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The northernmost population of *Podocytisus caramanicus* (*Fabaceae*) in the Balkan Peninsula: evidence from Kosovo

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Abstract

Podocytisus caramanicus (*Fabaceae*) is a monotypic genus with a disjunct range between southern Anatolia and the southern Balkans, representing a relict element of Mediterranean forest biodiversity. This study provides the first detailed reassessment of the species in Kosovo, where it forms the northernmost known population in the Balkans. Field surveys were carried out in 2025 in the Lepenc gorge to document its current distribution, population size, habitat characteristics, and associated vegetation. Morphometric traits were measured and compared with populations from North Macedonia, Greece, and Turkey, while the national conservation status was evaluated following IUCN criteria. The species was confirmed in five small subpopulations covering an area of occupancy of 12 km², confined to dry, south-facing calcareous slopes at 400–420 m a.s.l. dominated by *Quercus pubescens* and *Fraxinus ornus*. Habitat conditions are severely impacted by infrastructure development and settlement expansion, leading to pronounced fragmentation and decline. Morphometric results indicate the close similarity between the Kosovo and North Macedonian populations. The population's restricted extent, fragmentation, and continuing decline justify its classification as Endangered. Immediate in-situ and ex-situ conservation actions are essential to ensure the survival of this phylogenetically and biogeographically significant species.

Key words

biodiversity, Genisteae, plant taxonomy, SE Europe, threatened flora

Citation

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Introduction

The genus *Podocytisus* Boiss. & Heldr. (*Fabaceae*, tribe Genisteae) is a monotypic genus, represented only by *Podocytisus caramanicus* Boiss. & Heldr. This monotypic status is important because such genera often have particular morphological, karyological and ecological characteristics that provide information about the evolutionary processes and biogeographical history of larger plant tribes (Backlund & Bremer 1998). *Podocytisus* is considered among the "primitive genera" of *Genisteae* (Bronn) Dumort, with morphological features (e.g., winged legumes with tardy dehiscence) and chromosomal traits (predominantly $2n = 48$) that support its distinct systematic position, while also linking it closely with related genera such as *Laburnum* Fabr., *Hesperolaburnum* Marie & *Petteria* C. Presl. (Cusma-Velari & Feoli-Chiapella 2009). Biogeographically, *P. caramanicus* shows a disjunct distribution between southern Anatolia (type locality: Göksu valley, Taurus Mountains, Turkey) and the southern

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Balkans, including Greece, Albania, North Macedonia and Kosovo (Chamberlain 1970; Tan & al. 2025). Such a pattern emphasises that the genus is an element of the eastern Mediterranean with a fragmented range, reflecting complex historical dispersal and refugial processes. In the Balkans, the species is often restricted to calcareous valleys and gorges, where it forms scattered populations on dry slopes and rocky substrates. Its occurrence enriches the flora of the Balkans with a rare phylogenetic element, and underlines the role of the region as a centre of plant diversity and endemism (Griffiths & al. 2004; Tan & al. 2007; Rešetnik & Španiel 2022).

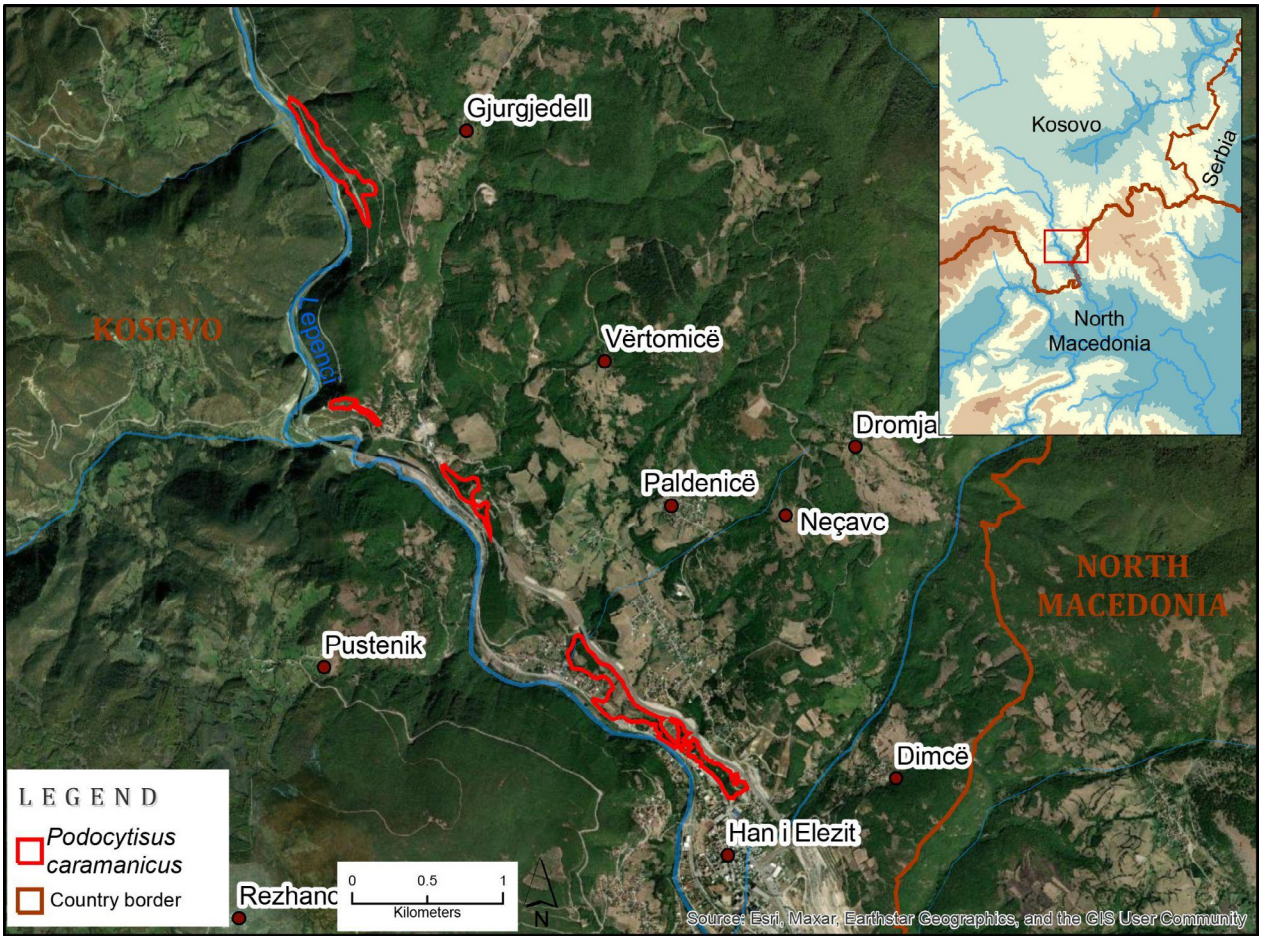
In Kosovo, *P. caramanicus* represents the northernmost known population in the Balkans. The species was first recorded by Mayer (1981) in the Lepenc Valley (between Kaçanik and Hani i Elezit), where flowering populations were documented at elevations of 200–400 m a.s.l. However, despite its taxonomic and biogeographic importance, no detailed field-based updates have been conducted or published since the first report 45 years ago. This long gap has led to uncertainties regarding population size, habitat condition, reproductive status and potential threats. Elsewhere in the Balkans, the species is considered rare and is sometimes threatened by habitat destruction, particularly from infrastructure development, grazing and fire (Avramović & al. 2008). Similar risks could also apply to the population in Kosovo, which inhabits a relatively narrow valley corridor affected by human activities. The aim of this study is therefore to provide an updated report on the status of *P. caramanicus* in Kosovo, based on recent field surveys. Specifically, we aim to 1) document the current distribution and population size, 2) record the associated plant species and habitat conditions, 3) assess the threats and conservation needs, 4) conduct morphometric analysis of the population in Kosovo and compare it to populations in North Macedonia, Greece and Turkey, and discuss its importance in the context of the overall distribution of the species in the Balkans.

With this approach, we attempt to close a decades-long knowledge gap and contribute basic data for the conservation and future research of this phylogenetically and biogeographically important plant taxon.

Methods

Field investigations were conducted throughout the entire vegetative period of 2025, and covered both flowering (late May–June) and fruiting stages (July–August)

Fig. 1. The known distribution of *Podocytisus caramanicus* in Kosovo.



of *P. caramanicus*. The study focussed on the only currently known population of the species in Kosovo, located in the Lepenc Valley between Hani i Elezit and the entrance to Kaçanik (Fig. 1). In addition to this population, targeted field surveys were conducted in other locations in Kosovo that share similar climatic and biogeographical characteristics (Berisha & al. 2025), but no other occurrences of the species were found. In the Lepenc Valley, the population was revisited several times, and its size and structure were assessed through repeated field observations and spatial mapping of individuals and subpopulations, combined with evaluation of plant density, regeneration, and distribution patterns. Simultaneously, associated plant species were recorded to characterise the surrounding vegetation, and the habitat was assessed in terms of soil type and visible disturbances. Potential threats, including grazing, infrastructure development and vegetation clearance, were qualitatively recorded. Representative specimens were collected and prepared as herbarium specimens, and deposited in the Herbarium of the University of Prishtina (UPH). Morphometric measurements of stems, leaves, flowers, and fruits of 40 freshly collected fully mature individuals were made with a digital calliper (to 0.1 mm precision), and the data summarised and compared with available measurements from populations in North Macedonia, Greece and Albania (Tan & al. 2025).

Results

1) *Distribution and population size*

The total distribution area of the *P. caramanicus* population in Kosovo is estimated to be only 0.28 km² (282,542 m²). It consists of five clearly separated subpopulations (Fig. 1), which extend from the North Macedonian border in the gorge of the Lepenc River near the villages of Neçavc and Gjurgjedell, northwards along the river gorge and up to the highway fences, to the outskirts of Kaçanik. The species has a very narrow distribution area, which is strictly limited to dry, south-facing calcareous slopes within the gorge, at altitudes of 400–420 m a.s.l.

2) *Associated plant taxa and habitat conditions*

Podocytisus caramanicus has been recorded in small, fragmented and locally affected populations throughout the Hani i Elezit area, mostly near villages and neighbourhoods and always along the main road towards Kaçanik. The species grows on dry, south-facing calcareous slopes of the Lepenc gorge, often at the edge of anthropogenically influenced habitats.

The accompanying vegetation is dominated by *Quercus pubescens* Willd., *Fraxinus ornus* L., *Paliurus spina-christi* Mill, *Bituminaria bituminosa* (L.) C.H.Stirt., *Hippocrepis emerus* (L.) Lassen, *Carpinus orientalis* Mill and *Linaria genistifolia* (L.) Mill., as well as other typical thermophilous species (Fig. 2). Based on the floristic composition and ecological characteristics, these stands can be phytosociologically assigned to the alliance *Eryngio campestris–Paliurion spinae-christi* (Jovanović 1985) Matevski & al. 2008, within the order *Paliuretalia* Trinajstić 1978 and the class *Crataego–Prunetea* Tx. 1962 (Matevski & al. 2008; Chytrý & al. 2020).

In all five subpopulations of *P. caramanicus*, the habitat was found to be significantly reduced in extent compared to its presumed original distribution. The decline is particularly visible where scattered houses and village gardens have been established, as well as through the expansion of local access roads and the construction of the highway connecting Kosovo with North Macedonia. Within the existing distribution range, numerous sites are also intersected by infrastructure elements such as electricity pylons and streetlights. As a result, the habitat is highly fragmented and subject to strong anthropogenic influences.

3) *Threats and conservation notes*

The Kosovo population of *P. caramanicus* has a very restricted distribution, fragmented into five small subpopulations confined to the Lepenc gorge. Following the IUCN Red List Guidelines (IUCN 2024), the Area of Occupancy (AOO) was calculated using the standard 2 × 2 km grid-cell method (4 km² per cell). The species occupies three grid cells, resulting in an AOO of 12 km².

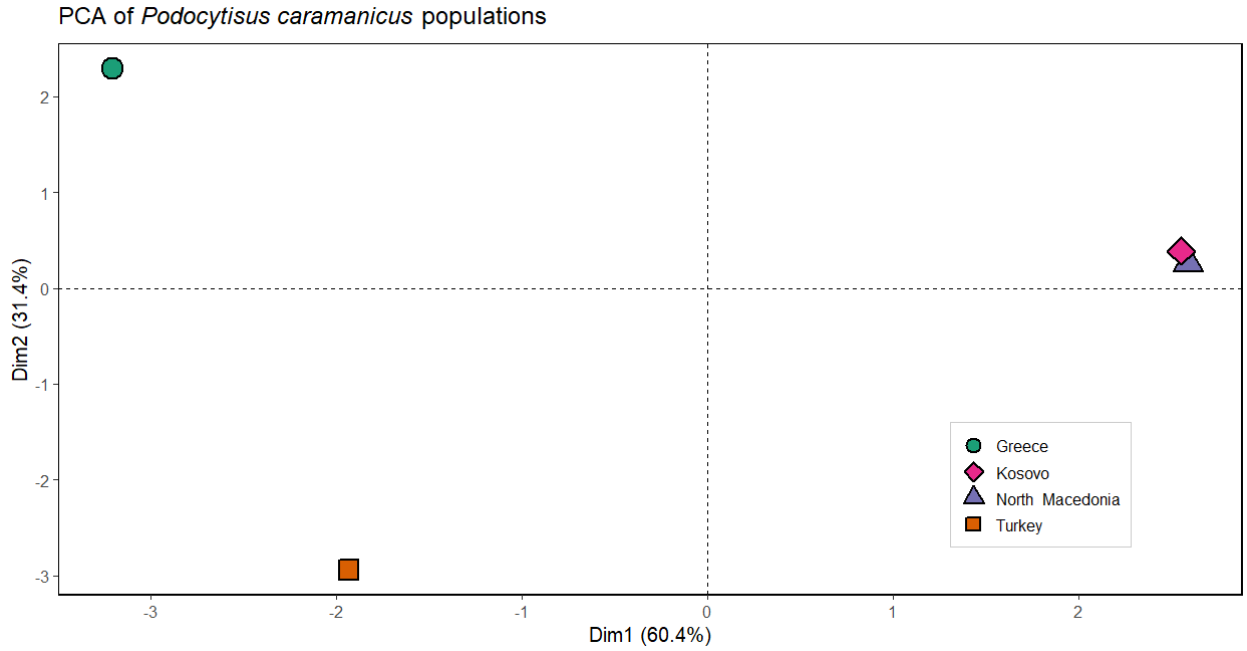
A comparison with historical data from 1981 indicates a substantial reduction in distribution and habitat quality, primarily driven by infrastructure development, including highway construction, expansion of local roads and settlements and additional fragmentation caused by utility installations (e.g., electricity pylons and street lighting). In accordance with IUCN definitions, the Extent of Occurrence (EOO) was treated consistently with AOO (EOO ≥ AOO). Based on the very restricted geographic range, occurrence within a single location (the Lepenc gorge) and the observed and inferred continuing decline in (i) distribution, (ii) area of occupancy and (iii) habitat extent and quality, *P. caramanicus* in Kosovo qualifies as Endangered [EN B1ab(i,ii,iii)+B2ab(i,ii,iii)] at the national level.

4) *Morphometric analysis*

The PCA analysis based on 15 morphometric characters revealed a clear differentiation between the four studied populations of *P. caramanicus* (Table 1; Fig. 3). The first two principal components together explained over 90% of the total variance (Dim1 = 60.4%, Dim2 = 31.4%). The populations from Kosovo and North Macedonia were close to each other, indicating strong morphological similarity, whereas the populations from Greece and Turkey were more clearly separated along both axes. The population from Kosovo was closest to the population from North Macedonia, indicating com-

Fig. 2. *Podocytisus caramanicus* in its natural habitat on dry, south-facing slopes in the Lepenc gorge, Hani i Elezit, Kosovo. (Photo: Berisha, N. - 26 June 2025).

Fig. 3. PCA analysis plot of morphometrical characters between four populations of the species.



mon morphometric profiles on several traits (e.g., leaflet dimensions, style length, and legume size). In contrast, the Greek population differed mainly in its larger floral organs (standard, wing, and keel petals), while the Turkish population was characterised by longer legumes and slightly broader leaflets. In Kosovo, the morphometric range partially overlapped with North Macedonia, but remained narrower compared to Greece and Turkey.

The traits that contributed most to the observed separation included petal dimensions, style length, legume length and number of seeds per legume, all of which emphasise the close relationship of the Kosovo population with the northern Balkans while distinguishing it from the more southern populations.

Table 1. Morphological characters of *Podocytisus caramanicus* populations from Greece, Turkey, North Macedonia and Kosovo.

Character type	Character	Greece	Turkey	North Macedonia	Kosovo
Vegetative traits	Habit/height	erect shrub, 1-2(2.5) m	erect shrub, 1-2(2.5) m	erect shrub, 1-2 m	erect shrub, 1-2 m
	Young twigs	glabrous	glabrous	glabrous	glabrous
	Leaflets	obovate, glabrous above	obovate, glabrous	obovate, glabrous	obovate, glabrous
	Terminal leaflets	(3)5-17(20) × 3-12 mm	10-20 × 5-13 mm	5-13(16) × 2.5-9.0 mm	6.75-13.5 × 3.88-7.75 mm
Floral traits	Inflorescence	lax raceme 5-30 cm	lax raceme 10-30 cm	lax raceme 5-25 cm	lax raceme 5-25 cm
	Raceme	5-15-flowered	5-10-flowered	(3)5-10-flowered	(4)5-9-flowered
	Pedicel length	5-10 mm (up to 15 in fruit)	4-12 mm	4.0-8.3 mm	5-7.5 mm
	Pedicel indumentum	glabrous	glabrous	glabrous	glabrous
	Calyx upper lip	3.0-4.5 mm	4.0-5.5 mm	3.2-3.6 mm	3-3.4 mm
	Calyx lower lip	4.5-6.0 mm	5-6 mm	3.5-4.2 mm	3.4-5 mm
	Corolla colour	bright yellow	bright yellow	bright yellow	bright yellow
	Standard length	10-15(18) mm, glabrous	12-15 mm, glabrous	9.0-13.2 mm, glabrous	9.8-12 × 5-5.6 mm, glabrous
	Wing petal length	10-15(18) mm, glabrous	12-15 mm, glabrous	7.6-10.2 mm, glabrous	8.2-9.8 × 4-4.6 mm, glabrous
	Keel length	10-15(18) mm, ventrally pilose in proximal third	10-15 mm, glabrous	8.0-11.1 mm, glabrous	7.9-10 × 2.2-3 mm, glabrous
	Standard/keel relation	standard = keel	standard = keel	slightly longer or = keel	slightly longer or = keel
	Stamens	monadelphous	monadelphous	monadelphous	monadelphous
	Anthers	glabrous	glabrous	glabrous	glabrous
	Style length	5-6 mm, reflexed, glabrous	5-6 mm, reflexed, glabrous	8.4-11.4 mm, reflexed, glabrous	8.8-10.2 mm, reflexed, glabrous
Fruit and seed traits	Legume	25-35(40) × 10-18 mm	30-35(50) × 8-12 mm	23-42 × 10-11 mm	27-43 × 8-12 mm
	Dorsal wing	2-3 mm broad	2.0-2.5 mm broad	2.0-2.5 mm broad	1.3-2.2 mm broad
	Ovule number	3-9	5-9	5-9	6-8
	Seeds per legume	3-6	3-6	5-6(9)	3-7(8)
	Seed size	4.5-5.0 × 3.5 mm	4-5 × 3.0-3.5 mm	5.0-5.5 × 3.5 mm	4-5 × 3.5 mm
	Seed shape	oblong-subreniform	oblong-subreniform	oblong-subreniform	oblong-subreniform
	Seed colour	pale brown - black	pale brown - black	pale brown - black	pale brown - black

Discussion

The genus *Podocytisus* is unique within the tribe *Genisteae*, being monotypic and regarded as one of its "primitive" lineages, with morphological and karyological traits linking it to related genera such as *Laburnum*, *Hesperolaburnum* (Cusma-Velari & Feoli-Chiapella 2009). Its disjunct distribution, restricted to southern Anatolia and the southern Balkans (Tan & al. 2025), highlights its biogeographical and evolutionary significance. Within this fragmented range, the population in Kosovo represents the northernmost known occurrence in the Balkans, adding particular conservation and scientific value.

For conservation assessment, it is important to clarify that the IUCN Area of Occupancy (AOO) must be estimated using standardized 2 × 2 km grid cells (4 km² per cell), whereas fine-scale measures of the area actually occupied in the field are not equivalent to the IUCN AOO and cannot be used directly for Red List criteria B2 or D2. Using the grid-based IUCN methodology, *P. caramanicus* in Kosovo occupies three grid cells, resulting in an AOO of 12 km², while the mapped fine-scale occupied habitat area is approximately 0.28 km². In addition, the IUCN Guidelines require that the Extent of Occurrence (EOO) cannot be smaller than the AOO, and the two parameters were therefore treated consistently.

Given its extremely restricted national distribution, fragmentation into five small subpopulations, confinement to a single location, and ongoing decline in habitat extent and quality due to intensive anthropogenic pressure, our IUCN-based national assessment supports classifying *P. caramanicus* in Kosovo as Endangered [EN B1ab(i,ii,iii)+B2ab(i,ii,iii)]. Considering the species' taxonomic singularity as a monotypic genus and its phylogenetically distinct position within Genisteae, the Kosovo population represents a high national conservation priority. Immediate in situ protection of the Lepenc gorge sites, combined with complementary ex situ conservation efforts, is essential to ensure the long-term persistence of this marginal northern population in the Balkans.

The morphometric analysis revealed that the Kosovo population is closest to the North Macedonian population, sharing comparable ranges of leaflet size, style length and legume dimensions, while populations from Greece and Turkey are differentiated by larger floral organs and longer legumes, respectively (Fig. 3). This suggests a strong regional affinity between the northern Balkan populations, while also underlining subtle but consistent geographic differentiation across the species' range. Similar observations were made in broader Balkan studies, which concluded that despite morphological variability, all populations belong to the same species.

From a biogeographical perspective, the Kosovo population occurs in the sub-Mediterranean region of the country, in dry, south-facing calcareous slopes at low elevation (400–420 m a.s.l.), corresponding to the warmest and driest ecological niche of the Lepenc gorge (Berisha & al. 2025). This is consistent with the species' preference across the Balkans, where it inhabits xeric, rocky gorges and slopes (Micevski 2001; Tan & al. 2025). Such ecological restriction further accentuates its vulnerability, as any habitat alteration directly threatens the survival of entire subpopulations (Médail & Diadema 2009).

In terms of conservation, our IUCN-based national assessment suggests that *P. caramanicus* in Kosovo should be classified as Endangered [EN B1ab(i,ii,iii)+B2ab(i,ii,iii)], due to its very restricted range, fragmented and declining habitat, and ongoing human pressures. Similar assessments have been applied to other narrow Balkan endemics with highly localized distributions (Meço & al. 2017; Mataruga & al. 2019; Millaku & al. 2025). Considering its taxonomic distinctiveness and phylogenetic position as a monotypic genus, *P. caramanicus* represents not only a regional conservation priority but also a species of wider evolutionary significance. Targeted protection of its remaining habitats in Kosovo, alongside *ex situ* propagation efforts are urgently needed to ensure its persistence. Seed germination techniques already exist but are challenging due to seed coat dormancy (Smiris & al. 2006).

Conclusion

This study provides the first detailed update in over 45 years on the status of *P. caramanicus* in Kosovo. The species is restricted to a very narrow distribution in the Lepenc gorge, where it survives in five small subpopulations under strong anthropogenic pressure. Morphometric data show a close relationship with the North Macedonian population, less so with the Greek and Turkish ones. In view of its taxonomic singularity, its disjunct biogeographic range, and its extremely restricted and threatened occurrence in Kosovo, *P. caramanicus* must be recognised as a high national conservation priority. Immediate in-situ and ex-situ conservation measures are necessary to ensure the survival of this relict species at the northern edge of its range in the Balkans.

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