The potential sensitivity to climate change of selected endangered and important Natura 2000 Habitats and plants from Bucegi Natural Park, Romania

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Abstract

This study was carried out in the Bucegi Natural Park, a protected area of the Romanian Carpathians. It aims at documenting the potential sensitivity of six widespread Natura 2000 habitat types and of all plants with conservative value (200 taxa) in the mountain area, to the changes in temperature and humidity, predicted for this century. Regional expert knowledge and environmental indicator values were considered in assessing the potential habitat’s sensitivity. The results support the evidence that sensitivity to temperature may be potentially higher for habitats at alpine and subalpine levels (bushes and grasslands) and medium for forest habitats. Sensitivity to moisture was detected as potentially high for forest habitats and as medium for bushes and grasslands at high mountain elevation. Microthermophilic plants have shown a greater share (76-79%) in alpine and subalpine communities, and the hydrophilic plants (86-96%) in forest communities. About 80% of plants of conservation value (microthermophilic or hydrophilic plants) may be potentially sensitive to predicted warming and drought and 44% of them (microthermophilic and hydrophilic plants) to the changes of both parameters. Climate scenarios (2011-2100) and sensitivity maps (Sat – image interpretation with GIS for the whole mountain area) are included.

Keywords: climate scenarios; Natura 2000 habitats; sensitivity maps; protected plants; nature conservation

Introduction

In recent years, attention has focused on climate change as a threat to natural heritage (ecosystems, habitats and species) assigned to different categories of protected areas (IPCC 2007). Special attention was addressed to the possible impact of climate change on plants and vegetation, as one of their fundamentals of life. The studies developed by Thuiller et al. (2005) for 1,350 European plant species (about 10% of European
Flora), show that more than half of them could be affected by climatic disturbance by 2080. Special attention needs alpine and arctic ecosystems, that may be particularly vulnerable to climate change (Klanderud and Totland, 2005). Information about the future of plants and habitats in protected areas already raises such concerns (Andrade et al., 2010; EEA, 2012). Many effects addressing Natura 2000 habitats (protected under Habitat Directive of the European Union) were already observed (Campbell et al., 2009; Erschbamer et al., 2009), which affected protected plants and habitats in different ways and with different magnitude (Andrade et al., 2010; Sârbu et al., 2014). Some studies (Araújo et al., 2011) even anticipate a possible reduction of plant and animal diversity in protected areas of Europe by more than 50% towards the end of this century, due to unsuitable environmental conditions. Significant changes are expected for the European plant communities: in Northern Europe 35% of the species may be new until 2100 and in Southern Europe up to 25% of the species have chances to disappear (Alkemade et al., 2011). The Inouye (2019) estimates for the mountains of Europe highlight that 36-55% of the alpine species, 31-51% of subalpine species and 19-46% of the montane species, will lose more than 80% of their habitats by 2070-2100. For the North American Flora, Zhang et al. (2016) underlined that about 2,000 species may lose more than 80% of their habitats due to climate change impact.

It is increasingly evident that climate change will come, in the near or not too distant future, a strong driver of changes in habitat conditions and species composition. This is regarded a serious long-term threat for many mountain areas in Europe. Recent studies (Engler et al., 2011; Dullinger et al., 2012) on higher plants species in high mountain areas of Europe warn that up to the end of 21st Century, a significant loss of habitats will be recorded for plants living at high altitudes. It is expected that up to 50% or 55% of these plants may lose more than 80% of their habitats inhabited today, due to emerging climatic disturbance. Despite the fact that mountain areas in general are sensitive to climatic impact, their vulnerability is certainly different and depends significantly on the amplitude of the shifts in climatic conditions and the response of the affected species as there are: genetic adaptation, biological migration and species extinction (Theurillat and Guisan, 2001; Beniston, 2003; EEA, 2012). In case of a high increase in the mean air temperature, profound changes may be expected in the higher mountain systems of Europe, such as the Alps (Theurillat et al., 1998) and the Carpathians (Sârbu et al., 2014). Changes in composition and distribution of plants, e.g. expressed by altitudinal shift (Pauli et al., 1996; Gottfried et al., 1999; Walther et al., 2005; Kullman, 2007; Erschbamer et al., 2009), will result in phenological modifications which will affect the life cycle of woody and herbaceous plants (Bazzaz, 1996; Cleland et al., 2006; Vitasse et al., 2011), will threat plant reproduction and growth (Lapenis et al., 2005; Gray et al., 2016), will support the spread of invasive plants (Hellmann et al., 2008; EEA, 2012) and will increase the risk of extinction of indicator species, rare and endemic plants (Lesica and McCune, 2004; Schöb et al., 2008; Sârbu et al., 2014). All these processes can induce a pronounced decrease of conservation value of Natura 2000 habitats, located at high elevation.

There are many factors that influence plants responses to climate change (Thuiller et al., 2005; Grimm et al., 2013; Sârbu et al., 2014; Matteodo et al., 2016), including also their ecological preferences and the magnitude of variation, that plants can withstand. Plants have specific requirements in terms of their environment, which are important for their survival and spread. The knowledge of plant preferences towards temperature and humidity, can offer information on the potential trends of change in functional and taxonomic groups of the communities, as direct consequences of heat and drought.

The present contribution represents a case study, addressed to the whole Bucegi Natural Park, a Carpathian protected area in Romania and part of the Natura 2000 Bucegi site. Six representative and very widespread types of Natura 2000 habitats from Bucegi Natural Park and all the plants with conservation value, from the entire Natura 2000 site Bucegi area (200 taxa) were considered. The following issues are discussed:

i) which are the trends of the temperature and humidity regime in Bucegi Natural Park, in this century?

ii) which plants can be potentially sensitive to the predicted changes in temperature and humidity?

iii) how sensitive can be the selected habitats, to predict climatic constraints?
**Materials and Methods**

**Study area**

Bucegi Natural Park (32,497.6 ha) is located in the South-Eastern part of the Romanian Carpathians, in the Alpine biogeographical region, and is a major component of the Natura 2000 Site Bucegi (Figure 1). It is a cold and humid mountain zone which displays a difference in altitude between 806 m and 2507 m. The winter starts early, with a long-lasting cover of snow across most of the alpine plateau of Bucegi. This mountainous region hosts a diversity of habitats from alpine and subalpine grasslands to tall forbs habitats, shrubs, rocks and screes habitats, chasmophyte vegetation on calcareous rocks, peat bags, forests (deciduous, coniferous and mixed), rivers and lakes. The flora is rich in higher plants (1183 cormophytes, about 30% of the Romanian flora), with numerous endemic and rare elements, some of them protected at national, European or global level. Other groups such as mosses (259 taxa) and lichens (485 taxa) are also well represented (APNB, 2011). From the existing habitat types, 24 are nominated for protection and conservation in the Habitat Directive. They belong to the following categories: rocks, bushes, swamps, grasslands, hydrophilic vegetation and deciduous, coniferous and mixed forests (APNB, 2011). Forests, grasslands and shrubs habitats are widespread and have a large share in the vegetation of Bucegi Natural Park (APNB, 2011).

**Assessment of habitats**

Six selected habitat types of characteristic and widespread categories in Bucegi (forests, grasslands and bushes) were considered in this study (Table 1). The threatened habitats, with priority for conservation according to Habitat Directive, are marked with an asterisk (*).

Two approaches were used for the sensitivity of habitats assessment: one was focused on regional expert knowledge and the other incorporated the information about the ecological envelope of the habitats, by assessing the current plant community composition (Wagner-Lücker, 2012; Wagner-Lücker *et al*., 2014; Figure 2).

**Table 1.** Natura 2000 habitats in the study area (* - globally threatened): Natura 2000 habitat code, class definition, altitude and climate (Mountford *et al*., 2008)

| Natura 2000 habitat code | Class definition | Average (m) | Climate Temperature (annual average, °C) | Rainfall (mm/year) |
|-------------------------|-----------------|-------------|----------------------------------------|------------------|
| 4070*                   | Bushes with *Pinus mugo* and *Rhododendron myrtifolium* | 1400-2000 | +2.2 - -0.2 | 1250-1425 |
| 6150                    | Siliceous alpine and boreal grasslands | 1550-2500 | +3.0 - -2.5 | 1100-1450 |
| 6230                    | Species-rich *Nardus* grasslands on siliceous substrates in mountain areas (and submountain areas in Continental Europe) | 800-2070 | +6.0 - -1.5 | 800-1400 |
| 9110                    | *Luzulo-Fagetum* beech forests | 600-1350 | +3.0 + 8.0 | 700-1300 |
| 91V0                    | Dacian beech forests (*Symphyto-Fagion*) | 500-1450 | +3.0 + 8.0 | 750-1200 |
| 9410                    | Acidophilous *Picea* forests on the montane to alpine levels (*Vaccinio-Piceetalia*) | 1000-1850 | +1.5 + 5.0 | 900-1400 |
Figure 1. Location and outline of Bucegi Natural Park, Romania (right) (Basic geodata: NUTS database@EuroGeographics 2006, Investigation area: Project partners 20101 Map: Neubert, Puschel, Witschas 2010), and distribution of the selected Natura 2000 habitat types (left) (Map: Wagner, Förster, Schmidt, 2012 – HABIT-CHANGE project). This map contains more than 65000 polygons representing the Habitat Types. Depending on the screen resolution or the print the image may appear spotted.

Figure 2. Framework for the habitat’s sensitivity assessment (Wagner-Lücker, 2012 - HABIT CHANGE project, outputs 4.3.5. 4.6.1. 4.6.2.)
The framework for the regional expert knowledge was based on Petermann’s approach (Petermann et al., 2007), who evaluated the sensitivity of Natura 2000 habitats in Germany. This assessment procedure was structured into seven sensitivity criteria (Wagner-Lücker et al., 2014): average or reduced conservation status, ability to regenerate, horizontal distribution, altitudinal distribution, decrease of territorial coverage, influence of neophytes, dependency on ground and surface water (Figure 2). For each habitat type each criterion was classified as: 1-low, 2-medium and 3-high. To describe the overall sensitivity of a habitat type in relation with its biogeographic position, these values were summed and categorized after Petermann et al. (2007) in three sensitivity categories: 1-low (<14), 2-medium (14-16), 3-high (>16) (Wagner-Lücker et al., 2014).

The variability of the ecological envelope of habitats was assessed using indicator values. These were derived from the characteristic species composition in each habitat. Temperature values (climatic parameter) and moisture values (edaphic parameter) were selected as indicator parameters. Three categories were used for temperature: low (species from high elevation, sustainable under low air temperature), medium (species from midlands, needing average air temperature) and high (species from low elevation, needing higher air temperature). Three categories were used for moisture: dry (species sustaining low soil moisture), moist (species needing average soil moisture) and wet (species needing high soil moisture). Both the indicator values of temperature and moisture were the base for the statistical calculation of the overall indicator value per habitat type. The frequency of the categorized indicator values per habitat type and per biogeographical region was then used in the sensitivity assessment: low, medium and high sensitivity.

To support the habitat type assessment, a detailed field survey was carried out in the vegetation period 2010-2012. Two areas of investigation have been selected from the perimeter of Bucegi Natural Park:

i) Zone A (2506 ha) located on the Bucegi Mountain Plateau (N 45°26’49”; E 25°27’11” and N 45°22’50”; E 25°29’45”), that includes the type of vegetation characteristic of the alpine level.

ii) Zone B (2646 ha) located along the Ialomiţa River (N 45°21’12”; E 25°23’54” and N 45°17’1”; E 25°26’29”) that includes wooded vegetation, mostly represented by forests.

Inside the investigation areas, 153 field survey units have been established (Figure 3). 80 referred to the selected habitat types in this study and 46 of them were described in terms of species richness, species abundance-dominance and ecological preferences of species, in relation to the climatic factors such as temperature and humidity. For each type of habitat, a unique taxa list was also developed, that was used to evaluate ecological preferences of plants/habitat type. Identification of the habitat types was carried out in accordance with the following sources: Doniţă et al. (2005), Gafta and Mountford (2008), Mountford et al. (2008), Sârbu et al. (2013).

Plants assessment

Plant assessment has focused on two aspects:

i) knowledge of the ecological preferences for temperature and humidity of the plants in the studied habitat types of Bucegi Natural Park (including plants with conservation value, that live there);

ii) identification of plants with conservation value throughout the entire Natura 2000 site Bucegi and knowledge of their preferences for temperature and humidity.

Scale for moisture and temperature (Popescu and Sanda, 1998; Ciocârlan, 2009; Sârbu et al., 2013) was used in determining ecological preferences of the species included in this study.

The identification of plants with conservation value was realised according to IUCN Red List (Bilz et al., 2011), Habitat Directive annexes (EEC, 1992), Bern Convention (Council of Europe, 1979), CITES (1979), Romanian Red List (Oltean et al., 1994), Romanian Flora (Săvulescu, 1952-1976), Illustrated Flora of Romania: Pteridophyta and Spermatophyta (Ciocârlan, 2009), and the list of the Management Plan of Natural Park Bucegi, Annex 8 (APNB, 2011). The general distribution of plants was assessed following Sârbu et al. (2013). Plant nomenclature is according to The Plant List (2013), Ciocârlan (2009) and Sârbu et al. (2013).
Climate scenarios

The studies carried out during the EU-Project ‘Habit-Change’ focused on Habitat-Types related to the flora present in a sample of 12 habitat types; the Bucegi example was selected as one of these landscape types. These encompassed a variety of countries and landscapes, like National Parks (PL 1, HU 2, AT/HU 1, SI 1), Nature/Natural Parks (RO 1, SI 1, IT 1, UA 1) and Biosphere Reserves (DE 2, RO 1). The Romanian team was partner in this consortium, caring for the Bucegi floristic contents.

For these 12 protected habitat types (i) the observed trends in hydro-climatic conditions over the last century, as well as (ii) the quantification of climate change impacts as boundary conditions, were meticulously determined to show the predicted trends in climate and climate scenarios, which finally produced regional results for each of the 12 protected habitat types. Six of them are included in this publication.

The methodology is explained in detail in section 2.2. (p.6), for the hydrological features, and in section 3.2. (p.39), of the Habit-Change-Project-Report: Climate change impacts as boundary condition and hydrological features (Stagl L., Hattermann, F. 2011. Climate change impacts as boundary conditions + Hydrological features of selected areas. 55pp.). This report is part of the CENTRAL-EUROPE-Program EU: HABIT-CHANGE – Adaptive management of climate-induced changes of habitat diversity in protected areas (2013). Project Number: 2CE168P3. First information is provided under https://www.keep.eu/project/5501/adaptive-management-of-climate-induced-changes-of-habitat-diversity-in-protected-areas. Further information is found at the same LINK (accessed again: 20190425).

Stagl and Hattermann (2011) provided the methodological background behind the graphs in Figure 4, showing the results of the individual climate models, on a monthly basis, for the two time periods, as well as the averaged development of the climatic conditions for each of the protected areas (Table 2).

![Figure 3. Location of the field surveys in 2010 (left) and 2012 (right) (Wagner-Lücker, 2012 – HABIT CHANGE project, output 4.3.2.)](image-url)
Figure 4. Bucegi Natural Park (Romania): Climate scenarios – Temperature and Precipitation 2011-2100 (source: HABIT-CHANGE project, outputs 3.2.3 and 3.2.7.). The color lines – Climate Models (GCM-RCM combinations).

Table 2. Parameters used to provide the essential methodological basis

| Number | Parameters |
|--------|------------|
| 1      | Analysis of a global climate dataset, 0.5 x 0.5-degree resolution |
| 2      | Re-analysed daily climate data, bias-corrected on observed data, bi-linearly interpolated to global land grid |
| 3      | Spatial resolution ~50 km x 50 km, for 'virtual climate stations' per grid cell |
| 4      | Original resolution retained for each of the 12 HABIT-CHANGE investigation areas, representing an average climate data set for each 50 km² cell area |
| 5      | Observed trends in hydro-climatic conditions cover two periods of 15 years: 1960-1974, 1987-2001, plotted as long-term average in the same diagram |

For assessing the different alpine habitats across the Bucegi massif remote sensing, in this case high-resolution satellite imagery (development level of 2012, spatial resolution: 5 m) was used. This work was carried out as part of the HABIT-CHANGE Project, supported by the CENTRAL EUROPE Programme (EU), which can be accessed on:

https://webcache.googleusercontent.com/search?q=cache:yue7Y_KkAikJ:https://www2.ioer.de/download/habit-change/HABIT-CHANGE_4_2_3-4_2_4-4_2_5_Remote_Sensing_2013-08-28.pdf+&cd=1&hl=en&ct=clnk&gl=at&client=firefox-b-d.

Participants of the University of Bucharest, as well as of the University of Vienna, were co-authoring this part of the above-mentioned project.

Mountain regions like the Bucegi are, at least in part, composed of remote and less accessible areas. Remote sensing methods are capable of acquiring and analysing information on different habitat types, especially when investigating larger areas (Bucegi: approx. 284 km²). Remote sensing also provides a basis for
repeatable investigations. Even though clouds are often present in mountain areas, the interpretation of vegetation types was possible to a great extent, since images of May, July and September 2010 were used for interpretation. Compared with other methods, e.g. ground-based exploration, remote sensing provides an overview on large areas instantly. In addition, this overview allows the determination where future, more detailed research may secure success.

The remote sensing imagery was georeferenced and used multi-temporal images. The Terrain Analysis used the ASTER Global Digital Elevation Model.

During the vegetation periods of 2010 and 2012 field data were collected for the six habitat types (Table 1).

Object-based image analysis (OBIA) was used to delineate polygons for the individual habitat-types. For assessing the alpine grassland and forest habitat types digital elevation model was combined with the RapidEye imagery. Due to cloud cover, which was the lowest in the July image, not all field survey units could be used, but the vegetation development was the best during this period. Water bodies were classified by spectral information. University of Bucharest provided military maps from which urban areas were extracted. Visual interpretation was used to delineate cloud cover in the July image. Spectrally evaluated sample points were generated for classification of land cover, and good land cover classes. eCognition Developer 8 software (Trimble; http://www.ecognition.com/document/ecognition-8-datasheet) was used for OBIA. Based on terrain (elevation, slope, aspect) and spectral values polygons of homogenous regions were produced by image segmentation.

The sample points defined the feature space of the different Land Cover Classes, using the Nearest Neighbour Classifier, a supervised classification algorithm of the eCognition software. Thereafter ‘Grassland’ (6150, 6230)’ Bushes (4070)’ and ‘Forest’ (deciduous 9110, 91V0, coniferous 9410) were divided into habitat types, with field survey points as classification samples.

Two sets of climate scenarios, highlighting trends of the thermic and rainfall regime for the period 2011-2100, were developed as part of the project HABIT-CHANGE (Figure 4). The diagram displays the monthly average for temperature and precipitation over a year. Coloured lines in the graph show monthly changes, simulated by an ensemble of different GCM (Global Climatic Models)/RCM (Regional Climatic Models) combinations. The grey bands indicate the total range of uncertainty.

Observed trends in hydrological conditions are displayed by two periods of 15 years each (1960-1974 and 1987-2001), taken as reference (HABIT-CHANGE - output 3.2.7. Stagl J. and Hattermann F., Potsdam Institute for Climate impact). For climate scenarios, based on the analysis of different GCM combinations, a reference period of 30 years (between years 1961-1990) was selected (HABIT-CHANGE - output 3.2.3. Stagl J and Hattermann FF, Potsdam Institute for Climate Impact).

Results

Climate scenarios

Climate scenarios, specially developed for the Bucegi Natural Park for the period 2011-2100, forecast a trend of increasing air temperature throughout the year, with emphasis towards the end of this century (+2.5 °C increase in the mean annual air temperature). Summer increase is considered more significant especially after 2040 (Figure 4). Trends predicted for precipitation are quite heterogeneous, since the climate scenarios for 2011-2040 did not show a clear change of current conditions in the Bucegi Natural Park. For the periods 2041-2070, and 2071-2100, respectively, a general reduction in rainfall is expected, which will be more significant in the summer period initially (Figure 4) but following the year 2070 water stress will affect almost all periods of the year.
Habitat sensitivity

For the six selected habitat types (Natura 2000 Code: 4070*, 6150, 6230*, 9110, 91V0, 9410), two maps of potential sensitivity to temperature and humidity were produced. These showed a potential of medium to high sensitivity to changes in air temperature (Figure 5) and edaphic humidity (Figure 6), predicted by the climate models.

i) The bushes and grassland habitats occurring at alpine and subalpine levels (Natura 2000 Code: 4070*, 6150, 6230*), were assessed as highly sensitive to temperature increase (Figure 5) and as medium sensitive to drought (Figure 6).

ii) The forest habitats (Natura 2000 Code: 9110, 91V0, 9410) were assessed as medium sensitive to increasing air temperature (Figure 5) and highly sensitive to moisture decrease (Figure 6).

Figure 5. Bucegi Natural Park, Romania – Potential sensitivity of the selected Natura 2000 habitat types to temperature (source: adapted from ‘current habitat types map’, HABIT-CHANGE project, output 3.1.9.). This map contains more than 85000 polygons representing temperature sensitivity. Depending on the screen resolution or the print the image may appear spotted.
Figure 6. Bucegi Natural Park, Romania – Potential sensitivity of the selected Natura 2000 habitat types to moisture (source: adapted from ‘current habitat types map’, HABIT-CHANGE project, output 3.1.9.). This map contains more than 85000 polygons representing moisture sensitivity. Depending on the screen resolution or the print the image may appear spotted.

For each of the considered habitat types a percentage assessment of the weight of ecological forms of the plants was made, using the plants’ preferences for humidity and temperature (Table 3). The associated graphs emphasize the groups of ecological categories that express the taxa preferences for low temperatures (hekistothermophyte-psichrothermophyte-microthermophyte) and high humidity values (mesophyte-mesohygrophyte-hygrophyte) respectively (Figures 7 and 8).

i) The plants from the alpine and subalpine levels (Natura 2000 Code: 4070*, 6150, 6230) prefer low temperature (76-79%), being evaluated as hekistothermophyte-psichrothermophyte-microthermophyte. The proportion of eurithermophytes was between 13-23% and the largest share was observed in the habitat type 4070*. In terms of humidity preferences, there are some variations, depending on the types of habitat, but most of the taxa (65-75%) belong to the mesophyte-mesohygrophyte-hygrophyte categories. The euriphytes and xerophytes were not observed, but the xeromesophytes had been well represented (23-29%) in the grassland habitats.
More than half of the species (55-60%) living in these habitats, prefer both low temperature and moisture (Table 3, Figures 7 and 8).

ii) Only 35-45% of the species inhabiting the forest habitats (Natura 2000 Code: 9110, 91V0, 9410) depend on low temperature (predominantly microthermophytes and fewer hekistothermophytes and psychrothermophytes). The eurthermophytes have a share of 17-29% and were better represented in the habitat type 9410. In the forest habitat types, most of the plants (86-96%) require sufficient humidity (mesophytes-mesohygrophytes-hygrophytes) and the majority are mesophytes and mesohygrophytes. The euriphytes (0.84%) were observed only in the forest type 9410. Less than half (35-45%) of the plants prefer cold and humid climatic conditions (Table 3, Figures 7 and 8).

Figure 7. Spectrum indices of temperature features, for plant species representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 3. Ordinate: percentage of species in each category

Figure 8. Spectrum indices of humidity features, for plant species representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 3. Ordinate: percentage of species in each category

In the six selected habitats, 59 taxa of conservation value were identified, during the field survey. This represents 30% of the total plants with conservation value from Natura 2000 site Bucegi. Their preferences for moisture and temperature were expressed as percentage (Table 4, Figures 9 and 10).

In the habitat type 4070*, a single protected plant (Annex 1) was identified (*Rhododendron myrtifolium* Schott & Kotschy - eurthermophyte and mesophyte). In grassland habitat type 6230* and respectively 6150
type, 66-85% of the plants with conservation value depend on low temperature (hekistothermophyte-psichrothermophyte-microthermophyte), 60-70% prefer moisture and 20-35% are xeromesophytes. In forest habitats, 50-60% of plants with conservation value belong to microthermophyte category, 30-40% are mesothermophyte, and most of them (95-100%) prefer conditions of sufficient humidity (mesophyte→hygrophyte).

**Table 3.** Selected Natura 2000 habitat types in the study area: species richness and ecological preferences for temperature and humidity, expressed as percentage (mean values/habitat type)

| Natura 2000 | Number | Temperature | Humidity |
|-------------|--------|-------------|----------|
| habitat code| of species| 0 1 1.5 2 2.5 3 3.5 4 4.5 | 0 1 1.5 2 2.5 3 3.5 4 4.5 5 |

| 4070*       | 17     | 23.50 5.88 0 17.67 5.88 47.07 0 0 0 | 17 5.88 47.07 0 0 0 |
| 6150        | 131    | 17.55 24.42 6.87 9.16 4.58 31.30 0 5.36 0 | 0 76 |
| 6230*       | 82     | 13.41 14.63 12.19 9.75 10.97 31.76 1.21 4.87 0 | 1.21 |
| 9110        | 69     | 17.39 0 2.89 0 1.44 36.23 2.89 39.16 0 | 0 0 |
| 91V0        | 107    | 19.62 0 0 0 0 34.57 1.86 43.95 0 | 0 0 |
| 9410        | 237    | 21.51 3.79 0.84 0.42 0 39.24 1.26 32.94 0 | 0 0 |

Temperature (T): 0 = eurithermophyte, 1 = hekistothermophyte, 1.5 = hekistothermophyte-psichrothermophyte, 2 = psichrothermophyte, 2.5 = psichrothermophyte-microthermophyte, 3 = microthermophyte, 3.5 = microthermophyte-mesothermophyte, 4 = mesothermophyte, 4.5 = mesothermophyte-submesothermophyte, 5 = subthermophyte. Humidity (H): 0 = euriphyte, 1 = xerophyte, 1.5 = xerophyte-xeromesophyte, 2 = xeromesophyte, 2.5 = xeromesophyte-mesophyte, 3 = mesophyte, 3.5 = mesophyte-mesohygrophyte, 4 = mesohygrophyte, 4.5 = mesohygrophyte-hygrophyte, 5 = hygrophyte.

**Figure 9.** Spectrum indices of temperature features, for plant species with conservation value representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 4. Ordinate: percentage of species in each category.
Table 4. Selected Natura 2000 habitat types in the study area: the richness of species of conservation value and their ecological preferences for temperature and humidity, expressed as percentage (mean values/habitat type)

| Natura 2000 habitat code | Number of species | Temperature | Humidity |
|--------------------------|------------------|-------------|----------|
|                          |                  | 0 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| 4070*                    | 1                | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6150                     | 26               | 7.69 | 30.77 | 3.84 | 19.23 | 3.85 | 30.77 | 0 | 0 | 0 | 3.85 |
| 6230*                    | 15               | 26.67 | 26.67 | 6.67 | 13.32 | 0 | 20.00 | 0 | 6.67 | 0 | 0 |
| 9110                     | 6                | 16.67 | 0 | 0 | 0 | 0 | 50.00 | 16.66 | 16.67 | 0 | 0 |
| 91V0                     | 7                | 0 | 0 | 0 | 0 | 0 | 57.15 | 0 | 42.85 | 0 | 0 |
| 9410                     | 23               | 17.39 | 0 | 4.35 | 0 | 0 | 52.18 | 0 | 26.08 | 0 | 0 |

Temperature (T): 0 = eurithermophyte, 1 = hekistothermophyte, 1.5 = hekistothermophyte-psichrothermophyte, 2 = psichrothermophyte, 2.5 = psichrothermophyte-microthermophyte, 3 = microthermophyte, 3.5 = microthermophyte-mesothermophyte, 4 = mesothermophyte, 4.5 = mesothermophyte-submesothermophyte, 5 = subthermophyte. Humidity (H): 0 = euriphyte, 1 = xerophyte, 1.5 = xerophyte-xeromesophyte, 2 = xeromesophyte, 2.5 = xeromesophyte-mesophyte, 3 = mesophyte, 3.5 = mesophyte-mesohygrophyte, 4 = mesohygrophyte, 4.5 = mesohygrophyte-hygrophyte, 5 = hygrophyte.

Figure 10. Spectrum indices of humidity features, for plants species with conservation value representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 4. Ordinate: percentage of species in each category

Sensitivity of plants with conservation value from the whole Bucegi Natura 2000 site perimeter

In this study 200 plant species, subspecies and varieties with conservation value were evaluated regarding their sensitivity to climate changes. Their categories of ‘threatened’ and their endemic status accords to several legislative documents and bibliographic resources (Table 5, Annex 1).

Regarding species which are included in different categories of the IUCN Red List (Annex 1), 38 are potentially sensitive to humidity decrease (most orchids, 27 taxa), and 14 taxa are potentially sensitive to temperature increase. 12 taxa are potentially sensitive to both factors: Campanula patula subsp. abietina,
Dactylorhiza cordigera, D. maculata, D. sambucina, Eriophorum scheuchzeri, Gentiana lutea, Gymnadenia conopsea, G. nigra, Ligularia sibirica, Pseudorchis albida, Tozzia carpathica, Traunsteinera globosa.

Table 5. The numerical situation of plants with conservation value in the various legislative documents and bibliographic resources

| Legislative documents / bibliographic resources                                                                 | Number of taxa |
|----------------------------------------------------------------------------------------------------------------|---------------|
| Red List of vascular plants in Romania (Oltean et al. 1994), declared as ‘Rare’ and ‘Vulnerable’                | 173           |
| IUCN Red List, as ‘Data Deficient’, ‘Least Concern’ or ‘Near Threatened’ (Bilz et al. 2011)                    | 44            |
| Habitat Directive Annexes II, IV, V                                                                           | 9             |
| CITES Appendix II                                                                                                | 32            |
| Sârbu et al. 2013, endemic to the Carpathian Mountains (Poa molineri subsp. glacialis, endemic to the Bucegi Mountains) | 57            |

Table 6. Analysis of ecological indices for moisture (H) and temperature (T) for 200 plant species of conservation value from Natura 2000 site Bucegi

|             | 0  | 1  | 1.5 | 2   | 2.5 | 3   | 3.5 | 4   | 4.5 | 5   |
|-------------|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
| **H**       |    |    |     |     |     |     |     |     |     |     |
| **T**       | 20 | 20 | 40  | 7   | 40  | 7   | 40  | 7   | 40  | 7   |

Shaded cells: Carpathian endemics. **Humidity** (H): 0 = euriphyte, 1 = xerophyte, 1.5 = xerophyte-xeromesophyte, 2 = xeromesophyte, 2.5 = xeromesophyte-mesophyte, 3 = mesophyte, 3.5 = mesophyte-mesohygrophyte, 4 = mesohygrophyte, 4.5 = mesohygrophyte-hygrophyte, 5 = hygrophyte. Here, **Temperature** (T): 0 = eurithermophyte, 1 = hekistothermophyte, 1.5 = hekistothermophyte-psychrothermophyte, 2 = psychrothermophyte, 2.5 = psychrothermophyte-microthermophyte, 3 = microthermophyte, 3.5 = microthermophyte-mesothermophyte, 4 = mesothermophyte, 4.5 = mesothermophyte-submesothermophyte, 5 = subthermophyte.

For the species nominated in the Annexes of the Habitat Directive, ecological preferences with respect to temperature and humidity are as follows:

i) Annexes II and IV: *Campanula serrata* (mesophyte, microthermophyte-mesothermophyte), *Draba dorneri* (xeromesophyte, psychrothermophyte), *Iris aphylla* (xeromesophyte, eurithermophyte), *Ligularia sibirica* (mesohygrophyte-hygrophyte, microthermophyte), *Tozzia carpathica* (mesohygrophyte, microthermophyte).

ii) Annex V: *Arnica montana* (mesophyte, microthermophyte-mesothermophyte), *Galanthus nivalis* (mesophyte, mesothermophyte), *Gentiana lutea* (mesophyte, microthermophyte), *Lycopodium alpinum* (mesophyte, psychrothermophyte). Only four taxa are potentially sensitive to both factors: *Gentiana lutea, Ligularia sibirica, Lycopodium alpinum, Tozzia carpathica*.

Among the plants included in CITES Appendix II, 28 taxa are sensitive to moisture decrease, 7 to temperature increase and 6 to both parameters: Dactylorhiza sambucina, D. cordigera, D. maculata, Gymnadenia conopsea, G. nigra and Pseudorchis albida.

The analysis of the endemic taxa in the Carpathian Mountains underline their specific preferences to temperature and humidity:

- In relation to soil moisture: 2 xerophyte-xeromesophytes (*Hesperis moniliformis, Saxifraga mutata* subsp. *demissa*), 23 xeromesophytes, 5 xeromesophyte-mesophytes, 15 mesophytes, 5 mesophyte-mesohygrophytes (*Achillea oxyloba* subsp. *shurii, Cardaminopsis neglecta, Dianthus glacialis* subsp. *gelidus, Plantago atrata* subsp. *carpatica, Veronica baumgartenii*), 7 mesohygrophytes (*Aconitum vulparia* subsp. *lasianthum, Cardamine glanduligera, Heracleum palatum, Hesperis nivea, H. oblongifolia, Ranunculus carpaticus, Symphytum cordatum*).

- In relation to air temperature: one eurithermophyte (*Draba aizoides* subsp. *zmudae*), 6 hekistothermophytes (*Astragalus australis* subsp. *bucescii, Dianthus glacialis* subsp. *gelidus, Erigeron*
nanus, Festuca bucegiensis, Hesperis oblongifolia, Thesium kernerianum), 16 psychothermophytes, 14 microthermophytes, 10 microthermophyte-mesothermophytes, 8 mesothermophytes, one mesothermophyte-submesothermophytes and one subthermophyte.

Species endemic to the Carpathian Mountains that could be affected both by rising temperatures and the decrease in rainfall are: Achillea oxyloba subsp. schurii, Anemone transsilvanica, Astragalus australis subsp. buceescii, Cardaminopsis neglecta, Cerastium transsilvanicum, Dianthus glacialis subsp. gelidus, Erigeron nanus, Festuca carpathica, Heracleum carpaticum, Hesperis nivea, H. oblongifolia, Phyteuma vagneri, Plantago atrata subsp. carpatica, Ranunculus carpaticus, Scabiosa lucida subsp. barbata, Scorzonoides pseudotaraxaci, Symphytum cordatum, Veronica baumgartenii.

The analysis of ecological indices for humidity and temperature (Popescu and Sanda, 1998, Ciocârlan, 2009), addressed to all the 200 plants of the Bucegi Mountains considered in this study, underlines that more than half range among the group of hekistothermophyte-microthermophyte (120 taxa/60%), and more than half are classified as mesophytes-hygrophytes (141 taxa/70.5%; Table 6 and Figures 11 and 12). Sensitive to both parameters (temperature increase and decrease of rainfall) are 88 protected taxa (44%) (Figure 12).

All the taxa nominated in IUCN Red List taxa recorded in this study are potentially sensitive to drought (85%) or warming (32%) to a different extent, and 27% are sensitive to both factors. Except Campanula patula subsp. abietina, all of them are rare species in Romania, according to Oltean et al. (1994).

In the case of plants listed in the Habitat Directive and CITES annexes, the aspects are more heterogeneous. According to these two documents most of the species included in the category ‘sensitive to drought’, and one third of those included in the category ‘sensitive to warming’, can be considered as potentially sensitive to the predicted changes of temperature and moisture regime. More than two thirds of the Carpathian endemic species considered in this study are sensitive to warming, about 46% are sensitive to moisture decrease, and 32% are potentially sensitive to both factors.

Figure 11. Spectrum indices for humidity (H) and temperature (T) features for plant species with conservation value of Natura 2000 site Bucgei (Annex 1). Abscissa: numbers refer to the ecological categories (1 – 5) described in Table 3. Ordinate: number of species in each category.
Discussion

The habitats of the Bucegi Natural Park may be exposed to a progressive increase in the mean annual air temperature, to longer drought periods in spring and summer, and to a decrease in snow pack thickness and duration, towards the end of this century (Figure 4). Climate projections for other high mountain areas in Europe, such as the Alps, show also a trend of warming and a possible increase of temperature between +1 °C and +2 °C, until 2100 (Förster et al., 2014).

The assessment of the potential sensitivity of the six Natura 2000 habitat types, considered in this study (code: 4070*, 6150, 6230*, 9110, 91V0, 9410), suggests that they may be sensitive to a different extent to the predicted temperature and humidity changes. They have a different floristic composition, developed by plants with different requirements to temperature and moisture, adapted to live in specific environmental conditions, which allow them to survive, to grow and spread.

- 4070* Bushes with Pinus mugo and Rhododendron myrtifolium, is a typical habitat for the subalpine level of Bucegi Mountain (1400-2000 m altitude). It requires low temperatures (+2.2 - -0.2 °C), sufficient humidity (1250-1425 mm/year) and snow (Mountford et al., 2008). This habitat shelters only a few plant species and is dominated (90%) by Pinus mugo Turra, a protected plant in Romania. It grows in a compact way, covering most of the habitat. The dominant species Pinus mugo (psichrothermophyte) (Popescu and Sanda, 1998) and 70% of the other species of phytocoenosis are depending on low temperature (hekistothermophytes, psichrothermophytes and microthermophytes). 36% of the plants are mesophytes and prefer a moderately humid substrat, but 40%, including the dominant specie Pinus mugo are mesophyte-mesohygrophyte and prefer a higher humidity. Approximately 66% of the species of this habitat type, develope under conditions of low temperature and humidity (Table 3) (e.g. Calamagrostis villosa (Chaix) J.F. Gmel., Caltha palustris L., Festuca aireoides Lam., Homogyne alpina (L.) Cass., Pinus mugo, Soldanella hungarica Simonk., Vaccinium myrtillus L.).
Siliceous alpine and boreal grasslands, are considered a glacial relict (Doniţă et al. 2005), including plant communities growing on the high crests of the mountains at alpine level (1550-2500 m altitude), preferring low temperature (annual average: +3 - -2.5 °C) and humidity (1100-1450 mm/year) (Mountford et al., 2008). These short grasslands are dominated by species like Agrostis rupestris All. (hekistothermophyte and mesophyte), Festuca airoides Lam. (syn. Festuca supina Schur) (psychrothermophyte and mesophyte) and Potentilla aurea L. subsp. chrysocraspeda (Lehm.) Nyman (psychrothermophyte, mesophyte). About 75% of the plants require low temperatures (hekistothermophyte and psichrothermophyte, microthermophyte), 65% prefer a humid substrate (mesophyte, mesohygrophyte and hydrophyte) and more than half (55%) need both kind of conditions for their development: low temperatures and edaphic humidity. Of the 26 taxa with conservation value observed in this type of habitat, 75% are predominantly hekistothermophyte and psichrothermophyte and 54% are predominantly mesophytes (Table 3). The endemic plant Dianthus glacialis Haenke subsp. gelidus (Schott, Nyman & Kotschy) Tutin, the rare plants Androsace chamaejasme Wulfen, Erigeron uniflorus L., Kobresia myosuroides (Vill.) Fiori, Loiselseuria procumbens (L.) Loisel., Gymnadenia nigra (L.) Rchb.f. (syn. Nigritella nigra) are only few of the species highly dependent on low temperature (hekistothermophytes, psychrothermophytes).

Species-rich Nardus grasslands on siliceous substrates in mountain areas (and submountain areas in Continental Europe), comprise the most wide-spread grassland type (35-40%), within the pasture area (800-2070 m altitude) of the Bucegi Mountains (Doniţă et al., 2005). Dominant species are Nardus stricta L. (80-90%) and Festuca airoides (mesophyte and psichrothermophyte). Nardus stricta is a xeromesophilic-mesohygrophilic and eurithermophilic plant (Popescu and Sanda, 1998), which can cope, for a short period of time, with variation in temperature (annual average: +6 - -1.5 °C) and humidity (800-1400 mm/year) (Mountford et al., 2008), but it is sensitive to prolonged drought or long-term high air temperature (Puşcaru et al., 1956). A ratio of 80% of all species comprised within this vegetation type requires low temperature (hekistothermophyte, psichrothermophyte and microthermophyte) and 70% need moist conditions (mesophyte, mesophyte-mesohygrophyte) (Table 3). More than half of the species (58%) need low temperature and sufficient humidity for their development. The value of this habitat, which is a priority for conservation, is provided by the presence of up to 15 protected plants: rare [Androsace chamaejasme, Dactylorhiza viridis (L.) R.M.Bateman, Pridgeon & M.W.Chase, Erigeron uniflorus, Gentiana acaulis L., Gymnadenia nigra, Oxytropis balleri Koch, Veronica alpina L.], endemic (Dianthus glacialis subsp.s. gelidus), and globally protected [Arnica montana L., Campanula patula L. subsp. abietina (Griseb. & Schenk) Simonk., Gymnadenia conopsea (L.) R.Br. subsp. conopsea, Pseudorchis albida (L.) Á. Löve & D. Löve]. All these taxa depend on low temperature (hekistothermophytes, psychrothermophytes, microthermophytes) and snow, and prefer a humid soil (mesophytes, mesohygrophytes).

Luzulo-Fagetum beech forests, include acidophilic beech forests, beech and fir forests, or beech, fir and spruce forests growing at 600 to 1350 m altitude. They require precipitation of 700-1300 mm/year and average annual temperatures of +3 to +8 °C (Mountford et al., 2008). The edificatory tree species are Fagus sylvatica L., Abies alba Mill. (mesophyte-mesohygrophyte and mesothermophyte) and Picea abies (L.) H. Karst., (mesophyte-hygrophyte and microthermophyte). The characteristic herbaceous taxa are Festuca drymeja Mert. & W.D.J. Koch, Symphytum cordatum Waldst. & Kit ex Willd. (mesohygrophyte, microthermophyte), Hieracium transsilvanicum Heuff. (mesophyte, eurithermophyte) and Luzula luzuloides (Lam.) Dandy & Wilmott (mesophyte, microthermophyte). About 95% of the forest plants are strongly dependent on edaphic humidity (mesophyte-hygrophyte and microthermophyte) and about 40% prefer low air temperatures (hekistothermophyte, psichrothermophyte and microthermophyte) (Table 3). Less than half of the species (38%) need both low temperatures and enough humidity during the vegetation period.
This type of habitat shelves a few protected plants with quite different demands on humidity and temperature, as for example: endemic as *Anemone transsilvania* (Fuss) Heuff. (mesophyte, mesothermophyte), *Ranunculus carpathicus* Herbich (mesohygrophyte, microthermophyte) and rare as *Dactylorhiza fuchsii* (Druce) Soó (mesophyte, eurithermophyte), *Dactylorhiza maculata* (L.) Soó (mesohygrophyte, microthermophyte), *Doronicum carpticum* (Griseb. & Schenk) Nyman (mesohygrophyte, psichrotermophyte), *Neotia nidus-avis* (L.) Rich. (mesophyte, mesothermophyte).

- **91V0** Dacian beech forests (*Symphyto-Fagion*), is a common forest type throughout the Carpathian ridge from 500 to 1450 m altitude and requires average annual temperature of +3 - +8 °C and rainfall of 750-1200 mm/year (Mountford *et al*., 2008). The habitat is characterised by beech, spruce and fir forests, dominated by *Fagus sylvatica* (mesophyte-mesohygrophyte and mesothermophyte). The characteristics herbaceous plants are mesophyte-mesohygrophyte and microthermophyte taxa like *Pulmonaria rubra* Schott, *Leucanthemum rotundifolium* DC. or *Symphytum cordatum*. Over 85% of the species recorded, have medium to high water requirements (mesophyte-hygrophyte), and 35% prefer cold air temperature (Table 3). One third of the species (31%) need both low temperature and sufficient moisture. The seven identified taxa with conservation value belong to mesophyte and mesohygrophyte categories. Five are microthermophytes (*Gymnadenia conopsea* subsp. *conopsea*, *Larix decidua* Mill. var. *carpatica* Domin, *Leucanthemum rotundifolium*, *Pulmonaria rubra*, *Ranunculus carpaticus*), and two are mesothermophytes (*Corallorhiza trifida* Châtel. and *Neottia nidus-avis*).

- **9410** Acidophilous *Picea* forests at the montane to alpine levels (*Vaccinio-Piceetea*), define a group of *Picea* forests wide-spread in the Romanian Carpathians, between 1000-1850 m altitude. They require average annual temperatures of +1.5 - +5 °C and precipitation between 900-1400 mm/year (Mountford *et al*., 2008). The dominant tree is *Picea abies* (L.) H. Karst. (mesophyte-hygrophyte and microthermophyte). Characteristic vascular plants like *Lycopodium selago* L., *L. annotinum* L., *Oxalis acetosella* L. and *Sorbus aucuparia* L. are mesohygrophyte and microthermophyte-meso thermophyte taxa. *Luzula sylvatica* (Huds.) Gaudin, *Soldanella hungarica* Simonk. and *Vaccinium vitis-idaea* L. are dominant vascular plants, depending more on edaphic humidity (mesohygrophytes and microthermophytes). The majority (90%) of the species (mesophyte→hygrophyte) of this forest type prefer humid soil (Table 3). Only 45% are dependent on low temperatures (many microthermophyte), and more than one third (42%) need both low temperatures and moisture. Of the 23 taxa with conservation value, identified in this type of habitat, 96% belong to mesophyte and mesohygrophyte categories and only 50% are microthermophytes. Some rare orchids such as *Dactylorhiza maculata* and *Gymnadenia conopsea* subsp. *conopsea* and the endemic *Ranunculus carpathicus* belong to this category.

The results of this study indicate that bushes (4070°*) and grassland habitat (6150 and 6230°*) can be considered as highly sensitive to warming but also as medium sensitive to drought. Their plants prefer low temperature and snow to a high proportion (70-80%) and many of the dominant taxa can be considered warm sensitive (hekistothermophyte and psichrothermophyte). Similar information was provided by Erschbamer *et al.* (2009) studies, referring to alpine grasslands from the Southern Alps. Alpine ecosystems dependent on low temperatures, snow and rainfall, generally create optimal conditions for highly specialized mountain species (Burrows, 1990; Körner, 1999). According to Ozenda and Borel (1991) plants from high altitude, which strongly depend on vernalisation and snow, will be the most vulnerable to warming and the alpine habitats can be considered among the most affected by climate change (Inouye, 2019). To a certain extent, the ecological preferences of plants well adapted to the existing climate conditions, may be also useful in predicting this trend. Studies on mountain areas in Europe (Alps, Balkans, Carpathian s.o.) show that reduced species tolerance to changes, promoted a higher rate of loss of species (Thuiller *et al*., 2005). These also claim that the risk of extinction of alpine plants in Europe will be higher even in moderate scenarios that use only two climatic variables (temperature and humidity) (Thuiller *et al*., 2005). Gottfried *et al.* (1999) predicts loss of areas...
suitable for some nival species, if temperature will increase by 1 to 2K and Barros et al. (2018) point out that prolonged drought can also lead to the loss of characteristic alpine species. But Theurillat et al. (1998) and Theurillat and Guisan (2001) underline that other high mountain ranges like the Alps appear to have a natural inertia and that alpine and nival species will be affected only when temperature will increase more than 3 to 4K. According to Matteodo et al. (2016) an increase in temperature by 4 °C, in the period 2071-2100, will reduce the snow volume by 50% and the alpine and subalpine grasslands of the Alps will undergo important changes.

Rapid climate change in wet and cold high mountain areas like Bucegi Mountain are open upward migration routes. The progressive reduction of cold mountain habitats will enhance the decline of species better adapted to low temperature, while those adapted to warmer conditions will extend their area (Pauli et al., 1996). This process was reported by Gottfried et al. (2012), calling it ‘thermophilization’. The expansion of thermophilic vascular taxa, and the moderate decline in regional endemic flora, was also reported by Stanisci et al. (2016) for the Apennines, as a response to warming. However, data from the High Alps (Pauli et al., 2007), referring to the period 1994-2004, indicate an ongoing decline of the cold-adapted species and an expansion of plants from lower elevations. The nival Saxifraga oppositifolia L. from the first category and the alpine Viola alpina Jacq. from the second category, are also present in the flora of Bucegi Mountains. The migration of species from lower altitude has already been reported not only in the Alps (Pauli et al., 2003), but also in the Rocky Mountains (2450-3050 m altitude), from Glacier National Park, Montana, USA (Lesica and McCune, 2004). The upward migration of some thermophilic plants as Cardamine pratensis L., Deschampsia caespitosa (L.) P. Beauv., Gnaphalium sylvaticum L. was also observed in our study in the case of Natura 2000 habitat type 6150.

Forest habitat types are particularly sensitive to the expected climatic changes (Lindner et al., 2010), especially to drought (Gilliam, 2016). In the Bucegi Mountains the evaluated forest plant communities’ habitats: 9110, 91V0, 9410, and especially the trees, depend on high humidity (85-96%) and the extensive drought may have directly damaging effects on tree species. One of the most vulnerable forest types can be considered the acidophilous Picea forests (Natura 2000 code: 9410), with a species composition, dominated by mesophilic, up to hygrophilic plants, respectively.

According to Frischbier et al. (2014), the typical species composition of Picea forests, if influenced by moderately warming conditions, may be significantly threatened by climate-induced spreading of beech (Fagus sylvatica), a mesothermophilic plant, until the middle of this century. Since climate models predict a significant increase in water deficit after 2050, tree species depending on water supply may be affected, including Fagus sylvatica. From this time on beech forests like “Luzulo-Fagetum beech forests” and “Dacian beech forests (Symphyto-Fagion)” will be subject to stronger climate change impact.

Hekistothermophytes, psychrothermophytes, mesohygrophytes and hygrophytes, as well as the microthermophytes and mesophytes, may be potentially affected by the predicted changes in climate in different ways (Sârbu et al., 2013; Sârbu et al., 2014). These ecological categories include most plants from high mountains of Europe and other geographic regions. Literature already provides information about the unfavourable effects of climate change on several protected alpine plants. Some of them are present in the flora of Bucegi Mountain, like Pinguicula vulgaris (Lesica and McCune, 2004), Saxifraga oppositifolia (Pauli et al., 1996), and Veronica alpina (Schöb et al., 2008).

Under the changing climatic conditions expected for this century, plants can have some options (Theurillat and Guisan, 2001; Corlett and Westcott, 2013): persisting in the modified climates by adaptation, migrating to more suitable climate areas or going extinct. This was also specified in the EEA Report – Climate change, impacts and vulnerability in Europe (EEA, 2012), where adaptation, migration and colonisation of new habitats, but also extinction, as a result of loss of suitable climatic conditions for species in protected areas, are considered as significant response mechanisms to climate change pressures. In this respect, it is possible that
some of the endemic species of the Bucegi Mountains, which belong to xerophytes-xeromesophytes (*Hesperis moniliformis*, *Saxifraga mutata* L. subsp. *demissa* (Schott & Kotschy) D.A. Webb) or to mesothermophytes categories (*Athananta turbith* (L.) Brot. subsp. *hungarica* (Borbás) Tutin, *Centaurea pinnatifida* Schur, *Crocus banaticus* J. Gay, *Dianthus carthusianorum* L. subsp. *tenuifolius* (Schur) Hegi, *Erysimum witmannii* Zaw. subsp. *transsilvanicum* P.W. Ball, *Koeleria macrantha* (Ledeb.) Schult. subsp. *transsilvanica* (Schur) A. Nyár., *Silene nutans* L. subsp. *dubia* (Herbich) Zapal.) may cope with warm and drier conditions in the future, to survive and to spread.

Other studied species requiring low temperature and moisture may accomplish an upward migration yet endangering the existence of the cryophilic plants (Pauli *et al.*, 2003). A migration process towards higher altitudes was reported by Erschbamer *et al.* (2009) for the Southern Alps, concerning *Androsace obtusifolia* All., *Erigeron uniflorus* and *Oxyria digyna* (L.) Hill. These species, also present in the flora of the Bucegi Mountains, are rare hekistothermophytes and mesophytes plants. Other hekistothermophytes, endemic to the Carpathians and with a capacity of migrating upward are: *Astragalus australis* (L.) Lam. var. *bucsescii* (Jav.) Gusul., *Erigeron nanus* Nutt., *Festuca bucegiensis* Markgr - Dann., *Hesperis oblongifolia* Schur, *Thesium kernerianum* Simonk. The question remains, if these endemic plants will be able to move fast enough to disperse naturally beyond the limits of their existing habitats, to keep up with climate change pressures.

The third option is extinction, which could strike the taxa heavily dependent on low temperatures, humidity and snow. Their persistence will be endangered as many of them are unable to move rapidly enough or because nival zones will be completely lost (Grabher *et al.*, 1994). This category includes protected plants at high altitude in the Bucegi Mountains, which are highly sensitive to warming, e.g. *Dianthus glacialis* subsp. *gelidus*, and *Hesperis moniliformis*.

According to Engler *et al.* (2011), the impact of climate change on the flora of the European mountains will be different, according to the level of increased warming accompanied by decreased precipitation. In this respect, the sensitivity of plants of the Carpathians to climate change was considered to be medium, when compared with the situation in other mountain ranges of Europe (e.g. Spanish Pyrenees, Austrian Alps) (Engler *et al.*, 2011). But, with respect to protected plants growing at high altitude in the Carpathians in restrictive ecological life conditions, we suggest that a possible high sensitivity to temperature and humidity may be taken into consideration, especially in the case of the predicted combination of less precipitation and warming.

**Conclusions**

This research represents an attempt to provide a first forecast on very possible changes in vegetation, in the Bucegi territorial mountain unit, in condition of the changes in temperature and humidity, predicted for this century. The following aspects support the uniqueness of the results: i) the forecast on vegetation development is based on the climate scenario, ii) all the plants with conservation value (200 taxa) from the Bucegi Natural Park were considered, iii) a whole mountain area is being described by Sat-image interpretation with GIS. The trends of the temperature and humidity regime in Bucegi Natural Park, in this century, consist in a clear and progressive rise and in serious changes of the water regime. As a scenario of long-term change, the microthermophilic and the hydrophilic plants of the Bucegi Mountains can be considered as potentially sensitive to predicted warming and drought. About 80% of the plants with conservation value evaluated in this study are included in these categories. The sensitivity can be theoretically higher for taxa that combine the two requests: more than half of the plants in alpine and subalpine habitats, more than a third of the plants in forest habitats and almost half of the plants with conservation value in the Natura 2000 site Bucegi. All six habitat types considered in this study were assessed as potentially sensitive to temperature and humidity changes, predicted for this century. Alpine and subalpine habitats may be considered more dependent on low
temperature, which is associated with the presence of snow, and forest habitats may be considered potentially more sensitive to drought.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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Annex 1. The list of rare species, endemic and/or endangered, of Natura 2000 site Bucegi: distribution and ecological preferences (humidity and temperature)

| Nr. | Taxon | IUCN Red List 2011 | Habitat Directive Annexes | Bern Convention Annexes | CITES Annexes | Romanian Red List (Oltean et al., 1994) | Distribution (cf Sârbu et al., 2013) | Ecological preferences |
|-----|-------|---------------------|---------------------------|-------------------------|--------------|--------------------------------------|--------------------------------------|------------------------|
| 1   | Achillea oxyloba (DC.) Sch.Bip. subsp. schurii (Sch.Bip.) Heimerl [syn. Achillea schurii] | - | - | - | R | Carp. orient. & merid. | mesophyte - mesohygrophyte | microthermophyte |
| 2   | Aconitum toxicum Rechb. | - | - | - | - | Carp.-Balc. | mesohygrophyte | microthermophyte - mesothermophyte |
| 3   | Aconitum vulparia subsp. lasianthum [accepted name Aconitum vulparia Rechb.] | - | - | - | - | Eur. Centr. & West Carp. | mesohygrophyte | microthermophyte - mesothermophyte |
| 4   | Alyssum repens Baumg. | - | - | - | - | Carp.-Balc. | euphyte | eurithermophyte |
| 5   | Anacamptis coriophora (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. Orchis coriophora] | LC | - | II | R | Centr. Eur. | mesophyte - mesohygrophyte | eurithermophyte |
| 6   | Anacamptis laxiflora (Lam.) R.M.Bateman, Pridgeon & M.W.Chase | LC | - | II | R | Pont.-Pan. | mesohygrophyte | mesothermophyte |
| 7   | Anacamptis morio (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. Orchis morio] | NT | - | II | R | Eur. | xeromesophyte - mesophyte | mesothermophyte |
| 8   | Anacamptis pyramidalis (L.) Rich. | - | - | - | V/R | Centr. Eur. - Submed.-Atl. | xerophyte | xeromesophyte | mesothermophyte |
| 9   | Androsace chamaejasme Wulfén | - | - | - | V/R | Circ. arct.-alp. | mesophyte | hekistothermophyte - psichrothermophyte |
| 10  | Androsace obtusifolia All. | - | - | - | R | Alp.-Carp. | mesophyte | mesohygrophyte | hekistothermophyte |
| 11  | Androsace villous L. var. arachnoidea (Schott, Nyman & Kotschy) R.Knuth | - | - | - | R | Carp. orient. & merid. | xeromesophyte | psichrothermophyte |
|   | Species                     | Distribution          | Life Form | Ecological Group          | Category         |
|---|-----------------------------|-----------------------|-----------|---------------------------|------------------|
| 12| Anemone transsilvanica (Fuss) Heuff. [syn. Hepatica transsilvanica] |          | -         | nt                        | Carp. (Romania)  |
|   |                             | V                    |           | mesophyte                 | microthermophyte |
| 13| Angelica archangelica L.    | V                    |           | mesohygrophyte            | microthermophyte |
|   |                             | R                    |           | xeromesophyte             | psichrothermophyte |
| 14| Anethum serapiense Waldst. & Kit. ex Willd. subsp. pyrethrum (Schue) Beldie | R         |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 15| Aquilegia nigricans Baumg. subsp. subcaposa (Borbas) Soo | R         |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 16| Aquilegia transsilvanica Schur | R        |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 17| Angelica archangelica L.    | R                    |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 18| Arnica montana L.           | LC                   | V         | V                         | Eur. (mont.)     |
|   |                             | R                    |           | mesophyte                 | microthermophyte |
| 19| Astragalus alpinus L.       | R                    |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 20| Astragalus australis (L.) Lam. var. bucculcei (Jav.) Gusul. | R         |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 21| Athamanta turbiti (L.) Brot. subsp. hungarica (Borbas) Tutin | R         |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 22| Bupleurum ranunculodes L.   | R                    |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 23| Campanula carpatica Jacq.   | R                    |           | Carp. (Romania)           | xeromesophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| 24| Cardaminopsis neglecta (Schult.) Hayek | R    |           | Carp. (Romania)           | mesohygrophyte    |
|   |                             | R                    |           | mesohygrophyte            | microthermophyte |
| No. | Species Name | Distribution | Life Form | Physiology | Life Form | Physiology |
|-----|--------------|--------------|-----------|------------|-----------|------------|
| 29  | Carduus kernerii Simonk. | - | - | - | - | Carp.-Balc. | xeromesophyte - mesophyte |
| 30  | Carex brachystachys Schrank | - | - | - | - | R | Pirinei - Alpi - Apennine - N-W Balc.- Carp. | mesohygrophyte - microthermophyte |
| 31  | Carex capillaris L. | - | - | - | - | R | Circ. arct.- alp. | mesophyte - psichrothermophyte |
| 32  | Carex cholodkoevici L.f. | - | - | - | - | R | Circ. bor. | hygrophyte - microthermophyte |
| 33  | Carex fuliginosa Schkuhr | - | - | - | - | R | Euras. arct.- alp. eur. | mesophyte - hekistermophyte - psichrothermophyte |
| 34  | Carex rupestris All. | - | - | - | - | R | Circ. arct.- alp. | xeromesophyte - mesophyte |
| 35  | Centaurea kotschyanu Heuff. | - | - | - | - | R | Carp.-balc. | xeromesophyte |
| 36  | Centaurea phrygia L. subsp. melanostachys (Borhás) Dostál | - | - | - | - | R | Carp. | mesophyte - microthermophyte - mesothermophyte |
| 37  | Centaurea pinnatifida Schur [syn. Cyanus pinnatifidus (Schar) Holub] | - | - | - | - | R | Carp. | xeromesophyte - mesothermophyte |
| 38  | Cephalanthera damasonium (Mill.) Druce | L.C | - | - | II | nt | Eur. | mesophyte - mesothermophyte |
| 39  | Cephalanthera longifolia (L.) Fritsch | L.C | - | - | II | nt | Eur. | mesophyte - mesothermophyte |
| 40  | Cephalanthera rubra (L.) Rich. | L.C | - | - | II | R | Eur. | mesophyte - mesothermophyte |
| 41  | Cerastium arvense L. subsp. lechenfeldianum (Schur) Asch. & Graebn. | - | - | - | - | R | Carp. orient. & merid.; Jugi | xeromesophyte - mesophyte - eurithermophyte |
| 42  | Cerastium transsilvanicum Schur | - | - | - | - | R | Carp. orient. & merid. | mesophyte - psichrothermophyte |
| 43  | Chamorcrhis alpina (L.) Rich. | L.C | - | - | II | R | Euras. arct.- alp. eur. | xeromesophyte - mesophyte - psichrothermophyte |
| 44  | Coninclusa vaginata (Speege) Thell. | - | - | - | - | R | Euras. bor. | mesophyte - microthermophyte |
| 45  | Crepis connexifolia (Gouan) A.Kern. | - | - | - | - | R | Alp. Eur. | mesophyte - microthermophyte |
| 46  | Crocus banaticus J.Gay | - | - | - | - | R | Carp. | mesophyte - mesothermophyte |
| 47  | Dactylorhiza cordigera (Fr.) Soó | L.C | - | - | II | R | Carp.-Balc. | mesohygrophyte - microthermophyte |
| 48  | Dactylorhiza fuchsii (Drace) Soó | L.C | - | - | II | R | Euras. | mesophyte - eurithermophyte |
| No. | Species Name | Common Name | Distribution | Life Form | Moisture Preference | Temperature Preference |
|-----|--------------|-------------|--------------|-----------|---------------------|------------------------|
| 49  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | mesothermophyte |
| 50  | Dactylorhiza maculata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 51  | Dactylorhiza sambucina (L.) Soó | - | II | R | Eur. | mesophyte | microthermophyte |
| 52  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 53  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 54  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 55  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 56  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 57  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 58  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 59  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 60  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 61  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 62  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 63  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 64  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 65  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 66  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 67  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 68  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| 69  | Dactylorhiza incarnata (L.) Soó | - | II | R | Eur. | mesohygrophyte | microthermophyte |
| No. | Species Name                        | Continent | Elevation | Life Form | Distribution                           | Habitat Type                  | Thermophytes                  |
|-----|------------------------------------|-----------|-----------|-----------|----------------------------------------|------------------------------|------------------------------|
| 70  | Epipogium aphyllum Sw.             | LC        |           | II        | R                                      | Euras. mesophyte              | microthermophyte - mesothermophyte |
| 71  | Erigeron alpinus L.                |           |           |           | R                                      | Euras. alp. mesophyte         | hekistothermophyte            |
| 72  | Erigeron atticus Vill.             |           |           |           | R                                      | Alp. Eur. xeromesophyte - mesophyte | psichrothermophyte            |
| 73  | Erigeron nanus Nutt.               |           |           |           | V/R                                    | Carp. mesophyte hekistothermophyte |
| 74  | Erigeron uniflorus L.              |           |           |           | R                                      | Circ. arct.- alp. mesophyte   | hekistothermophyte - psichrothermophyte |
| 75  | Eriophorum angustifolium Honck.    | LC        |           |           | R                                      | Circ. hygrophyte mesothermophyte |
| 76  | Eriophorum scheuchzeri Hoppe       |           |           |           | R                                      | Circ. arct.- alp. hygrophyte  | psichrothermophyte            |
| 77  | Eriophorum nanum (L.) Schrad. ex Gaudin s.l. |           |           |           | R                                      | Alp.-Carp. xeromesophyte - psichrothermophyte |
| 78  | Erysimum witmannii Zaw. subsp. transsilvanicum P.W. Ball |           |           |           | R                                      | Carp. merid. xeromesophyte mesothermophyte |
| 79  | Festuca amethystina L.             |           |           |           | R                                      | Alp.-Centr. Eur. mesophyte    | mesothermophyte              |
| 80  | Festuca bucegenis Markgr.-Dann.    |           |           |           | R                                      | Carp. merid. xeromesophyte hekistothermophyte |
| 81  | Festuca carpathica F.Dietr.        |           |           |           | R                                      | Carp. orient. & merid. mesophyte | microthermophyte             |
| 82  | Festuca versicolor Tausch          |           |           |           | R                                      | Carp. xeromesophyte subthermophyte |
| 83  | Galanthus nivalis L.               | NT        | V         |           | nt                                     | Centr. Eur. - Submed. mesophyte | mesothermophyte              |
| 84  | Gentiana acaulis L.                |           |           |           | R                                      | Alp. Eur. mesophyte           | microthermophyte             |
| 85  | Gentiana frigida Haenke            |           |           |           | R                                      | Alp.-Carp. mesophyte hekistothermophyte |
| 86  | Gentiana lutca L.                  | LC        | V         |           | V/R                                    | Alp. Eur. mesophyte           | microthermophyte             |
| 87  | Gentiana punctata L.               |           |           |           | R                                      | Alp. Eur. mesophyte           | microthermophyte             |
| 88  | Gentianella bulgarica (Velen.) Holub |           |           |           | R                                      | Carp.-Balc. xeromesophyte - mesophyte | mesothermophyte             |
| 89  | Geranium caeruleatum Schur [syn. Geranium sylvaticum subsp. caeruleatum] |           |           |           | R                                      | Carp.-Balc. mesophyte - mesohygrophyte | microthermophyte - mesothermophyte |
| 90  | Geum reptans L.                    |           |           |           | R                                      | Alp. Eur. mesohygrophyte      | psichrothermophyte            |
| 91  | Goodfrya repens (L.) R.Br.         | LC        |           | II        | R                                      | Circ. mesophyte eurithermophyte |
| Entry | Species | Location | Life Form | Phenology | Leaves | Flowers | Fruits | Notes |
|-------|---------|----------|-----------|-----------|--------|---------|--------|-------|
| 92    | Gymnadenia conopsea (L.) R.Br. | LC | - | II | R | Eur. | mesophyte | microthermophyte |
| 93    | Gymnadenia nigra (L.) Rehder f. [syn. Nigritella nigra] | LC | - | II | V/R | Eur. | mesophyte | psichrothermophyte |
| 94    | Gymnadenia rubra Wettst. [syn. Nigritella rubra] | - | - | V/R | E Alp.-Carp. | mesophyte | eurithermophyte |
| 95    | Gypsophila petraea (Baumg.) Rehbb. | - | - | R | Carp. orient. & merid. | xeromesophyte | mesothermophyte |
| 96    | Hedysarum heteronides (L.) Schinz & Thell. | - | - | R | Circ. | mesophyte | psichrothermophyte | microthermophyte |
| 97    | Helictotrichon planiculme (Schrad.) Pilg. | - | - | R | Carp.-Balc.-Suder. | mesophyte | microthermophyte | mesothermophyte |
| 98    | Heracleum carpticum Poc. | - | - | V/R | Ducic | mesophyte | microthermophyte |
| 99    | Heracleum palmatum Baumg. | - | - | nt | Carp. (Romania) | mesohygrophyte | microthermophyte | mesothermophyte |
| 100   | Herminium monorchis (L.) R.Br. | DD | - | II | R | Eur. | mesophyte | mesothermophyte |
| 101   | Hesperis moniliformis Schur [syn. Hesperis matronalis subsp. moniliformis] | - | - | R | Carp. orient. & merid. | xerophyte | xeromesophyte | microthermophyte |
| 102   | Hesperis nivea Baumg. | - | - | R | Carp. orient. & merid. | mesohygrophyte | psichrothermophyte |
| 103   | Hesperis oblongifolia Schur | - | - | R | Carp. orient. & merid. | mesohygrophyte | heliosthermophyte |
| 104   | Hieracium rotundatum Kitz. ex Schult. [syn. Hieracium transilanicum] | - | - | R | Carp.-Balc.- Centr. Eur. | mesophyte | eurithermophyte |
| 105   | Hormogonum alpinum (L.) O.Appel subsp. brevicaulis (Spreng.) O.Appel | - | - | R | Alp. Eur. | mesohygrophyte | eurithermophyte |
| 106   | Hypericum richeri Vill. subsp. transilanicum (Čelák.) Ciocârlan | - | - | Carp. orient. & merid. | xeromesophyte | microthermophyte | mesothermophyte |
| 107   | Iris aphylla L. | DD | II/IV | Cont. Eur. | xeromesophyte | eurithermophyte |
| 108   | Jacobaea abrotanifolia (L.) Moench subsp. carpatica (Heebich) B.Nord. & Greuter [syn. Senecio carpaticus] | - | - | R | Carp.-Balc. | mesophyte | psichrothermophyte |
| 109   | Juncus filiformis L. | - | - | Carp. orient. & merid. | hygrophyte | microthermophyte | mesothermophyte |
| No. | Species Name                                      | Distribution             | Lifeform Group 1 | Lifeform Group 2 | Lifeform Group 3 | Lifeform Group 4 |
|-----|--------------------------------------------------|--------------------------|------------------|------------------|------------------|------------------|
| 110 | *Loiseleuria procumbens* (L.) Loisel.            | - R                      | xeromesophyte    | mesophyte        | psichrothermophyte |
| 111 | *Kobresia myosuroides* (Vill.) Fiori             | - R                      | mesophyte        | hekistothermophyte |
| 112 | *Kobresia simplicissima* (Wahlenb.) Mack.        | - R                      | xeromesophyte    | mesophyte        | hekistothermophyte |
| 113 | *Koeleria macrantha* (Ledeb.) Schult. *transsilvanica* (Schar) A.Nyár. | - R                      | xeromesophyte    | mesothermophyte  |
| 114 | *Larix decidua* Mill. *var. carpatica* Domin    | - R                      | mesophyte        | microthermophyte  |
| 115 | *Leontopodium alpinum* Cas.                     | - V/R                    | mesophyte        | psichrothermophyte |
| 116 | *Leucanthemum rotundifolium* DC. [syn. *Leucanthemum waldsteinii*] | - R                      | mesophyte        | mesohygrophyte   |
| 117 | *Ligularia glauca* (L.) O.Hoffm.                 | - R                      | mesophyte        | microthermophyte  |
| 118 | *Ligularia sibirica* (L.) Cas.                  | DD II/IV I V            | mesohygrophyte   | microthermophyte  |
| 119 | *Ligusticum mutellinoides* Vill.                | - R                      | mesohygrophyte   | hekistothermophyte |
| 120 | *Linaria alpina* (L.) Mill.                     | - R                      | mesohygrophyte   | eurithermophyte   |
| 121 | *Linum estraecilare* Kit.                       | - nt                     | mesohygrophyte   | eurithermophyte   |
| 122 | *Lloydia serotina* (L.) Rehb.                   | - R                      | xeromesophyte    | eurithermophyte   |
| 123 | *Lomatogonium carinthiacum* (Wulfen) A.Braun     | - R                      | xeromesophyte    | psichrothermophyte |
| 124 | *Lonicera caerulea* L.                          | - R                      | mesophyte        | microthermophyte  |
| 125 | *Lycopodium alpinum* L.                         | - V                      | mesophyte        | psichrothermophyte |
| 126 | *Monotropa hypopitys* L.                         | - R                      | mesophyte        | microthermophyte  |
| 127 | *Neotinea ustulata* (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. *Orchis ustulata*] | - II R                 | mesophyte        | microthermophyte  |
| No. | Species                                      | Distribution | Life Form         | Mesophytes | Thermophytes |
|-----|---------------------------------------------|--------------|-------------------|------------|-------------|
| 128 | Neottia cordata (L.) Rich. [syn. Listera cordata] | LC           | -                 | II         | R           |
|     |                                             |              |                   | Circ.      | mesohygrophyte | eurithermophyte |
| 129 | Neottia nidus-avis (L.) Rich.               | LC           | -                 | II         | R           |
|     |                                             |              |                   | Euras.     | mesophyte   | mesothermophyte |
| 130 | Neottia ovata (L.) Bluff & Fingerh. [syn. Listera ovata] | LC           | -                 | II         | R           |
|     |                                             |              |                   | Euras.     | mesophyte - mesohygrophyte | mesothermophyte |
| 131 | Ophiobrychis montana DC. subsp. transsilvanica (Simonk.) Jäv. | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp. (Romania) | xeromesophyte | psichrothermophyte |
| 132 | Ophrys insectifera L.                       | LC           | -                 | II         | R           |
|     |                                             |              |                   | Eur.       | xeromesophyte | mesothermophyte |
| 133 | Orchis mascula (L.) L.                      | LC           | -                 | II         | R           |
|     |                                             |              |                   | Submedit.  | mesophyte   | mesothermophyte |
| 134 | Orchis militaris L.                         | LC           | -                 | II         | R           |
|     |                                             |              |                   | Euras.     | mesophyte   | mesothermophyte |
| 135 | Oxyria digyna (L.) Hill                     | -            | -                 | -          | R           |
|     |                                             |              |                   | Circ.      | mesohygrophyte | hekistothermophyte |
| 136 | Oxytropis carpathica R.Uechter.             | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp.      | xeromesophyte - mesophyte | psichrothermophyte |
| 137 | Oxytropis halleri Koch                      | -            | -                 | -          | R           |
|     |                                             |              |                   | Alp. eur.  | xeromesophyte | psichrothermophyte |
| 138 | Papaver alpinum L. subsp. corona-sancti-stephani (Zapal.) Borza | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp. orient. & merid. | xeromesophyte | microthermophyte |
| 139 | Phyteuma confusum A.Kern.                   | -            | -                 | -          | R           |
|     |                                             |              |                   | Alp.-Carp.-Balc. | mesophyte | microthermophyte |
| 140 | Phyteuma vagneri A.Kern.                    | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp.      | mesophyte   | psichrothermophyte |
| 141 | Pinguicula alpina L.                        | -            | -                 | -          | R           |
|     |                                             |              |                   | Euras.      | mesohygrophyte - hygrophyte | eurithermophyte |
| 142 | Pinguicula vulgaris L.                      | LC           | -                 | -          | R           |
|     |                                             |              |                   | Circ.      | mesohygrophyte - hygrophyte | eurithermophyte |
| 143 | Pinus cembra L.                             | -            | -                 | -          | R           |
|     |                                             |              |                   | Euras.      | mesophyte | psichrothermophyte - microthermophyte |
| 144 | Plantago atrata Hoppe subsp. carpatica (Pilg.) Soó | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp.      | mesophyte | mesohygrophyte | microthermophyte |
| 145 | Plantago genianoides Sm.                    | -            | -                 | -          | R           |
|     |                                             |              |                   | Carp.-Balc.-Anat. | mesohygrophyte | microthermophyte |
| 146 | Platranthera bifolia (L.) Rich.             | LC           | -                 | II         | R           |
|     |                                             |              |                   | Euras.     | mesophyte - mesohygrophyte | eurithermophyte |
| 147 | Platranthera dolantha (Custer) Rehb.        | LC           | -                 | II         | R           |
|     |                                             |              |                   | Euras.     | mesophyte   | mesothermophyte |
| No. | Species | Distribution | Life Form | Phenology | Habitat |
|-----|---------|--------------|-----------|----------|---------|
| 148 | Pleurospermum austriacum (L.) Hoffm. | Eur. Centr. (mont.) | mesohygrophyte | microthermophyte |
| 149 | Poa molinier Balb. subsp. glacialis Beldie | Bucegi | xeromesophyte | microthermophyte |
| 150 | Poa remota Forselles | Euras. bor. | mesophyte - mesohygrophyte | microthermophyte - mesothermophyte |
| 151 | Polemonium caeruleum L. | Circ. | mesohygrophyte | microthermophyte - mesothermophyte |
| 152 | Potentilla palustris (L.) Scop. | Circ. bor. | hygrophyte | microthermophyte |
| 153 | Primula halleri J.F.Gmel. | Alp. Eur. | mesophyte | microthermophyte |
| 154 | Pseudorchis albida (L.) Á.Löve & D.Löve | Eur. (mont.) | mesophyte | microthermophyte |
| 155 | Pulmonaria officinalis Schott | Carp.-Balc. | mesophyte | microthermophyte |
| 156 | Pyrola carpathica Holub & Křísa | Pirin.alp.-Apen.-W Balc.-Carp. | mesohygrophyte | hekistothermophyte |
| 157 | Ranunculus carpathicus Herbich | Dacic | mesohygrophyte | microthermophyte |
| 158 | Ranunculus thora L. | Pirin.alp.-Apen.-W Balc.-Carp. | mesohygrophyte | hekistothermophyte |
| 159 | Rhododendron myrtifolium Schott & Kotschy | Carp.-Balc. | mesophyte | eurithermophyte |
| 160 | Salix alpina Scop. | Alp.-Carp. | mesohygrophyte | hekistothermophyte - psichrothermophyte |
| 161 | Salix bicolor Ehrh. ex Willd. | Alp.-W&Centr. Eur. | mesohygrophyte | hekistothermophyte - psichrothermophyte |
| 162 | Salix daphnoides Vill. | Centr. Eur. | mesohygrophyte - hygrophyte | microthermophyte |
| 163 | Salix retusa L. | Alp. Eur. | mesophyte | psichrothermophyte |
| 164 | Saussurea alpina (L.) DC. | Circ. alp.-alp. | mesophyte | hekistothermophyte |
| 165 | Saussurea discolor (Willd.) DC. | Alps, Carp. Apennine | mesophyte | hekistothermophyte |
| Species | Author(s) | Location | Lifeform 1 | Lifeform 2 | Lifeform 3 | Lifeform 4 |
|---------|-----------|----------|------------|------------|------------|------------|
| Saxifraga carpatica | Sternb. | Carp.-Balc. | mesophyte | mesohygrophyte | psychrothermophyte |
| Saxifraga cernua L. | C. | Carp.-Balc. | mesohygrophyte | psychrothermophyte |
| Saxifraga mutata L. subsp. demissa (Schott & Korsch.) D.A.Webb | [syn. Saxifraga demissa] | | V/R | Carp. merid. | xerophyte | mesohygrophyte | psychrothermophyte |
| Saxifraga oppositifolia L. | C. | Carp.-Balc. | mesohygrophyte | psychrothermophyte |
| Saxifraga cernua L. | C. | Carp.-Balc. | mesohygrophyte | psychrothermophyte |
| Saxifraga oppositifolia L. | C. | Carp.-Balc. | mesohygrophyte | psychrothermophyte |
| Scabiosa lucida Vill. subsp. barbata Nydr. | Carp. (Romania) | mesophyte | microthermophyte |
| Scorzoneroides pseudotaraxaci (Schur) Holub | Carp. | mesohygrophyte | microthermophyte |
| Sedum grisebachii Boiss. & Heldr. | Carp.-Balc. | mesophyte | mesothermophyte |
| Sesleria bielzii Schur | Carp.-Balc. | mesophyte | mesothermophyte |
| Sesleria rigida Heuff. ex Rebh. [syn. Sesleria baynaldiana] | Carp.-Balc. | mesohygrophyte | subthermophyte |
| Silene nutans L. subsp. dubia (Herich) Zapal. | Carp. (Romania) | mesophyte | mesothermophyte |
| Soldanella pusilla Baumg. | Carp.-Balc. | mesohygrophyte | microthermophyte |
| Streptopus amplexifolius (L.) DC. | Afr. medit. | mesohygrophyte | microthermophyte |
| Symphytum cordatum Waldst. & Kit ex Willd. | Carp. | mesohygrophyte | microthermophyte |
| Taxacum fontanum Hand.-Mazz. | Euras. alp. | mesohygrophyte | psychrothermophyte |
| Taxus baccata L. | Afr. medit. | mesohygrophyte | mesothermophyte - submesothermophyte |
| Tephroseris papposa (Rchb.) Schur [syn. Senecio papposus] | Carp.-Balc. | mesophyte | microthermophyte |
| Thalictrum alpinum L. | Circ. bor.-arct.-alp. | mesophyte | microthermophyte |
|   | Species                                    | Distribution               | Lifeform                      | Water Tolerance                    |
|---|-------------------------------------------|-----------------------------|-------------------------------|-----------------------------------|
| 185| *Thesium kernerianum* Simonk.             | -                           | R                             | xeromesophyte - hekistothermophyte|
| 186| *Thlaspi dacicum* Heuff. s.l.             | -                           | R                             | xeromesophyte - psichrothermophyte|
| 187| *Thymus kernerianus* Jalis [syn. *Thymus marginatus*] | -                           | R                             | mesophyte - microthermophyte     |
| 188| *Thymus comosus* Heuff. ex Griseb. & Schenk | -                           | nt                            | microthermophyte - mesothermophyte|
| 189| *Thymus pulcherrimus* Schur               | -                           | R                             | xeromesophyte - psichrothermophyte|
| 190| *Tozzia carpathica* Woloszack             | DD                          | R                             | mesohygrophyte - microthermophyte|
| 191| *Traunsteinera globosa* (L.) Rchb.        | L.C.                        | R                             | mesophyte - microthermophyte     |
| 192| *Trisetum alpestris* (Host) P.Beauv.      | -                           | R                             | mesophyte - microthermophyte     |
| 193| *Trisetum macrotrichum* Hack.            | -                           | R                             | mesophyte - microthermophyte     |
| 194| *Trollius europaeus* L. s.l.              | -                           | R                             | mesohygrophyte - microthermophyte|
| 195| *Vaccinium uliginosum* L.                 | -                           | R                             | xeromesophyte - mesophyte        |
| 196| *Veronica alpina* Jacq.                  | -                           | R                             | mesohygrophyte - hekistothermophyte|
| 197| *Veronica aphylla* L.                    | -                           | R                             | mesohygrophyte - psichrothermophyte|
| 198| *Veronica haugartenii* Roem. & Schult.   | -                           | R                             | mesohygrophyte - microthermophyte|
| 199| *Viola alpina* Jacq.                     | -                           | R                             | mesohygrophyte - microthermophyte|
| 200| *Viola dacica* Borbás                    | -                           | R                             | mesohygrophyte - microthermophyte|