

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 scree habitats, chasmophyte vegetation on calcareous rocks, peat bogs, 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 <i>Pinus mugo</i> and <i>Rhododendron myrtifolium</i>	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 <i>Nardus</i> grasslands on siliceous substrates in mountain areas (and submountain areas in Continental Europe)	800-2070	+6.0 - -1.5	800-1400
9110	<i>Luzulo-Fagetum</i> beech forests	600-1350	+3.0 - +8.0	700-1300
91V0	Dacian beech forests (<i>Symphyto-Fagion</i>)	500-1450	+3.0 - +8.0	750-1200
9410	Acidophilous <i>Picea</i> forests on the montane to alpine levels (<i>Vaccinio-Piceetea</i>)	1000-1850	+1.5 - +5.0	900-1400

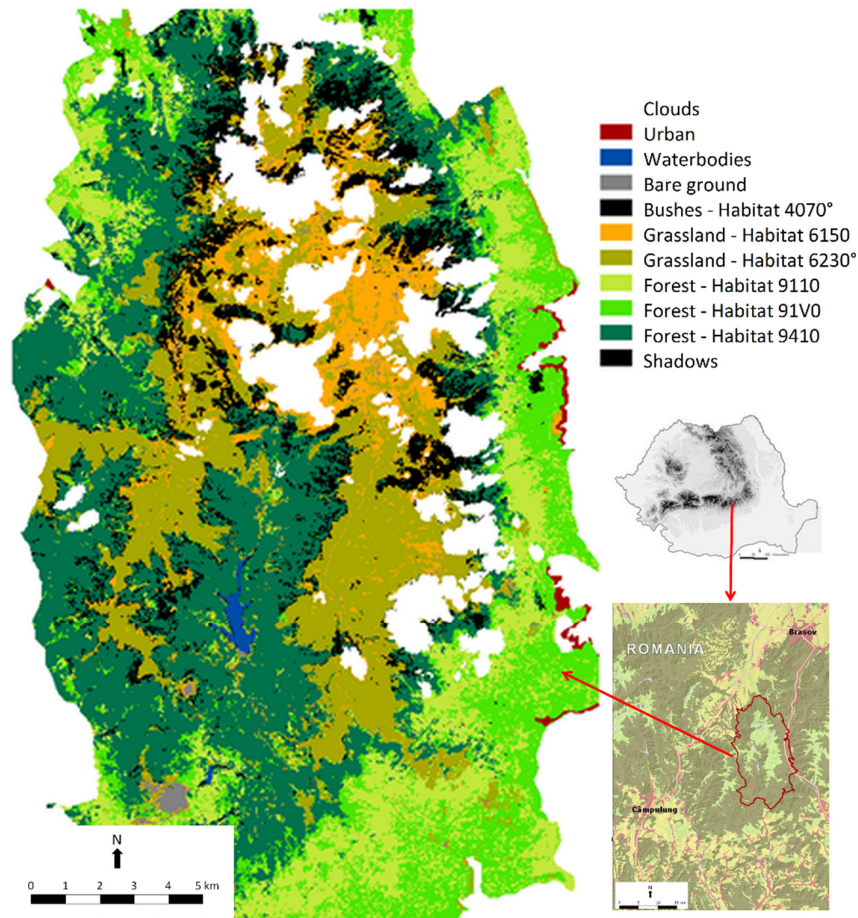


Figure 1. Location and outline of Bucegi Natural Park, Romania (right) (Basic geodata: NUTS database@EuroGeographics 2006, Investigation area: Project partners 20101 Map: Neubert, Puschel, Witschas 2010), and distribution of the selected Natura 2000 habitat types (left) (Map: Wagner, Förster, Schmidt, 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

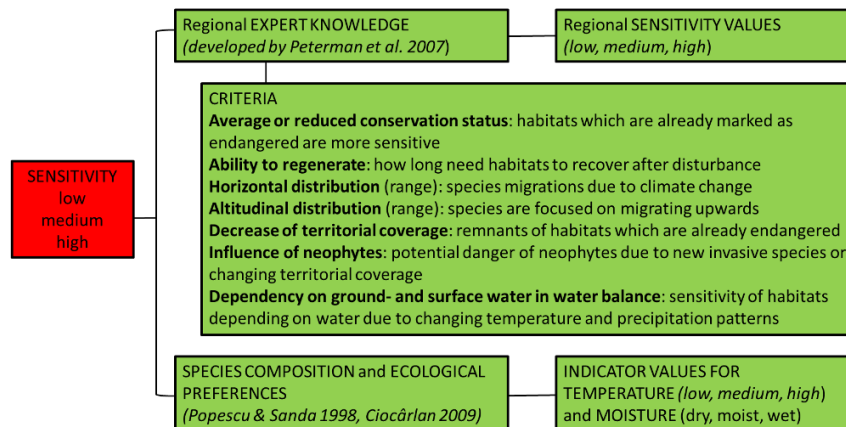


Figure 2. Framework for the habitat’s sensitivity assessment (Wagner-Lücker, 2012 - HABIT CHANGE project, outputs 4.3.5. 4.6.1. 4.6.2.)

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 tree 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 Ialomița River (N 45°21'12"; E 25°23'54" and N 45°17'1"; E 25°26'29") that includes wooden 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: Doniță *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).

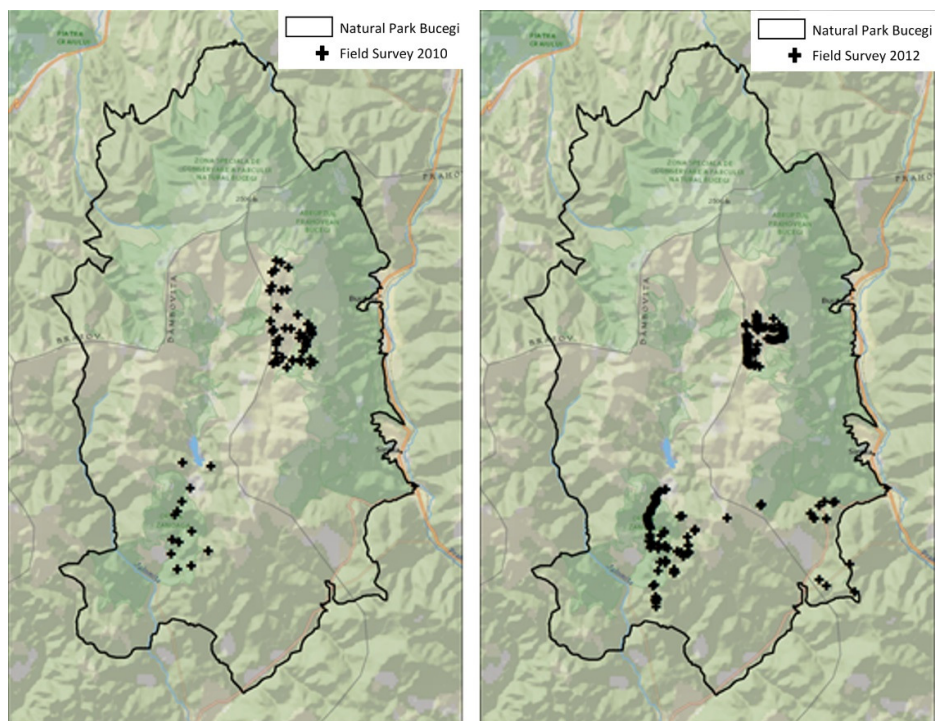


Figure 3. Location of the field surveys in 2010 (left) and 2012 (right) (Wagner-Lücker, 2012 – HABIT CHANGE project, output 4.3.2.)

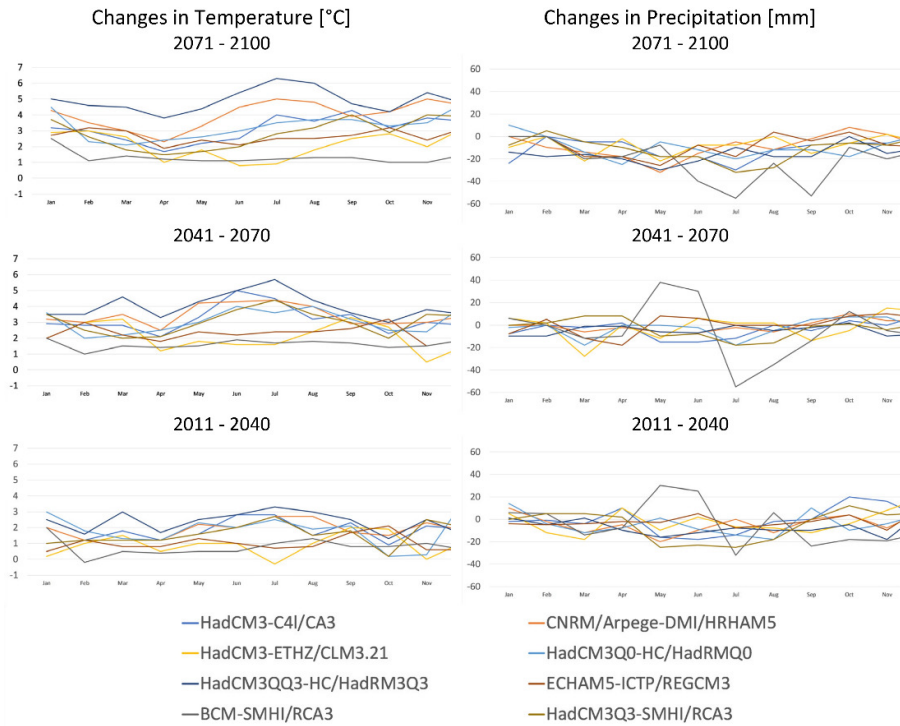


Figure 4. Bucegi Natural Park (Romania): Climate scenarios – Temperature and Precipitation 2011-2100 (source: HABIT-CHANGE project, outputs 3.2.3. and 3.2.7.). The color lines – Climate Models (GCM-RCM combinations)

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 km ² 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).

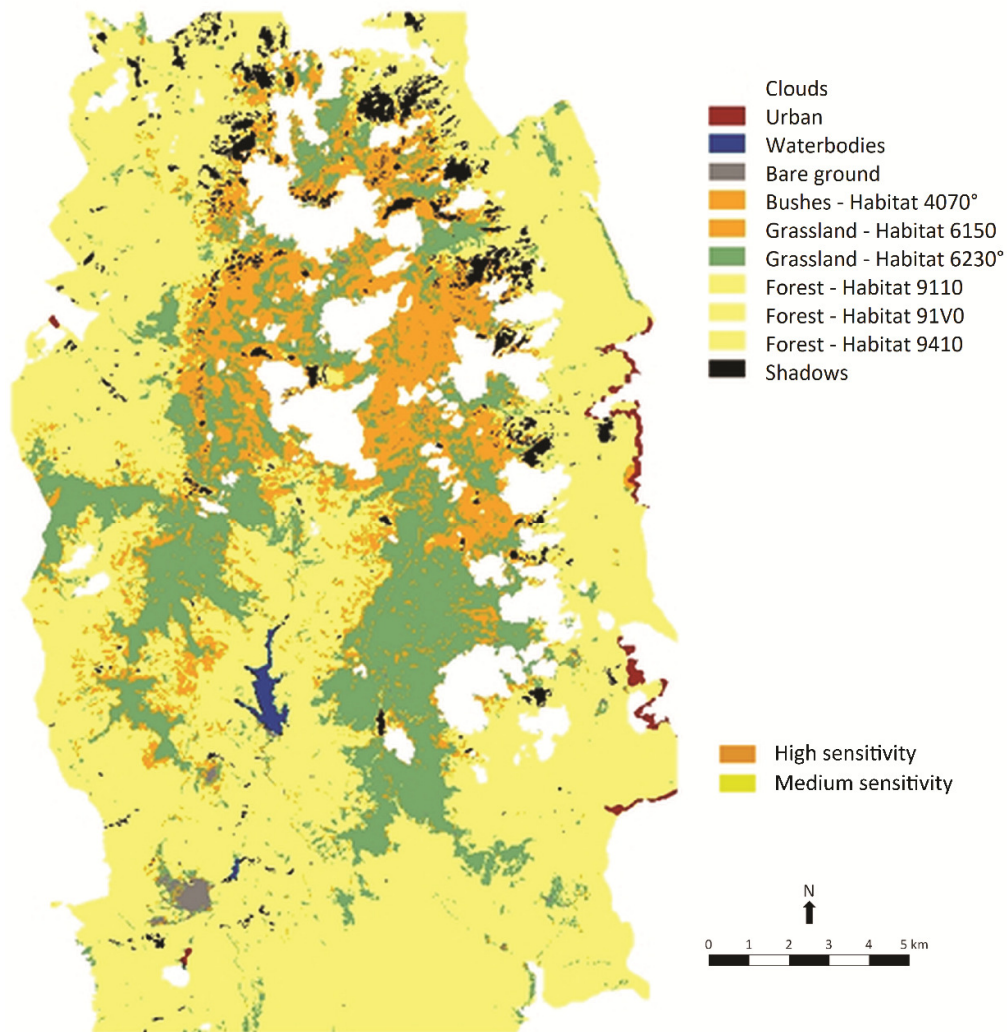


Figure 5. Bucegi Natural Park, Romania – Potential sensitivity of the selected Natura 2000 habitat types to temperature (source: adapted from ‘current habitat types map’, HABIT-CHANGE project, output 3.1.9.). This map contains more than 85000 polygons representing temperature sensitivity. Depending on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

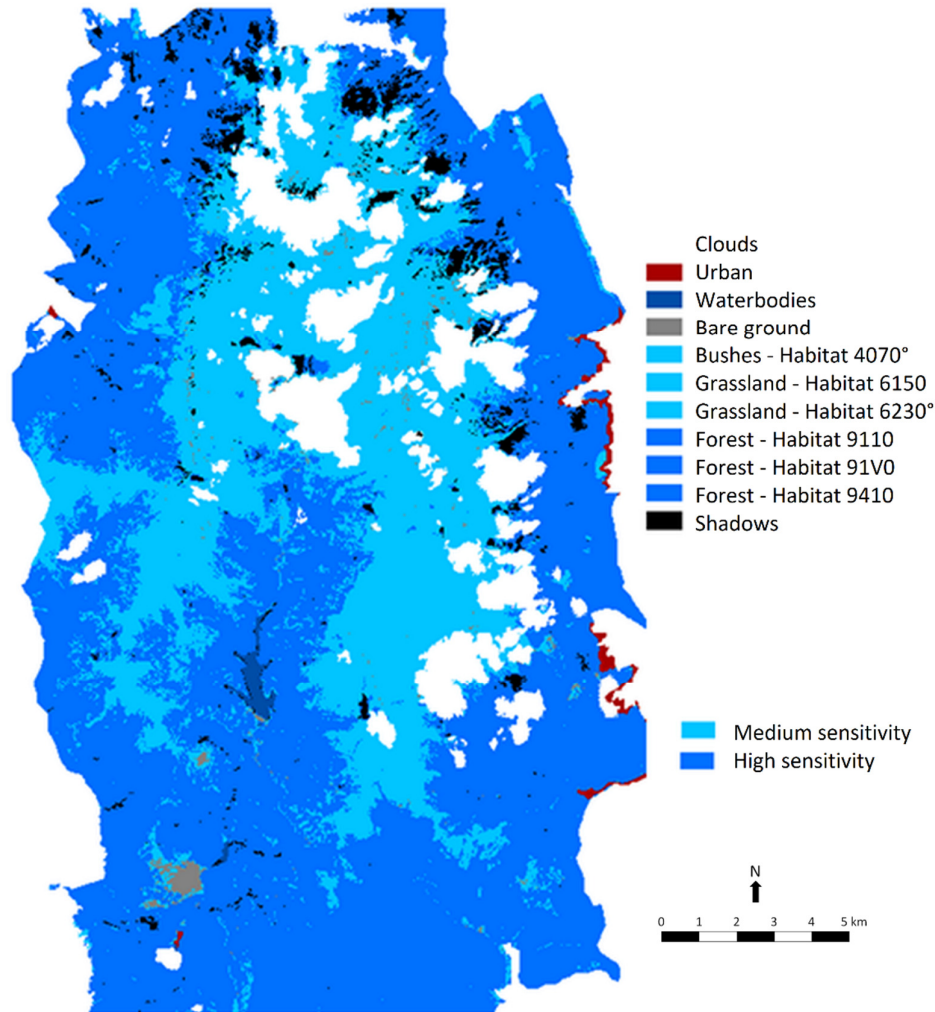


Figure 6. Bucegi Natural Park, Romania – Potential sensitivity of the selected Natura 2000 habitat types to moisture (source: adapted from ‘current habitat types map’, HABIT-CHANGE project, output 3.1.9.). This map contains more than 85000 polygons representing moisture sensitivity. Depending on the 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 (hegistothermophyte-psichrothermophye-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 hegistothermophyte-psichrothermophytes-microthermophytes. 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 (predominant microthermophytes and fewer hekistothermophytes and psychrothermophytes). The eurithermophytes 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).

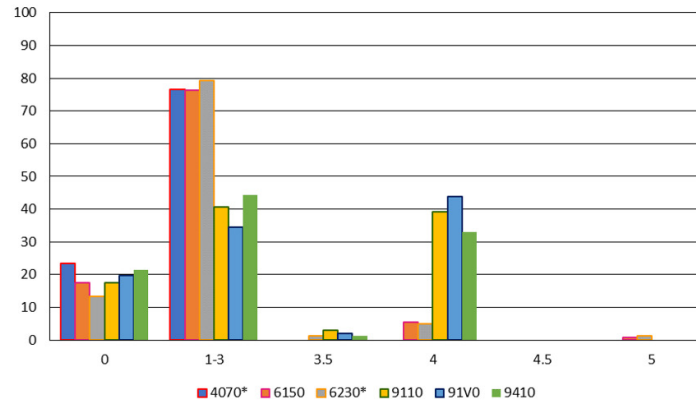


Figure 7. Spectrum indices of temperature features, for plant species representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 3. Ordinate: percentage of species in each category

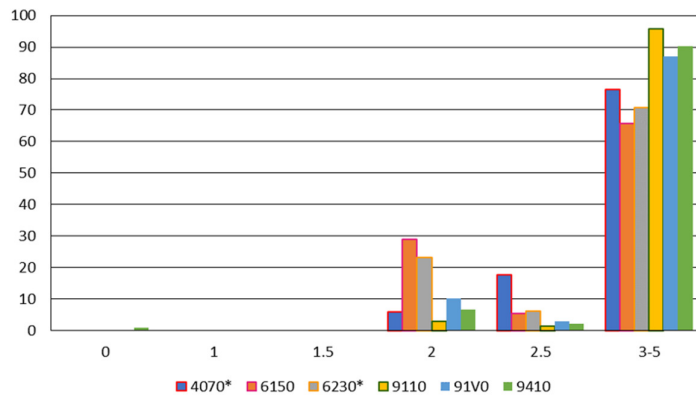


Figure 8. Spectrum indices of humidity features, for plant species representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 3. Ordinate: percentage of species in each category

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 - eurithermophyte and mesophyte). In grassland habitat type 6230* and respectively 6150

type, 66-85% of the plants with conservation value depend on low temperature (hehistothermophyte-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 habitat code	Number of species	Temperature									
		0	1	1.5	2	2.5	3	3.5	4	4.5	
4070*	17	23.50	5.88	0	17.67	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
91V0	107	19.62	0	0	0	0	34.57	1.86	43.95	0	0
9410	237	21.51	3.79	0.84	0.42	0	39.24	1.26	32.94	0	0
		Humidity									
		0	1	1.5	2	2.5	3	3.5	4	4.5	5
4070*	17	0	0	0	5.88	17.65	35.30	29.41	5.88	5.88	0
6150	131	0	0	0	29.00	5.34	48.09	6.10	9.95	0.76	0.76
6230*	82	0	0	0	23.17	6.09	51.21	8.53	9.79	0	1.21
9110	69	0	0	0	2.89	1.45	66.70	2.89	23.18	0	2.89
91V0	107	0	0	0	10.28	2.80	56.07	11.22	18.70	0.93	0
9410	237	0.84	0	0	6.75	2.11	55.70	6.75	24.47	0.42	2.96

Temperature (T): 0 = eurithermophyte, 1 = hehistothermophyte, 1.5 = hehistothermophyte-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.

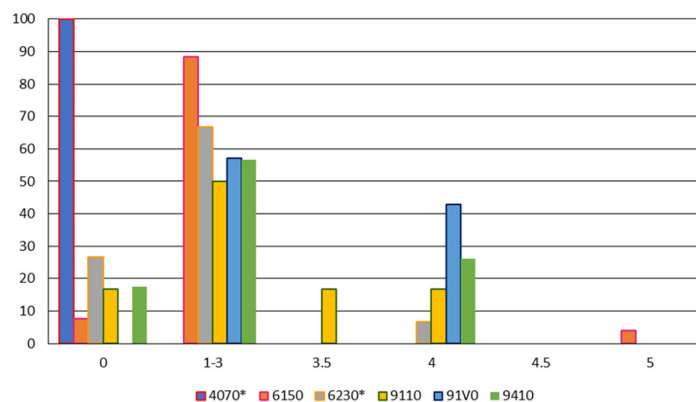
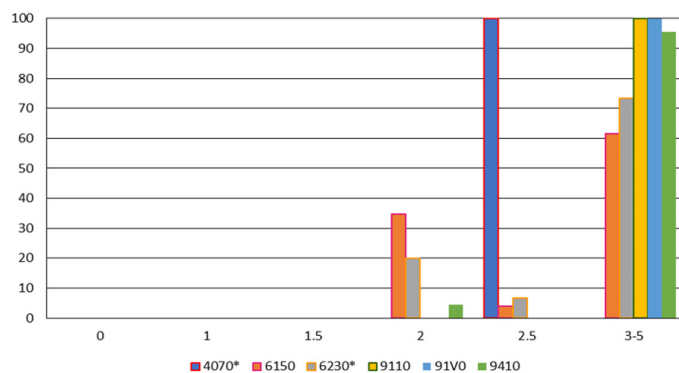


Figure 9. Spectrum indices of temperature features, for plant species with conservation value representing the six Natura 2000 habitats of Bucegi Natural Park. Abscissa: numbers refer to the ecological categories (1-5) described in Table 4. Ordinate: percentage of species in each category

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									
		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
		Humidity									
		0	1	1.5	2	2.5	3	3.5	4	4.5	5
4070*	1	0	0	0	0	100	0	0	0	0	0
6150	26	0	0	0	34.62	3.85	42.30	11.53	3.85	3.85	0
6230*	15	0	0	0	20.00	6.67	46.67	13.33	13.33	0	0
9110	6	0	0	0	0	0	66.67	0	33.33	0	0
91V0	7	0	0	0	0	0	42.86	28.57	28.57	0	0
9410	23	0	0	0	4.35	0	43.48	17.39	26.08	8.70	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 <i>et al.</i> 1994), declared as 'Rare' and 'Vulnerable'	173
IUCN Red List, as 'Data Deficient', 'Least Concern' or 'Near Threatened' (Bilz <i>et al.</i> 2011)	44
Habitat Directive Annexes II, IV, V	9
CITES Appendix II	32
Sârbu <i>et al.</i> 2013, endemic to the Carpathian Mountains (<i>Poa molineri</i> subsp. <i>glacialis</i> , endemic to the Bucegi Mountains) and Carpathian Balkan area	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	1	0	3	33	22	74	23	31	7	6
T	20	20	7	40	3	50	22	32	2	4

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. **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.

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, psichrothermophyte), *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, psichrothermophyte). 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. *schurii*, *Cardaminopsis neglecta*, *Dianthus glacialis* subsp. *gelidus*, *Plantago atrata* subsp. *carpatica*, *Veronica baumgartenii*), 7 mesohygrophytes (*Aconitum vulparia* subsp. *lasianthum*, *Cardamine glanduligera*, *Heracleum palmatum*, *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 psychrothermophytes, 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. *bucsecsii*, *Cardaminopsis neglecta*, *Cerastium transsilvanicum*, *Dianthus glacialis* subsp. *gelidus*, *Erigeron nanus*, *Festuca carpathica*, *Heracleum carpaticum*, *Hesperis nivea*, *H. oblongifolia*, *Phyteuma vagneri*, *Plantago atrata* subsp. *carpathica*, *Ranunculus carpaticus*, *Scabiosa lucida* subsp. *barbata*, *Scorzoneroides 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.

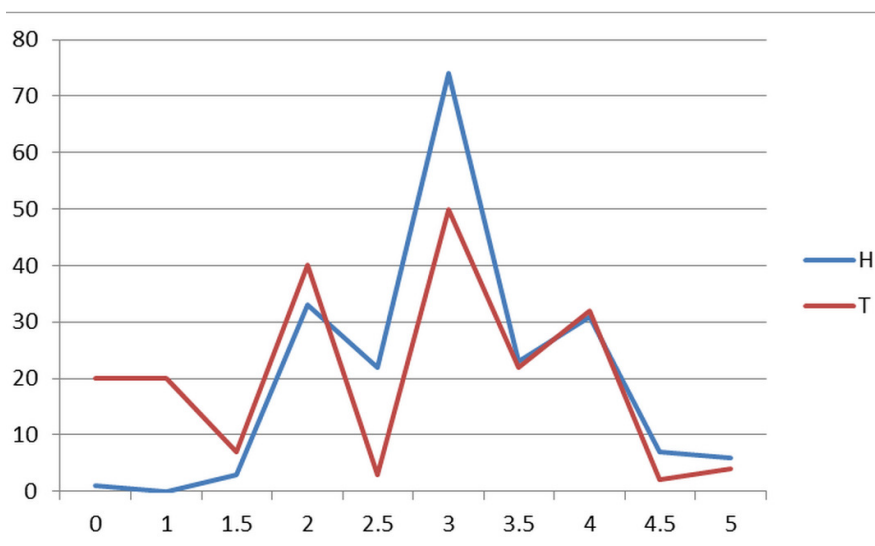


Figure 11. Spectrum indices for humidity (H) and temperature (T) features for plant species with conservation value of Natura 2000 site Bucegi (Annex 1). Abscissa: numbers refer to the ecological categories (1 – 5) described in Table 3. Ordinate: number of species in each category

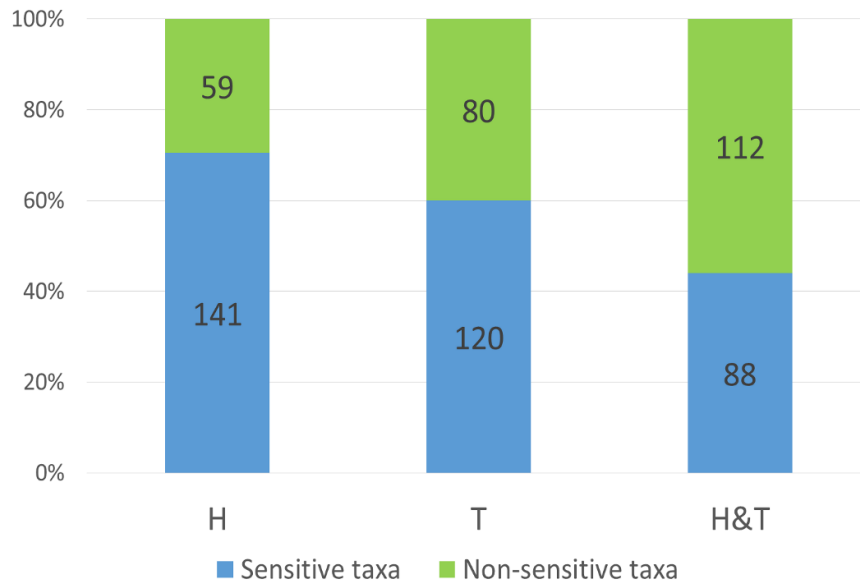


Figure 12. Share of species of conservation value of Natura 2000 site Bucegi (Annex 1) potentially sensitive to moisture (H – humidity) decrease, to air temperature (T - temperature) increase, and to both parameters (H & T)

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 airoides* Lam., *Homogyne alpina* (L.) Cass., *Pinus mugo*, *Soldanella hungarica* Simonk., *Vaccinium myrtillus* L.).

- 6150 Siliceous alpine and boreal grasslands, are considered a glacial relict (Doniță *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. (hegistothermophyte 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 (hegistothermophyte and psychrothermophyte, 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 hegistothermophyte and psychrothermophyte 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, *Loiseleuria procumbens* (L.) Loisel., *Gymnadenia nigra* (L.) Rchb.f. (syn. *Nigritella nigra*) are only few of the species highly dependent on low temperature (hegistothermophytes, psychrothermophytes).
- 6230 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 (Doniță *et al.*, 2005). Dominant species are *Nardus stricta* L. (80-90%) and *Festuca airoides* (mesophyte and psychrothermophyte). *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 (Pușcaru *et al.*, 1956). A ratio of 80% of all species comprised within this vegetation type requires low temperature (hegistothermophyte, psychrothermophyte and microthermophyte) and 70% need moist conditions (mesophytes, 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 halleri* Koch, *Veronica alpina* L.], endemic (*Dianthus glacialis* subsp. *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 (hegistothermophytes, psychrothermophytes, microthermophytes) and snow, and prefer a humid soil (mesophytes, mesohygrophytes).
- 9110 *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 about 40% prefer low air temperatures (hegistothermophyte, psychrothermophyte 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 transilvanica* (Fuss) Heuff. (mesophyte, mesothermophyte), *Ranunculus carpaticus* Herbich (mesohygrophite, microthermophyte) and rare as *Dactylorhiza fuchsii* (Druce) Soó (mesophyte, eurithermophyte), *Dactylorhiza maculata* (L.) Soó (mesohygrophite, microthermophyte), *Doronicum carpaticum* (Griseb. & Schenk) Nyman (mesohygrophite, psichrothermophyte), *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-mesohygrophite and mesothermophyte). The characteristics herbaceous plants are mesophyte-mesohygrophite 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-hygrophite), 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 mesohygrophite 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 vidus-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-hygrophite and microthermophyte). Characteristic vascular plants like *Lycopodium selago* L., *L. annotinum* L., *Oxalis acetosella* L. and *Sorbus aucuparia* L. are mesohygrophite and microthermophyte-mesothermophyte taxa. *Luzula sylvatica* (Huds.) Gaudin, *Soldanella hungarica* Simonk. and *Vaccinium vitis-idaea* L. are dominant vascular plants, depending more on edaphic humidity (mesohygrophites and microthermophytes). The majority (90%) of the species (mesophyte→hygrophite) 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 mesohygrophite categories and only 50% are microthermophytes. Some rare orchids such as *Dactylorhiza maculata* and *Gymnadenia conopsea* subsp. *conopsea* and the endemic *Ranunculus carpaticus* 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 [*Athamanta 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. *transilvanicum* P.W. Ball, *Koeleria macrantha* (Ledeb.) Schult. subsp. *transilvanica* (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. *bucescii* (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 <i>et al.</i> , 1994)	Distribution (cf Sârbu <i>et al.</i> , 2013)	Ecological preferences	
								Humidity	Temperature
1	<i>Achillea oxyloba</i> (DC.) Sch.Bip. subsp. <i>schurii</i> (Sch.Bip.) Heimerl [syn. <i>Achillea schurii</i>]	-	-	-	-	R	Carp. orient. & merid.	mesophyte - mesohygrophyte	microthermophyte
2	<i>Aconitum toxicum</i> Rchb.	-	-	-	-	-	Carp.-Balc.	mesohygrophyte	microthermophyte - mesothermophyte
3	<i>Aconitum vulparia</i> subsp. <i>lasianthum</i> [accepted name <i>Aconitum vulparia</i> Rchb.]	-	-	-	-	-	Eur. Centr. & West Carp.	mesohygrophyte	microthermophyte - mesothermophyte
4	<i>Alyssum repens</i> Baumg.	-	-	-	-	-	Carp.-Balc.	euriphyte	eurithermophyte
5	<i>Anacamptis coriophora</i> (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. <i>Orchis coriophora</i>]	LC	-	-	II	R	Centr. Eur.	mesophyte - mesohygrophyte	eurithermophyte
6	<i>Anacamptis laxiflora</i> (Lam.) R.M.Bateman, Pridgeon & M.W.Chase	LC	-	-	II	R	Pont.-Pan.	mesohygrophyte	mesothermophyte
7	<i>Anacamptis morio</i> (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. <i>Orchis morio</i>]	NT	-	-	II	R	Eur.	xeromesophyte - mesophyte	mesothermophyte
8	<i>Anacamptis pyramidalis</i> (L.) Rich.	-	-	-	-	V/R	Centr. Eur. - Submed.-Atl.	xerophyte - xeromesophyte	mesothermophyte
9	<i>Androsace chamaejasme</i> Wulfen	-	-	-	-	V/R	Circ. arct.-alp.	mesophyte	hekistothermophyte - psichrothermophyte
10	<i>Androsace obtusifolia</i> All.	-	-	-	-	R	Alp.-Carp.	mesophyte - mesohygrophyte	hekistothermophyte
11	<i>Androsace villosa</i> L. var. <i>arachnoidea</i> (Schott, Nyman & Kotschy) R.Knuth	-	-	-	-	R	Carp. orient. & merid.	xeromesophyte	psichrothermophyte

12	<i>Anemone transilvanica</i> (Fuss) Heuff. [syn. <i>Hepatica transilvanica</i>]	-	-	-	-	nt	Carp. (Romania)	mesophyte	microthermophyte
13	<i>Angelica archangelica</i> L.	-	-	-	-	V	Euras. bor.	mesohygrophyte - hygrophyte	microthermophyte - mesothermophyte
14	<i>Anthemis carpatica</i> Waldst. & Kit. ex Willd. subsp. <i>pyrethriformis</i> (Schur) Beldie	-	-	-	-	R	Carp.	xeromesophyte	psichrothermophyte
15	<i>Aquilegia nigricans</i> Baumg. subsp. <i>subscaposa</i> (Borbás) Soó	-	-	-	-	R	Carp. (Romania)	xeromesophyte - mesophyte	microthermophyte
16	<i>Aquilegia transilvanica</i> Schur	-	-	-	-	R	Carp.	xeromesophyte - mesophyte	microthermophyte
17	<i>Armeria alpina</i> (DC.) Willd.	-	-	-	-	R	Alp.-Carp.	mesophyte - mesohygrophyte	eurithermophyte
18	<i>Arnica montana</i> L.	LC	V	-	-	V	Eur. (mont.)	mesophyte	microthermophyte - mesothermophyte
19	<i>Astragalus alpinus</i> L.	-	-	-	-	R	Euras. arct.-alp.	xeromesophyte - mesophyte	hekistothermophyte
20	<i>Astragalus australis</i> (L.) Lam. var. <i>bucsecii</i> (Jav.) Gusul.	-	-	-	-	R	Carp. (Romania)	mesophyte	hekistothermophyte
21	<i>Athamanta turbith</i> (L.) Brot. subsp. <i>hungarica</i> (Borbás) Tutin	-	-	-	-	R	Carp. merid.	xeromesophyte	mesothermophyte
22	<i>Bupleurum ranunculoides</i> L.	-	-	-	-	R	Alp. Eur.	mesophyte	hekistothermophyte
23	<i>Campanula carpatica</i> Jacq.	-	-	-	-	R	Carp. orient. & merid.	mesophyte	microthermophyte - mesothermophyte
24	<i>Campanula patula</i> L. subsp. <i>abietina</i> (Griseb. & Schenk) Simonk.	DD	-	I	-	-	Carp.-Balc.	mesophyte - mesohygrophyte	microthermophyte
25	<i>Campanula serrata</i> (Kit. ex Schult.) Hendrych	LC	II/IV	-	-	-	Carp.	mesophyte	microthermophyte - mesothermophyte
26	<i>Campanula transilvanica</i> Schur ex André	-	-	-	-	V/R	Carp.-Balc.	mesophyte	microthermophyte
27	<i>Cardamine glanduligera</i> O.Schwarz [syn. <i>Dentaria glandulosa</i>]	-	-	-	-	-	Carp.	mesohygrophyte	microthermophyte - mesothermophyte
28	<i>Cardaminopsis neglecta</i> (Schult.) Hayek	-	-	-	-	R	Carp.	mesophyte - mesohygrophyte	psichrothermophyte

29	<i>Carduus kernerii</i> Simonk.	-	-	-	-	-	Carp.-Balc.	xeromesophyte - mesophyte	microthermophyte
30	<i>Carex brachystachys</i> Schrank	-	-	-	-	R	Pirinei - Alpi - Apennine-N-W Balc.-Carp.	mesohygrophyte	microthermophyte
31	<i>Carex capillaris</i> L.	-	-	-	-	R	Circ. arct.-alp.	mesophyte	psichrothermophyte
32	<i>Carex chordorrhiza</i> L.f.	-	-	-	-	R	Circ. bor.	hygrophyte	microthermophyte - mesothermophyte
33	<i>Carex fuliginosa</i> Schkuhr	-	-	-	-	R	Euras. arct.-alp. eur.	mesophyte	hekistothermophyte - psichrothermophyte
34	<i>Carex rupestris</i> All.	-	-	-	-	R	Circ. arct.-alp.	xeromesophyte - mesophyte	psichrothermophyte
35	<i>Centaurea kotschyana</i> Heuff.	-	-	-	-	R	Carp.-balc.	xeromesophyte	subthermophyte
36	<i>Centaurea phrygia</i> L. subsp. <i>melanocalathia</i> (Borbás) Dostál	-	-	-	-	R	Carp.	mesophyte	microthermophyte - mesothermophyte
37	<i>Centaurea pinnatifida</i> Schur [syn. <i>Cyanus pinnatifidus</i> (Schur) Holub]	-	-	-	-	R	Carp.	xeromesophyte	mesothermophyte
38	<i>Cephalanthera damasonium</i> (Mill.) Druce	LC	-	-	II	nt	Eur.	mesophyte	mesothermophyte
39	<i>Cephalanthera longifolia</i> (L.) Fritsch	LC	-	-	II	nt	Eur.	mesophyte	mesothermophyte
40	<i>Cephalanthera rubra</i> (L.) Rich.	LC	-	-	II	R	Eur.	mesophyte	mesothermophyte
41	<i>Cerastium arvense</i> L. subsp. <i>lerchenfeldianum</i> (Schur) Asch. & Graebn.	-	-	-	-	R	Carp. orient. & merid.; Jug.	xeromesophyte - mesophyte	eurithermophyte
42	<i>Cerastium transilvanicum</i> Schur	-	-	-	-	R	Carp. orient. & merid.	mesophyte	psichrothermophyte
43	<i>Chamorchis alpina</i> (L.) Rich.	LC	-	-	II	R	Euras. arct.-alp. eur.	xeromesophyte - mesophyte	psichrothermophyte
44	<i>Conioselinum vaginatum</i> (Spreng.) Thell.	-	-	-	-	R	Euras. bor.	mesophyte	microthermophyte
45	<i>Crepis conyzifolia</i> (Gouan) A.Kern.	-	-	-	-	R	Alp. Eur.	mesophyte	microthermophyte
46	<i>Crocus banaticus</i> J.Gay	-	-	-	-	-	Carp.	mesophyte	mesothermophyte
47	<i>Dactylorhiza cordigera</i> (Fr.) Soó	LC	-	-	II	R	Carp.-Balc.	mesohygrophyte	microthermophyte
48	<i>Dactylorhiza fuchsii</i> (Druce) Soó	LC	-	-	II	R	Euras.	mesophyte	eurithermophyte

49	<i>Dactylorhiza incarnata</i> (L.) Soó	LC	-	-	II	R	Euras.	mesohygrophyte	mesothermophyte
50	<i>Dactylorhiza maculata</i> (L.) Soó	LC	-	-	II	R	Eur.	mesohygrophyte	microthermophyte
51	<i>Dactylorhiza sambucina</i> (L.) Soó	LC	-	-	II	R	Eur.	mesophyte	microthermophyte
52	<i>Daphne blagayana</i> Freyer	-	-	-	-	V/R	Alp.-Carp.- Balc.	mesophyte - mesohygrophyte	mesothermophyte
53	<i>Dianthus carthusianorum</i> L. subsp. <i>tenuifolius</i> (Schur) Hegi [syn. <i>Dianthus tenuifolius</i>]	-	-	-	-	nt	Carp.	xeromesophyte	mesothermophyte
54	<i>Dianthus glacialis</i> Haenke subsp. <i>gelidus</i> (Schott, Nyman & Kotschy) Tutin	-	-	-	-	R	Carp. orient. & merid.	mesophyte - mesohygrophyte	hekistothermophyte
55	<i>Dianthus spiculifolius</i> Schur	-	-	-	-	R	Carp.	xeromesophyte	mesothermophyte - submesothermophyte
56	<i>Doronicum carpaticum</i> (Griseb. & Schenk) Nyman	-	-	-	-	R	Alp. Eur.	mesohygrophyte	psichrothermophyte
57	<i>Draba aizoides</i> L. subsp. <i>zmudae</i> Zapal.	-	-	-	-	R	Carp.	xeromesophyte	eurithermophyte
58	<i>Draba compacta</i> Schott, Nyman & Kotschy	-	-	-	-	R	Carp.-Balc.	xeromesophyte	psichrothermophyte
59	<i>Draba dorneri</i> Heuff.	DD	II/IV	I	-	V/R	Dacic	xeromesophyte	psichrothermophyte
60	<i>Draba fladnitzensis</i> Wulfen	-	-	-	-	R	Circ. Bor.	xeromesophyte	microthermophyte - mesothermophyte
61	<i>Draba haynaldii</i> Stur	-	-	-	-	V/R	Carp. orient. & merid.	xeromesophyte	psichrothermophyte
62	<i>Draba kotschyi</i> Stur	-	-	-	-	nt	Carp. orient. & merid.	xeromesophyte	psichrothermophyte
63	<i>Epilobium alpestre</i> (Jacq.) Krock.	-	-	-	-	R	Alp. eur.	mesohygrophyte	microthermophyte
64	<i>Epilobium alsinifolium</i> Vill.	-	-	-	-	R	Arct.-Alp.- Eur.	hygrophyte	psichrothermophyte
65	<i>Epilobium anagallidifolium</i> Lam.	-	-	-	-	R	Circ. arct.- alp.	mesohygrophyte - hygrophyte	psichrothermophyte
66	<i>Epipactis atrorubens</i> (Hoffm.) Besser	LC	-	-	II	R	Euras.	xeromesophyte - mesophyte	eurithermophyte
67	<i>Epipactis belleborine</i> (L.) Crantz	LC	-	-	II	R	Euras.	mesophyte	mesothermophyte
68	<i>Epipactis microphylla</i> (Ehrh.) Sw.	NT	-	-	II	R	Centr. Eur.- Medit.	mesophyte	mesothermophyte
69	<i>Epipactis purpurata</i> Sm.	LC	-	-	II	R	Centr. Eur.- Subatl.	mesophyte	mesothermophyte

70	<i>Epipogium aphyllum</i> Sw.	LC	-	-	II	R	Euras.	mesophyte	microthermophyte - mesothermophyte
71	<i>Erigeron alpinus</i> L.	-	-	-	-	R	Euras. alp.	mesophyte	hekistothermophyte
72	<i>Erigeron atticus</i> Vill.	-	-	-	-	R	Alp. Eur.	xeromesophyte - mesophyte	psichrothermophyte
73	<i>Erigeron nanus</i> Nutt.	-	-	-	-	V/R	Carp.	mesophyte	hekistothermophyte
74	<i>Erigeron uniflorus</i> L.	-	-	-	-	R	Circ. arct.-alp.	mesophyte	hekistothermophyte - psichrothermophyte
75	<i>Eriophorum angustifolium</i> Honck.	LC	-	-	-	-	Circ.	hygrophyte	mesothermophyte
76	<i>Eriophorum scheuchzeri</i> Hoppe	LC	-	-	-	R	Circ. arct.-alp. Eur.	hygrophyte	psichrothermophyte
77	<i>Eritrichium nanum</i> (L.) Schrad. ex Gaudin s.l.	-	-	-	-	R	Alp.-Carp.	xeromesophyte	hekistothermophyte - psichrothermophyte
78	<i>Erysimum witmannii</i> Zaw. subsp. <i>transilvanicum</i> P.W. Ball	-	-	-	-	R	Carp. merid.	xeromesophyte	mesothermophyte
79	<i>Festuca amethystina</i> L.	-	-	-	-	R	Alp.-Centr. Eur.	mesophyte	mesothermophyte
80	<i>Festuca bucegiensis</i> Markgr.-Dann.	-	-	-	-	R	Carp. merid.	xeromesophyte	hekistothermophyte
81	<i>Festuca carpathica</i> F.Dietr.	-	-	-	-	R	Carp. orient. & merid.	mesophyte	microthermophyte
82	<i>Festuca versicolor</i> Tausch	-	-	-	-	R	Carp.	xeromesophyte	subthermophyte
83	<i>Galanthus nivalis</i> L.	NT	V	-	II	nt	Centr. Eur. - Submed.	mesophyte	mesothermophyte
84	<i>Gentiana acaulis</i> L.	-	-	-	-	R	Alp. Eur.	mesophyte	microthermophyte
85	<i>Gentiana frigida</i> Haenke	-	-	-	-	R	Alp.-Carp.	mesophyte	hekistothermophyte
86	<i>Gentiana lutea</i> L.	LC	V	-	-	V/R	Alp. Eur.	mesophyte	microthermophyte
87	<i>Gentiana punctata</i> L.	-	-	-	-	R	Alp. Eur.	mesophyte	microthermophyte
88	<i>Gentianella bulgarica</i> (Velen.) Holub	-	-	-	-	R	Carp.-Balc.	xeromesophyte - mesophyte	mesothermophyte
89	<i>Geranium caeruleatum</i> Schur [syn. <i>Geranium sylvaticum</i> subsp. <i>caeruleatum</i>]	-	-	-	-	R	Carp.-Balc.	mesophyte - mesohygrophyte	microthermophyte - mesothermophyte
90	<i>Geum reptans</i> L.	-	-	-	-	R	Alp. Eur.	mesohygrophyte	psichrothermophyte
91	<i>Goodyera repens</i> (L.) R.Br.	LC	-	-	II	R	Circ.	mesophyte	eurithermophyte

92	<i>Gymnadenia conopsea</i> (L.) R.Br.	LC	-	-	II	R	Eur.	mesophyte - mesohygrophyte	microthermophyte
93	<i>Gymnadenia nigra</i> (L.) Rchb.f. [syn. <i>Nigritella nigra</i>]	LC	-	-	II	V/R	Euras. arct.- alp. Eur.	mesophyte	psichrothermophyte
94	<i>Gymnadenia rubra</i> Wettst. [syn. <i>Nigritella rubra</i>]	-	-	-	-	V/R	E Alp.-Carp.	mesophyte	eurithermophyte
95	<i>Gypsophila petraea</i> (Baumg.) Rchb.	-	-	-	-	R	Carp. orient. & merid.	xeromesophyte	mesothermophyte
96	<i>Hedysarum hedysaroides</i> (L.) Schinz & Thell.	-	-	-	-	R	Circ. arct.- alp.	mesophyte	psichrothermophyte - microthermophyte
97	<i>Helictotrichon planiculme</i> (Schrad.) Pilg.	-	-	-	-	R	Carp.-Balc.- Sudet.	mesophyte	microthermophyte - mesothermophyte
98	<i>Heracleum carpaticum</i> Porc.	-	-	-	-	V/R	Dacic	mesophyte	microthermophyte
99	<i>Heracleum palmatum</i> Baumg.	-	-	-	-	nt	Carp. (Romania)	mesohygrophyte	microthermophyte - mesothermophyte
100	<i>Herminium monorchis</i> (L.) R.Br.	DD	-	-	II	R	Euras.	mesophyte	mesothermophyte
101	<i>Hesperis moniliformis</i> Schur [syn. <i>Hesperis matronalis</i> subsp. <i>moniliformis</i>]	-	-	-	-	R	Carp. orient. & merid.	xerophyte - xeromesophyte	microthermophyte
102	<i>Hesperis nivea</i> Baumg.	-	-	-	-	R	Carp. orient. & merid.	mesohygrophyte	psichrothermophyte
103	<i>Hesperis oblongifolia</i> Schur	-	-	-	-	R	Carp. orient. & merid.	mesohygrophyte	hekistothermophyte
104	<i>Hieracium rotundatum</i> Kit. ex Schult. [syn. <i>Hieracium transilvanicum</i>]	-	-	-	-	-	Carp.-Balc.- Centr. Eur.	mesophyte	eurithermophyte
105	<i>Hornungia alpina</i> (L.) O.Appel subsp. <i>brevicaulis</i> (Spreng.) O.Appel	-	-	-	-	R	Alp. Eur.	mesohygrophyte	eurithermophyte
106	<i>Hypericum richeri</i> Vill. subsp. <i>transilvanicum</i> (Čelak.) Ciocârlan	-	-	-	-	-	Carp. orient. & merid.	xeromesophyte - mesophyte	microthermophyte - mesothermophyte
107	<i>Iris aphylla</i> L.	DD	II/IV	-	-	-	Cont. Eur.	xeromesophyte	eurithermophyte
108	<i>Jacobaea abrotanifolia</i> (L.) Moench subsp. <i>carpathica</i> (Herbich) B.Nord. & Greuter [syn. <i>Senecio carpathicus</i>]	-	-	-	-	R	Carp.-Balc.	mesophyte	psichrothermophyte
109	<i>Juncus filiformis</i> L.	-	-	-	-	R	Circ. arct.- alp.	hygrophyte	microthermophyte - mesothermophyte

110	<i>Loiseleuria procumbens</i> (L.) Loisel.	-	-	-	-	R	Circ. arct.-alp.	xeromesophyte - mesophyte	psichrothermophyte
111	<i>Kobresia myosuroides</i> (Vill.) Fiori	-	-	-	-	R	Circ. arct.-alp.	mesophyte	hekistothermophyte
112	<i>Kobresia simpliciuscula</i> (Wahlenb.) Mack.	-	-	-	-	R	Circ. bor.-arct.-alp.	xeromesophyte - mesophyte	hekistothermophyte
113	<i>Koeleria macrantha</i> (Ledeb.) Schult. subsp. <i>transilvanica</i> (Schur) A.Nyár.	-	-	-	-	R	Carp. (Romania)	xeromesophyte	mesothermophyte
114	<i>Larix decidua</i> Mill. var. <i>carpatica</i> Domin	-	-	-	-	R	Carp.-Sudet.	mesophyte	microthermophyte - mesothermophyte
115	<i>Leontopodium alpinum</i> Cass.	-	-	-	-	V/R	Euras. alp.	mesophyte - mesohygrophyte	psichrothermophyte
116	<i>Leucanthemum rotundifolium</i> DC. [syn. <i>Leucanthemum waldsteinii</i>]	-	-	-	-	R	Carp. & Jugosl. Centr.	mesophyte - mesohygrophyte	microthermophyte
117	<i>Ligularia glauca</i> (L.) O.Hoffm.	-	-	-	-	R	Carp.-Balc.-Siberian	mesophyte - mesohygrophyte	microthermophyte
118	<i>Ligularia sibirica</i> (L.) Cass.	DD	II/IV	I	-	R	Euras. bor.	mesohygrophyte - hygrophyte	microthermophyte
119	<i>Ligusticum mutellinoides</i> Vill.	-	-	-	-	R	Euras. arct.-alp.	mesophyte	hekistothermophyte - psichrothermophyte
120	<i>Linaria alpina</i> (L.) Mill.	-	-	-	-	R	Eur. (alp.)	xeromesophyte - mesophyte	eurithermophyte
121	<i>Linum extraaxilare</i> Kit.	-	-	-	-	nt	Carp.-Balc.	xeromesophyte - mesophyte	eurithermophyte
122	<i>Lloydia serotina</i> (L.) Rchb.	-	-	-	-	R	Circ. arct.-alp.	xeromesophyte - mesophyte	eurithermophyte
123	<i>Lomatogonium carinthiacum</i> (Wulfen) A.Braun	-	-	-	-	R	Circ.-alp.	xeromesophyte	psichrothermophyte
124	<i>Lonicera caerulea</i> L.	-	-	-	-	R	Circ. arct.-alp.	mesophyte - mesohygrophyte	microthermophyte
125	<i>Lycopodium alpinum</i> L.	-	V	-	-	-	Circ. arct.-alp.	mesophyte	psichrothermophyte
126	<i>Monotropa hypopitys</i> L.	-	-	-	-	R	Circ.	mesophyte	microthermophyte
127	<i>Neotinea ustulata</i> (L.) R.M.Bateman, Pridgeon & M.W.Chase [syn. <i>Orchis ustulata</i>]	LC	-	-	II	R	Eur.	mesophyte	mesothermophyte

128	<i>Neottia cordata</i> (L.) Rich. [syn. <i>Listera cordata</i>]	LC	-	-	II	R	Circ.	mesohygrophyte	eurithermophyte
129	<i>Neottia nidus-avis</i> (L.) Rich.	LC	-	-	II	R	Euras.	mesophyte	mesothermophyte
130	<i>Neottia ovata</i> (L.) Bluff & Fingerh. [syn. <i>Listera ovata</i>]	LC	-	-	II	R	Euras.	mesophyte - mesohygrophyte	mesothermophyte
131	<i>Onobrychis montana</i> DC. subsp. <i>transilvanica</i> (Simonk.) Jáv.	-	-	-	-	R	Carp. (Romania)	xeromesophyte	psichrothermophyte
132	<i>Ophrys insectifera</i> L.	LC	-	-	II	R	Eur.	xeromesophyte	mesothermophyte
133	<i>Orchis mascula</i> (L.) L.	LC	-	-	II	R	Submedit.	mesophyte	mesothermophyte
134	<i>Orchis militaris</i> L.	LC	-	-	II	R	Euras.	mesophyte	mesothermophyte
135	<i>Oxyria digyna</i> (L.) Hill	-	-	-	-	R	Circ. arct- alp.	mesohygrophyte	hehistothermophyte
136	<i>Oxytropis carpathica</i> R.Uechtr.	-	-	-	-	R	Carp.	xeromesophyte - mesophyte	psichrothermophyte
137	<i>Oxytropis halleri</i> Koch	-	-	-	-	R	Alp. eur.	xeromesophyte	psichrothermophyte
138	<i>Papaver alpinum</i> L. subsp. <i>corona-sancti-stephani</i> (Zapal.) Borza	-	-	-	-	R	Carp. orient. & merid.	xeromesophyte	microthermophyte
139	<i>Phyteuma confusum</i> A.Kern.	-	-	-	-	R	Alp.-Carp.- Balc.	mesophyte	microthermophyte
140	<i>Phyteuma vagneri</i> A.Kern.	-	-	-	-	R	Carp.	mesophyte	psichrothermophyte
141	<i>Pinguicula alpina</i> L.	-	-	-	-	R	Euras. arct- alp.	mesohygrophyte - hygrophyte	eurithermophyte
142	<i>Pinguicula vulgaris</i> L.	LC	-	-	-	R	Circ.	mesohygrophyte - hygrophyte	eurithermophyte
143	<i>Pinus cembra</i> L.	-	-	-	-	R	Euras. arct- alp.	mesophyte	psichrothermophyte - microthermophyte
144	<i>Plantago atrata</i> Hoppe subsp. <i>carpatica</i> (Pilg.) Soó	-	-	-	-	R	Carp.	mesophyte - mesohygrophyte	microthermophyte
145	<i>Plantago gentianoides</i> Sm.	-	-	-	-	R	Carp.-Balc.- Anat.	mesohygrophyte	microthermophyte
146	<i>Platanthera bifolia</i> (L.) Rich.	LC	-	-	II	R	Euras.	mesophyte - mesohygrophyte	eurithermophyte
147	<i>Platanthera clorantha</i> (Custer) Rchb.	LC	-	-	II	R	Euras.	mesophyte	mesothermophyte

148	<i>Pleurospermum austriacum</i> (L.) Hoffm.	-	-	-	-	R	Eur. Centr. (mont.)	mesohygrophyte	microthermophyte
149	<i>Poa molineri</i> Balb. subsp. <i>glacialis</i> Beldie	-	-	-	-	R	Bucegi	xeromesophyte	microthermophyte
150	<i>Poa remota</i> Forselles	-	-	-	-	R	Euras. bor.	mesophyte - mesohygrophyte	microthermophyte - mesothermophyte
151	<i>Polemonium caeruleum</i> L.	-	-	-	-	R	Circ.	mesohygrophyte	microthermophyte - mesothermophyte
152	<i>Potentilla palustris</i> (L.) Scop.	-	-	-	-	R	Circ. bor.	hygrophyte	microthermophyte
153	<i>Primula halleri</i> J.F.Gmel.	-	-	-	-	R	Alp. Eur.	mesophyte	microthermophyte
154	<i>Pseudorchis albida</i> (L.) Á.Löve & D.Löve	LC	-	-	II	R	Eur. (mont.)	mesophyte	microthermophyte
155	<i>Pulmonaria rubra</i> Schott	-	-	-	-	-	Carp.-Balc.	mesophyte	microthermophyte
156	<i>Pyrola carpatica</i> Holub & Křisa	-	-	-	-	R	Carp.	mesophyte	microthermophyte - mesothermophyte
157	<i>Ranunculus carpaticus</i> Herlich	-	-	-	-	R	Dacic	mesohygrophyte	microthermophyte
158	<i>Ranunculus thora</i> L.	-	-	-	-	R	Pirin.alp.- Apen.-W Balc.-Carp.	mesohygrophyte	hehistothermophyte
159	<i>Rhododendron myrtifolium</i> Schott & Kotschy	-	-	-	-	V	Carp.-Balc.	mesophyte	eurithermophyte
160	<i>Salix alpina</i> Scop.	-	-	-	-	R	Alp.-Carp.	mesohygrophyte	hehistothermophyte - psychrothermophyte
161	<i>Salix bicolor</i> Ehrh. ex Willd.	-	-	-	-	R	Alp.- W&Centr. Eur.	mesohygrophyte	hehistothermophyte - psychrothermophyte
162	<i>Salix daphnoides</i> Vill.	-	-	-	-	R	Centr. Eur.	mesohygrophyte - hygrophyte	microthermophyte
163	<i>Salix retusa</i> L.	-	-	-	-	R	Alp. Eur.	mesophyte - mesohygrophyte	psychrothermophyte
164	<i>Saussurea alpina</i> (L.) DC.	-	-	-	-	R	Circ. arct.- alp.	mesophyte	hehistothermophyte
165	<i>Saussurea discolor</i> (Willd.) DC.	-	-	-	-	R	Alps, Carp. Apennine	mesophyte	hehistothermophyte

166	<i>Saxifraga carpatica</i> Sternb.	-	-	-	-	R	Carp.-Balc.	mesophyte - mesohygrophyte	psichrothermophyte
167	<i>Saxifraga cernua</i> L.	-	-	-	-	R	Circ. arct.- alp.	mesohygrophyte - hygrophyte	hekistothermophyte
168	<i>Saxifraga mutata</i> L. subsp. <i>demissa</i> (Schott & Kotschy) D.A.Webb [syn. <i>Saxifraga demissa</i>]	-	-	-	-	V/R	Carp. merid.	xerophyte - xeromesophyte	psichrothermophyte
169	<i>Saxifraga oppositifolia</i> L.	-	-	-	-	R	Circ. arct.- alp.	mesophyte - mesohygrophyte	psichrothermophyte
170	<i>Saxifraga retusa</i> Gouan	-	-	-	-	R	Alp. Eur.	xeromesophyte	hekistothermophyte
171	<i>Scabiosa lucida</i> Vill. subsp. <i>barbata</i> Nyár.	-	-	-	-	R	Carp. (Romania)	mesophyte	microthermophyte
172	<i>Scorzoneroides pseudotaraxaci</i> (Schur) Holub [syn. <i>Leontodon montanus</i> subsp. <i>pseudotaraxaci</i>]	-	-	-	-	R	Carp.	mesophyte	psichrothermophyte
173	<i>Secale montanum</i> L.	-	-	-	-	R	Medit.	xeromesophyte - mesophyte	subthermophyte
174	<i>Sedum grisebachii</i> Boiss. & Heldr.	-	-	-	-	R	Carp.-Balc.	mesophyte	mesothermophyte
175	<i>Sesleria bielzii</i> Schur	-	-	-	-	R	Carp.-Balc.	mesophyte	psichrothermophyte
176	<i>Sesleria rigida</i> Heuff. ex Rchb. [syn. <i>Sesleria haynaldiana</i>]	-	-	-	-	-	Carp.-Balc.	xeromesophyte - mesophyte	subthermophyte
177	<i>Silene nutans</i> L. subsp. <i>dubia</i> (Herbich) Zapal.	-	-	-	-	R	Carp. (Romania)	xeromesophyte	mesothermophyte
178	<i>Soldanella pusilla</i> Baumg.	-	-	-	-	R	Carp.-Balc.	mesohygrophyte	microthermophyte
179	<i>Streptopus amplexifolius</i> (L.) DC.	-	-	-	-	R	Circ.	mesohygrophyte	microthermophyte
180	<i>Symphytum cordatum</i> Waldst. & Kit ex Willd.	-	-	-	-	-	Carp.	mesohygrophyte	microthermophyte
181	<i>Taraxacum fontanum</i> Hand.-Mazz.	-	-	-	-	R	Euras. alp.	mesohygrophyte	psichrothermophyte
182	<i>Taxus baccata</i> L.	-	-	-	-	V/R	Atl.-Medit.- Centr. Eur.	mesophyte	mesothermophyte - submesothermophyte
183	<i>Tephrosia papposa</i> (Rchb.) Schur [syn. <i>Senecio papposus</i>]	-	-	-	-	-	Carp.-Balc.	mesophyte	microthermophyte
184	<i>Thalictrum alpinum</i> L.	-	-	-	-	R	Circ. bor.- arct.-alp.	mesophyte	microthermophyte

185	<i>Thesium kernerianum</i> Simonk.	-	-	-	-	R	Dacic	xeromesophyte	hekistothermophyte
186	<i>Tblaspi dacicum</i> Heuff. s.l.	-	-	-	-	R	Carp.	xeromesophyte	psichrothermophyte
187	<i>Thymus biboriensis</i> Jalas [syn. <i>Thymus marginatus</i>]	-	-	-	-	-	Carp.	xeromesophyte - mesophyte	microthermophyte
188	<i>Thymus comosus</i> Heuff. ex Griseb. & Schenk	-	-	-	-	nt	Carp.	xeromesophyte	microthermophyte - mesothermophyte
189	<i>Thymus pulcherrimus</i> Schur	-	-	-	-	R	Carp.	xeromesophyte	psichrothermophyte
190	<i>Tozzia carpathica</i> Woloszack	DD	II/IV	-	-	R	Carp.-Balc.	mesohygrophyte	microthermophyte
191	<i>Traunsteinera globosa</i> (L.) Rchb.	LC	-	-	-	R	Centr. Eur. (mont.)	mesophyte	microthermophyte
192	<i>Trisetum alpestre</i> (Host) P.Beauv.	-	-	-	-	R	Alp.-Carp.	mesophyte	microthermophyte
193	<i>Trisetum macrotrichum</i> Hack.	-	-	-	-	R	Carp.	mesophyte	microthermophyte - mesothermophyte
194	<i>Trollius europaeus</i> L. s.l.	-	-	-	-	R	Eur.	mesohygrophyte	microthermophyte
195	<i>Vaccinium uliginosum</i> L.	-	-	-	-	R	Circ. bor.	xeromesophyte - mesophyte	psichrothermophyte
196	<i>Veronica alpina</i> L.	-	-	-	-	R	Circ. arct.-alp.	mesohygrophyte	hekistothermophyte
197	<i>Veronica apbylla</i> L.	-	-	-	-	R	Alp. Eur.	mesophyte - mesohygrophyte	psichrothermophyte
198	<i>Veronica baumgartenii</i> Roem. & Schult.	-	-	-	-	R	Carp.	mesophyte - mesohygrophyte	psichrothermophyte
199	<i>Viola alpina</i> Jacq.	-	-	-	-	R	Alp.-Carp.	xeromesophyte	psichrothermophyte - microthermophyte
200	<i>Viola dacica</i> Borbás	-	-	-	-	R	Carp.-balc.	mesophyte	microthermophyte