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## The correlation between plant endemism and biogeographic factors – a case study from Leqinat Mt., Kosovo

### Abstract

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A significant contribution to the proper ecosystem functioning and services is provided by the vascular plant species richness. Therefore, understanding the environmental, and in particular, biogeographical predictors of vascular plant richness – and richness with endemism, can accordingly support conservation efforts of biodiversity as well as ecosystem services at a proper scale. This study used field survey data, as well as herbarium materials and literature sources to explore the relation between plant endemism and natural habitats in a particular region of a National Park in “Bjeshkët e Nemuna” (Kosovo). A number of environmental factors were recorded for this study, with particular focus on the natural habitats of 65 Balkan endemic plant taxa in the Mt. Leqinat, in a narrow area ( $6 \text{ km}^2$ ) but yet exceedingly rich floristic diversity. A correlation between habitat diversity and richness with endemic plant taxa was confirmed. In total, 20 EUNIS habitat types were recorded with endemic plant taxa, where (E4.4) - Calcareous alpine grasslands proved to be the richest in terms of endemics they harbor. Total floristic diversity in relation to altitude, reaches the highest values in the range between 1.800 to 2.000 m. a.s.l. As a measure proposed to further improve conservation management within this area of the National Park is to better control human activities, and therefore establish a balance between strict protection and the sustainable use of natural resources.

*Key words:* balkans, biogeography, biodiversity conservation.

### Introduction

High mountainous regions of the Balkan Peninsula constitute a well-known, and perhaps one of the richest centers of plant diversity and endemism of Europe, representing an area of the continent with more than 6500 vascular plant taxa (Tomović & al. 2014), out of whom, more than 2700 are endemic ones (Stevanović & al. 2005; Amidžić & al. 2013), whereas about 400 of them are treated as local endemics (Horvat & al. 1974; Rexhepi 1994, 2007; Stevanović & al. 2007; Tomović & al. 2014). However, these figures must necessarily be higher in reality, because Greece alone (along with its islands) counts 1278 endemic plant taxa (Dimopoulos & al. 2013). In the western part of Balkans, the Dinaric

Mts. – as a high mountain system are particularly distinguished with remarkable diverse flora (Horvat & al. 1974, Redžić 2011). These mountains span from Slovenia in the North to the Northern Albania in the South, while the Albanian Alps (Albanian: Alpet Shqiptare/Montenegrin: Prokletije) represent the southernmost part of the Dinarides. Their unshared floristic richness is believed to have come as a consequence of long-term isolation and high (average) altitudes. Based on this, the relation between the floristic diversity and the consequent number of endemic and relict plant taxa – along with a diversity of ecological parameters has been the subject of previous studies (Mersinllari & al. 2008; Millaku & al. 2008; Shuka & al. 2008; Rakaj 2009; Frajman & al. 2014; Vukojičić & al. 2014; Caković & al. 2017; Shuka & al. 2020). Apart from this, the flora of the Alps has also been continuously studied, both in terms of species general distribution, their numbers and abundances (Rexhepi 1982, 1986, 1997; Amidžić & Krivošej 1998; Amidžić & al. 2013; Berisha & al. 2020) and in terms of species conservation and posed threats (Stevanović 1999; Millaku ed. 2013; Vuksanović & al. 2016; Millaku & al. 2017; Shuka & al. 2020; Kuzmanović & al. 2021).

Based on available literature references, herbarium specimens deposited in the Herbarium of the Faculty of Mathematics and Natural Sciences of the University of Prishtina as well as collected data from our field surveys conducted from 2009 until 2019 – a total of 1648 plant taxa are recorded in the Albanian Alps of Kosovo. Kosovo is believed to harbor some ~ 3000 plant taxa in total (Millaku ed. 2013; Tomović & al. 2014) either though yet there are no exact figures, so Albanian Alps make ~ 55% of the entire country's flora.

Since the Albanian Alps in Kosovo include a relatively wide geographical area, in our current study we have been focused on a narrower, yet floristically very rich area, that of the Leqinat Mt. massif. In the Leqinat area alone, an area encompassing forest and grasslands of 6 km<sup>2</sup> – we have data on the presence of a total of 873 plant taxa, and out of them 65 being Balkan endemics (7.4 % - Annex I). From the Red Book of Vascular flora of Kosovo (Millaku ed. 2013), 27 plant taxa from Leqinat Mt. were assessed to belong any of IUCN conservation categories (lower risk = NT, LC, or threatened VU, EN, CR) in the country level. Of these, 19 are endemic plants that belong to different IUCN conservation categories: EN = 3, VU = 1, NT = 6 and LC = 9 (Electronic Supplementary File 1 table 1). This further reinforces the conclusion that this area is of particular importance in terms of diversity and floristic composition of Kosovo. In Kosovo, it is estimated that there are 360 Balkan endemic plant taxa (Rexhepi 2000; Tomović & al. 2014), and Leqinat Mt. make 18% of the entire endemic plant taxa, and it belongs to the richest region of Kosovo, based on the calculated conservation importance on a map 20×20 km grid square (Berisha & al. 2020). However, so far the influential biogeographical features of this particular area have never been properly analyzed, to be able to explain the reasons for such a remarkable floristic richness. Thus, the aims of the present study are: (i) to determine the correlation between habitat diversity and endemic plant taxa richness, (ii) to determine the correlation between altitude (m a.s.l.) and the plant taxa richness, and (iii) to determine the correlation between the mountain isolation, exposition and their plant taxa diversity. We believe that these data of this particular region of the National Park “Bjeshkët e Nemuna” will prove to be a very valuable tool for proper conservation actions and planning, as well for further comprehensive studies.

## Material and methods

### The data set

A total area of 6 km<sup>2</sup> was included in the present study (Fig. 1). This region of the Mt. Leqinat has a well known native flora, that was recorded and continuously updated and revised from 1987 until 2019 – with many detailed floristic and vegetation studies (Lakušić 1968; Rexhepi 1994; Amidžić 1998; Millaku 1999, 2001). These data include both literature data, newly documented records of plant taxa – accompanied by voucher specimens supporting their presence. A crucial point on these data-sets is represented by the number of endemic plant taxa. Endemicity of plant taxa was merged into one level, by uniting Balkan endemics with local endemics. The proportion of the number of endemics to the overall number of plant taxa is also an important measure of endemism. Based on available existing data, herbarium materials, and our field data, we analyzed also floristic gradient and richness over the altitude on the studied mountain.

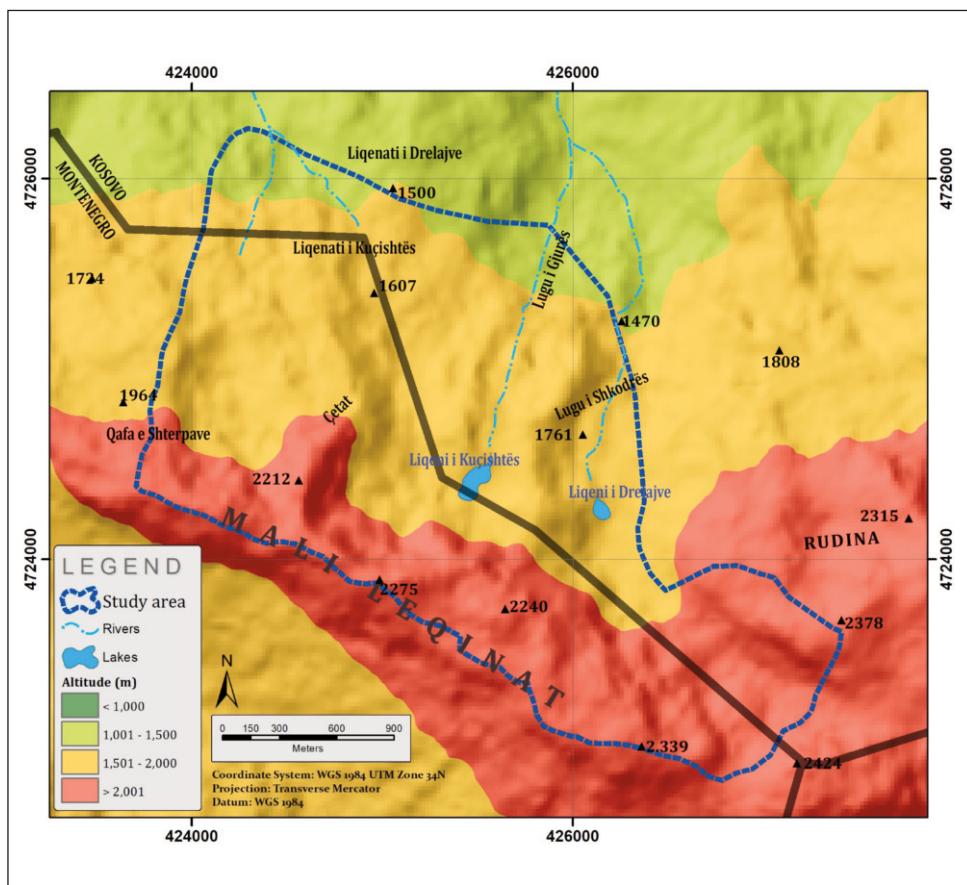


Fig. 1. The geographical location of the studied area.

### *Study area*

The Leqinat Mt area is located in the Albanian Alps of Kosovo, which is a chain of Mountains between Kosovo, Albania and Montenegro. The study area has a surface of 6 km<sup>2</sup> and is distinguished by a mountainous relief, situated in the border area between two countries: Kosovo in the east and Montenegro in the west. In hydrographic terms, this area belongs to Lumbardhi i Pejës River basin, whose waters flows towards the Adriatic Sea.

In geological and tectonic terms, the Leqinat Mt. area belongs to the Durmitor Area - Bjeshkët e Nemuna (Pruthi 1986). It is composed mainly of dolomitic red limestones with cephalopods of middle Triassic age. Slopes have a gradient of about 40° towards the east (E) and northeast (NE). At the higher part and the top of the Mt. (2275 m a.s.l.), the limestones and dolomites predominate the substrate. Naturally, as a result of alteration processes, influenced by temperature amplitudes, mountain calcareous and acidic screes, as well as inland cliffs are found. The relief is mountainous, with hypsometry of the terrain having values of 1300 m a.s.l. up to the top of the Mountain reaching 2275 m a.s.l. The terrain is covered with steep mountain ridges and valleys, which are believed that have been created by the geological activity of high gradient rivers, Pleistocene glaciation and weathering. The most popular valleys are Lugu i Shkodrës and Lugu i Gjuricës, while in the upper part there are two alpine glacial lakes: Kuqishtë Lake (1850 m a.s.l.) and Drelaj Lake (1795 m a.s.l.).

The mountainous terrain features area with slopes with significant inclination. The average slope inclination of the whole study area is 27°. Slopes with an inclination between 20-40° are dominant ones. At the foot of Mt. Leqinat, the slope inclination is over 40°, while the lowest slopes are at the bottom of the cirques, where the cirque (glacial) lakes are located. The study area has mainly northern and northeastern aspect.

The area has a typical mountainous climate, with an average annual air temperature between 4-6 °C and an average annual rainfall of 1200-1400 mm, with snow lasting until late spring – May (Map of Rains and Air Temperature 1983). Despite of these mountainous climatic conditions, the hydrographic features of the study area are predetermined by the lithological settings (limestone dominated), resulting a poor surface drainage network. During the Pleistocene age, when glaciers had an impact on the Balkan Peninsula, glacial lakes were created, the most distinguished ones being lakes of Kuqishtë and Drelaj (Fig. 2).

### *Correlation of plant diversity and endemism with bio-geographical variables*

Independent variables tested as potential predictors of species diversity with concern to 65 analyzed Balkan endemic plant taxa were: habitat diversity ( $H_D$ ), maximum elevation (E, m), and the total number of habitats ( $T_H$ ) (ESF1 Table 2). In plant ecology studies, the calculation and interpretation of habitat diversity appears a demanding issue (Kohn & Walsh 1994; Triantis & al. 2006; Sfenthourakis & Triantis 2009; Zhang & al. 2015). As a measure of habitat diversity herein we used the number of natural habitats (classified according to EUNIS 2007) where the taxa were present, using also some presumably important environmental features for plants, such as physiography, slope, substrate composition, aspect as well as vegetation type. In order to achieve this calculation for each endemic taxa, we utilized data from topographic and geological maps, data from herbarium vouchers, satellite imagery as well as extensive field recordings and verified data concerning all of the above mentioned factors. In order to explore the relationships between the endemics  $H_D$ , E and  $T_H$ , the related statistical estimations were carried out using R Studio (R Core Team 2020).



Fig. 2. Few examples of different natural habitats in the studied area on Leqinati Mt. Top left: dry calcareous grasslands nearby the forest edge. Top right: a landscape just above the Kuqishtë Lake, depicting screes, large slopes of stone walls as well as scattered *Picea abies* (L.) H. Karst. and *Pinus peuce* Griseb. trees. Bottom left: Drelaj Lake, bushes and forests nearby. Bottom right: grasslands, subalpine deciduous scrubs and *P. peuce* forests.

## Results

### *Species richness*

Based on our field surveys, herbarium materials available as well as based on extensive literature sources, we confirm that the Mt. as a whole contains 873 plant taxa. Depending on these data, we were able to analyze the floristic richness over the altitude of the Mt., where we have particularly depicted the highest parts of the Mt., having the larger proportion of floristic richness (Fig. 3) – with the altitude between 1800 up to 2000 m. a.s.l., being the richest part, where more than 700 plant taxa occur. We do not provide here the species list, as they can be found on other floristic publications, as mentioned earlier here, it was not our intention to do a floristic inventory, rather than to survey the endemic taxa and their relation to the natural, diverse habitats.

### *Habitat diversity and endemic plants*

The study area includes a variety of natural habitats, very rugged and diverse landscapes, making it particularly interesting and valuable on national and regional scales (Fig.

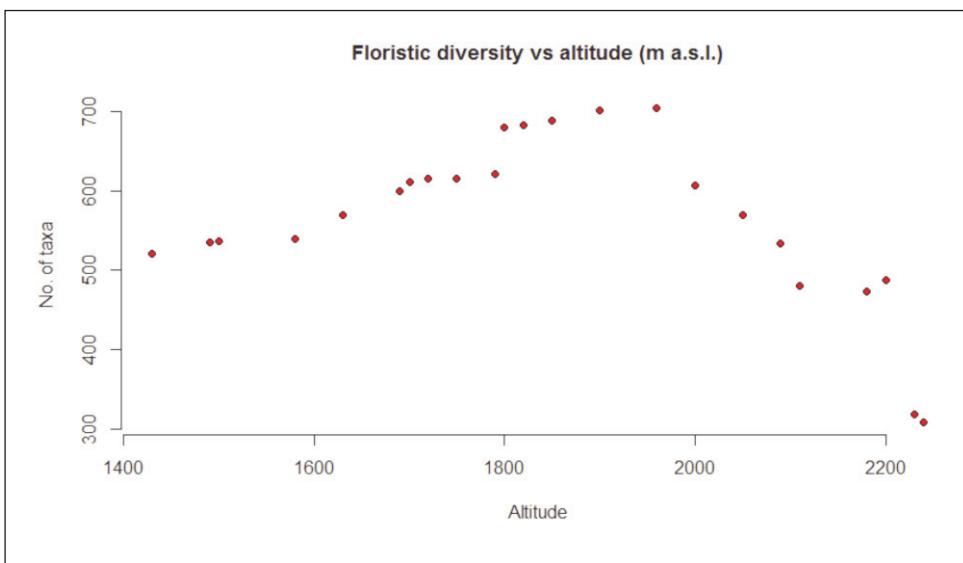


Fig. 3. The graphical plot depicting the relation between overall floristic diversity over the altitude of the Mt. Leqinat (1400 m – 2300 m. a.s.l.).

2). Concerning the natural habitat types (classified according to EUNIS) that harbor endemic taxa, we were able to distinguish 20 of them (Table 1), with the alpine calcareous grasslands (E4.4) and the calcareous screes (H2.6) being the richest ones, sheltering alone 35 out of 65 recorded endemic taxa. The average habitat diversity for all endemic plant species ranges between values 2 and 2.5, according to the performed analysis (Fig. 4 – Habitat diversity). Whereas, if we look conversely at taxa and the number of EUNIS habitat types they were affiliated with, they predominantly belonged to 1 or 2 EUNIS habitats, rarely being recorded into 3 or more habitats (Fig. 4 – Type of Habitat).

#### Predictors of endemic richness

A distinct collinearity among the independent factors used for predicting endemic taxa richness was observed, especially with habitat diversity. Nonetheless, since habitat diversity represents the linear function of the given area, it always displayed higher correlation coefficients with endemic taxa richness. It was observed, that with the increase of habitat diversity (inclination rate, altitude, bedrock composition, geology, etc.), the richness on its floristic composition as well as on its endemic richness grew proportionally. Based on Herbarium samples examination (e.g. Herbarium voucher of endemic plant – *Aquilegia blecicii* Podobnik– Fig. 5), it was noticeable that the Northern and North-Eastern slopes of the Mt were richer in endemics, compared to other expositions. In addition to this, even though the value of altitude for calculation reasons was united with other factors as the Habitat Diversity (HD), again, if we separate it as a single factor concerning the richness with endemic plants, it was observed that we have a particular altitude scale between 1800 to 2200 m a.s.l., where the number of endemic plants is notably higher (Fig. 4 – Altitude gradient).

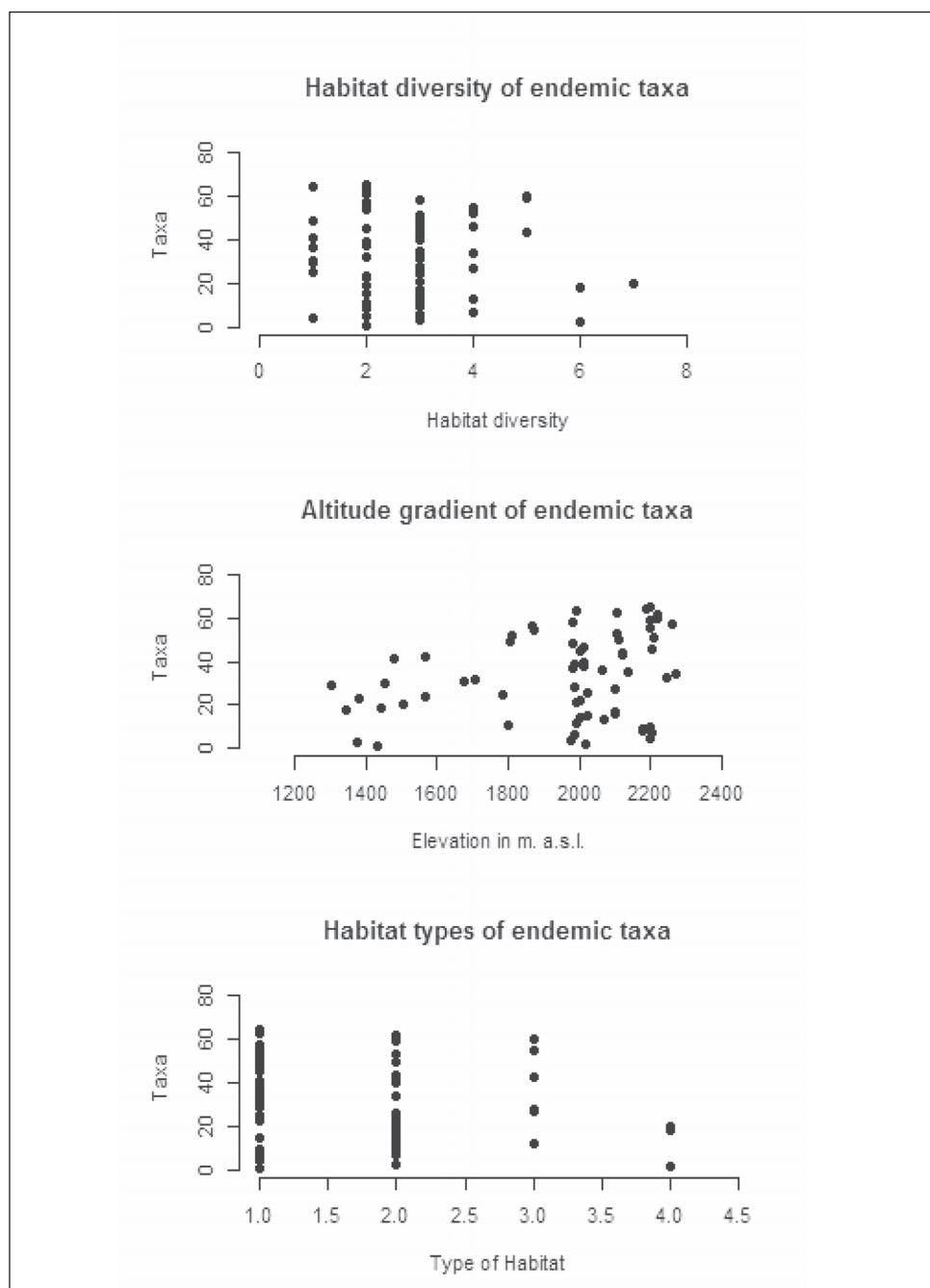


Fig. 4. Three plotted graphs of endemic plant taxa versus their Habitat Diversity (HD) value (first, from up-down), endemic plant taxa versus the altitude in m. a.s.l., as a separated factor from HD (second, from up-down) and the endemic taxa versus the EUNIS habitat types occupied (third, from up-down).

Table 1. EUNIS Habitat types and their corresponding endemic plant taxa they contain in numbers.

Endemic taxa	EUNIS code	Habitat description
24	E4.4	Calcareous alpine and subalpine grasslands
11	H2.6	Calcareous and ultra-basic screes of warm exposures
10	E4.39	Oro-Moesian acidophilous grassland
9	E4.5	Alpine and subalpine enriched grassland
9	F2.3	Subalpine deciduous scrub
8	E1.2	Perennial calcareous grassland and basic steppes
7	H3.2	Basic and ultra-basic inland cliffs
5	F2.2	Evergreen alpine and subalpine heath and scrub
5	H2.4	Temperate-montane calcareous and ultra-basic screes
4	E1.92	Perennial open siliceous grassland
4	E5.4	Moist or wet tall-herb and fern fringes and meadows
3	H3.1	Acid siliceous inland cliffs
2	E4.31	Alpic <i>Nardus stricta</i> swards and related communities
2	F3.2	Submediterranean deciduous thickets and brushes
2	G3.1	Coniferous - <i>Abies</i> and <i>Picea</i> woodland
1	D2.2	Poor fens and soft-water spring mires
1	D4.1	Rich fens, including eutrophic tall-herb fens and calcareous flushes
1	D4.2	Basic mountain flushes and streamsides, with a rich arctic-montane flora
1	F2.1	Subarctic and alpine dwarf willow scrub
1	G4.6	Mixed <i>Abies</i> - <i>Picea</i> - <i>Fagus</i> woodland

## Discussion

The results of this study put a special emphasis on the important role that habitat diversity plays in shaping endemic taxa richness. This type of notable correlation between habitat diversity and plant taxa richness in general, and endemics in particular, has already been reported by different authors (e.g., Hobohm 2000; Guilhaumon & al. 2008; Alsterberg & al. 2017; Vladimirov & al. 2020), although varying estimation approaches to habitat diversity were used. The diversity of natural habitats, due to their heterogeneity in topography and geology, among other factors, promotes plant species richness – and that in particular, of those plant species that have a tendency to thrive only in certain, rather isolated or narrow natural habitats, as is the case with endemic plants taxa (Hannus & Numers 2008; Sfenthourakis & Triantis 2009; Stein & al. 2014). The number of endemic plant taxa, as expected from the nature of the studied area, is significantly high for the national and regional scale, taking into account the total intensive study area of only 6 km<sup>2</sup>. Nevertheless, at a local scale, elevation, habitat diversity and isolation can still predict richness with endemic plant taxa – with elevation as a dimension calculated within the habitat diversity value.

It should be noted that the area of Leqinat Mt., within the “Bjeshkët e Nemuna” National Park represents one of the most distinctive and richest areas in terms of floristic diversity. In this area, there are 27 plant taxa which are estimated to belong any of the IUCN conservation categories in Kosovo (Millaku ed. 2013), either lower risk (NT, LC)

or threatened (VU, EN, CR) ones. With this detailed information we are now offering, we verify the presence of 65 Balkan endemic plant taxa, which further distinguishes the importance of this natural area. Out of these 65 endemics, 3 are IUCN-internationally (Farjon 2017) categorized plant taxa at lower risk of endangerment (*Pinus peuce* Griseb. (NT), *Aquilegia blecicii* A. Podob. (DD) and *Geum bulgaricum* Pančić (LC)).

Aside from purely theoretical importance and study attraction, endemicity studies and their general evaluation plays a decisive role in the development of comprehensive, rather practical, conservation strategies (Bonn & al. 2002). Moreover, plant diversity and diversity with endemic in particular, represent one of the best available predictors of diversity and richness of other living taxa as well (Brunbjerg & al. 2018) and has already been used as such tool in the designation of biodiversity hotspots (Médail & Quézel 1999). In addition, a useful approach in this regard has led to the use of species-area relationship (Duarte & al. 2008).

## Conclusions

The presented results show that endemicity richness studies, habitat diversity factor, along with natural habitat types, can easily serve as environmental predictors of vascular plant richness and can aid the conservation management of protected areas. Local endemic taxa, as well as wider geographical ones, appear to be mainly affected by habitat diversity. Elevation was observed as an important factor affecting the bulk of endemic species richness. Habitat diversity yet is confirmed as the principal factor shaping endemic plant taxa richness of Leqinat Mt., and should be further examined in order to gain important insight into wider plant diversity patterns. Finally, attention should be focused on the roles of plant species composition on sustainable management effectiveness of the protected areas of Kosovo. Due to the presence of two glacial lakes in the area, the area is visited on average by many tourists during the year. Therefore, it would be highly advisable to provide them with enough notice information about the importance and values of the Leqinat Mt. area.

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