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Phytosociology of *Stipa*-dominated steppe-like vegetation on the ultramafics of the Central Balkans

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ABSTRACT:
Despite the fact that dry grassland vegetation on ultramafics has been the object of continuous research in previous centuries, there remains a knowledge gap in regard to the initial stages of vegetation on ultramafic substrates. The *Stipa*-dominated dry grasslands of Serbia and Kosovo representing various initial phases in the overgrowth of ultramafic rocks were the object of the present study. A total of 213 relevés were made in different steppe-like *Stipa* species-dominated grasslands on ultramafics of Serbia including Kosovo, and were then analysed in the context of Balkan dry grassland vegetation of the *Festuco-Brometea* class. For cluster analyses, new relevés were analysed in order to characterize them floristically and sintaxonomically. For describing associations, we used the concept of "relative fidelity" allowing us to find the optimum occurrence of a species within a group of floristically similar communities. The threshold of the phi value was selected at 0.1 for new associations. Four new associations were distinguished: *Stachyo scardicae-Stipetum tirsae* ass. nov., *Euphorbio glabriflorae-Stipetum pulcherrimae* ass. nov., *Alysso serbici-Stipetum pulcherrimae* ass. nov. and *Thymo striati-Stipetum mayerii* ass. nov.. Relevés dominated by *Stipa novakii* were asigned to previously described *Stipetum novaki* Kabaš et D. Lakušić 2013. The first three new associations were assigned to *Potentillion visianii*, while the latter was assigned to the *Centaureo kosaninii-Bromion fibrosi* alliance of the *Halacsyetalia sentneri* order.

Keywords:
dry grasslands, *Festuco-Brometea*, *Halacsyetalia sendtneri*, relic, syntaxonomy

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INTRODUCTION

Stipa-dominated vegetation is primarily represented by the zonal Palearctic steppes as one of the largest biomes on Earth. These steppes form an extensive belt in Eurasia, streching from Bulgaria in the west all the way to Manchuria in the east (Wesche *et al*. 2016). Their main constituents are xerophilous grasses, mainly representatives of *Stipa*, *Festuca*, *Koeleria*, etc. Parts of the Pannonian steppe as the major exclave of the Eurasian steppes are present on the Balkan Peninsula, partly in Serbia and Croatia (Wesche *et al*. 2016). These steppes in Serbia are limited to its northern part representing the southern rim of the Pannonian plane. Also, some relic fragments of these steppes have remained today within the light black pine forests, representing the nuclea from which the steppe vegetation has been spreading through secondary habitats such as carbonate or low competition ultramafic sites. In these and similar places within the teritorry of the Central Balkans, *Stipa* species (feather grasses) are known to be the common constituents of "hilly-", "montane-" or "rocky-steppes", known as secondary grassland communities distributed on dry carbonate and ultramafic substrates throughout Serbia, Bulgaria and Macedonia (Stoyanoff 1926; Micevski 1971; Jovanović-Dunjić 1983; Jakovljević *et al*. 2011).

However, the complicated infraspecific taxonomy within *Stipa* and the lack of stable differential characters have caused problems with the identification of species. Despite the fact it is one of the most important genera forming the dry grasslands (and its members serve as a name-giving species for various dry grassland syntaxa), the genus *Stipa* has a very complicated and unstable taxonomy (similar to other grass genera such as *Festuca*, *Koeleria,* and *Sesleria*), especialy in regard to genus circumscription and the number of species within it.

The same is valid for the *Stipa* representatives on the territory of the Central Balkans, particularly in Serbia and Kosovo (for details see Kabaš 2016), where *Stipa* species are also very abundant on dry grasslands on ultramafics (Kabaš *et al.* 2013; Kabaš 2016). The ultramafic sites investigated in this study, are by their nature very extreme habitats. Their dark colour, the presence of toxic trace metals, low water capacity, poorly developed soils, and generally extremly xeric conditions impose unfavorable conditions for the plants growing there. Considering the fact that ultramafic rocks typically have very discrete and limited distribution patterns (although variable in size and the extent of isolation) (Brooks 1987), sharply defined boundaries are visible in nature with regard to the adjacent non-ultramafic vegetation, giving the impression of "islands in the sea" of the other surrounding bedrock types. This being the case, it is no wonder that ultramafic vegetation hosts numerous endemic (Stevanović *et al.* 2003) and relic plant species originating from the steppe and forest-steppe regions of Eurasia (Jakovljević *et al.* 2011), thus representing specific refugia during the Ice Age. However, the knowledge of *Stipa*-dominated dry grassland vegetation, along with that related to ultramafic vegetation as a whole, remains incomplete. Kabaš (2016) dealt in detail with the steppe-like *Stipa* species-dominated vegetation on shallow ultramafic soils. Also, several papers describing *Stipa* species-dominated associations on ultramafics were published in the second half of the last century and later on (*Stipo mayerii-Convolvuletum compacti* Millaku et al. 2011, *Stipetum novakii* Kabaš et D. Lakušić 2013). However, these studies did not involve syntaxonomic revisions or relationships within the *Halacsyetalia sendtneri* Ritter-Studnička 1970 order, or the other orders of the *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947 class. These associations were all traditionally classified within ultramafic vegetation on shallow soils of the *Halacsyetalia sendtneri* order. Moreover, recent reviews and studies point out the lack of information on the open types of vegetation on ultramafics of the Balkan Peninsula (Tatić & Veljović 1992; Jakovljević *et al.* 2011; Aćić *et al.* 2014).

Taking all of this into consideration, the diversity of the feather grass-dominated dry grassland vegetation, together with their syntaxonomic position and characterisation, have not yet been resolved. Having this in mind, the aims of this study were to describe and characterize communities dominated by *Stipa* species; to describe their floristic diversity and to determine the syntaxonomic position of *Stipa* species-dominated steppe-like vegetation on shallow ultramafic soils in the Central Balkan Peninsula.

MATERIALS AND METHODS

Study area. Field research for the purposes of this study was conducted on the territory of the central part of the Balkan Peninsula. The study area actually corresponds to the distribution of the ultramafic substrates in western and central parts of Serbia and Kosovo (Fig. 1). Biogeographically, this area belongs to the eastern part of the Illyrian and the northern part of the Scardo-Pindian biogeographycal subregions of the Middle European floristic region and the climatic conditions within the studied area are somewhat complex (Horvat *et al.* 1974). Namely, in the Illyrian part there are influences from the humid Atlantic climate coming via the Dinaric Alps. However, in this area a specific climate type prevails, the moderately-continental humid climate [type VI 2b according to Walter & Leith (1964), 2.1 according to Stevanović & Stevanović 1995]. This particular climate is characterized by 720-900 mm of precipitation per year, and by the abscence of dry and semi-dry periods. The mean annual temperature varies from 5.1 to 9.9°C, whilst the mean temperature of the coldest month (january) varies between -0.7 and 1.9°C.

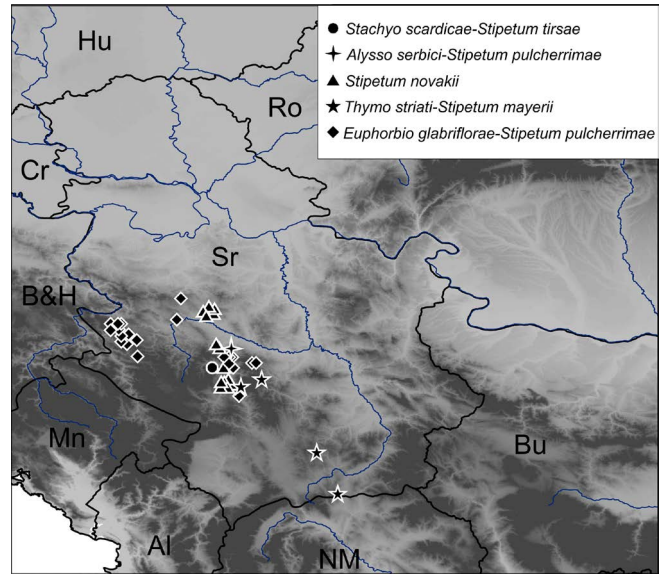

Fig. 1. Map of the study area with the distribution of the relevés belonging to new associations. Legend: Al – Albania, Bu – Bulgaria, B&H - Bosnia and Herzegovina, Cr – Croatia, Hu – Hungary, Gr – Greece, Mn – Montenegro, NM - North Macedonia, and Sr - Serbia.

This climate type is also modified due to the presence of mountains, in which case it is referred to as a variety between a moderately-continental and mountain climate of the Middle European type [type VI 2b/X 1 according to Walter & Leith (1964), 2.1/4.1 according to Stevanović & Stevanović 1995]. On the other hand, the Scardo-Pindian part of the studied area is under the influence of the dry Mediterranean climate (Adriatic and Aegean influences) arriving through gorges and canyons. Here, climatic subtypes with transitions between a Mediterranean and moderately-continental humid climate prevail [IV 5 and IV 6 according to Walter & Leith (1964), 1.2/2.1 and 1.3/2.2 according to Stevanović & Stevanović 1995], with an average of 700 mm of precipitation per year and a pronounced dry (up to two months) and semi-dry period (up to four months). The mean annual temperature varies from 10.5 to 15.8°C, whilst the mean temperature of the coldest month (january) varies between -1.5 and 2°C.

The targeted bedrock in the whole studied area were the ultramafic rocks. Ultramafic rocks are a group of siliceous rocks characterized by calcium deficiency, high concentrations of Al, Fe, Mg, Ni, Co, and Cr, and only a few plant nutrients. Unlike other siliceous rocks, the pH value varies from 5.5-8, making its reaction neutral to basic (sometimes even ultrabasic) (Kruckeberg 2002). As a rule, on this kind of mother rock, the soil layer is skeletoid and poorly developed, while the pedogenesis is slow and incomplete (Walker 1954; Malpas 1992; Kruckeberg 2002), however, on flat terrains, somewhat thicker soils can be formed.

Submediterranean termophilous oriental hornbeam and oak forests on the shallow soils of the Central and Southern Balkans (*Quercetalia pubescenti-petraeae* Klika 1933, Mucina *et al.* 2016) represent the potential vegetation throughout the investigated area. The natural vegetation is considerably degraded due to human impacts, and also erosion on the steep slopes. Human activities regarding land use were very intense in the past on the Balkan Peninsula, resulting in the degradation of the climax forest vegetation and the expansion of secondary grasslands. The ultramafic areas of Serbia and Kosovo were once covered by forests (Pančić 1859), however, this is not usually the case nowadays. Activities such as tree felling, wood logging, resin collecting, the conversion of forest land into cultivated areas, grazing, and even forest fires are the reasons why open habitats with secondary steppe-like grassland vegetation are widespread in these areas today. Moreover, the ultramafics contain commercial deposits of chromium, nickel and other minerals, and have been frequently mined since the Middle Ages (Tatić & Veljović 1992). Accordingly, the vegetation throughout the whole studied area is in secondary state conditions, where open dry grasslands dominate the landscape.

Table 1. Review of new *Stipa*-dominated relevés used for the analyses on third data matrix.

No.	Subnomen	No. of relevés	Locality	Literature source
1	stand with *Stipa epilosa*	5	Ušće	this paper
2	stand with *Stipa mayeri*	6	Kopaonik Krmeljica	this paper
3	stand with *Stipa mayeri*	3	Kopaonik Vlajkovci	this paper
4	stand with *Stipa mayeri*	15	Presevo Miratovac	this paper
5	stand with *Stipa novaki*	5	Brđanska klisura	this paper
6	stand with *Stipa novaki*	5	Maglić grad	this paper
7	stand with *Stipa novaki*	15	Raška Gubavac	this paper
8	stand with *Stipa novaki*	25	Raška Rudine	this paper
9	stand with *Stipa novaki*	10	Raska Trnava	this paper
10	stand with *Stipa novaki*	2	Maglić grad Debelo brdo	this paper
11	stand with *Stipa pulcherrima*	6	Goč	this paper
12	stand with *Stipa pulcherrima*	5	Gokčanica	this paper
13	stand with *Stipa pulcherrima*	3	Brezna	this paper
14	stand with *Stipa pulcherrima*	10	Tara Kremna	this paper
15	stand with *Stipa pulcherrima*	5	Murtenica	this paper
16	stand with *Stipa pulcherrima*	7	Polumir	this paper
17	stand with *Stipa pulcherrima*	4	Zlatibor Mokra Gora	this paper
18	stand with *Stipa pulcherrima*	16	Kopaonik Selište	this paper
19	stand with *Stipa pulcherrima*	5	Suvobor	this paper
20	stand with *Stipa pulcherrima*	7	Tučkovo	this paper
21	stand with *Stipa pulcherrima*	11	Zlatibor Ribničko jezero	this paper
22	stand with *Stipa pulcherrima*	12	Zlatibor Semegnjevo	this paper
23	stand with *Stipa pulcherrima*	10	Stolovi	this paper
24	stand with *Stipa tirsa*	10	Ušće Studenica	this paper

Field sampling and data sampling. During the spring and summer seasons in the years 2011-2015, a total of 213 relevés were sampled within the feather grass steppe-like dry grasslands. The review of these relevés is given in Table 1. Plots were recorded within the stands developed on shallow skeletal soils over the ultramafic bedrock on the territory of Western and Central Serbia and Kosovo. We sampled feather grass grasslands in different stages of succession, so the plant cover within the plots varied from very sparsely vegetated to those with almost closed plant cover.

The precise geographical coordinates for each relevé were obtained using a GPS device (with 10 m precision). The GPS coordinates, together with all other relevé data were stored in the Grassland Vegetation of Serbia Database (GIVD number: EU-RS-002, Aćić *et al.* 2012).

Having in mind the fact that the outcomes of numerical analyses are very sensitive to different plot sizes (see Chytrý & Otýpková 2003; Dengler 2003; Michl *et al.* 2010, etc.), the size of all new relevés was 25 m^2.

Only vascular plants were recorded in the plots, while bryophytes and lichens were omitted both due to identification problems and the fact that these were not recorded in the relevés from the literature used for comparison. Plant cover values were recorded in accordance with the Braun-Blanquet 7 point scale (Braun-Blanquet 1964).

Data analysis and phytosociological methods. Prior to numerical analyses the original cover–abundance values for individual taxa were transformed to an ordinal scale as proposed by van der Maarel (1979). In order to gain insight into the basic structure of the data and reveal the floristic similarities among the analyzed vegetation, we performed numerical analyses. The dataset matrix contained 213 relevés and 203 taxa, encompassing new *Stipa*-dominated relevés from Serbia and Kosovo. Cluster analyses were done in PC-ORD 5.0 (McCune & Mefford 1999) using the relative Euclidean index and the beta-flexible method with $\beta = -0.25$, and square root transformation. The OptimClass method (Tichý *et al.* 2010) was used for identifying the optimal partition. For ordination, DCA analysis was used in order to reveal the basic data structure in two dimensional space. The table sorting was based on the results of cluster analysis and performed using Juice 7.0 (Tichý 2002), but supplemented with the results of SIMPER analyses. The diagnostic species of clusters interpreted as new associations were defined in JUICE by calculating the fidelity of each species to each group, using the phi coefficient as a measure of fidelity. The phi coefficient was calculated based on cover values, using SQRT transformed cover values, and tested with Fisher's exact test ($p=0.05$). The treshold of the phi value was selected at 0.10 for new associations. Species with phi coefficient values higher than 0.10 were considered diagnostic. In this particular case (considering the peculiarities of the vegetation studied) we used the concept of "relative fidelity" allowing us to find the optimum occurrence of a species within the group of floristically similar communities (Willner 2006; Willner *et al.* 2009). This being the case, we calculated the diagnostic value (phi) taking into account the distribution of the species within the group of *Stipa*-dominated relevés as an abstract vegetation unit, containing lower-level units for which diagnostic taxa are to be determined. Species with Braun-Blanquet cover-abundance values ≥3 in any of the relevés for any association were accepted as dominant. Species recorded in a minimum of 60% of the relevés for any association were considered constant. The differences among the clusters were calculated by SIMPER (Similarity Percentage analysis), and the statistical significance of these differences was tested with the non-parametric ANOSIM test (Analysis of Similarities), based on the Bray-Curtis distance (Clarke 1993). The significance was computed by permutation of group membership, with 10.000 replicates. The tests were carried out using PAST version 2.17 (Hammer *et al.* 2001). The analytic tables for new associations present the results of the cluster analysis and table sorting (Supplementary Tables 1–5).

Nomenclature. In general, plant nomenclature and taxonomy followed Flora Europaea (Tutin *et al.* 2001). Taxonomic concepts for *Stipa* species follow Martinovský & Moraldo (1980).

The naming and designation of new syntaxa followed the rules and recommendations of the International Code of Phytosociological Nomenclature (Theurillat *et al.* 2021, ICPN). The syntaxonomic nomenclature of syntaxa above the association rank follows the latest synthesis of European syntaxa of Mucina *et al.* (2016).

RESULTS

Classification and ordination of the studied syntaxa. The cluster analysis separated 5 clusters, divided on the basis of floristic differences, mostly due to the domination of different *Stipa* species in the relevés (Fig. 2). Cluster 1 consisted of 78 relevés mainly dominated by *Stipa novakii* Martinovský, while *Stipa epilosa* Martinovský was dominant in a small number of relevés. Compact cluster 2 included only 10 relevés dominated by *Stipa tirsa* Steven. Cluster 3 encompassed 91 relevés dominated by *Stipa pulcherrima* C. Koch. and the small and compact cluster 4 consisted of 10 relevés also dominated by *S. pulcherrima*. Finally, the last one, Cluster 5 included 24 relevés with the domination of *Stipa mayeri* Martinovský. These groupings obtained in the cluster analysis were also supported by the DCA (detrended correspondence analysis) which separated the obtained groups into two-dimensional ordination space (Fig. 3). A synoptic table was computed in order to emphasize the floristic

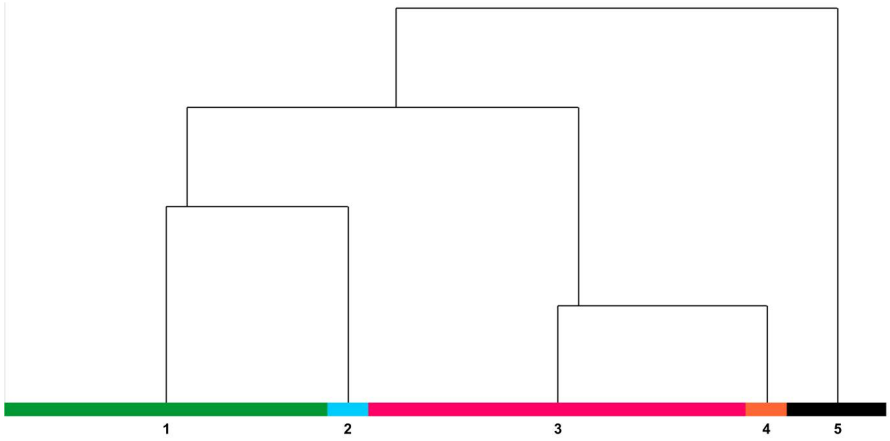

Fig. 2. Cluster analysis on the third data matrix. Cluster 1 - *Stipetum novakii* Kabaš et D. Lakušić 2013; Cluster 2 - *Stachyo scardicae-Stipetum tirsae* ass. nov.; Cluster 3 - *Euphorbio glabriflorae-Stipetum pulcherrimae* ass.nov.; Cluster 4 - *Alysso serbici-Stipetum pulcherrimae* ass. nov.; Cluster 5 - *Thymo striati-Stipetum mayerii* ass.nov.

Table 2. Differences among the synoptic columns (corresponding to associations) depicted by the average dissimilarity (%) and p values. The fields marked in green show statistically significant differences among the columns.

	Stipetum novakii	*Euphorbio glabriflorae-Stipetum pulcherrimae*	*Alysso serbici-Stipetum pulcherrimae*	*Thymo striati-Stipetum mayeri*	*Stahyo scardicae-Stipetum tirsae*
Stipetum novakii	0	82.02	90.50	83.15	82.72
Euphorbio glabriflorae-Stipetum pulcherrimae	0.0001	0	80.63	83.90	85.63
Alysso serbici-Stipetum pulcherrimae	0.0001	0.0001	0	89.29	93.17
Thymo striati-Stipetum mayeri	0.0001	0.0001	0.0001	0	86.46
Stahyo scardicae-Stipetum tirsae	0.0001	0.0001	0.0001	0.0001	0

separation of the groups obtained in the cluster analysis and to improve their characterization (Supplementary Table 6). All of the differences among the synoptic columns (relevé groups) proved to be statistically significant and are shown by the average dissimilarity (%) and *p* values (Table 2).

The new relevés from the *Stipa*-dominated dry grasslands were interpreted as 5 floristically well defined associations from the ultramafics of Serbia and Kosovo (Fig. 2): *Stipetum novakii* Kabaš et D. Lakušić 2013 (Supplementary Table 1), *Stachyo scardicae-Stipetum tirsae* ass. nov., *Euphorbio glabriflorae-Stipetum pulcherrimae* ass. nov., *Alysso serbici-Stipetum pulcherrimae* ass. nov. and *Thymo striati-Stipetum mayerii* ass. nov. (Supplementary Table 6).

Note: The new associations were first published in a doctoral thesis (Kabaš 2016), but since such publications are not availiable to the wider scientific audience, these are considered not to be effective publications [Article 1, ICPN].

Stachyo scardicae-Stipetum tirsae ass. nov.
(*Halacsyetalia sendtneri* Ritter-Studnička 1970, *Potentillion visianii* Ritter-Studnička 1970)
Syn.: *Chrysopogono grylli-Stipetum tirsae* Kabaš 2016 nom. ined. [Art. 1]
Holotypus: rel. 3, Supplementary Table 2, Fig. 4a
Locus classicus: Western Serbia, Ušće, Studenica (N 43.462342°, E 20.57166°)
Dominant species: *Stipa tirsa*.

Diagnosis: The stands of *Stachyo scardicae-Stipetum tirsae* represent perennial dry grasslands, developed on mildly southern exposed ultramafic slopes with an inclination of about 25° (Fig. 4a). The soils are generally poorly developed. However, the stand has very closed vegetation cover of 80-95% (with the exception of one relevé in which the cover is only 20%). All the relevés were recorded at an altitude of about 500 m. The dominant and characteristic species *Stipa tirsa*, as well as *Chrysopogon gryllus,* grow in dense tufts, forming stands of up to 50-70 cm high, with an average cover of 86%. A total of 30 species was recorded in 10 relevés, pointing to the relative floristic poverty of the stands. Nevertheless, endemic serpentinophytes such as *Silene bupleuroides* subsp. *staticifolia, Stachys recta* subsp. *baldacci,* and *Stachys scardica* were recorded, thus indicating the clear influence of the bedrock type on this steppe-like community composition. The habitats were highly degraded, mainly due to grazing, which was very intensive in the past, but also fragmeneted as a result of recent road construction activities. The presence of bushes (*Lembotropis nigricans* and *Juniperus oxycedrus*), as well as woody species (*Fraxinus ornus* and *Quercus pubescens*) could point to the progressive vegetation succession approaching its climax on the one hand, or to inapropriate (abandoned) pasture management on the other.

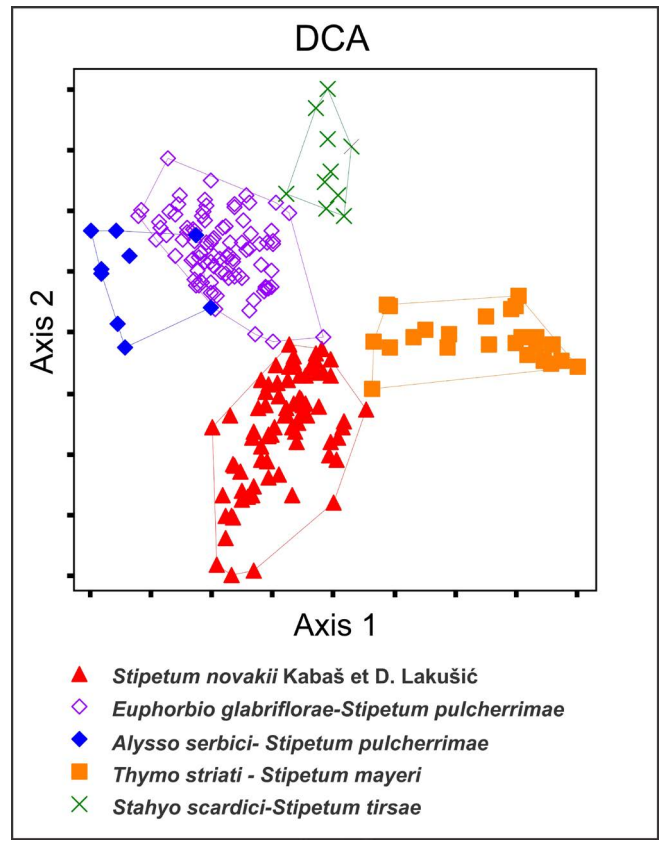

Fig. 3. DCA ordination on the third data matrix.

Euphorbio glabriflorae-Stipetum pulcherrimae ass. nov. (*Halacsyetalia sendtneri* Ritter-Studnička 1970, *Potentillion visianii* Ritter-Studnička 1970)
Holotypus: rel. 1, Supplementary Table 3, Fig. 4b
Locus classicus: Western Serbia, Tara, Kremna (N 43.86183°, E 19.578676°)
Dominant species: *Stipa pulcherrima, Euphorbia glabriflora*.
Diagnosis: The stands of *Euphorbio glabriflorae-Stipetum pulcherrimae* are perennial dry grasslands, developed on ultramafic south-exposed slopes with an inclination of 30-80° (Fig. 4b). The soils are poorly developed, especially on the steep slopes due to soil erosion. All the relevés were recorded at altitudes between 300 and 1000 m. The dominant and characteristic feather grass *S. pulcherrima* grows in dense tufts, forming communities up to 70 cm tall, with the plant cover ranging from 20 to 80%. In the total of 91 relevés assigned to this association 132 species were recorded. In addition to *S. pulcherrima*, the physiognomy of the stand is also shaped by the species *Euphorbia glabriflora*, whose small bushes give the community a recognizable appearance. In addition to *E. glabriflora*, the relevés are also rich in other Balkan serpentine endemics such as *Fumana bonapartei*, *Halacsya sendtneri*, *Stachys recta* subsp. *baldacci* etc. Similar to other localities inhabited by *Stipa*-dominated dry grasslands, the habitats are more or less degraded (defragmeneted, trampled), due to their position being close to roads or tourist centers. Accordingly, these stands represent different transitional pro- or degradational stages of ultramafic rocky grassland vegetation (such as pioneer open habitats on ultramafic rocks in one case, or scrub vegetation in the other).

Note: Since this association was described on the basis of 91 relevés, it was impractical to provide such a large analytical table, so we have provided ten random relevés, including a holotypus, but also synoptic table (Supplementary Table 1), which may serve for a better insight into the floristic and sociological properties of the stands. This association was first described in a doctoral thesis (Kabaš 2016) under the name *Stipa pulcherrima-Euphorbia glabriflora* community.

Alysso serbici-Stipetum pulcherrimae ass. nov.
(*Halacsyetalia sendtneri* Ritter-Studnička 1970, *Potentillion visianii* Ritter-Studnička 1970)
Syn.: *Ornithogalo ortophylli-Stipetum pulcherrimae* Kabaš 2016 nom. ined. [Art. 1]
Holotypus: rel. 5, Supplementary Table 4, Fig. 4c
Locus classicus: Central Serbia, Mt. Stolovi, Ravni sto (N 43.59635°, E 20.65088°)
Dominant species: *Stipa pulcherrima*, *Carex humilis*, *Euphorbia glabriflora*.

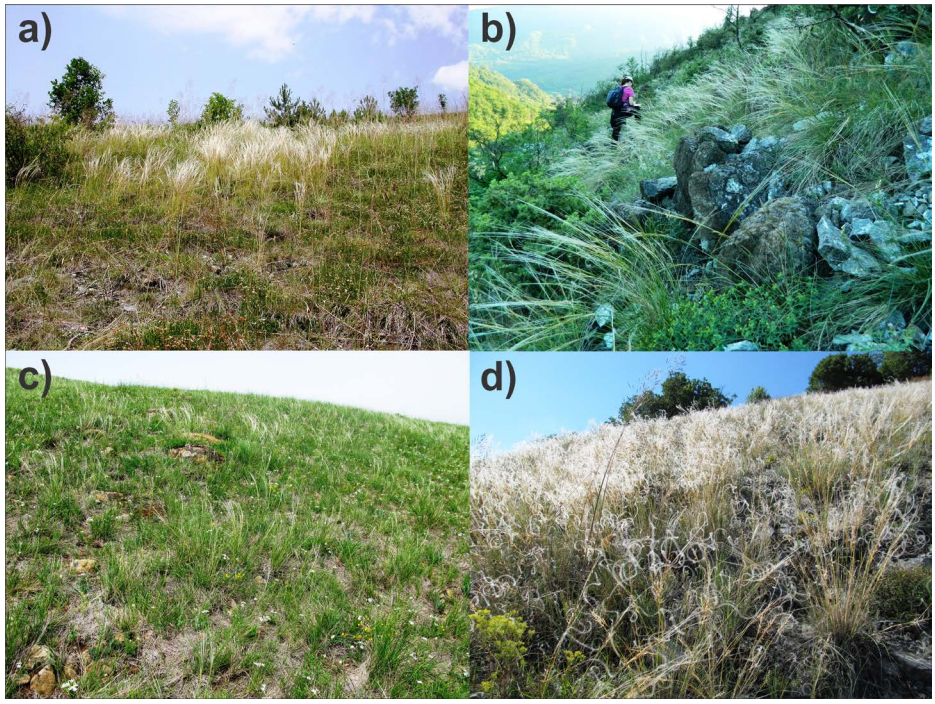

Fig. 4. Stands of new associations: a) *Stachyo scardicae-Stipetum tirsae* ass. nov. from the Studenica locality near Ušće (Photo: Vukojičić S.); b) *Euphorbio glabriflorae-Stipetum pulcherrimae* ass. nov. from the Polumir locality in the Ibar valley (Photo: Stanković V.); c) *Alysso serbici-Stipetum pulcherrimae* ass. nov. from the Ravni Sto locality Mt. Stolovi (Photo: Lakušić D.); d) *Thymo striati-Stipetum mayerii* ass. nov. from the Miratovac locality near Preševo (Photo: Kuzmanović N.).

Diagnosis: The stands of *Alysso serbici-Stipetum pulcherrimae* represent perennial dry grasslands, developed on southern and south-eastern exposed ultramafic slopes with an inclination of 8-35° (Fig. 4c). The soils are as a rule poorly developed, especially on the steeper slopes due to soil erosion. However, on flatter terrains, the soils are better developed and somewhat thicker, so the stands themselves have a higher percentage of vegetation cover. All the relevés were recorded at an altitude of about 1000 m. The dominant and characteristic feather grass *S. pulcherrima* grows in tufts, forming stands up to 50 cm high, with a cover ranging from 70-90% (83% average) of the relevé area. A total of ten relevés were recorded, in which 47 species were noted. The stands of the association are floristically poor, however, the endemic Balkan taxa grow there, such as *Alyssum montanum* subsp. *serbicum*, *Cytisus procumbens* var. *petrovicii, Euphorbia glabriflora*, *Stachys scardica*, etc. The habitats here were highly degraded, especially due to grazing, which was very intensive in the past. These activities, although abandoned, have left a severe mark on the vegetation, resulting in a mosaic of different succesional phases, rich in ecotones such as extensive fertilized pastures, abandoned pastures, rocky steppe-like grasslands and meadow-steppe.

Thymo striati-Stipetum mayerii ass. nov.
(*Halacsyetalia sendtneri* Ritter-Studnička 1970, *Centaureo kosaninii-Bromion fibrosi* Blečić et al. 1969)
Syn.: *Thymo striati-Stipetum mayeri* Kabaš 2016 nom. ined. [Art. 1]

Holotypus: rel. 14, Supplementary Table 5, Fig. 4d
Locus classicus: Southern Serbia, Preševo, Miratovac (N 42.27199°, E 21.6438°)
Dominant species: *Astragalus onobrychis, Euphorbia glabriflora, Stipa mayeri*
Diagnosis: The stands of *Thymo striati-Stipetum mayerii* are perennial dry grasslands, developed on the southern slopes of ultramafic slopes with an inclination of 30-70° (Fig. 4d). The stands of this association are recorded in Southern Serbia, in the Miratovac locality close to Preševo, at an altitude of about 600 m, but also in Central Serbia, on the southern foothills of Kopaonik Mt. in the localities of Vlajkovci (650 m) and Krmeljica (1050 m). The dominant and nominal feather grass *S. mayeri* grows here in dense tufts, forming stands up to 60 cm high, with a vegetation cover varying from 40-90% of the relevé area. Within the total of 24 relevés, 79 species were recorded. The soil horizon was very poorly developed; even within the stands with high cover the outcrops of bare mother rock were visible. Numerous endemic serpentinophytes were recorded in the stands: *Alyssum montanum* subsp. *serbicum*, *Euphorbia glabriflora*, *Chamaecytisus jankae*, *Stachys rhodopaea*, *Silene bupleuroides* subsp. *staticifolia* and *Silene paradoxa*. The stands recorded on Kopaonik Mt. were slightly different, with a high abundance of *Artemisia alba*. These stands represent the initial phases of vegetation succession with lower total cover and some species indicating the pioneer stages, such as: *Artemisia alba*, *Plantago holosteum*, *Silene armeria*, etc. The presence of the relic steppe species *Stipa tirsa* was of particular note, implicating the

steppe-like conditions at the site as well as the steppe-like character of the stand itself.

DISCUSSION

In spite of the fact that feather-grasses play an important role in the formation of dry grasslands on ultramafics (Kabaš 2016), until recently there were no studies dedicated to feather-grass dominated grasslands in particular, and such studies were local in their scope at best (Millaku *et al.* 2011; Kabaš *et al.* 2013). The story becomes even more complicated due to the fact that Balkan *Stipa* representatives (and the genus in general) have very complicated and unstable taxonomy and relations, especialy within the series *Pulcherrimae*, from which five taxa were recorded only within Central Balkan ultramafics (Kabaš 2016). Out of the five species recorded in this study, four were of the *Pulcherrimae*, whilst one was of the *Tirsae* series (*S. tirsa*). All the species formed their stands with almost the same ecology and similar floristic composition thanks to the rather uniform conditions on the ultramafics within the study area. Moreover, certain methodological issues had to be addressed prior to interpreting our results. Firstly, the nature of ultramafic outcrops is such that they have very limited and descrete distribution patterns in nature. In this sense we have the relevés made over a representative area of Central Balkan ultramafics, as our study area. The other issue is that all the new relevés were recorded within one vegetation type - *Stipa*-dominated dry grasslands. We focused our research especially on this type since it is very extensively developed within the study area, and the literature indicated the lack of the data on this open vegetation type on ultramafics (Tatić & Veljović 1992; Jakovljević *et al.* 2011; Aćić *et al.* 2014). Thirdly, the fact that some new syntaxa were described on the basis of a small number of relevés is due to the dominant *Stipa* species having the status of a narrow endemic species, with very limited range or the fact that some of them were recorded for the first time, also within very limited and isolated patches.

Namely, amongst the stands of five different *Stipa*-dominated dry grassland types we have distinguished four new syntaxa on the association level, while the relevés dominated by *S. novaki* were assigned to previously described association *Stipetum novakii* Kabaš et D. Lakušić 2013 (Kabaš *et al.* 2013). Moreover, the results of the classification and ordination analyses have justified five distinctive groups of relevés. Their uniqueness and differences are best depicted in the Synoptic table (Supplementary Table 6), and are suported by the results of the SIMPER analysis and ANOSIM test of significance. Since many species diagnostic for the order *Halacsyetalia sendtneri* (sensu Kuzmanović *et al.* 2016) such as: *Alyssum montanum* subsp. *serbicum*, *Bromus pannonicus*, *Euphorbia glabriflora*, *Potentilla australis*, *Silene bupleuroides* subsp. *staticifolia*, *Silene paradoxa*, *Stachys scardica*, etc. (Table 2), were found withinin the studied vegetation, its position is undoubtedly within this order. The association *Thymo striati-Stipetum mayeri* was classified within the vegetation of the rocky steppic grasslands of Southern Serbia, Kosovo and Northern Albania - *Centaureo kosaninii-Bromion fibrosi*. The dominance of the narrow endemic serpentinophyte *Stipa mayeri*, as well as the geography of the stands, led us to make such a choice. On the other hand, all the other new associations were classified within the *Potentillion visianii* alliance based on floristic properties and distribution. Namely, characteristic species of the *Potentillion visianii* alliance such as *Stipa novakii, Tragopogon pterodes, Haplophyllum boissierianum,* and *Silene serbica*, were abundant within the stands of our new syntaxa (for details see Kuzmanović *et al.* 2016). The fact remains that some of the diagnostic species of new associations, such as *Stipa pulcherrima* and *S. tirsa* are recognized in recent supra-national and even national studies as diagnostic for different higher syntaxa within the *Festuco-Brometea* class (Jovanović-Dunjić 1956; Mucina *et al.* 2016; Willner *et al.* 2019), however, this does not invalidate our results, again due to the specific nature of the ultramafic area and its vegetation. The common and overlapping distribution areas of the *Stipa* species in the Central Balkans are evident, based on which the Balkan territory is considered the center of their diversity (Martinovský & Moraldo 1980), also corresponds with the migration routes of the Pontic flora as a consequence of Quaternary climatic fluctuations (Stoyanoff 1926; Micevski 1971; van der Hammen *et al.* 1971; Follieri *et al.* 1988). It is thus not surprising that several different types of feather grass grasslands were found on this small-scale geographic space. However, what is especially interesting is the fact that *Stipa*-dominated stands tend to develop very extensively over ultramafic bedrocks, which seem to serve them as specific refugia where steppe relics are able to survive (Kabaš 2016; Kabaš *et al.* 2017, 2018).

Syntaxonomical scheme of the studied vegetation

Festuco-Brometea Br.-Bl. et Tx. ex Soó 1947
Halacsyetalia sendtneri Ritter-Studnička 1970
Potentillion visianii Ritter-Studnička 1970

1. *Stipetum novakii* Kabaš et D. Lakušić 2013.
2. *Stachyo scardicae-Stipetum tirsae* ass. nov.
3. *Euphorbio glabriflorae-Stipetum pulcherrimae* ass. nov.
4. *Alysso serbici-Stipetum pulcherrimae* ass. nov.

Centaureo kosaninii-Bromion fibrosi Blečić et al. 1969

5. *Thymo striati-Stipetum mayerii* ass. nov.

CONCLUSION

Although these stands are dominated by different *Stipa* species, their ecology, physiognomy and floristic composition are rather similar. Ultramafic bedrock, as their common denominator, tends to uniform this vegetation with the same complex of ecological factors. Developing in specific conditions of eroded and poorly developed soils, in secondary landscapes, these stands were unable to reach their full potential in terms of their sociology and floristic diversity. That is why they could not be characterized with a large (sufficient) number of highly diagnostic species, while on the other hand, the breakthrough of the species from surrounding non-ultramafic dry grassland vegetation is obvious and intensive. However, no matter how much alike these communities are, it is important to recognize and describe them, in the light of their relic and endemic value, as well as to determine their syntaxonomic position. Hence, our new associations may be considered to represent the fragments of relic extrazonal steppe vegetation in relict habitats (sensu Mucina 2016).

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REZIME

Botanica SERBICA

Fitocenologija stepolike vegetacije sa dominacijom vrsta roda *Stipa* na ultramafitima Centralnog Balkana

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Uprkos činjenici da su suvi travnjaci na ultramafitskoj podlozi bili predmet kontinuiranih istraživanja u prethodnim vekovima, i dalje nedostaju podaci o inicijalnim stadijumima vegetacije na ovim substratima. Suvi travnjaci sa dominacijom vrsta roda *Stipa* koji u Srbiji i na Kosovu predstavljaju različite inicijalne faze u obrastanju ultramafitskih stena su bili objekat ove studije. Napravljeno je ukupno 213 fitocenoloških snimaka u različitim stepolikim travnjacima sa dominacijom vrsta roda *Stipa* na području Srbije i Kosova, i oni su analizirani i stavljeni u kontekst suvih balkanskih travnjaka iz klase *Festuco-Brometea*. Urađena je klasifikacija (klaster analiza) i ordinacija snimaka u cilju njihove florističke i sintaksonomske karakterizacije i uvida u strukturu njihovog grupisanja. Za opisivanje novih asocijacija korišćen je koncept "relativne vernosti" koji je omogućio pronalaženje optimalnog javljanja vrste u okviru grupe floristički sličnih zajednica. Prag phi vrednosti je postavljen na 0,1 za nove asocijacije. Opisane su četiri nove asocijacije: *Stachyo scardicae-Stipetum tirsae* ass. nov., *Euphorbio glabriflorae-Stipetum pulcherrimae* ass. nov., *Alysso serbici-Stipetum pulcherrimae* ass. nov. and *Thymo striati-Stipetum mayerii* ass. nov. Snimci u kojima je dominirala *S. novakii* su dodeljeni prethodno opisanoj asocijaciji *Stipetum novaki* Kabaš et D. Lakušić 2013. Prve tri nove asocijacije su svrstane u svezu *Potentillion visianii*, dok je poslednja klasifikovana unutar sveze *Centaureo kosaninii-Bromion fibrosi* u okviru vegetacijskog reda *Halacsyetalia sentneri*.

Ključne reči: suva travna staništa, *Festuco-Brometea*, *Halacsyetalia sendtneri*, relikt, sintaksonomija