus avellana*, *Chamaecytisus austriacus* and *Crataegus monogyna*. Undergrowth is formed mainly by *Poa nemoralis*, *Dactylis glomerata*, *Brachypodium sylvaticum*, *Galium pseudoaristatum*.

3.2.5 *Ostrya carpinifolia* community (HDC: – ; 4.8 ha)

Hop hornbeam communities are locally distributed in the area at 500 m a.s.l. on northern slopes with prevailing inclination of 10°-35°. Soils are shallow, moderately dry litosols. The dominant species in the tree layer is *Ostrya carpinifolia*, but *Quercus dalechampii* is also forming substantial cover. Single trees of *Fagus sylvatica*, *Castanea sativa* and *Carpinus orientalis* are also common. Shrub layer is mainly formed by the same species like in the tree layer together with *Chamaecytisus austriacus*, *Corylus avellana*, *Crataegus monogyna* and *Rosa* sp. The composition of the undergrowth is uniform, with higher abundance of *Dactylis glomerata*, *Galium pseudoaristatum*, *Festuca heterophylla* and *Poa nemoralis*.

Platanus orientalis woods (cluster 25 Fig. 2) are only distributed along the Petrichka River at the lower part of the territory and were classified to *Salici-Populetea* class.

3.2.6 Ass. *Petasito hybridi-Platanetum orientalis* (HDC: 92C0; 3.4 ha)

The association is locally distributed at 600-650 m a.s.l. on slightly inclined north facing slopes. Soils are rich, moderately deep, alluvial. *Platanus orientalis* is forming mono-dominant communities with low cover (less than 10%) of other tree species like *Fagus sylvatica* and *Ostrya carpinifolia*. Shrub layer is formed by young individuals of the above mentioned trees as well as *Rubus caesius*, *Acer platanoides* and *Sambucus nigra*. Species with high cover in the undergrowth are *Dryopteris* spp., *Aegopodium podagraria*, *Geranium robertianum*, *Physospermum cornubiense* and *Lunaria rediviva*.

Shrublands and grasslands are covering very small areas (2% and 0.2% of the total area respectively) due to the intentional selection of the boundaries of the reserve to protect the well preserved *Castanea sativa* and *Fagus sylvatica* forests. Shrubby vegetation (clusters 18-20 Fig. 2) is classified to *Loiseleurio-Vaccinietea* and *Rhamno-Prunetea* classes.

3.2.7 Ass. *Festuco-Juniperetum sibiricae* (HDC: 4060; 24.4 ha)

The association is present at the beech forests belt, just above the timberline at 950-1150 m a.s.l. Soils are shallow to moderately deep, regosols. *Juniperus sibirica* is forming the highest cover but species like *Chamaecytisus absinthioides*, *Vaccinium myrtilus*, and *Rubus caesius* are also well presented (10%-35%). The herb layer is dominated by *Calamagrostis arundinacea*, *Festuca valida*, *Thymus jankae* and *Luzula luzuloides*.

3.2.8 *Rosa*, *Crataegus*, *Prunus* community (HDC: – ; 1.0 ha)

This community is very locally distributed at the beech forests belt in forest openings at the place of abandoned secondary grasslands at 1300-1700 m a.s.l. Soils are shallow to moderately deep, regosols. Dominant species are *Rosa* sp., *Crataegus monogyna* and *Prunus spinosa*. Other species with higher values are *Chamaecytisus absinthioides*, *Rubus caesius*, *Festuca hirtovaginata*, *Thymus jankae*, *Brachypodium pinnatum*, *B. sylvaticum*, *Dactylis glomerata*. At certain places stands are showing a transition to ass. *Festuco-Juniperetum sibiricae*.

Herb communities (clusters 21-23 and 26-27 Fig. 2) showed greater diversity than other vegetation types and were assigned to five phytosociological classes: *Trifolio-Geranietea*, *Festuco-Brometea*, *Juncetea trifidi*, *Mulgedio-Aconitetea* and *Galio-Urticetea*.

3.2.9 Ass. *Festucetum validae* (HDC: 62D0; 0.9 ha)

Communities of this association are locally distributed in the sub-alpine and beech forests zones on western slopes with inclination 5°-15°. Soils are shallow to moderately deep, regosols. Species with high cover values are: *Festuca valida*, *Thymus jankae*, *Calamagrostis arundinacea*, *Juniperus sibirica*, *Vaccinium myrtilus*, *Luzula luzoloides*.

3.2.10 *Calamagrostis arundinacea* community (HDC: – ; 0.4 ha)

These communities are locally distributed in the sub-alpine zone of the reserve above the timber line on north and northwestern slopes with inclination of 10°-25°. *Calamagrostis arundinacea* is a dominant species and subdominants are *Rubus caesius*, *Epilobium angistifolium* and *Festuca valida*. Individuals of shrubs like *Fagus sylvatica*, *Juniperus sibirica* and *Vaccinium myrtilus* are also present in the community.

3.2.11 *Festuca hirtovaginata* community (HDC: 6210; 0.06 ha)

These communities are locally distributed in the beech forests zone on southern slopes with inclination 3°-8°. Soils are shallow, dry litosols. Communities have semi-open horizontal structure with no single species dominating. The group of species with high cover values contain *Festuca hirtovaginata*, *Carex caryophyllea*, *Phleum phleoides*, *Agrostis castellana*, *Thymus jankae*.

3.2.12 Ass. *Pteridietum aquiline* (HDC: – ; 0.8 ha)

The association is present at the beech forests belt on flat or slightly inclined terrains. Soils are regosols. Horizontal structure is closed with high cover of *Pteridium aquilinum* (90%-100%).

3.2.13 Ass. *Urtico-Sambucetum ebuli* (HDC: – ; 0.3 ha)

The association was found in a single locality in the beech zone at 1300 m a.s.l. on flat or slightly inclined terrains. Soils are moderately deep regosols. Communities have a specific species composition, rich in ruderal species. *Sambucus ebulus* is dominating with cover of 80%-90%.

Proposed syntaxonomical scheme:

Cl. *Salici purpureae-Populetea nigrae* Rivas-Martinez et Cantó ex Rivas-Martinez et al. 2001
  Ord. *Populetalia albae* Br.-Bl. ex Tchou 1948
    All. *Platanion orientalis* Kárpáti et Kárpáti 1961
      Ass. *Petasito hybridi-Platanetum orientalis* Kárpáti et Kárpáti 1961
Cl. *Querco-Fagetea* Braun-Blanq. et Vlieger in Vlieger 1937
  Ord. *Fagetalia sylvaticae* Pawł. et al. 1928
    All. *Fagion sylvaticae* Luquet 1926
      Ass. *Asperulo odoratae-Fagetum sylvaticae* Sougnez et Thill 1959
      Ass. *Aremonio agrimonoidis-Fagetum sylvaticae* Boşcaiu in Resmeriţă 1972
Cl. *Quercetea pubescentis* (Oberd. 1948) Doing Kraft 1955
  Ord. *Quercetalia pubescenti-petreae* Klika 1933
    All. *Carpinion orientalis* Horvat 1958
      Ostrya carpinifolia community
    All. *Quercion confertae Horvat 1954*
      Ass. *Tilio tomentosae-Castanetum sativae* Dafis 1973
    All. *Quercion petraeo-cerridis* (Lakušić et Jovanović 1980) Čarni et al. 2009
      Quercus dalechampii community
Cl. *Loiseleurio-Vaccinietea* Eggl. 1952 ex Schub. 1960
  Ord. *Rhododendro-Vaccinietalia* Braun-Blanq. in Braun-Blanq. et Jenny 1926
    All. *Juniperion nanae* Br.-Bl. et al. 1939
      Ass. *Festuco-Juniperetum sibiricae* Roussakova in Tzonev et al. 2009
        facies of *Chamaecytisus absinthioides*
Cl. *Rhamno-Prunetea* Rivas Goday et Borja Carbonell, 1961
  Ord. *Prunetalia spinosae* Tüxen 1952
    All. *Berberidion vulgaris* Br.-Bl. 1950
      Rosa, *Crataegus*, *Prunus* community
Cl. *Trifolio-Geranietea sanguinei* T. Müller 1962
  Ord. *Melampyro pratensis-Holcetalia mollis* Passarge 1979
    All. *Holco mollis-Pteridion aquilini* Passarge (1994) 2002
      Ass. *Pteridietum aquilini* Jouanne & Chouard 1929

Cl. *Festuco-Brometea* Braun-Blanq. et Tüxen ex Soó 1947
Ord. *Astragalo-Potenilletalia* Micevski 1971
All. *Armerio-Potentillion* Mic. 1978
Festuca hirtovaginata community
Cl. *Juncetea trifidi* Hadač in Klika et Hadač 1944
Ord. *Seslerietalia comosae* Simon 1958
All. *Poion violaceae* Horvat 1937
Ass. *Festucetum validae* Horvat et al. 1937

Cl. *Mulgedio-Aconitetea* Hadač et Klika in Klika et Hadač 1944
Ord. *Calamagrostietalia vilosae* Pawlowski et al. 1928
All. *Calamagrostion arundinaceae* Oberd. 1950
Calamagrostis arundinacea community
Cl. *Galio-Urticetea* Passarge ex Kopecky 1969
Ord. *Lamio albi-Chenopodietalia boni-henrici* Kopeckỳ 1969
All. *Geo-Alliarion* Lohm et Oberd. in Görs et Müler 1969
Ass. *Urtico-Sambucetum ebuli* Braun-Blanq. et al. 1952

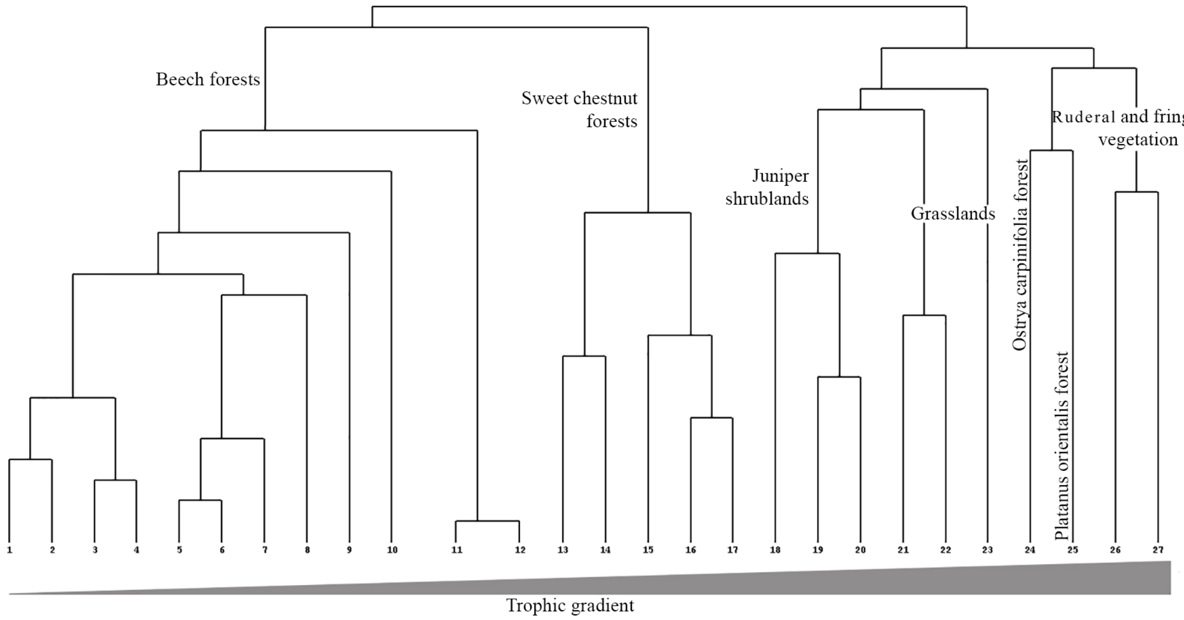

Figure 2: Dendrogram of phytosociological relevés (Relative Sorensen clustering method; flexible betta (-0.25) used for similatiry). Legend: *Asperulo odoratae-Fagetum sylvaticae* (clusters 1-10), *Aremonio agrimonoidis-Fagetum sylvaticae* (clusters 11 and 12), *Tilio tomentosae-Castanetum sativae* (clusters 13-15), *Quercus dalechampii* community (clusters 16 and 17), *Festuco-Juniperetum sibiricae* (clusters 18-20), *Festucetum validae* (cluster 21), *Calamagrostis arundinacea* community (cluster 22), *Festuca hirtovaginata* community (cluster 23), *Ostrya carpinifolia* community (cluster 24), *Petasito hybridi-Platanetum orientalis* (cluster 25), *Urtico-Sambucetum ebuli* (cluster 26), *Pteridietum aquilini* (cluster 27).

4 DISCUSSION

4.1 Flora

Kongura reserve comprises 7.3% of the species in the Bulgarian flora. Vascular plant diversity is relatively low compared to some other areas with similar size, e.g. Vitanovo Reserve in Strandzha Mts [36] has smaller size but the number of vascular plant species is higher by ca. 54%. This can be explained by the fact that almost the entire territory of Kongura reserve is covered by beech and sweet chestnut forests, by the siliceous bedrock and by the lack of diversity of substrate and expositions. The share of *Polypodiophyta* in the flora of Kongura reserve – 2.67% of all species – is slightly higher than in some other studied sites, e.g. Vrashka Chuka protected site (0.8%, [82]), Mt Golo Bardo (0.6%, [51]) as well as for the whole country (1.1%, cf. [4]). This fact was noted first by [54] and can be explained with the presence of suitable habitats and environmental conditions, e.g. prevalence of forested habitats, northern expositions, relatively high soil and air humidity.

Regarding the presentation of the different families, the relatively high share of *Rosaceae* and relatively low share of *Asteraceae* and *Poaceae* in the flora of Kongura reserve are notable if compared with the data for the total Bulgarian flora ([4]). Again, this can be explained with the availability of suitable habitats for *Rosaceae* (especially for shrubs and trees), and lack of such for *Asteracea*e and *Poaceae* (e.g. large open areas). For similar reasons the higher representation of the genera *Campanula, Galium* and *Viola* is obvious if compared with data for the whole country [4].

The analysis of the biological types and life forms in the flora of Kongura reserve shows an overall pattern characteristic for the temperate mountainous floras in the Balkans – strong prevalence of herbaceous perennial species, respectively hemicryptophytes [20]. However, it is noteworthy the relatively high representation of shrubs and trees, respectively phanerophytes, and the low presentation of annuals and therophytes which relates to the habitat availability. For example, the phanerophytes in the flora of Mt Golo Bardo are 10% (ca. two times lower than in Kongura) and therophytes are 18% (four times higher than in Kongura) [51].

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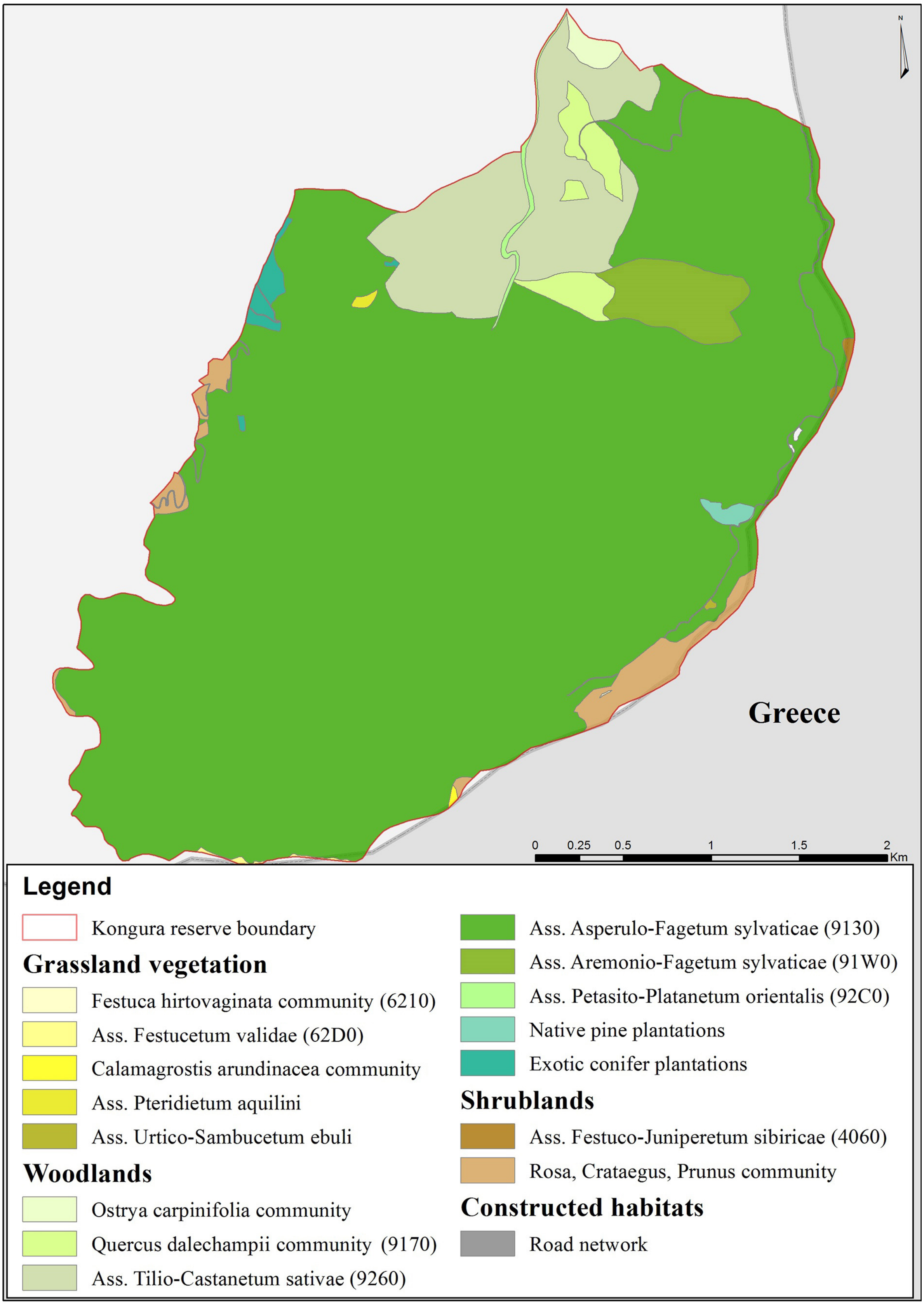

Figure 3: Map of vegetation units on Kongura reserve. Codes in brackets represent the codes of habitats in the Habitat directive: 6210 – Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*), 62D0 – Oro-Moesian acidophilous grasslands, 9170 – *Galio-Carpinetum* oak-hornbeam forests, 9260 – *Castanea sativa* woods, 9130 – *Asperulo-Fagetum* beech forests, 91W0 – Moesian beech forests, 92C0 – *Platanus orientalis* and *Liquidambar orientalis* woods (*Platanion orientalis*), 4060 – Alpine and Boreal heaths.

The phytogeographical analysis shows that in the flora of Konura reserve prevail the following floristic elements – subMediterranean, Euro-Asiatic, Euro-Siberian, Euro-Mediterranean, European, Boreal and subBoreal, which altogether comprise nearly 73% of the total flora. This pattern is similar to the pattern in other studied areas, e.g. Mt Golo Bardo [51]. However, the representation of the Mediterranean and subMediterranean chorotypes is obviously lower (21.4% in Golo Bardo) and corresponds better to the share in the mountain regions – 11.9% [20]. This intermediate position of Kongura reserve can be explained with the higher elevation and position further to the south.

The endemism in the flora of Kongura reserve is low – only about 3.33% if compared with the data for the whole country – ca. 11% of the total Bulgarian flora [3]. This corresponds well with the low number of endemic species for the whole mountain and floristic region of Belasitsa as well as with the ecological structure of endemism in Bulgaria. As [80] state, with a few exceptions the Bulgarian endemics grow in open places, and are heliophytes and xerophytes, but this is true also for the Balkan endemics.

Although the number of the species of conservation concern is rather low, the reserve is of crucial importance for the preservation of these species. It harbours some of the best subpopulations at national level, e.g. of *Castanea sativa*, *Medicago carstiensis*, and *Viola speciosa*.

4.2 Vegetation

4.2.1 Syntaxonony

This investigation is one of the few comprehensive studies about vegetation diversity in SW part of Bulgaria [25, 68]. In addition this is one of the few studies about fringe [29, 75, 42, 37], ruderal [31, 32, 39, 56, 42, 43, 37, 24] and shrubland vegetation belonging to *Rhamno-Prunetea* class [41] in the country. Due to the small size of the study area as well as the limited distribution of some vegetation types we were unable to classify them to already described associations, so they were classified as communities. Beech and sweet chestnut forests are among the best studied communities of all vegetation types present on the mountain [57, 58]. Further studies should be conducted for analyzing communities of *Festuca hirtovaginata*, *Calamagrostis arundinaceae* and shrublands dominated by *Rosa sp.*, *Crataegus monogyna* and *Prunus spinosa*.

Despite the wide distribution of *Quercus dalechampii* forests in Bulgaria their syntaxonomical position according to Braun-Blanquet approach is still uncertain. According to the variety of described formations and associations following the dominant approach, its communities will be probably classified to more than one class. Problem for classification of Balkan durmast oak forests is also the fact that *Quercus dalechampii* is often recorded as *Quercus petraea* agg., including *Quercus petraeae*, *Q. dalechampii* and *Q. polycarpa*, [8] or even misidentified as any of the species of the group. Mesophitic woodlands of *Quercus dalechampii* with *Fagus sylvatica*, *Carpinus betulus*, *Poa nemoralis* and *Luzula luzuloides* might be separated as “mesophytic type” and should be classified to *Querco-Fagetea* class. This vegetation type is known from other parts of the country such as Balkan Range (unpublished data), Rila Mt, Pirin Mt, Sredna Gora Mts (unpublished data) and Western Frontier Mts [25]. On the other hand xerophytic communities of *Quercus dalechampii* are found together with *Pinus nigra*, *Fraxinus ornus*, *Carpinus orientalis*, *Brachypodium pinnatum* and *Dactilis glomerata*. They should be assigned to *Carpinion orientalis* alliance of *Quercietea pubescenti* class. This “xerophytic type” is known up to now from Balkan Range (Chamdzha reserve, Vassilev & Gavrilova in preparation), Western Frontier Mts (Gabra reserve, [28]) *Quercus dalechampii* communities from Kongura reserve show an intermediate position determined by their mountainous distribution on one hand and the Mediterranean influence on the other. These ecological characteristics as well as the species composition convinced us to consider *Quercion petraeo-cerridis* alliance (*Quercietea pubescenti* class) as suitable for our communities. [1]) report communities of the same alliance only 50 km west from the Kongura reserve, on the territory of Macedonia. Future analysis with supranational dataset from the areal of *Quercus dalechampii* in S and SE Europe will give the real syntaxonomical position of its communities.

4.2.2 Ecology

Agglomerative classification of the data resulted in sorting of relevés along the gradient of soil trophic status (Fig. 2), which appeared to be the most important environmental factor responsible for their separation. The oligotrophic beech forests of *Asperulo-Fagetum* were positioned at the left edge of the dendrogram whereas eutrophic ruderal communities of *Urtico-Sambucetum ebuli* appeared on the right-most part.

Vegetation belts in Kongura reserve as well as on the whole Belasitsa Mt. are well preserved like in most high Bulgarian mountains (Stara Planina, Rila, Pirin, the Rhodopes). Xero-mesophytic forests of *Quercetea pubescenti* class (*Castanea sativa*, *Quercus dalechampii* and *Ostrya carpinifolia* stands) are distributed at the bottom of the altitudinal gradient up to 800 m a.s.l. Higher parts of the slopes are covered by mesophytic beech forests belonging to *Querco-Fagetea* class, which form the timberline in the reserve at about 1500-1700 m a.s.l. Grasslands of *Juncetea trifidi* class are distributed above the beech woodlands up to the top of the mountain. They are very weakly presented in the reserve because beech and sweet chestnut forests were the target communities subject to protection. They usually grow in a complex with shrublands of *Loiseleurio-Vaccinietea* class outside the reserve’s territory. The other herb communities do not form a separate belt but grow on forest openings in the forest zone. *Platanus orientalis* communities are also zonally distributed, intersecting the beech and sweet chestnut belts along the small streams.

Within the reserve’s territory we encountered the tendency of shrub encroachment in grasslands. At higher altitude *Festuca valida* grasslands were overgrown by *Juniperus sibirica* whereas at lower places *Festuca hirtovaginata* communities were almost completely replaced by *Rosa* sp., *Crataegus monogyna* and *Prunus spinosa*.

4.2.3 Importance for conservation

Looking from conservational point of view, among all 13 communities at association level, there are 8 habitat types (Fig. 3) protected by Appendix 1 of the Bulgarian Biological Diversity Act (2007) and Directive 92/43/EEC. Most habitat types (6210, 62D0, 9170, 9130, 91W0 and 4060) are widespread on the territory of the country, whereas 92C0 *Platanus orientalis* and *Liquidambar orientalis* woods (*Platanion orientalis*) is

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distributed only in Macedono-Rhodope mountains and neighboring lowlands but its largest areas are on the territory of Belasitsa Mt. Similar example is habitat type 9260 – *Castanea sativa* woods, 80% of the national cover of which is also on northern slopes of Belasitsa Mt.

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Annex I: List of taxa

POLYPODIOPHYTA

***Aspidaceae*:** *Dryopteris filix-mas* (L.) Schott, *Gymnocarpium dryopteris* (L.) Newman; ***Aspleniaceae*:** *Asplenium adiantum-nigrum* L., *A. trichomanes* L.; ***Athyriaceae*:** *Athyrium filix-femina* (L.) Roth, *Cystopteris fragilis* (L.)Bernh.; ***Hypolepidaceae*:** *Pteridium aquilinum* (L.) Kuhn.; ***Polypodiaceae*:** *Polypodium vulgare* L.

PINOPHYTA

***Cupressaceae*:** *Juniperus sibirica* Burgsd.; ***Pinaceae*:** *Pinus sylvestris* L.

MAGNOLIOPHYTA

Magnoliopsida

***Aceraceae*:** *Acer campestre* L., *A. heldreichii* Orph.; *A. hyrcanum* Fisch. & C.A. Mey; *A. platanoides* L.; *A. pseudoplatanus* L.; ***Apiaceae*:** *Aegopodium podagraria* L., *Ferulago sylvatica* (Besser) Rchb., *Huetia cynapioides* (Guss.) P. W. Ball, *Peucedanum oligophyllum* (Griseb.) Vandas, *Physospermum cornubiense* (L.) DC., *Sanicula europaea* L., *Seseli libanotis* (L.) Koch; ***Aquifoliaceae*:** *Ilex aquifolium* L.; ***Araliaceae*:** *Hedera helix* L.; ***Aristolochiaceae*:** *Asarum europaeum* L.; ***Asteraceae*:** *Achillea grandifolia* Friv., *A. millefolium* L., *Anthemis tinctoria* L., *Arctium lappa* L., *Artemisia vulgaris* L., *Centaurea biebersteinii* DC., *C. stenolepis* A. Kern., *C. stoebe* L., *Cichorium inthybus* L., *Cirsium candelabrum* Griseb., *C. ligulare* Boiss., *C. vulgare* (Savi) Ten., *Doronicum columnae* Ten., *Erigeron acris* L., *Galinsoga parviflora* Cav., *Hieracium hoppeanum* Schult., *H. murrorum* L., *H. pilosella* L., *H. racemosum*Waldst. &Kit., *H. sparsum* Friv., *Inula conyza* DC., *Lapsana communis* L., *Leucanthemum vulgare* Lam., *Mycelis muralis* (L.) Dum., *Omalotheca sylvatica* (L.) Sch. Bip. & F.W. Schultz, *Senecio papposus* (Reichenb.) Less., *Tanacetum corymbosum* (L.) Schultz-Bip., *T. macrophyllum* (Waldst. & Kit.) Sch. Bip., *T. vulgare* L.; ***Balsaminaceae*:** *Impatiens noli-tangere* L.; ***Betulaceae*:** *Betula pendula* Roth, *Carpinus betulus* L., *C. orientalis* Mill., *Corylus avellana* L., *Ostrya carpinifolia* Scop.; ***Boraginaceae*:** *Buglossoides purpurocaerulea* (L.) I.M. Johnst., *Echium vulgare* L., *Myosotis nemorosa* Besser, *Pulmonaria mollis* Hornem., *P. officinalis* L., *P.rubra* Schott, *Symphytum ottomanum* L.; ***Brassicaceae*:** *Alliaria petiolata* (M.Bieb.) Cavara & Grande, *Arabis glabra* (L.) Bernh., *A.sagittata* (Bertol.) DC., *A.turrita* L., *Cardamine bulbifera* (L.) Crantz, *Lunaria rediviva* L.; ***Campanulaceae*:** *Campanula glomerata* L., *C. patula* L., *C. persicifolia* L., *C. rapunculoides* L., *C. sparsa* Friv., *C. trachelium* L.; ***Caprifoliaceae*:** *Sambucus ebulus* L., *S. nigra* L.; ***Caryophyllaceae*:** *Cerastium alpinum* L., *C. dubium* (Bastard) Guépin, *Dianthus armeria* L., *D. petraeus* Waldst. & Kit., *Lychnis coronaria* (L.) Desr., *L. flos-cuculi* L., *Moehringia trinervia* (L.) Clairv., *Saponaria officinalis* L., *Silene italica* (L.) Pers., *S. latifolia* Poir., *S. vulgaris* (Moench) Garcke, *Stellaria graminea* L., *S. holostea* L., *S. media* (L.) Vill.,*Viscaria vulgaris* Röhl.; ***Celastraceae*:** *Euonymus europaeus* L., *E. latifolius* (L.) Mill.; ***Cornaceae*:** *Cornus mas* L., *C. sanguinea* L.; ***Crassulaceae*:** *Sedum cepaea* L., *Umbilicus erectus* DC.; ***Cuscutaceae*:** *Cuscuta epithymum* (L.) L.; ***Dioscoreaceae*:** *Tamus communis* L.; ***Dipsacaceae*:** *Knautia drymeia* Heuff., *Scabiosa columbaria* L., *S. ochroleuca* L., *S. triniifolia* Friv.; ***Ericaceae*:** *Bruckenthalia spiculifolia* (Salisb.) Rchb., *Vaccinium myrtillus* L., *V.uliginosum* L., *V. vitis-idaea* L.; ***Euphorbiaceae*:** *Euphorbia amygdaloides* L., *E. polychroma* A. Kern., *Mercurialis perennis* L.; ***Fabaceae*:** *Astragalus glycyphyllos* L., *Chamaecytisus absinthioides* (Janka) Kuzm., *Ch. austriacus* (L.) Link, *Ch. hirsutus* (L.) Link., *Ch. supinus* (L.) Link, *Coronilla emerus* L. subsp. *emeroides* (Boiss. &Spruner) Holmboe, *C.varia* L., *Genista carinalis* Griseb., *G. depressa* M. Bieb., *G. lydia* Boiss., *G. ovata* Waldst. et Kit., *Lathyrus laxiflorus* (Desf.) Kuntze, *L. niger* (L.) Bernh., *L. pratensis* L., *L. venetus* (Mill.) Wohlf., *L. vernus* (L.) Bernh., *Lotus aegaeus* (Griseb.) Boiss., *L. corniculatus* L., *Medicago carstiensis* Wulf., *Trifolium alpestre* L., *T. arvense* L., *T. aureum* Poll., *T. pratense* L., *T. repens* L., *Vicia cracca* L.; ***Fagaceae*:** *Castanea sativa* Mill., *Fagus sylvatica* L., *Quercus dalechampii* Ten.; ***Geraniaceae*:** *Geranium robertianum* L., *G. sylvaticum* L.; ***Hypericaceae*:** *Hypericum maculatum* Crantz, *H. olympicum* L., *H. perforatum* L.; ***Lamiaceae*:** *Acinos alpinus* (L.) Moench, *A. arvensis* (Lam.) Dandy, *Ajuga genevensis* L., *Calamintha grandiflora* (L.) Moench, *Clinopodium vulgare* L., *Galeopsis tetrahit* L., *Glehoma hederacea* L., *Lamium galeobdolon* (L.) Crantz, *L. garganicum* L., *L. maculatum* L., *L. purpureum* L., *Melittis melissophyllum* L., *Mentha longifolia* (L.) Huds., *M. spicata* L., *Nepeta nuda* L., *Origanum vulgare* L., *Prunella vulgaris* L., *Salvia glutinosa* L., *Stachys alpina* L., *S. germanica* L., *S. sylvatica* L., *Teucrium chamaedrys* L., *Thymus jankae* Čelak.; ***Malvaceae*:** *Althaea officinalis* L., *Lavatera thuringiaca* L.; ***Oleaceae*:** *Fraxinus ornus* L.; ***Onagraceae*:** *Circaea luteciana* L., *Epilobium angustifolium* L., *E. montanum* L.; ***Orobanchaceae*:** *Orobanche gracilis* Sm., *O. reticulata* Wallr.; ***Oxalidaceae*:** *Oxalis acetosella* L.; ***Papaveraceae*:** *Chelidonium majus* L., *Corydalis solida* (L.) Clairville; ***Plantaginaceae*:** *Plantago major* L., *P. subulata* Roth; ***Platanaceae*:** *Platanus orientalis* L.; ***Plumbaginaceae*:** *Armeria rumelica* Boiss.; ***Polygonaceae*:** *Bilderdykia convolvulus* (L.) Dumort., *Rumex acetosa* L., *R. acetosella* L., *R. pulcher* L.; ***Primulaceae*:** *Cyclamen hederifolium* Aiton, *Lysimachia punctata* L., *Primula acaulis* (L.) L., *P. veris* L.; ***Pyrolaceae*:** *Orthilia secunda* (L.) House; ***Ranunculaceae*:** *Anemone ranunculoides* L., *Clematis vitalba* L., *Helleborus odorus*Waldst. & Kit., *Isopyrum thalictroides* L., *Ranunculus acris* L., *R. ficaria* L., *R. nemorosus* DC., *R. repens* L.; ***Rosaceae*:** *Agrimonia eupatoria* L., *Aremonia agrimonoides* (L.) DC., *Cotoneaster nebrodensis* (Guss.) K. Koch, *Crataegus monogyna* Jacq., *Fragaria moschata* Weston, *F. vesca* L., *F. viridis* Duchesne, *Geum urbanum* L., *Malus sylvestris* Mill., *Potentilla inclinata* Vill., *P. micrantha* DC., *Prunus avium* (L.) L., *P. spinosa* L., *Rosa arvensis* Huds., *R. canina* L., *R. dumalis* Bechst., *R. pendulina* L., *Rubus caesius* L., *R. canescens* DC., *R. idaeus* L., *R. sanguineus* Friv., *Sanguisorba minor* Scop., *Sorbus aria* (L.) Crantz, *S. borbasii* Jav., *S. torminalis* (L.) Crantz; ***Rubiaceae*:** *Asperula aristata* L., *Cruciata glabra* (L.) Opiz, *Galium album* Mill.,*G. anisophyllon* Vill., *G. aparine* L., *G. odoratum* (L.) Scop., *G. pseudaristatum* Schur, *G. schultesii* Vest, *G.verum* L.; ***Salicaceae*:** *Populus tremula* L., *Salix caprea* L.; ***Santalaceae*:** *Thesium linophyllon* L.; ***Saxifragaceae*:** *Saxifraga rotundifolia* L.; ***Scrophulariaceae*:** *Digitalis grandiflora* Mill., *D. viridiflora* Lindl., *Euphrasia liburnica* Wettst., *Lathraea squamaria* L., *Odontites serotina* (Lam.) Dum., *Scrophularia aestivalis*Griseb., *S.scopolii* Hoppe ex Pers., *Verbascum abietinum* Borbas, *V. longifolium* Ten. subsp. *pannosum* (Vis. & Pančić) Murb., *Veronica chamaedrys* L., *V. officinalis* L., *V. verna* L., *V. vindobonensis* (M. Fisch.) M. Fisch.; ***Solanaceae*:** *Atropabella-donna* L., *Solanum dulcamara* L.; ***Tiliaceae*:** *Tilia cordata* Mill.,*T. tomentosa* Moench; ***Urticaceae*:** *Urtica dioica* L.; ***Valerianaceae*:** *Valeriana officinalis* L.; ***Violaceae*:** *Viola canina* L., *V. odorata* L., *V. riviniana* Rchb., *V. speciosa* Pant., *V. tricolor* L.

Liliopsida

***Araceae*:** *Arum maculatum* L.; ***Cyperaceae*:** *Carex caryophyllea* Latour.,*Carex hirta* L.; ***Iridaceae*:** *Crocus chrysanthus* (Herb.) Herb.; ***Juncaceae*:** *Luzula campestris* (L.) DC., *L. luzuloides* (Lam.) Dandy, *L. sylvatica* (Huds.) Gaudin; ***Liliaceae*:** *Lilium martagon* L., *Ornithogalum nutans* L., *Paris quadrifolia* L., *Polygonatum latifolium* (Jacq.) Desf., *P. odoratum* (Mill.) Druce, *Scilla bifolia* L., *Veratrum lobelianum* Bernh.; ***Orchidaceae*:** *Cephalanthera longifolia* (L.) Fritsch, *Epipactis helleborine* (L.) Crantz, *Neottia nidus-avis* (L.) Rich.; ***Poaceae*:** *Agrostis capillaris* L., *A. castellana* Boiss. & Reut., *Alopecurus pratensis* L., *Brachypodium sylvaticum* (Huds.) Beauv., *B. pinnatum* (L.) P. Beauv., *Calamagrostis arundinacea* (L.) Roth, *Dactylis glomerata* L., *Deschampsia flexuosa* (L.)Trin., *Festuca heterophylla* Lam., *F. hirtovaginata* (Acht.) Markgr.-Dann., *F. rubra* L., *F.* (Uechtr.) Pénzes, *Melica uniflora* Retz., *Milium effusum* L., *Phleum phleoides* (L.) H. Karst., *Ph. pratense* L., *Poa annua* L., *P. nemoralis* L.

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JUNCUS FILIFORMIS L. (JUNCACEAE), A NEW SPECIES IN THE FLORA OF MACEDONIA

[1]TEOFILOVSKI A., [2]NIKOLOV Z., [1]MANDŽUKOVSKI D.
[1]*Public enterprise Makedonski sumi, Skopje, Macedonia*
[2]*Macedonian museum of natural history, Skopje, Macedonia*
Corresponding author e-mail address: acoteofilovski@hotmail.com

ABSTRACT: In this work *Juncus filiformis* is reported for the first time in the flora of Macedonia. The species was discovered in the subalpine belt of Mt Šar Planina - on Bogovinje Leak coast. Chorological and ecological data regarding the discovered population with additions of a photograph of live specimens, a photograph of fruiting inflorescence of herbarium specimens, and a distribution map are presented. A short discussion of taxonomical position of the species and short description are also given.
Keywords: *Juncus filiformis*, new, species, flora, Macedonia.

1 INTRODUCTION

The genus *Juncus* L. comprises c. 300 species which are widely distributed in both hemispheres, but most abundantly in the temperate and cold regions. A monographic study of this genus in the flora of Macedonia so far has been not carried out but according to data incorporated in the check lists of some particular regions and in the other floristical works the number of species could be estimated to c. 20 native and one naturalized species. They inhabit mainly moist and wet habitats in mountain areas. Recently, new chorological data regarding several species of this genus in Macedonia have been disclosed (Teofilovski 2011), while *J. minutulus* (Albert & Jahand.) Prain has been reported for the first time in the flora of Macedonia (Matevski & Teofilovski 2011).

During the recent floristic researches on Mt Šar Planina (NW Macedonia), at the Bogovinje Lake coast we have discovered a small population of one representative of the genus *Juncus*, which has been identified as *J. filiformis* L., so far not known from the territory of the Republic of Macedonia.

2 MATERIALS AND METHODS

During the field work herbarium material were collected and deposed in the private herbarium of the first author. The determination was performed according to the treatments of this genus in the several standard floras (Snogerup, 1980; Kirschner et al., 2002; Romero Zacro, 2010). The relevant floristic works were checked for possible presence of chorological data regarding the territory of Republic of Macedonia.

3 RESULTS AND DISCUSSION

3.1 Distribution in Macedonia

Juncus filiformis L. - Mt Šar Planina: on the Bogovinje Lake coast, 1950 m, 09.08.2015, coll. A. Teofilovski, Z. Nikolov & D. Mandžukovski (herb. Teofilovski; herb. Mac. Mus. Nat. Hist., n. 12572). (Fig. 1, 2, 3).

This is the first record of this species for the flora of Macedonia. Only a few patches of individuals was observed in southeast part of the Bogovinje Lake coast, growing in a shallow water and on wet places of the coastline, on siliceous geological substrate. The species is possibly more widespread around this lake, but unfortunately only southeast part of its coast was checked and thus no additional field data were provided.

3.2 General and regional distribution

The general range of this boreo-montane species includes the temperate areas of the north hemisphere. In the north parts of the range it occurs from near sea level to low alpine zone, while in the south mostly in high mountains up to 2200 m or more, growing on various at least temporarily wet habitats, usually on acid soils (Kirschner et al., 2002).

In the Balkan Peninsula, *J. filiformis* is a rare species, which is so far known from several localities in Croatia, Bosnia and Hercegovina, Montenegro, Serbia, Bulgaria, and Greece, but it is not yet reported from Kosovo, Albania, and European part of Turkey.

The closest finding sites are located c. 150 km northeast (Vlasina, SE Serbia) (Nikolić, 1976), c. 150 km southeast (NC Greece) (Dimopoulus & al., 2013), c. 180 km northwest (Nikšič - Budoške Bare, W Monte Negro) (Babunja, 2013), and c. 210 km east (Mt Rila and Mt Pirin, W Bulgaria) (Georgiev et Kožuharov, 1964).

Nikolić (1976) reported *J. filiformis* also for Pčinja valley - Rt (S Serbia), apparently by mistake, based on herbarium specimens labeled with "Macedonia, Pčinja - Rt" (coll. P. Černjavski, 26.5.1926, n. 28645). According to the investigation of Niketić (2011) "Rt" is actually misplaced name used by P. Černjavski for locality Banjski Rid, situated above Katlanovska Banja in the Macedonian part of Pčinja valley. We checked a scan of the cited herbarium specimens but they seem undeterminable since their inflorescences are almost fully undeveloped.

Figure 1: Distribution of *Juncus filiformis* in Macedonia

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Figure 2: *Juncus filiformis* (Photo A. Teofilovski)

3.3 Description and taxonomy

Juncus filiformis L. Sp. Pl.: 326. 1753

Rhizome with short internodes, horizontal. Steams 10-60 cm, the uppermost basal sheath with a short lamina. Non-flowering shoots usually few or absent. Lowest bract (½)1-1½ times as long as stem; second bract sometimes leaf-like, though short. Inflorescence with 4-10 flowers, dense. Perianth-segments 2.5-3.5 mm, ovate to narrowly ovate or the inner oblong; outer aristate; inner obtuse. Anthers c. 0.5 mm, ⅓-½ as long as filaments. Capsule (2.5-)3-3.5(-4.5) mm, trigonus ovoid, usually shortly mucronate, light brown, about equaling perianth. Seeds 0.5 mm, obliquely ovoid, faintly reticulate, with one inconspicuous appendage (Snogerup, 1980).

J. filiformis is taxonomically well defined species belonging to the *J.* subgen. *Agathryon* sect. *Juncotypus* Dumort. This section has a world-wide distribution comprising 67 perennial species which are characterised with pseudo lateral inflorescence, lower inflorescence bract terete, erect, seeming to be a continuation of stem, basal leaves bladeless, cauline leaves ± absent, sterile shoots terete, stem-like (Kirschner et al., 2002). Another three species of this section also occur in Macedonia (*J. inflexus* L., *J. effusus* L., and *J. conglomeratus* L.).

4 CONCLUSIONS

J. filiformis is recorded for the first time from the territory of the Republic of Macedonia. A small population of this species has been discovered in the subalpine belt of Mt Šar Planina – on the Bogovinje Lake coast, on 1950 m a.s.l. It grows in shallow water and on wet places of the lake coastline, on siliceous geological substrate. The nearest known finding sites are located c. 150 km northeast (Vlasina, SE Serbia) and c. 150 km southeast (NC Greece).

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Figure 3: *Juncus filiformis* - inflorescences (herbarium specimens)

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FLORA, HABITATS AND VEGETATION OF CHAMDZHA MANAGED RESERVE, CENTRAL BALKAN RANGE

[1]VASSILEV K., [2]GAVRILOVA A.
[1]*Institute of Biodiversity and Ecosystem Research – Bulgarian Academy of Sciences, Sofia, Bulgaria*
[2]*Department of Dendrology, Faculty of Forestry, University of Forestry – Sofia., Bulgaria*
Corresponding author e-mail address: kiril5914@abv.bg

ABSTRACT: Chamdzha reserve is a managed reserve, situated on the southern slopes of Central Balkan Range, which occupies an area of 66.4 ha. The aim of this study was to explore floristic, habitat and vegetation diversity of the reserve. Totally the flora is represented by 51 families, 184 genera and 299 vascular plants (without mosses). The richest families are *Asteraceae*, *Poaceae*, *Fabaceae*, *Rosaceae*, *Caryophyllaceae*, *Brassicaceae*, *Boraginaceae* and *Apiaceae*. One hundred and eleven medical plants and 7 species of conservation concern were found (5 Balkan endemics, 3 included in the Red List of Bulgarian vascular plants and in the National Biological Biodiversity Act). Fourteen relevés were collected during 2014 following to the Braun-Blanquet approach. The vegetation diversity is represented by 5 classes (*Erico-Pinetea*, *Querco-Fagetea*, *Quercetea pubescentis, Koelerio-Corynephoretea* and *Festuco-Brometea*), 4 alliances (*Erico-Fraxinion orni*, *Carpinion orientalis*, *Carpinion betuli*, and *Festucion valesiacae*), 1 association and 5 communities. Woodland vegetation covers 61.2 ha whereas grassland vegetation includes only 0.15 ha. Natural communities represent 5 habitats protected by Directive 92/43/EEC and the Bulgarian Biodiversity Act.
Keywords: managed reserve, Bulgaria, Stara planina, *Erico-Pinetea*, *Koelerio-Corynephoretea*

1 INTRODUCTION

Chamdzha managed reserve has a territory of 66.4 ha. It was established to protect a rare natural formation of black pine (*Pinus nigra* Arnold) in the Balkan Range (Stara planina), situated on its southern slopes. The category "managed reserve" according to the Bulgarian legislation is closest to the definition of the IUCN category IV - Habitat/Species Management Area. Various natural as well as semi-natural and anthropogenic phytocenoses surround the reserve.

The floristic complex of Chamdzha reserve was poorly studied in the past. Some old data about the diversity of vascular plants in the region including the territory of the managed reserve are represented in the studies of [24] and [35]. In addition, some general information about the floristic composition of the natural black pine forests can be found in [24] and [48]. Vegetation diversity in the reserve has not been studied before.

The aim of this study is to reveal the floristic and syntaxonomic diversity of Chamdzha managed reserve and to assess their current condition.

2 MATERIAL AND METHODS

2.1 Study area

The study was conducted in Chamdzha managed reserve, situated in the southern slope of central part of the Balkan Range (Stara planina), near Hristo Danovo village. It covers 66.4 ha at altitude from 550 to 775 m a.s.l. (Fig. 1). Prevailing slope incline is between 15 and 35^{o}. The climate is temperate to continental, characterized by warm summer and cold winter [40]. The precipitation maximum is in May-June and minimum in January and February. The bedrock type is granite and soils are Luvisols and Vertisols [11]

The potential natural vegetation is mostly comprised of south and east Balkan, as well as Crimean-west Caucasian colline Oriental hornbeam-downy oak forests (Mapping unit G34) [43].

The territory of the reserve is also part of NATURA 2000 site BG000494 Centralen Balkan – buffer. (http://natura2000.moew.government.bg/Home/ProtectedSite?code=BG0001493&siteType=HabitatDirective).

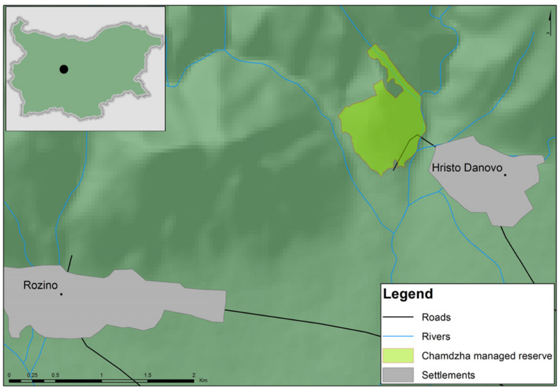

Figure 1: Map of the study area

2.2 Sampling of the flora

The field studies of the flora were conducted in June-August 2014. The transect sampling method was applied. The taxonomic scheme adopted generally follows [9]. Biological types and life-forms are based on field observations and checked with relevant literature sources, e.g. [12, 13, 14, 38, 48, 51]. Conservation status of the species was determined according to [1, 2, 3, 7, 32]. Floristic elements follow [4]. The group of medicinal plants was determined according [8] and Regulation №RD-83/3.02.2014 of the MOEW (Ministry of Environment and Water) regarding the special regimes of protection and management of medicinal plants in 2014 on the territory of the country.

2.3 Vegetation sampling

During the vegetation season 2014 a total of 14 relevés were collected following the Braun-Blanquet approach [26, 54]. The sample plots were set in the most homogenous part of communities in a manner to cover all vegetation types in the study area. We used square-shaped form of sample plots with plot size of 16 m^2 for

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Ss. Cyril and Methodius University in Skopje
Faculty of Forestry in Skopje

grassy and 100 m^2 for woody vegetation. All relevés were stored in TURBOVEG database [39] and in the Balkan Vegetation Database (GIVD ID: EU-00-019) [29] and the Balkan Dry Grassland Database (GIVD ID: EU-00-013) [27]

Altitude and location were measured by Garmin eTrex Vista (GPS). The exposition was determined by compass. Slope was assessed visually in categories (1) < 5 □, (2) between 5-10 □ and (3) > 10 □. Soil are classified as shallow (<10 cm depth), (2) moderately deep (10-20 cm) or deep (> 20 cm).

2.4 Data analysis of relevés

The classification was made using the program PC-ORD [6] incorporated in JUICE 7.0 software package [30]. Relative Sorensen was used for calculating of species similarity and flexible betta (-0.25) as distance measure.

2.5 Habitat classification and mapping

Habitat types were determined according to Habitat Directive [25, 44]. Assignment of each vegetation unit to a certain Habitat Directive Code (HDC) was given in the text. Mapping was done using ArcGIS 10.0 software [16]. Spatial data was collected in the field using Garmin eTrex Vista (GPS) and was later overlaid over the most recent orthophoto images available. Outlining the polygons was done manually by using data collected in the field as well as the orthophoto images. Mapping was done in scale 1:5000.

3 RESULTS

3.1 Flora

The flora of Chamdzha managed reserve comprises of 51 families, 187 genera and 299 species, which sums up 32.1% of the family diversity in the country, 20.3 % of the genera and 7.6 % of the species. Most of the inventoried species are spermatophytes – 46 families (90.2%), 179 genera (95.7 %) and 291 species (97.3%). On the territory of Chamdzha managed reserve no representatives of *Lycopodiophyta* or *Equisetophyta* were found. The taxonomic structure of the flora is presented in Tabl.1. *Polypodiophyta* comprises 5.9% of the total number of families, 2.7% of the genera and 2.3% of the species in the reserve. On the other hand *Pinophyta* comprises of 3.9% of all families, 1.6% of the genera and 1.3% of the species and *Magnoliophyta* presents 90.2%, 95.7% and 96.3% families, genera and species respectively. The list of taxa is provided in Annex I.

Table I: Taxonomic structure of the flora

Taxon	no. of species	no. of genera	no. of families
Polypodiophyta	7	5	3
Pinophyta	4	3	2
Magnoliophyta	288	179	46
Magnoliopsida	*239*	*152*	*42*
Liliopsida	*49*	*27*	*4*
Total number	**299**	**187**	**51**

The richest in species families are *Asteracea* – 42 species (14%), *Poaceae* – 38 species (12.7%), *Fabaceae* – 35 species (11.7%), *Lamiaceae* and *Rosaceae* – 19 species each (6.4%), *Caryophyllaceae* and *Brassicaceae* – 10 species each (3.3%), *Boraginaceae* and *Apiaceae* – 8 species each (2.7%).

The life forms of the flora of Chamdzha managed reserve is presented in Fig. 2.

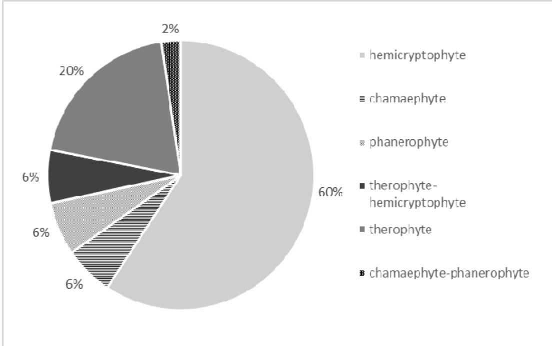

Figure 2: Life forms spectrum of the flora of the Chamdzha managed reserve

The phytogeographic composition of the flora of Chamdzha managed reserve is presented in Table 3.

Table III: Floristic elements in the flora of Chamdzha managed reserve

Floristic element	no. of species	Share (%)
subMed	45	15.1
Eur-Med	41	13.7
Eur-As	37	12.4
Eur	21	7
Boreal	19	6.4
Eur-Sib	18	6
SBoreal	17	5.7
Kos	16	5.4
Pont-Med	10	3.3
subBoreal	7	2.3
Bal	4	1.3
Med	5	1.7
SPont	5	1.7
Others – Eur-OT, Med-As, Ap-Bal, Pan-Bal, Pont-OT, Med-CAs, subBal, Bal-Anat, Eur-Med-CAs, CSEur, Bal-Dac, Carp-Bal, Pont-subMed, Alp-Med, Eur-CAs, Alp-Carp, Pont, Med-OT, SSib, subMed-CAs, subMed-As, Pont-CAs	54	18
Total number	**299**	**100**

There are five Balkan endemics [3] – *Anthemis macedonica*, *Scabiosa triniifolia*, *Chamaecytisus jankae*, *Hypericum umbellatum*, *Campanula lanata* found in the reserve. Three species are included in the Bulgarian Red List of vascular plants [2] – *Campanula lanata* (VU), *Jovibarba heuffelii* (NT) and *Minuartia saxifraga* (LC). One species (*Campanula lanata*) is enlisted in App. 3 of [7] and [32] assigned as “endangered”.

3.2 Vegetation

Classification of relevés did not show a great diversity of communities on the territory of Chamdzha managed reserve. The list of established syntaxa consists of 5 classes, 5 orders, 4 alliances, 1 association and 5 communities (clusters 1-12 Fig. 3, Annex II). *Pinus nigra* forests are the most widespread vegetation type and cover more than 63% of the reserve's territory. They are following by *Quercus dalechampii* woodlands covering 31%.

3.2.1 Ass. *Cetrario aculeatae-Plantaginetum subulatae* (HDC: 8230; 0.09 ha)

This association is locally distributed on the territory of the reserve. Its communities occur on eroded, slightly to moderately inclined slopes (10^o-30^o) with varying expositions. Soils are shallow and rocky. Stands have open horizontal structure and low amount of accumulated litter. Bedrock type is granite. The most frequent species are *Scleranthus perennis*, *Sedum hispanicum*, *Agrostis capillaris*, *Hieracium pilosella*, *Cladonia foliacea*, *Cetraria aculeata*, *Polytrichum piliferum*, *Racomitrium canescens* agg. This association is found at a small scale within stands of woodland vegetation types. The total cover of vegetation is predominantly between 65-80% as cover of herb and cryptogam layers are almost equal (between 30 and 50%).

3.2.2 *Pinus nigra* community (HDC: 9530; 41.78 ha)

This vegetation type has widest distribution in the reserve and was found on slopes with varying exposition and inclination between 5 and 40^o. Soils are shallow to moderately deep. *Pinus nigra* (cover 50-100%) is the dominant species in the tree layer and subdominants are *Quercus dalechampii, Carpinus orientalis* and *Quercus cerris* with cover between 10-30%. Shrub layer has cover between 10-25% and is formed by shrubs of the same species as well as *Coryllus avellana*, *Chamaecytisus jankae*, *C. supinus*, *Crataegus monogyna*, *Prunus spinosa* are found. Herb layer has low cover (10-30%) and is formed mainly by *Poa nemoralis*, *Dactylis glomerata*, *Brachypodium sylvaticum*, *Moehringia pendula, Lerchenfeldia flexuosa* and *Galium flavescens*.

3.2.3 *Quercus dalechampii* community (HDC: 9170; 7.67 ha)

Communities of *Quercus dalechampii* are found in northern part of the reserve on slopes with north and north-east exposition. Soils are moderately deep. Balkan durmast oak is the dominant species in the tree layer with cover between 60 and 80%, whereas in shrub layer dominant species is *Carpinus betulus* with cover between 20-50% Single shrubs of *Pinus nigra*, *Quercus cerris*, *Carpinus orientalis*, *Crataegus monogyna*, *Prunus spinosa, Chamaecytisus jankae* are forming the shrub layer. Herb layer is formed mainly by *Poa nemoralis*, *Lerchenfeldia flexuosa*, *Festuca heterophylla, Galium flavescens, Moehringia pendula.*

3.2.4 *Carpinus orientalis-Pinus nigra* community (HDC: 9530)

Communities of *Carpinus orientalis-Pinus nigra* (cluster 10, Fig. 2) have limited distribution on the territory of the reserve. They form transitional vegetation types with *Pinus nigra* community. *Carpinus orientalis-Pinus nigra* communities are found on slightly to moderately steep slopes (10-25^o) with southern exposition. Soils are shallow to moderately deep. There is not clear dominant species, but subdominants are *Carpinus orientalis* (30-60%) and *Pinus nigra* (20-60%). Shrub layer has low cover (10-15%) and is formed by the same species as well as some single shrubs (*Fraxinus ornus*, *Chamaecytisus calcareous*, *Crataegus monogyna*). Herb layer has low cover, which varies between 5-15%. Undergrowth is formed mainly by *Melica uniflora*, *Dactylis glomerata*, *Brachypodium sylvaticum*.

3.2.5 *Carpinus orientalis - Quercus dalechampii* community (HDC: 91M0; 12.68 ha)

This vegetation type is locally found in the reserve on eastern and southern slopes with prevailing inclination 10-15^o. The dominant species are *Quercus dalechampii* and *Carpinus orientalis*. Shrub layer is formed by young individuals of above mentioned trees as well as *Crataegus monogyna*, *Prunus spinose*, *Fraxinus ornus*, *Acer campestre*and *Quercus cerris*. Species with higher cover (5-10%) in herb layer are *Poa nemoralis*, *Lerchenfeldia flexuosa*, *Festuca heterophylla*, *Arabis procurrens*, *A. sagittata*, *Galium flavescens* and *Moehringia pendula*.

3.2.6 *Festuca valesiaca* community (HDC: 6210; 0.06 ha)

This community is locally distributed on slightly inclined, south facing slopes, close to abandoned agricultural areas. Soils are rich, moderately deep. This community has close horizontal structure with total cover of vegetation 90-95%. Dominant species are *Festuca valesiaca*, *Dichantium ischaemum* and *Koeleria nitidula*. As a result of abandonment of pastures during last 20 years cover of shrubs (*Prunus spinosa*, *Crataegus monogyna*) was increasing and reached 20-25%.

Proposed syntaxonomical scheme:

Cl. *Erico-Pinetea* Horvat 1959
Ord. *Erico-Pinetalia* Horvat 1959
All. *Erico-Fraxionion orni* Horvat 1959
Pinus nigra community

Cl. *Quercetea pubescentis* (Oberd. 1948) Doing Kraft 1955
Ord. *Quercetalia pubescenti-petreae* Klika 1933
All. *Carpinion orientalis* Horvat 1958
Carpinus orientalis-Pinus nigra community
Carpinus orientalis-Quercus dalechampii community
Cl. *Querco-Fagetea* Braun-Blanq. et Vlieger in Vlieger 1937
Ord. *Fagetalia sylvaticae* Pawł. et al. 1928
All. *Carpinion betuli* Issler 1931
Quercus dalechampii community

Cl *Koelerio-Corynephoretea* Klika in Klika et Novák 1941
Ord. *Sedo-Scleranthetalia* Br.-Bl. 1955
Ass. *Cetrario aculeatae-Plantaginetum subulatae* Pedashenko et al. 2013

Cl. *Festuco-Brometea* Br.-Bl. & Tüxen 1943 ex Soó 1947
Ord. *Festucetalia valesiacae* Br.-Bl. & Tüxen 1943
All. *Festucion valesiacae* Klika 1931
Festuca valesiaca community 1952

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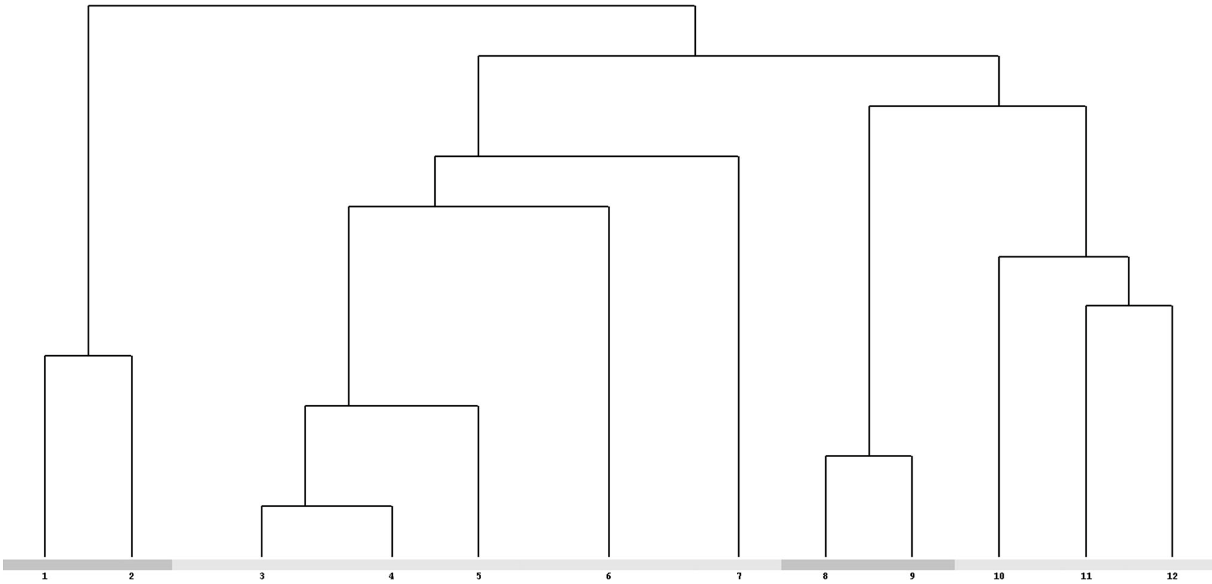

Figure 3: Dendrogram of phytosociological relevés (Relative Sorensen used for similarity and flexible betta (-0.25) as clustering method). Legend: *Cetrario aculeatae-Plantaginetum subulatae* (clusters 1-2), *Pinus nigra* community (clusters 3-7), *Quercus dalechampii* community (clusters 8-9), *Carpinus orientalis-Pinus nigra* community (cluster 10), *Carpinus orientalis- Quercus dalechampii* community (clusters 11-12).

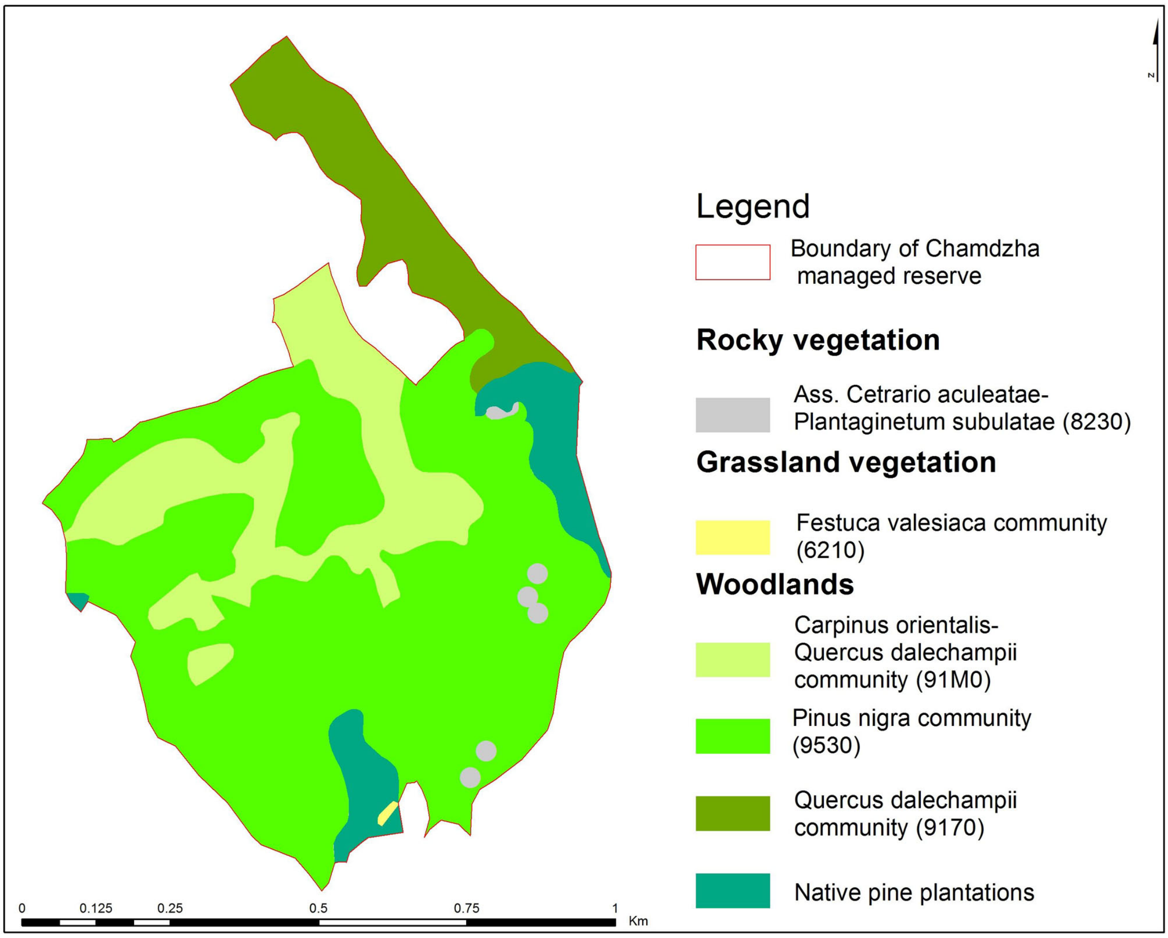

Figure 4: Map of vegetation units of Chamdzha managed reserve. Codes in brackets represent the codes of habitats in the Habitat directive: 8230 – Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of the *Sedo albi-Veronicion dillenii*, 6210 – Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*), 9170 – *Galio-Carpinetum* oak-hornbeam forests, 91M0 – Pannonian-Balkanic turkey oak-sessile oak forests, 9530 – *(Sub-) Mediterranean pine forests with endemic black pines

4 DISCUSSION

4.1 Flora

Chamdzha managed reserve comprises 7.6% of the species in the Bulgarian flora. Vascular plant diversity is relatively low compared to some other areas characterized with similar vegetation diversity, e.g. Chervenata Stena Reserve (631 species) in Rhodope Mts [34] and Ali Botush Reserve in Mt. Slavyanka (more than 600 species, unpublished data). This can be explained by the fact that Chamdzha reserve has smaller size and bedrock type is granite but not limestone like in other two reserves. It is well known that calcareous substrates are characterized by rich flora and a lot of endemic and rare plants [15,49]. On the other hand silicate substrates are characterized by poorer flora and less number of endemic and rare plants [15]. According to results about taxonomic structure of flora of the reserve the presence of *Pteridiophyta* is 2.3 % of all species, which is higher from the average for the country [4]. This can be explained by the prevalence of forest and rocky habitats, where environmental conditions are suitable for distribution of such species.

Regarding the presentation of the different families, share of *Rosaceae* and *Caryophyllacea* is relatively higher compare with the data for the total Bulgarian flora [4]. This can be explained with presence of many woody species of *Rosaceae* and availability of suitable habitats for many species of *Caryophyllacea*.

The analysis of the biological types in the flora of Chamdzha managed reserve shows the prevalence of hemicriptophytes, which is typical for regions with continental climate in Europe and the Balkans. Also the presence of shrubs and trees, respectively phanerophytes is high because the domination of woody habitats. Therophytes are represented by 18.4%, which is high taking into account the size of the territory covered by grassland vegetation.

The phytogeographical analysis shows that in the flora of Chamdzha managed reserve prevail the following floristic elements – subMediterranean, Euro-Mediterranean, Euro-Asiatic, European, Boreal, subBoreal and Euro-Siberian, which comprise nearly 66.4% of the total flora. This pattern is similar to the pattern in other area in the country [18, 20, 28, 34]. The high number of the subMediterranean, Euro-Mediterranean and Euro-Asiatic groups (41.2 %) is a result of wide distribution of xerothermic vegetation types in the reserve.

The presence of endemic species is low- only 1.7%, comparing with data for the whole country – ca. 11% of the total Bulgarian flora [4]. Endemic species and species of conservation concern represent 2.4% of all species. Some species (*Campanula lanata*, *Jovibarba heuffelii* and *Minuartia saxifraga)* are restricted to rocky cliffs locally found in the reserve. On the other hand *Chamaecytisus jankae* is widespread in shrub layer of woody vegetation types.

4.2 Vegetation

4.2.1 Syntaxonomy

This investigation is the first study about vegetation diversity in Chamdzha managed reserve. Due to the small size of the study area as well as the limited distribution of some vegetation types we were unable to classify them to already described associations, so majority of them were classified as communities. Black pine and Balkan durmast oak forests are the most wildly distributed vegetation types.

Pinus nigra woodlands are distributed and studied mainly in southern part of the country - Rhodope mts [10, 21, 34, 42], West Frontier Mts [20], Pirin mt [45], Mt Slavyanka (unpublished data) and more limited in northern Bulgaria - Vrachanska mt [47]. Similar results were found about the national distribution of habitat 9530 *(Sub-) Mediterranean pine forests with endemic black pines in NATURA 2000 network in Bulgaria [http://natura2000.moew.government.bg/Home/Protected Site?]. It is located in 24 NATURA 2000 sites with national coverage of 25045 ha.

From syntaxonomical point of view black pine forest are still poorly studied in the country. All studies have been done following the Dominance approach and provide only descriptive information about communities [10, 20, 21, 22, 34, 41, 42, 45]. This is the first research of syntaxonomy of *Pinus nigra* communities in the country following the Braun-Blanquet approach. Future analysis with other unclassified relevés from other parts of the country will reveal the existing diversity of this vegetation in Bulgaria. However, based on data collected up to now, we found that there are 2 types of *Pinus nigra* communities in Bulgaria based on different bedrock type – "species rich communities" found on calcareous substrates and "species poor communities" distributed on silicate substrates.

Quercus dalechampii forests on the territory of the reserve are belonging to xero-mesophytic type analyzed by [19] from Kongura reserve.

On the other hand there are some transitional vegetation types between *Pinus nigra*, *Quercus dalechampii* and *Carpinus orientalis* phytocoenosis in the reserve. This is also found in West Frontier Mts [17] and Rhodope Mts [22]. *Pinus nigra* forms communities also with *Fagus sylvatica* [10, 41], *Picea abies* [10, 34], *Pinus sylvestris* [34], *P. heldreichii* [45], *Abies alba* [10], *Ostrya carpinifolia* [41], *Juniperus communis* & *Cotinus coggygrya* [21], *Genista carinalis* [22], *Quercus pubescens* [42] and *Festuca balcanica* [47].

Grassland vegetation has limited distribution on the territory of the reserve. *Cetrario aculeatae-Plantaginetum subulatae* association was originaly described by [18] from the area of Beklemeto mountain pass, which is only several kilometers away from the managed reserve. It has wider distribution on south slopes of the Balkan Range (Stara planina) on silicate terrains. Future analysis of collected data in Balkan Dry Grassland Database [27] will reveal its actually existing distribution.

4.2.2 Ecology

Agglomerative classification of the data resulted in sorting of relevés along the gradient of soil depth (Fig. 2), which appeared to be the most important environmental factor responsible for their separation. On shallow soils, are found *Cetrario aculeatae-Plantaginetum subulatae* association and *Pinus nigra* communities. On the other vegetation types are found on deeper soils.

Due to the small difference of altitudinal range (225 m.) all vegetation types are found in the belt of Xero-mesophytic oak forests. As a result ecological conditions are similar and there is no much difference in species composition of shrub and herb layer in different woody vegetation types.

4.2.3 Importance for conservation

Looking from conservational point of view, among all 6 communities at association level, there are 5 habitat types (Fig. 3) protected by Appendix 1 of the Bulgarian Biological Diversity Act (2007) and Directive 92/43/EEC. All habitat types (9530, 9570, 91M0, 8230 and 6210) are widespread on the territory of the country. However, territories covered by habitat 8230 Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of *Sedo albi-Veronicion dilleni* in the country are limited to very small areas. On the territory of the reserve habitat 9530 *(Sub-) Mediterranean pine forests with endemic black pines represents relict locality of this vegetation. All habitats types are well preserved and subjected on low anthropogenic pressure.

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Annex I: List of taxa, distributed on the territory of Chamdzha managed reserve

POLYPODIOPHYTA
Aspleniaceae**:** *Asplenium adianthum-nigrum* L.*, A. ruta-muraria* L.*, A. trichomanes* L.*, Ceterach officinarum* DC*, Phyllitis scolopendrium* (L.) Newman*; **Athyriaceae:** Cystopteris fragilis*(L.) Bernh.*; **Polypodiaceae**:* *Polypodium vulgare* L.

PINOPHYTA
Cupressaceae**:** *Juniperus oxycedrus* L.*; **Pinaceae**: Abies alba* Mill.*, Pinus nigra* Arnold*, P. sylvestris* L.

MAGNOLIOPHYTA
Magnoliopsida
Aceraceae**:** *Acer campestre* L.*, A. platanoides* L.*; A. tataricum* L.*; **Anacardiaceae:** Cotinus coggygria* Scop*;*
Apiaceae: *Anthriscus sylvestris* (L.) Hoffm.*, Bupleurum rotundifolium* L.*, Daucus carota* L.*, Eryngium campestre* L.*, Myrrhoides nodosa* (L.) Cannon*, Orlaya grandiflora* (L.) Hoffm.*, Physospermum cornubiense* (L.) DC.*, Seseli rigidum* Waldst. & Kit. ***Apocynaceae*****:** *Vinca herbacea* Walds. & Kit. ***Araceae***: *Arum maculatum* L. ***Araliaceae:*** *Hedera helix* L.; ***Asclepiadaceae***: *Vincetoxicum hirundinaria* Medic. ***Asteraceae*****:** *Achillea collina* J. Becker ex Reichenb.*, A. crithmifolia* Waldst. et Kit.*, A. millefolium* L.*, A. setacea* Waldst. & Kit.*, Anthemis austriaca* Jacq.*, A. macedonica* Boiss.*, A. tinctoria* L.*, Artemisia vulgaris* L.*, Carlina vulgaris* L.*, Centaurea cyanus* L.*, C. deusta* Ten.*, C. diffusa* Lam.*, Centaurea stoebe* L. (Syn. *C. rhenana* Boreau)*, Chamomilla recutita* (L.) Rauschert*, Chondrilla juncea* L.*, Cichorium intybus* L.*, Cirsium arvense* (L.) Scop.*, Crepis sancta* (L.) Babc.*, C. setosa* Haller f.*, Filago eriocephala* Guss.*, Galinsoga parviflora* Cav.*, Hieracium glaucinum* gr.*, H. hoppeanum* Schultes*, H. olympicum* Frein.*, H. praealtum* Vill. Ex Goch.*, H. praealtum* Vill. Ex Goch. ssp. *bauchinii, H. pilosella* L.*, H. pilloseloides* Vill*, H. schmidtii* Tausch*, Lactuca perennis* L.*, L. saligna* L.*, Lapsana communis* L.*, Leontodon crispus* Vill.*, Logfia arvensis* (L.) Holub*, Mycelis muralis* (L.) Dumort.*, Senecio jacobaea* L.*, S. vernalis* Waldst. & Kit.*, Sonchus arvensis* L.*, Taraxacum officinale* F. H. Wigg.*, Xanthium strumarium* L.*, Xeranthemum annuum* L.; ***Betulaceae*****:** *Carpinus betulus* L., *C. orientalis* Mill., *Corylus avellana* L., *Ostrya carpinifolia* Scop.; ***Boraginaceae*****:** *Buglossoides arvensis* (L.) I. M. Johnst.*, B. purpurocaerulea* (L.) I. M. Johnst.*, Cynoglossum officinale* L.*, Echium vulgare* L.*, Myosotis ramosissima* Rochel*, Nonea atra* Griseb.*, Symphytum officinale* L.*, S. ottomanum* Friv.
Brassicaceae**:** *Alliaria petiolata* (M.Bieb.) Cavara & Grande*, Alyssum parviflorum* Bieb.*, Arabis procurrens* Waldst. & Kit.*, A. sagittata* (Bertol) DC.*, A. turrita* L.*, Berteroa incana* (L.) DC*, Capsella bursa-pastoris* (L.) Medic.*, Erophila verna* (L.) Chevall.*, Erysimum diffusum* Ehrh.*, Thalspi kovatsii* Heuffel*; **Campanulaceae**: Campanula glomerata* L. spp. *hispida* (Witašek) Hayek*, C. persicifolia* L.*, C. lanata* Friv.*, C. rapunculoides* L.*, C. rapunculus* L.*, C. trachelium* L.*, Jasione heldreichii* Boiss. et Orph.*;*
Caprifoliaceae**:** *Sambucus ebulus* L.*, S. nigra* L.; ***Caryophyllaceae*****:** *Cerastium luridum* Guss.*, Dianthus petraeus* Waldst. & Kit.*, Minuartia saxifraga* (Friv.) Graebner*, Moehringia pendula* (Waldst. & Kit.) Fenzl*, Petrorhagia prolifera* (L.) P. W. Ball & Heywood*, Scleranthus perennis* L.*, Silene armeria* L.*, S. bupleuroides* L. Chater et Walters*, S. italica* (L.) Pers.*, Viscaria vulgaris* Röhl. ssp. *atropurpurea* (Griseb.) Stoj.*; **Celastraceae**: Euonymus europaeus* L.*, E. verrucosos* Scop.*; **Cistaceae:** Helianthemum nummularium* (L.) Mill.*; **Convolvulaceae:** Convolvulus arvensis* L.*; **Cornaceae**: Cornus mas* L.; ***Crassulaceae*****:** *Jovibarba heuffelii* (Schott) A. et D. Lőve*, Sedum album* L.*, S. hispancum* L.*, S. urvillei* DC*; **Dioscoreaceae**: Tamus communis* L.;
Dipsacaceae**:** *Cephalaria transsylvanica* (L.) Roem. & Schult.*, Scabiosa triniifolia* Friv.*; **Euphorbiaceae**: Euphorbia amygdaloides* L.*, E. cyparissias* L.*, Mercurialis perennis* L.*; **Fabaceae**: Astragalus onobrychis* L.*, Chamaecytisus jankae* (Velen.) Rothm.*, C. supinus* (L.) Link*, Chamaespartium sagittale* (L.) Gibbs*, Coronilla varia* L.*, Dorycnium herbaceum* Vill.*, Genista januensis* Viv.*, G. tinctoria* L.*, Lathyrus pratensis* L.*, L. tuberosus* L.*, L. vernus* Bernh.*, Lotus corniculatus* L.*, Medicago falcata* L.*, M. lupulina* L.*, M. minima* (L.) Bartal.*, Melilotus alba* Medicus*, Robinia pseudoacacia* L.*, Trifolium alpestre* L.*, T. angustifolium* L.*, T. arvense* L.*, T. campestre* Schreb*, T. diffusum* Ehrh.*, T. dubium* Sibth.*, T. medium* L.*, T. ochroleucon* Huds.*, T. pratense* L.*, T. repens* L.*, T. setiferum* Boiss*, T. striatum* L.*, Vicia cracca* L.*, V. grandiflora* Scop.*, V. sativa* L.*, V. tetrasperma* (L.) Schreb.*, V. varia* Host*, V. villosa* Roth*; **Fagaceae**: Fagus sylvatica* L.*, Quercus cerris* L.*, Q. Dalechampii* Ten.*, Q. pubescens* Willd.*, Q. rubra* L.*; **Geraniaceae**: Erodium cicutarium* (L.) L'Hér.*, Geranium lucidum* L.*, G. molle* L.*, G. Robertianum* L.*, G. rotundifolium* L.*; **Hypericaceae**: Hypericum linarioides* Bosse*, H. perforatum* L.*, H. umbellatum* A. Kern.*; **Lamiaceae**: Acinos alpinus* (L.) Moench ssp. *hungaricus* (Simonkai) Sojak*, A. rotundifolius* Pers.*, Ajuga reptans* L.*, Ballota nigra* L.*, Calamintha nepeta* (L.) Savi*, Clinopodium vulgare* L.*, Galeopsis ladanum* L.*, G. tetrachit* L.*, Glechoma hederacea* L.*, Marrubium peregrinum* L.*, Lamium purpureum* L.*, Origanum vulgare* L.*, Prunella vulgaris* L.*, Satureja coerulea* Janka*, Teucrium chamaedrys* L.*, Thymus callieri* Borbas ex Velen.*, T. pulegioides* L.*, T. sibthorpii* Bentham*, T. striatus* Vahl*; **Malvaceae**: Malva sylvestris* L.*; **Oleaceae**: Fraxinus excelsior* L.*, F. Ornus* L.*, Ligustrum vulgare* L.*; **Papaveraceae**: Chelidonium majus* L.*, Papaver laevigatum* M. Bieb.*; **Plantaginaceae**: Plantago lanceolata* L.*;* ***Polygonaceae*****:** *Polygonum aviculare* L.*, Rumex acetosa* L.*, R. Acetosella* L.*, R. crispus* L.*; **Primulaceae**: Lysimachia punctata* L.; ***Pyrolaceae*****:** *Orthilia secunda* (L.) House; ***Ranunculaceae*****:** *Clematis vitalba* L.*, Helleborus odorus* Waldst. & Kit.; ***Rosaceae*****:** *Agrimonia eupatoria* L.*, Aremonia agrimonoides* (L.) DC.*, Crataegus monogyna* Jacq.*, Filipendula vulgaris* Moench*, Fragaria vesca* L.*, F. Viridis* Duchesne*, Geum urbanum* L.*, Potentilla argentea* L.*, P. laciniosa* Waldst. & Kit. ex Nestl.*, P. reptans* L.*, Prunus avium* (L.) L.*, P. cerasifera* Ehrh.*, P. mahaleb* L.*, P. spinosa* L.*, Pyrus pyraster* Burgsd.*, Rosa canina* L.*, R. micrantha* Borrer ex Sm.*, Rubus discolor* Weihe & Nees*, Sanguisorba minor* Scop. ***Rubiaceae*****:** *Cruciata glabra* (L.) Ehrend.*, C. laevipes* Opiz*, Galium aparine* L.*, G. flavescens* Borbas*, G. lucidum* All.*, G. odoratum* (L.) Scop.*, G. pseudoaristatum* Schur*, G. spurium* L.*, G. verum* L.*, Sherardia arvensis* L.*;*
Saxifragaceae**:** *Saxifraga rotundifolia* L.; ***Scrophulariaceae*****:** *Digitalis lanata* Ehrh.*, Euphrasia pectinata* Ten.*, Verbascum densiflorum* Bertol.*, V. lychnitis* L.*, V. nigrum* L.*, Veronica chamaedrys* L.*, V. verna* L.*, V. vindobonensis* (M. A. Fisch.) M.

A. Fisch.; ***Tiliaceae*****:** *Tilia cordata* Mill.; ***Urticaceae*****:** *Parietaria officinalis* L., *Urtica dioica* L.; ***Verbenaceae:*** *Verbena officinalis* L.; ***Violaceae*****:** *Viola arvensis* Murr., *V. Canina* L., *V. reichenbachiana* Jord. ex Boreau;

Liliopsida

Cyperaceae**:** *Carex caryophyllea* Latourr., *C. digitata* L., *C. divulsa* Stokes ex With., *C. echinata* Murr., *C. remota* L.; ***Juncaceae*****:** *Luzula campestris* (L.) DC., *L. forsteri* (Sm.) DC., *L. pilosa* (L.) Willd.; ***Liliaceae*****:** *Muscari neglectum* Guss. ex Ten., *M. tenuiflorum* Tausch, *Ruscus aculeatus* L.; ***Poaceae*****:** *Agrostis capillaris* L., *Anthoxanthum odoratum* L., *Apera spica-venti* (L.) P. Beauv., *Arrhenatherum elatius* (L.) P. Beauv. ex J & C. Presl, *Brachypodium pinnatum* (L.) P. Beauv., *B. sylvaticum* (Huds.) P. Beauv., *Bromus commutatus* Schrad., *B. mollis* L., *B. sterilis* L., *Chrysopogon gryllus* (L.) Trin., *Cynodon dactylon* (L.) Pers., *Cynosurus cristatus* L., *C. echinatus* L., *Dactylis glomerata* L., *Dasypyrum villosum* (L.) Cand, *Dichantium ischaemum* (L.) Roberti, *Elymus repens* (L.) Gould, *Festuca heterophylla* Lam., *F. rubra* L., *F. valesiaca* Schleich. ex Gaudin, *Hordelymus europaeus* (L.) Harz., *Koeleria macrantha* (Ledeb.) Schult., *K. nitidula* Velen., *Lerchenfeldia flexuosa* (L.) Schur, *Lolium perenne* L., *Melica ciliata* L., *M. uniflora* Retz., *Phleum phleoides* (L.) Karsten, *P. pratense* L., *Poa angustifolia* L., *P. annua* L., *P. bulbosa* L., *P. compressa* L., *P. nemoralis* L., *P. sylvicola* Guss., *P. trivialis* L., *Setaria pumila* (Poir.) Schult., *Vulpia myurus* (L.) C. C. Gmel.

Annex II: Synoptic table of vegetation syntaxa of Chamdzha managed reserved. About woody species were used following abbreviations: tr - for tree layer, sh - for shrub layer and juv - for juvenile species.

Relevé No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Altitude [m]	779	880	748	847	611	924	664	923	920	923	850	582	640	660
Exposure	90	135	45	360	90	180	225	180	135	180	180	90	360	45
Inclination [degree]	15	5	30	10	25	15	30	10	10	10	15	20	30	60
Plot size [m^2]	16	16	100	100	100	100	100	100	100	100	100	100	100	100
Total coverage [%]	70	80	85	80	90	75	85	75	80	85	75	85	85	90
Cover of tree layer [%]	0	0	65	70	80	60	60	50	50	70	70	60	70	60
Cover of shrub layer [%]	0	8	15	10	40	10	50	20	15	5	35	65	60	40
Cover of herb layer [%]	35	80	25	15	30	15	40	35	80	30	5	15	30	20
Cover of mosses [%]	40	20	3	3	2	0	35	1	70	1	0	2	15	70
Cover of lichens [%]	10	0	2	2	0	0	0	0	0	0	0	0	0	0
Latitude	42,73813	42,74239	42,73492	42,73933	42,73296	42,74742	42,73096					42,73137	42,73386	42,73416
Longitude	24,58528	24,58161	24,58913	24,58279	24,59299	24,57252	24,59228					24,59372	24,59178	24,59085
Species number	23	23	16	12	22	13	19	8	10	14	11	24	27	21
Ch. species of cl. *Koelerio-Corynephoretea*														
Veronica verna	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Poa bulbosa	+	1	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium arvense	+	1	.	.	.	.	.	.	.	.	.	.	.	.
Scabiosa triniifolia	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Chamomilla recutita	2	2	.	.	.	.	.	.	.	.	.	.	.	.
Ceratodon purpureus	2	1	.	.	.	.	+	.	.	.	.	.	.	.
Scleranthus perennis	3	2	1	.	.	.	2	.	.	.	.	.	.	.
Polytrichum piliferum	1	2	+	.	.	.	2	.	.	.	.	.	.	.
Hieracium pilosella	.	2	.	.	+	.	.	.	.	.	.	.	.	.
Syntrichia ruralis	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch. species of cl. *Erico-Pinetea* & all. *Erico-Fraxionion orni*														
Pinus nigra (tr)	.	.	3	3	4	4	4	4	2	.	2	4	.	.
Pinus nigra (sh)	.	.	2	.	.	.	2	.	.	.	.	.	.	.
Ch. species of cl. *Querco-Fagetea* & all. *Carpinion betuli*														
Carpinus betulus (sh)	.	.	.	.	.	.	.	.	.	3	2	.	.	.
Quercus dalechampii (tr)	.	.	3	3	2	2	.	.	.	3	4	.	3	4
Quercus dalechampii (sh)	.	.	+	2	2	.	.	2	2	+	2	.	.	.
Melica uniflora	.	.	.	.	.	.	.	.	.	2	2	2	+	.

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Ch. species of cl. *Quercetea pubescentis* & all. *Carpinion orientalis*														
Carpinus orientalis (sh)	.	.	1	.	1	.	.	+	2	.	.	4	3	4
Acer campestre (sh)	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Prunus mahaleb (juv)	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Tamus communis	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Acer campestre (tr)	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Poa nemoralis	.	.	.	2	.	.	.	.	.	.	+	.	2	+
transgressive ch. species of cl. *Erico-Pinetea* & *Quercetea pubescentis*														
Fraxinus ornus (sh)	.	.	+	.	2	.	.	.	.	.	.	1	2	2
Other species														
Fraxinus ornus (juv)	.	.	.	.	.	.	.	.	.	+	+	.	.	.
Ruscus aculeatus	.	.	.	.	.	.	.	.	.	3	.	.	.	.
Helleborus odorus	.	.	.	.	.	.	.	.	.	+	+	.	.	.
Carpinus orientalis (tr)	.	.	.	.	2	.	.	.	2	.	.	.	.	.
Abies alba (juv)	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Pinus nigra (juv)	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Quercus cerris (tr)	.	.	.	.	.	.	.	.	2	2	.	.	.	.
Lerchenfeldia flexuosa	.	.	2	+	+	2	+	3	2	.	.	.	.	2
Geranium lucidum	.	.	.	.	.	.	.	.	.	+	+	.	.	.
Geranium molle	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Ceterach officinarum	.	.	.	.	+	.	.	.	.	.	.	+	+	+
Campanula rapunculoides	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Porella platyphylla	.	.	.	.	.	.	.	.	.	.	.	+	.	+
Viola reichenbachiana	.	.	.	.	.	.	.	.	.	+	.	+	+	.
Arabis procurrens	.	.	.	.	.	.	.	.	.	.	.	.	+	2
Arabis sagittata	.	.	.	.	.	.	.	.	.	.	.	.	2	+
Galeopsis tetrachit	.	.	.	.	.	.	.	.	.	.	.	+	1	.
Asplenium adiantum-nigrum	.	.	.	.	.	.	.	.	.	.	.	+	.	+
Hypericum linarioides	+	.	.	.	.	.	+	.	.	.	.	.	.	.
Genista januensis (sh)	.	.	+	+	.	.	+	.	.	.	.	.	.	.
Quercus dalechampii (juv)	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Polypodium vulgare	.	.	.	.	.	.	.	+	+	.	.	.	2	.
Achillea collina	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Quercus cerris (sh)	.	.	.	.	.	.	2	.	.	.	.	.	.	.
Campanula persicifolia	.	.	.	.	.	.	.	+	.	.	.	+	.	.
Hieracium olympicum	.	.	.	.	.	+	.	+	+	.	.	.	.	.

continued

continuation of Annex II

Lamium purpureum	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Sedum hispanicum	+	.	.	.	.	+	1	.	.	.	.	.	1	.
Acer platanoides (sh)	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Silene bupleuroides	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Galium flavescens	.	.	.	.	+	.	2	.	.	.	.	.	+	.
Dianthus petraeus	.	.	1	.	.	.	+	.	.	.	.	.	.	.
Lathyrus vernus	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Bryum argenteum	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Luzula pillosa	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Agrimonia eupatoria	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Lapsana communis	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Hieracium piloselloides	.	.	2	2	+	.	.	.	.	.	.	.	.	+
Grimmia pulvinata	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Chamaecytisus jankae (sh)	+	1	+	1	2	2	+	.	.	.	.	.	.	.
Hedera helix	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Veronica chamaedrys	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Galium aparine	.	.	.	.	+	+	.	.	.	.	.	+	.	+
Phleum phleoides	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Atrichum undulatum	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Festuca heterophylla	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Dactylis glomerata	.	.	.	.	+	.	.	.	.	.	+	.	.	+
Quercus rubra (juv)	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Hypnum cupressiforme	.	.	+	1	+	.	.	.	.	.	.	+	.	2
Saxifraga rotundifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Viscaria vulgaris	.	.	.	+	+	.	.	.	.	.	.	.	.	.
Moehringia pendula	.	.	.	.	2	+	+	.	.	.	.	.	+	2
Agrostis capillaris	.	2	.	.	.	.	1	.	.	.	.	.	.	.
Carex digitata	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Lophocolea minor	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Grimmia anodon	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Jovibarba heuffelli	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Aremonia agrimonoides	.	.	.	+	.	.	.	.	.	.	.	.	.	+
Galium pseudaristatum	.	.	.	+	.	.	.	.	.	.	.	.	.	+
Tamus communis	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Verbascum lychnitis	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Achillea crithmifolia	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Rosa canina (sh)	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Campanula rapunculus	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Melica ciliata	.	.	.	.	.	.	.	.	.	.	.	.	+	.

continued

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continuation of Annex II

Metzgeria conjugata	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Moehringia trinervia	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Festuca rubra	.	3	.	.	.	.	.	.	.	.	.	.	.	.
Silene armeria	+	.	.	.	.	+	.	.	.	.	.	.	.	.
Galium odoratum	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Myrrhoides nodosa	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Filago eriocephala	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula luzuloides	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Muscari tenuiflorum	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Luzula forsteri	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Rumex acetosella	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Chondrilla juncea	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Jasione heldreichii	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Acinos rotundifolius	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium hoppeanum	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum scoparium	.	.	+	.	+	.	2	.	.	.	.	.	.	+
Carex caryophyllea	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Euphrasia pectinata	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Bromus sterilis	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Hedwigia ciliata	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Symphytum ottomanum	.	.	.	.	.	.	.	.	.	.	+	.	+	.
Mercurialis perennis	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Hieracium species	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Arabis turrita	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Thlaspi kovatsii	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Thymus sibthorpii	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium alpestre	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Luzula campestris	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Hypericum umbellatum	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Vulpia myuros	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Muscari neglectum	.	.	.	.	.	.	.	+	.	+	.	.	.	.
Racomitrium canescens	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Mycelis muralis	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Trifolium medium	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Cystopteris fragilis	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Koeleria nitidula	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Chamaespartium sagittale	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Genista tinctoria (sh)	.	.	.	.	.	+	.	.	.	.	.	.	.	.

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FLORISTIC-VEGETATIONAL VARIABILITY OF THE ASSOCIATION *EPIMEDIO-CARPINETUM BETULI* (HORVAT 1938) BORHIDI 1963 IN THE NORTH OF CROATIA

VUKELIĆ J., ŠAPIĆ I., BARIČEVIĆ D.
University of Zagreb, Faculty of Forestry, Zagreb, Croatia
Corresponding author e-mail address: dario.baricevic@zg.htnet.hr

ABSTRACT: The paper analyzes 246 phytocoenological relevés of the association *Epimedio-Carpinetum betuli* (I. Horvat 1938) Borhidi 1963 in northern Croatia using the standard principles of the Central European Phytocoenological School [5] and applying recent statistical methods [10, 6, 30]. The association is divided into six subassociations with sociologically closely affiliated differential species. The first part of the research implies formalized classification to analyze and correct the selection of diagnostic and differential species in traditional subassociations formed on the basis of previous studies. The second part uses a statistical method to form three clusters, determine their differential species and compare them with the earlier classification of the association. The results of the analysis have revealed a relatively low floristic variability, whereas structural classification has confirmed a smaller number of the described associations. In addition to providing an objective classification of the community *Epimedio-Carpinetum,* the study will also contribute to future analyses of Illyrian oak-hornbeam forests in their distribution range, as well as to the synthesis of the *Carpinetum* communities of Europe.
Keywords: *Epimedio-Carpinetum betuli*, northern Croatia, statistical analysis, differential species.

1 INTRODUCTION

The forests of sessile oak and common hornbeam in the north of Croatia belong to the earliest descriptions of forest communities of south-eastern Europe [11]. The most distinctive features of the association *Querco-Carpinetumcroaticum*I. Horvat 1938 are its wealth of flora and diagnostic value of the species of the Illyrian floristic element. On these bases Horvat [12] establishes a separate alliance of oak-hornbeam forests of the Illyrian region (*Carpinion betuli illyrico-podolicum* Horvat 1958), thus delineating them from the Central European forests. His attitude provoked a number of discussions [3, 4, 8, 14, 34], but phytocoenologists of south-eastern Europe retained this alliance in their later works. They pointed out the absence of their characteristic species, but attributed diagnostic importance to the present species from the Illyrian beech forests of the alliance *Fagion illyricum* (=*Aremonio-Fagion* /Horvat 1938/ Borhidi in Török, Podani et Borhidi 1989). Particularly active in the study of the *Carpinion* communities of south-eastern Europe were Slavic phytocoenologists, so Marinček [in 33], in line with the then valid code of phytocoenological nomenclature, named the alliance *Carpinion illyrico-podolicum* as *Erythronio-Carpinion betuli* (Horvat 1938) Marinček 1993 in Wallnöfer et al. 1993; however, this alliance was soon afterwards divided into three sub-alliances [16, 17]. The alliance *Erythronio-Carpinion* is currently recognized in the majority of the surveys of forest vegetation of Europe [25, 1 et al.].

Following research by Horvat, the Illyrian oak-hornbeam forests were nomenclaturally defined by Borhidi [3], who named the association *Epimedio-Carpinetum betuli*. Research into this association has continued in Croatia, resulting in about five hundred relevés to date [23, 24, 29, 15, 27, 21, 31, 2, 18, 28, 26 et al.]. In addition to the association *Epimedio-Carpinetum betuli,* the relevés also describe the association *Festuco drymeiae-Carpinetum betuli*, but it is not analyzed in this paper.

In the cited works, the association *Epimedio-Carpinetum betuli* is divided into six subassociations: *erythronietosum* Horvat 1938, on moderately acidophilic podzolic soils of north-western Croatia, *staphyletosum* Horvat 1938, on neutrophil-alkaline carbonate soils of the same area**,** thetypical and most common subassociation *caricetosum pilosae* Horvat 1963, mesophilic *asperuletosum* Wraber 1961 and two acidophilic *castanetosum* Wraber 1958 and *luzuletosum albidae* Wraber 1961 with a more pronounced anthropogenic impact. A comparative analysis of the differences and justifiability of the subassociations was not made, while the criteria used to describe them frequently relied on a small number of differential species determined by the first authors of the subassociations I. Horvat and M. Wraber. Since such research activities are supported by new statistical techniques, the goal of our paper was to, with the help of these techniques, analyze the variability and distribution of the association *Epimedio-Carpinetum* in nothern Croatia. The results should critically question the justifiability of the traditional classification from previous studies (1), assess the value of diagnostic species (2), possibly define a new statistically justified classification (3), but also answer other important questions concerning the composition and structure of this well known association. A statistical analysis of the overall phytocoenological material of a larger area has an advantage, since it eliminates the narrowly distributed local syntaxa which were developed under the impact of some local factors. On the other hand, it provides a more comprehensive picture of the impact of the macro-climate, other regional factors and naturally, the biogeographic area. Finally, the present European classifications, Natura 2000 in the first place, are based on such regional types.

2 RESEARCH AREA

The association *Epimedio-Carpinetum betuli* is a zonal association of the colline belt of a larger part of continental Croatia. The most important areas are located in the mountains between the rivers Sava and Drava in Croatia, then on the northern boundary part of the Dinaric mountain range south of Karlovac, and on the slopes of karst fields in the Dinaric region. It occurs between 150 and 450 m above sea level, most frequently on slope pseudogley, eutric cambisol and luvisol above different parent bedrock. The average annual temperature in the eastern part of the distribution range is 10.5 °C, in the central part it is 10.3°C, and in the southern part it amounts to 10.0°C. Precipitation also ranges in the same direction from 700 mm annually, to 1,100 mm (central part), to 1,500 mm at Ogulin. Generally, the climate is moderately warm and humid, while in the eastern part of the distribution range it is semi-humid. Precipitation distribution is favourable (over 50 % in the vegetation period), making the climate conducive to the development of forest vegetation. Apart from climate, there are other ecological factors that are suitable for the life of man, and therefore sessile oak - hornbeam forests were massively cut down very early in history. In northern Croatia (Fig. 1) they inhabit the lower slopes of higher mountains in Pannonia and surround them in a ring-like fashion. In the lower hills (up to 350 m), they occupy comprehensive complexes which are interrupted by colline-submontane beech forests on the northern sides.

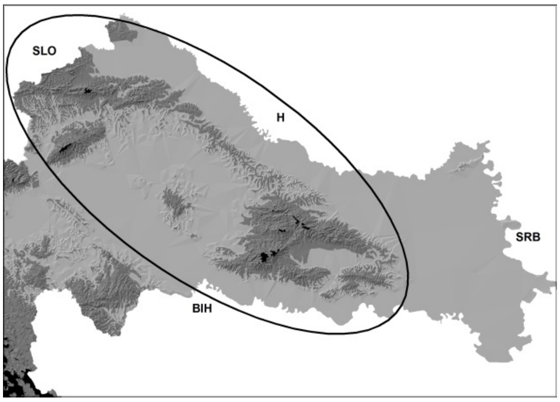

Figure 1: Map of the research area

3 MATERIAL AND METHODS

A phytocoenological analysis of the association *Epimedio-Carpinetum betuli* is based on the principles of the Zurich-Montpellier or the standard Central European School [5]. All the cited research was conducted in accordance with the mentioned School. The most important feature is the unique methodology of field phytocoenological sampling as a prerequisite for comparison and analysis of the results. Two basic analyses were conducted in the project: the first analyzes and evaluates the past (traditional) phytocoenological classification of the association *Epimedio-Carpinetum betuli*, and the second divides the same relevés into clusters formed by means of statistical classification.

A total of 246 phytocoenological relevés were used to analyze previous phytocoenological classification. In all the original papers they were classified into the association *Epimedio-Carpinetum betuli*, or into some of its subassociations:

- *erythronietosum* – 33 relevés, [11, 23, 15, 31]
- *staphyletosum* – 41 relevés, [11, 23, 29, 15, 31]
- *caricetosum pilosae* – 107 relevés, [23, 15, 31, 2, 28]
- *asperuletosum* – 23 relevés,[27, 28]
- *castanetosum sativae* – 25 relevés, [18]
- *luzuletosum albidae* – 17 relevés.[29, 27, 15]

Vegetation relevés were entered into TURBOVEG database [10]. Cluster analysis was performed in PRIMER 6 software [6], with Euclidian distance as a measure of similarity. Diagnostic species were determined by means of JUICE 7.0 software package [30] on the basis of the analysis of Fidelity measure. The plant covers that occur in more layers were combined. Each plant species was considered with total cover, regardless of the number of structural layers in which it occurred in a particular relevé. Mosses were not evidenced in the majority of studies and were therefore not taken into consideration.

In the first analysis the relevés were classified into six groups (Table I) according to the original subassociations described by the previous authors of research. Species participating with over 30% and fidelity index above 30 were taken as their differential species.

The second analysis was performed on the basis of statistical classification of the same relevés using cluster analysis, which resulted in their grouping within 3 clusters.

Research results (Tables I and II) show only differential, constant, dominant and Illyrian floral element species. Constant species were defined as those with a frequency ≥ 50% inside the vegetation unit (cluster), whereas dominant species were those with a cover value > 25% in at least 20% of the relevés belonging to a particular vegetation unit. Differential species were listed separately. The analysis of ecological conditions using Ellenberg's ecoindicator coefficients [7] was performed in JUICE 7.0 programme [30]. The plant nomenclature was adjusted to the *Flora Croatica* database [19]. The nomenclature of plant communities was adjusted to the survey of forest vegetation of Croatia [32] and subassociation as determined by Croatian phytosociologies in the cited papers [11,13,18, 27, 28].

4 RESULTS AND DISCUSSION

A total of 276 species of higher plants were recorded in 246 relevés of the association *Epimedio-Carpinetum betuli.* The most important species of the Illyrian floral element distributed in all the six subassociations include *Lonicera caprifolium*, *Epimedium alpinum*, *Ruscus hypoglossum*, *Cyclamen purpurascens*, *Aposeris foetida*, *Knautia drymeia* ssp. *drymeia* and *Primula vulgaris*. A major part of the subassociations also contain *Lamium orvala*, *Erythronium dens-canis*, *Aremonia agrimonoides* and *Vicia oroboides*. The species *Omphalodes verna, Cardamine trifolia, Helleborus purpurascens* and *Crocus vernus* ssp. *vernus* occur in only one subassociation. In two subassociations in the eastern part of the study area there is an abundance of the species *Helleborus odorus*. It is the presence of these species in oak-hornbeam forests of the Illyrian floral province that constitutes the main reason for the establishment of the alliance *Erythronio-Carpinion betuli*.

From a relatively large number of the species, 55 species were observed in all the subassociations. Constant species of the association are *Carpinus betulus*, *Quercus petraea*, *Prunus avium*, *Fagus sylvatica*, *Crataegus monogyna*, *Corylus avellana*, *Ligustrum vulgare*, *Cornus sanguinea*, *Acer campestre, Fraxinus ornus, Viola reichenbachiana*, *Pulmonaria officinalis*, *Galium odoratum*, *Asarum europaeum*, *Stellaria holostea*, *Hedera helix*, *Carex sylvatica*, *Rubus hirtus, Epimedium alpinum* and *Galium sylvaticum.* They are generally not differential for particular subassociations. The dominant species are *Carpinus betulus* and *Quercus petraea*.

Table I: Schortened synoptic table with percentage frequency and modified fidelity phi coefficient based on the traditional division of associations *Epimedio-Carpinetum betuli*

Group No.	1		2		3		4		5		6	
No. of relevés	107		23		33		25		17		41	
Subassociations	caric		aspe		eryt		casta		luzu		staph	
Differential species												
Tilia tomentosa	28	49.5	.	---	.	---	.	---	.	---	.	---
Melica uniflora	52	45.5	13	---	6	---	.	---	12	---	10	---
Carex pilosa	60	40.1	13	---	9	---	32	10.3	6	---	15	---
Viola hirta	41	37.4	26	17.4	.	---	.	---	6	---	5	---
Glechoma hirsuta	44	36.6	22	8.7	3	---	12	---	6	---	2	---
Acer tataricum	45	40.9	30	22.0	6	---	.	---	.	---	.	---
Helleborus odorus	37	39.0	26	22.6	.	---	.	---	.	---	.	---
Galeobdolon luteum	42	17.3	65	41.1	12	---	12	---	18	---	2	---
Prunella vulgaris	5	---	35	35.6	3	---	.	---	18	10.6	2	---
Galium odoratum	65	6.9	91	30.3	61	2.5	44	---	29	---	56	---
Asarum europaeum	41	---	96	30.1	67	3.2	48	---	47	---	80	16.1
Sanicula europaea	30	---	87	29.8	52	---	60	5.6	35	---	59	4.3
Erythronium dens-canis	2	---	.	---	64	60.2	20	5.9	6	---	.	---
Crocus vernus agg.	3	---	.	---	58	50.8	16	---	.	---	20	4.3
Anemone nemorosa	24	---	.	---	82	41.1	56	17.2	6	---	56	17.3
Milium effusum	11	---	35	7.3	58	30.1	.	---	18	---	44	16.4
Doronicum austriacum	3	---	.	---	52	41.8	36	23.2	.	---	10	---
Convallaria majalis	12	---	.	---	64	37.9	48	22.0	.	---	34	7.9
Luzula pilosa	4	---	.	---	58	34.7	52	28.9	18	---	15	---
Fragaria vesca	20	---	30	---	82	33.7	20	---	41	---	73	25.9
Frangula alnus	1	---	.	---	33	29.7	8	---	12	---	17	7.2
Cephalanthera longifolia	11	---	.	---	.	---	60	66.6	.	---	.	---
Castanea sativa	10	---	9	---	24	---	100	55.2	53	12.2	41	1.7
Melampyrum pratense	10	---	22	---	33	---	88	50.9	41	6.7	10	---
Euonymus latifolius	1	---	.	---	.	---	32	47.3	.	---	5	---
Prenanthes purpurea	2	---	.	---	9	1.4	36	45.2	.	---	2	---
Potentilla micrantha	47	19.3	26	---	6	---	68	40.6	6	---	12	---
Lamium orvala	6	---	.	---	42	12.8	68	37.9	12	---	49	19.0
Fraxinus ornus	64	19.1	9	---	21	---	80	34.0	18	---	63	19.0
Hedera helix	46	---	48	---	52	---	96	31.4	47	---	83	19.4
Acer platanoides	7	---	4	---	6	---	36	30.1	6	---	20	8.3
Gentiana asclepiadea	6	---	9	---	61	22.6	76	36.9	35	---	32	---
Hieracium murorum	9	---	.	---	33	22.4	36	25.7	6	---	7	---
Luzula luzuloides	11	---	.	---	48	8.8	64	23.0	100	56.0	10	---
Hieracium racemosum	19	---	13	---	15	---	40	16.8	47	24.2	10	---
Staphylea pinnata	3	---	.	---	.	---	.	---	.	---	66	76.4
Hacquetia epipactis	.	---	.	---	9	---	28	13.5	.	---	63	55.9
Scilla bifolia agg.	.	---	.	---	6	---	.	---	.	---	34	49.1
Helleborus atrorubens	4	---	.	---	9	---	.	---	6	---	44	49.0
Melampyrum nemorosum	9	---	.	---	21	5.8	.	---	12	---	56	47.9
Campanula trachelium	3	---	4	---	24	8.8	8	---	6	---	56	46.8
Vicia oroboides	12	4.9	.	---	3	---	.	---	.	---	39	46.8
Tamus communis	36	10.6	.	---	21	---	28	2.0	.	---	71	45.5
Solidago virgaurea	6	---	9	---	15	---	.	---	12	---	49	42.3
Mercurialis perennis	7	---	.	---	9	1.0	.	---	.	---	34	41.3
Salvia glutinosa	7	---	13	---	.	---	24	10.4	.	---	49	41.0
Viburnum lantana	20	5.3	.	---	6	---	20	5.8	.	---	46	38.5
Acer pseudoplatanus	19	---	9	---	52	10.9	56	15.0	29	---	73	30.7
Senecio nemorensis agg.	2	---	.	---	9	---	40	31.3	.	---	39	30.1
Dominant species												
Carpinus betulus	100	6.4	100	6.4	100	6.4	88	---	100	6.4	100	6.4
Quercus petraea	100	14.6	83	---	100	14.6	68	---	94	5.7	98	10.9
Constant species												
Fagus sylvatica	90	5.6	87	2.1	70	---	92	8.5	100	18.6	73	---
Corylus avellana	48	---	83	---	91	10.1	88	6.7	94	13.9	90	9.3
Carex sylvatica	65	---	91	18.5	70	---	52	---	76	3.5	83	10.0
Prunus avium	79	8.4	65	---	82	11.6	72	2.1	41	---	80	10.4

Pulmonaria officinalis	55 $^{---}$	65 $^{2.7}$	79 $^{15.2}$	68 $^{5.3}$	24 $^{---}$	83 $^{19.1}$
Ligustrum vulgare	50 $^{---}$	48 $^{---}$	58 $^{4.7}$	44 $^{---}$	41 $^{---}$	73 $^{18.6}$
Crataegus monogyna	54 $^{---}$	48 $^{---}$	61 $^{1.8}$	64 $^{4.9}$	47 $^{---}$	78 $^{17.6}$
Viola reichenbachiana	58 $^{6.0}$	43 $^{---}$	73 $^{19.2}$	32 $^{---}$	35 $^{---}$	66 $^{13.1}$
Acer campestre	79 $^{16.4}$	74 $^{12.2}$	55 $^{---}$	72 $^{10.5}$	24 $^{---}$	61 $^{---}$
Epimedium alpinum	66 $^{14.1}$	65 $^{13.0}$	61 $^{8.9}$	28 $^{---}$	47 $^{---}$	37 $^{---}$
Cornus sanguinea	62 $^{2.9}$	57 $^{---}$	55 $^{---}$	72 $^{12.2}$	24 $^{---}$	83 $^{22.1}$
Rubus hirtus s.lat.	86 $^{35.4}$	30 $^{---}$	24 $^{---}$	64 $^{15.7}$	35 $^{---}$	39 $^{---}$
Stellaria holostea	60 $^{---}$	74 $^{13.5}$	88 $^{26.2}$	24 $^{---}$	53 $^{---}$	56 $^{---}$
Galium sylvaticum	40 $^{---}$	13 $^{---}$	82 $^{26.5}$	60 $^{7.0}$	35 $^{---}$	83 $^{27.5}$
Illirian floral element						
Lonicera caprifolium	14 $^{---}$	65 $^{13.8}$	61 $^{9.7}$	52 $^{2.0}$	53 $^{2.9}$	54 $^{3.5}$
Ruscus hypoglossum	14 $^{---}$	22 $^{4.2}$	3 $^{---}$	20 $^{2.2}$	35 $^{19.9}$	15 $^{---}$
Primula vulgaris	22 $^{---}$	39 $^{---}$	73 $^{29.5}$	28 $^{---}$	24 $^{---}$	56 $^{14.4}$
Aposeris foetida	11 $^{---}$	52 $^{---}$	91 $^{27.5}$	76 $^{13.9}$	47 $^{---}$	88 $^{24.7}$
Knautia drymeia	24 $^{---}$	43 $^{6.5}$	42 $^{5.5}$	16 $^{---}$	29 $^{---}$	63 $^{25.0}$
Cyclamen purpurascens	10 $^{---}$	17 $^{---}$	33 $^{---}$	48 $^{14.3}$	35 $^{2.2}$	54 $^{19.7}$

Differential species of the subassociations are decisive for the classification of the association. According to the studies of the cited authors, the differential species of the compared subassociations are:

- *erythronietosum: Erythronium dens-canis, Lathyrus montanus,*
- *staphyletosum: Staphylea pinnata, Hacquetia epipactis, Craex digitata, Salvia glutinosa, Vicia oroboides, Aconitum vulparia, Rhamnus cathartica;*
- *caricetosum pilosae: Carex pilosa, Potentilla micrantha, Hepatica nobilis;*
- *asperuletosum: Galium odoratum, Asarum europaeum, Sanicula europaea;*
- *castanetosum: Castanea sativa, Melampyrum pratense, Gentiana asclepiadea, Pteridium aquilinum, Luzula luzuloides, Serratula tinctoria;*
- *luzuletosum: Luzula luzuloides.*

In the first statistical analysis the subassociations were distributed into six groups (subassociations), according to the standpoints of the phytocoenologists in the cited works. The goal of our analysis was to re-examine their standpoints and use a statistical method to determine differential species. Our subjective criterion guiding the selection was the following: participation in more than 30% of the relevés of a particular subassociation and the fidelity index above 30. The results of the analysis are given in Table I. Of 21 differential species determined by the original researchers, our analysis confirmed 14 and grouped as many as 37 new ones. Since the majority of the species had broader distribution, the previous phytocoenologists did not consider them sociologically significant for discriminating the subassociations. These are, for example, *Tilia tomentosa*, *Melica uniflora*, *Viola hirta*, *Hedera helix*, *Prenanthes purpurea, Fraxinus ornus*, *Senetio ovatus*, *Convallaria majalis* etc. On the other hand, a differential status was not confirmed for a smaller number of species (e.g. *Lathyrus montanus*, *Carex digitata*, *Hepatica nobilis, Serratula tinctoria*). In the primary research, these species had received this status on the basis of their higher participation, but in a small number of relevés.

In the second analysis we wanted to highlight some new possibilities of classifying the association *Epimedio-Carpinetum betuli* on the basis of the same phytocoenological relevés. Cluster analysis was employed to group the relevés into three clusters, which were then used for further analysis.

Cluster I: comprises 36 relevés formed for the most part of the former groups 3 and 6, i.e. of the subassociations *erythronietosum* (13 relevés) and *staphyletosum* (21 relevés). The differential species of the new cluster include all the differential species of the former subassociation *staphyletosum* and the majority of the differential species of the former subassociations *erythronietosum* and *asperuletosum.* This cluster is the richest in the species of the Illyrian floral geoelement. A total of 11 species occur with over 30% in all the relevés in the cluster.

Cluster II: comprises 99 relevés, of which 90% belonged to the subassociation *caricetosum pilosae* in the previous analysis, and the rest mainly to the subassociation *asperuletosum*. The subassociation *caricetosum pilosae* had 7 differential species and they all regained their differential status. Along with these, the following species were also determined as differential: *Quercus cerris*, *Euphorbia amygdaloides, Lathyrus vernus, Lamium galeobdolon* and *Potentilla micrantha*. In the previous analysis, the first three did not prove to be differential species, *Potentilla micrantha* was found in the subassociation *castanetosum*, while *Lamium galeobdolon* was found in the subassociation *asperuletosum*.

Cluster III: comprises 111 phytocoenological relevés grouped from all the subassociations. This heterogeneous cluster contains all the relevés of the subassociations *castanetosum* and *luzuletosum*, while of other subassociations, the relevés lacking differential species determined in the two remaining clusters. It was also found that relevés with acidothermophilic species were more fully present, where *Castanea sativa* and *Luzula luzuloides* feature as differential species. Acidophytes *Melampyrum pratense*, *Hieracium racemosum*, *Hieracium murorum*, *Gentiana asclepidea*, *Aposeris foetida* and other species have distinctly high participation. The backbone of this cluster is formed by the subassociations *castanetosum* and *luzuletosum,* and six species of the Illyrian floral geoelement are present in more than 30% of all the relevés.

According to the results of the analysis, the former subassociations *caricetosum pilosae* in Cluster II and *castanetosum* and *luzuletosum* in Cluster III manifest the highest degree of homogeneity.

The differential species of the subassociation *asperuletosum* are widely distributed and had a lower fi -

Table II: Schortened synoptic table with percentage frequency and modified fidelity phi coefficient identifiend by cluster analysis

Group No.	1		2		3	
No. of relevés	36		99		111	
Differential species						
Heracleum sphondylium	81	65.1	12	---	16	---
Ranunculus lanuginosus	67	64.4	1	---	12	---
Euonymus europaeus	83	60.7	27	---	13	---
Milium effusum	75	58.5	14	---	17	---
Crocus vernus agg.	58	58.4	1	---	11	---
Campanula trachelium	61	58.4	2	---	13	---
Lamium orvala	72	57.0	1	---	29	---
Aegopodium podagraria	61	55.5	3	---	15	---
Melampyrum nemorosum	58	52.4	3	---	16	---
Staphylea pinnata	50	52.1	2	---	9	---
Scilla bifolia agg.	39	52.0	2	---	.	---
Hacquetia epipactis	53	50.8	.	---	15	---
Daphne mezereum	64	49.2	1	---	30	---
Helleborus atrorubens	44	48.4	8	---	2	---
Galanthus nivalis	31	46.3	.	---	1	---
Ranunculus ficaria	44	44.0	10	---	5	---
Frangula alnus	36	41.5	2	---	7	---
Arum maculatum	39	41.4	10	---	2	---
Convallaria majalis	58	41.1	6	---	30	---
Paris quadrifolia	31	39.9	4	---	2	---
Glechoma hederacea	36	37.3	8	---	5	---
Malus sylvestris	39	37.1	4	---	13	---
Carex digitata	36	36.7	5	---	9	---
Mercurialis perennis	33	35.8	4	---	8	---
Ulmus glabra	39	35.7	3	---	15	---
Vicia oroboides	36	35.0	6	---	10	---
Prunus spinosa	31	34.5	7	---	4	---
Scrophularia nodosa	44	33.5	9	---	19	---
Moehringia trinervia	33	33.5	10	---	5	---
Geranium phaeum	33	32.9	8	---	7	---
Serratula tinctoria	39	30.2	.	---	25	6.6
Helleborus odorus	.	---	45	58.7	1	---
Rubus hirtus s.lat.	6	---	87	55.1	51	4.8
Acer tataricum	6	---	52	55.1	4	---
Melica uniflora	.	---	53	52.1	14	---
Viola hirta	3	---	46	51.8	5	---
Glechoma hirsuta	3	---	46	47.5	10	---
Carex pilosa	17	---	56	37.0	22	---
Quercus cerris	6	---	38	36.1	12	---
Tilia tomentosa	3	---	26	36.0	3	---
Galeobdolon luteum	11	---	47	35.6	18	---
Potentilla micrantha	8	---	49	33.9	26	---
Euphorbia amygdaloides	.	---	30	30.6	14	---
Lathyrus vernus	22	---	60	30.4	34	---
Castanea sativa	19	---	2	---	57	49.4
Luzula luzuloides	25	---	6	---	45	32.0
Sanicula europaea	47	2.2	23	---	67	29.8
Dominant species						
Carpinus betulus	100	6.7	100	6.7	97	---
Quercus petraea	100	15.1	96	1.1	91	---
Constant species						
Fagus sylvatica	58	---	89	17.0	90	19.1
Galium odoratum	58	---	69	11.6	55	---
Carex sylvatica	83	15.7	70	---	68	---
Prunus avium	94	26.3	79	---	65	---
Hedera helix	78	23.0	41	---	67	6.9
Asarum europaeum	100	50.3	42	---	57	---
Pulmonaria officinalis	100	45.1	57	---	57	---
Ligustrum vulgare	92	42.8	57	---	39	---

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Faculty of Forestry in Skopje

Galium sylvaticum	$89^{41.9}$	37^{---}	53^{---}
Corylus avellana	$100^{39.0}$	43^{---}	$86^{16.5}$
Cornus sanguinea	$94^{38.3}$	64^{---}	50^{---}
Acer campestre	$97^{36.9}$	$76^{2.1}$	50^{---}
Stellaria holostea	$89^{33.2}$	64^{---}	48^{---}
Crataegus monogyna	$86^{31.3}$	57^{---}	52^{---}
Viola reichenbachiana	$83^{31.1}$	58^{---}	45^{---}
Illyrian floral elemente			
Ruscus hypoglossum	3^{---}	$17^{9.6}$	$18^{11.4}$
Erythronium dens-canis	$14^{4.0}$	6^{---}	$16^{9.0}$
Epimedium alpinum	50^{---}	$71^{22.8}$	43^{---}
Knautia drymeia	$58^{27.6}$	16^{---}	$43^{5.8}$
Lonicera caprifolium	$86^{54.0}$	9^{---}	$49^{1.0}$
Cyclamen purpurascens	$56^{34.6}$	8^{---}	$34^{2.4}$
Primula vulgaris	$81^{48.8}$	18^{---}	40^{---}
Aposeris foetida	$100^{60.4}$	4^{---}	$69^{16.6}$

delity index than all the differential species of other subassociations. As it turned out, this subassociation does not show individuality in northern Croatia. It was primarily established because the sampled plots lacked the favoured differential Illyrian species from other subassociations (*staphyletosum* and *erythronietosum* in the first place*)*, while species of beech forests listed in Table I dominated. It should be mentioned that the association *Asperulo-Carpinetum* Wraber 1969 was described in Slovenia.

The subassociation *luzuletosum* follows a similar pattern. In the first analysis it had only two differential species (*Luzula luzuloides* and *Hieracium racemosum*) which occur in the new Cluster III with a high percentage of participation. Since chestnut was singled out as the differential species, the subassociation *castanetosum* should be given priority.

In relation to the previous insights, what is most surprising is the absence of the subassociation *erythronietosum*. Its 33 relevés were for the most part grouped into Cluster I and III. Of its differential species, *Erythronium dens-canis* and *Luzula pilosa* do not have diagnostic importance, whereas all the other species have differential importance for Cluster I, i.e. for the subassociation *staphyletosum*. Evidently, the diagnostic species from the previous studiesy could not accentuate the identity of the subassociation *erythronietosum* clearly enough to form its own cluster. However, it may have local importance, because the difference between the subassociations *staphyletosum* and *erythronietosum* was also confirmed by pedological research [9]. Undoubtedly, in the process of merging the majority of the relevés of these two subassociations into Cluster I, an important role was played by the biogeographic position of the sampled forest stands. Namely, the study area in the north-western Croatia is the richest in the species of the Illyrian floral geoelement, and so these relevés were grouped into Cluster I.

The former subassociation *staphyletosum* is represented by 41 relevés. Of this, 21 relevés was placed in Cluster I, which gathered all the differential species of the subassociation, including *Staphylea pinnata*. The remaining relevés were grouped into Cluster III. These relevés are characterized by a poorer floristic composition, lessened participation of Illyrian species, absence of diagnostic species of the subassociation *staphyletosum* and higher participation of the species *Castanea sativa*, *Solidago virgaurea*, *Sanicula europaea* and others. This can well be illustrated with a concrete example of the percentage ratio of some particular species of the former subassociation *staphyletosum* after it was grouped into two clusters. The participation ratio of the species *Staphylea pinnata* in Cluster I in relation to Cluster III is 86:45 %, that of the species *Heracleum sphondylium* is 90:25 %,of *Ranunculus lanuginosus* it is 81:20 %, of *Hacquetia epipactis* it is 90:35 %, etc. All the relevés from the Samobor Mountains were grouped into Cluster III [29].

The subassociation *caricetosum pilosae* underwent the least changes in relation to the traditional standpoints. All the differential species remained the same in the new analysis as well, but some new ones were also added. The number of Illyrian species decreases from the west towards east, while some, such as *Lamium orvala* and *Hacquetia epipactis,* are completely absent. However, it is in this subassoociation that important Illyrian species *Epimedium alpinum* and *Helleborus odorus* are the best represented, despite being the only ones that occur in more than 30% of the relevés in Cluster II. Important differential species in the central and eastern distribution range of the community are *Tilia tomentosa*, *Heleborus odorus*, *Acer tataricum* and *Quercus cerris*. It will be interesting to compare the relationship of these 99 relevés towards the related associations *Festuco drymeiae-Carpinetum* Vukelić ex Marinček 1994*,* and *Carici pilosae-Carpinetum betuli* Neuhäusl et Neuhäuslova-Novotna 1964. They are characterized by the smaller number and cover of Illyrian species and high participation of the species *Carex pilosa* and *Festuca drymeia*.

The analysis of ecological conditions conducted with Ellenberg's ecoindicator coefficients [7] did not show significant differences between individual clusters. According to these conditions, the association *Epimedio-Carpinetum betuli* occurs in semi-light (4.58 to 4.81), moderately warm (5.54 to 5.73) and fresh (4.81 to 5.04) habitats. They are moderately acidophilic to moderately basophilic (6.41 to 6.80) and moderately rich in nutrients (4.88 to 5.21).

By summarizing the problem of differential species in this manner, it is evident that they were determined primarily by means of numerical methods. In these methods all the species are put on the same level, regardless of their sociological affiliation. In this sense, it is possible to combine research methodologies for the purpose of achieving the best possible results. By analyzing as many relevés or syntaxa as possible, the fidelity value of more widely distributed ("common") species is lessened, while the sociologically more closely affiliated species gain increasing importance. Moreover, an unbalanced number of relevés of a particular taxon may give a distorted image, which is also the problem of this analysis. This is the reason that we recommend our results primarily as guidelines for future research.

5 CONCLUSIONS

Based on the analysis of 246 relevés and participation of 276 species of higher plants of the association *Epimedio-Carpinetum betuli*, we re-examined its classification into traditional subassociations and proposed a possible new classification. The analysis is based first and foremost on differential species, for which of decisive importance was their participation and fidelity index in a particular syntaxon, i.e. cluster. A small number of differential species which were sociologically closely affiliated to a particular subassociation was frequently the reason for describing a larger number of subassociations, but this often did not correspond to the real field condition. In our study, the fund of differential species in traditionally formed subassociations was significantly increased, which facilitates field research and mapping.

In the second statistical analysis all the relevés were grouped into three clusters. In these clusters, the subassociations *caricetosum pilosae* and *staphyletosum* retained their basic identity, regardless of the fact that a part of the relevés was grouped into other clusters. The subassociation *asperuletosum* does not have distinct differential species and does not show an independent character. Its species are relatively abundantly present in other subassociations. The subassociation *luzuletosum* coincides with the subassociation *castanetosum* in terms differential species and character, but the latter should be given priority. The relevés of the subassociation *erythronietosum* on deeper, more humid and shadier soils can be added to the subassociation *staphyletosum*, while those on steeper, drier and moderately acidophilic to neutrophilic soils with the species *Erythronium dens-canis* require more detailed study and analysis within the stands grouped in Cluster III.

The results of research suggest the need for further studies and a new syntaxonomic classification of the association *Epimedio-Carpinetum betuli* on the northern boundary of the Illyrian floral province. The results will also be useful for future research into the Illyrian oak-hornbeam forests in their overall distribution range, but also the *Carpinetum* communities in a wider European space.

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INSTRUCTIONS TO AUTHORS

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ABSTRACT: These notes provide important information on how to prepare and submit your article. Read the notes carefully and follow them as precisely as possible. **Any inaccuracy will cause delay at the Technical Editors and in the publication of the Forest Review**. Your article must be **written in English (UK)** and the layout should be exactly the same as this master document. **In order to prepare your layout, save this document with a new name and use it as a guide. Replace the text of this document with the text of your article without changing the layout, font type and size, line spacing, page margins and structure of this template** (see section 3). **Do not insert page numbers or page headers/footers**. If you have any question, please do not hesitate to contact us (see section 7.3).
Keywords: select 3 to 6 keywords.

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Articles will be published in the Forest Review only if correctly submitted.

The electronic version of your article must be submitted to the Technical Editor/s by e-mail according to the technical guidelines (see sections below), by one of the authors, together with **two suggested reviewers** (see section 11).

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Please make sure that the article you submit is the **final version** with all **numberings in the correct order. Do not submit the article more than once.**

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Please consider that the complete article in pdf format, including illustrations, may not exceed **10 A4 pages**. This is a very good proven capacity for final articles.

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The **title** of the article should be informative and concise. It must be followed by the author(s) name(s) – listing the principal author first, organisation, complete address, telephone, fax and e-mail address.

No logos may appear in the title.

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Next, in order of importance, select three to six of the most relevant **keywords** and include them in your article. The keywords should be separated with commas.

The **body** of the text must be in **two columns**. Number each heading using decimal numbering. Follow the layout specifications in section 3 below.

3 LAYOUT SPECIFICATIONS

The layout of your article should have exactly the same format as this master document.

Before you start working on your article, if you use Adobe Acrobat, select the printer option “Acrobat Distiller” (version 5.0) or Adobe pdf (version 6.0), in order to avoid accidental misplacement of layout elements afterwards when converting the Word file into PDF format.

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Font type: **Times New Roman**. Font size: **9pt**. Line spacing: **single**. Text alignment: **justified left and right**. Captions should have the same font and size as the typeface used for the text. Make sure that illustrations are clear and easy to read. Please do not use any other font than Times New Roman.

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Page size must be **A4** (210 mm x 297 mm).
Margins: top: 32 mm; bottom: 19 mm; left and right: 25 mm.

The **body of the text must be in two equal columns** of 73.6 mm each. All written parts and images must fit **inside** these margins (for further details see subsection 4.1 about figures and subsection 4.2 about tables).

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Begin at the top of the first page with the **title** of the article in bold capital letters and centered.

Leave one blank line between the title and the name of the author(s).

List the surname preceded by the initial of the first name; when several authors prepare an article, the name of the main one should appear first. On the following lines, give the name of the company or institute, wherever applicable, with the full address; the name of each organisation should be easy to depict. This paragraph must be centered and without any blank space.

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Leave two blank lines between the abstract and the body of the text of your article, which must be in two columns.

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Leave one blank line before each section and one blank line before the heading of each sub-section. Headings and sub-headings should be numbered (e.g. 3, 3.1, 3.2). Separate the numbers from the text of the heading with two spaces.

There should be no blank line after the title of the sub-sections but only an indentation to indicate the beginning of a paragraph. Section headings should be in capital letters. Sub-section headings should be in upper and lower case. Headings should be normal text – not underlined or in bold.

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Illustrations (photographs, drawings, graphs, charts, etc.) should not exceed 50% of the whole article and should be placed as near as possible their citation. Illustrations must not be taken from previously-printed materials.

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All illustrations must be numbered progressively in bold decimals (e.g. **Figure 1**:) and have a reference in the text (e.g. Fig. 1). Captions should be as clear as possible, to allow comprehension of the illustration without reference to the text.

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Illustrations must be clear also when printed in black and white.

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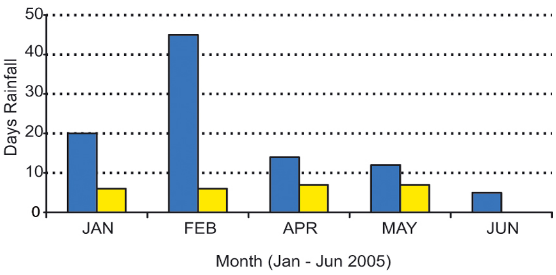

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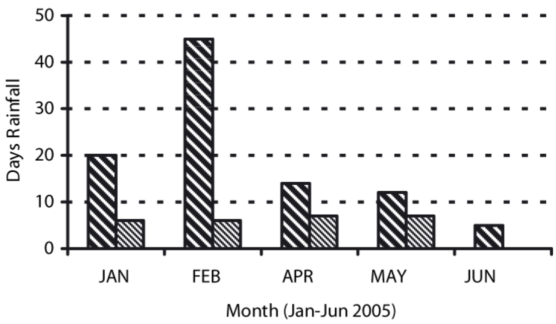

Figure 1: Clear line drawings are essential

4.2 Tables

Tabular presentation of data is an easy way to condense many items. Tables must be numbered in bold Roman numerals (e.g. **Table I**), and have a reference in the text. Captions should be as clear as possible, for an easy comprehension of the tables.

Table I: Overview of biomass resources available

Biomass Sources	Quantity	Moisture	Residue
Sewage Sludge	1.86	1.73	1.40
Septage	0.32	0.28	0.16
Fruit Pulp	3.78	3.89	4.02

4.3 References and notes

References and notes must not appear as footnotes in the pages, but should be listed together at the end of the text, in the dedicated sections.

When referring to them in the text, please type the corresponding reference number in brackets. Use round brackets for the notes (1) and square brackets for the references [1].

To make them easier to find, indent your notes and references from the second line, as in the examples (see sections 5 and 6).

4.4 Acknowledgements

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9 ACKNOWLEDGEMENTS

- We thank you for successfully following these instructions. This will make the Reviewers easier to read and avoid queues at the Technical Editors!
- The Authors are grateful to the students-members of DREN - Forestry Students' Association for their helpful cooperation.
- …….

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