Scale-dependent species diversity in a sandy dry grassland (*Festucion vaginatae*) of Vojvodina (Serbia)

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Abstract: We analysed a stand of Pannonian subcontinental fescue sandy grassland in the Deliblato Sands (Deliblatska peščara; South-Eastern Banat, Vojvodina, Serbia) with nested-plot sampling on areas from 0.0001 to 100 m² (= "EDGG biodiversity plot"). The stand belongs to the class *Koelerio-Corynephoretea*, order *Sedo acris-Festucetalia* (syntax. syn.: *Festucetalia vaginatae*) and alliance *Festucion vaginatae*. Mean species richness values (e.g. 27.5 species on 10 m², with 25.0 vascular plants and 2.5 non-vascular plants) were low (only about 25%) compared maximum values known from other European dry grasslands at the different scales, but they matched well data of base-rich sandy grasslands in other parts of Europe. Only the diversity contribution of bryophytes and lichens (less than 10% on 10 m²) was unusually low for that type of vegetation. The overall species-area relationship had a *z*-value of 0.177, which indicates low species turnover (low beta-diversity). As in other studies the specific *z*-value of vascular plants was much higher than that of non-vascular plants. This paper sheds a first light on scale- and taxon-dependent phytodiversity patterns in Serbian grasslands and calls for more extensive follow-up studies.

Keywords: alpha diversity; beta diversity; biodiversity; *Festucetalia vaginatae*; *Koelerio-Corynephoretea*; *Sedo acris-Festucetalia*; species-area relationship (SAR); species richness; syntaxonomy

Nomenclature: Euro+Med (2006–2015) for vascular plants.

Abbreviations: ICPN = International Code of Phytosociological Nomenclature (Weber et al. 2000)

Introduction

Dry grasslands of Europe host a particularly big fraction of the biodiversity of the continent (Vrahnakis et al. 2013; Dengler et al. 2014), while at the same time they are highly threatened and thus of high conservation priority (WallisDeVries et al. 2002; Janišová et al. 2011; Baumbach & Pfützenreuter 2013; European Commission 2013). Various semi-natural dry grassland types of Europe have been demonstrated to hold the highest small-scale vascular plant species richness globally for grain sizes below 100 m² (Wilson et al. 2012; Chytrý et al. 2015), but they also can have outstanding diversity of bryophytes and lichens (e.g. Boch & Dengler 2006; Löbel & Dengler 2008).

Serbia, a land-locked country located in SE Europe and partly belonging to Central Europe (north of the Danube) and partly to the Balkan Peninsula (south of the Danube), despite its relatively small size of less than 90,000 km² has a very rich flora (see Stevanović et al. 1995), with 3,730 known vascular plant species and subspecies (Tomović 2007). Vegetation diversity is also high with approximations ranging from about 600 to 1,200 plant communities (Lakušić 2005). Regarding grasslands, the most abundant are semi-natural types, formed in the forest zone as a consequence of deforestation, while there are also natural grasslands, distributed as final vegetation stage on places inappropriate for forest development, including high-mountainous (above timberline) areas, flooded land in lowland valleys and xeric steppe and/or salinized habitats in the northern part of the country (Vojvodina) (Dajic Stevanovic et al. 2010). Major research on grassland biodiversity in Serbia started in 1950s and was conducted with the Braun-Blanquet approach, resulting in many remarkable reports on floristic and vegetation diversity of different geographic areas of the country (see Kojić et al. 2004). However, for a long time vegetation classification in Serbia developed relatively independently from the rest of Europe,

resulting in idiosyncratic classification schemes. Only recently increasing efforts have been made to place the Serbian vegetation diversity into a European context, most remarkably for saline grasslands (Eliáš et al. 2013). Also the recent works by Aćić et al. (2014, 2015) for nomenclatural and syntaxonomic revision of the dry grasslands at a national scale can be seen as a first, important step towards European integration.

While in other European regions, diversity patterns of dry grasslands have been extensively studied (see reviews by Dengler 2005; Dengler et al. 2014), only little is known from Serbia so far. The analysis of the alpha diversity (total species number) of the classes of grassland vegetation s.l. of Serbia showed that the highest and lowest floristic richness was found in the *Festuco-Brometea* and *Salicetea herbaceae*, respectively (Dajic Stevanovic et al. 2010).

Here we took the opportunity of the preparatory meeting for the EDGG Field Workshop 2016 in Belgrade in June 2015, to carry out a first sampling of the so-called "EDGG biodiversity plots" (Turtureanu et al. 2014) with the aim to document scale- and taxon-dependent diversity patterns in Serbian grasslands. For this purpose we chose the Special Nature Reserve "Deliblato Sands" northeast of the capital, and there a stand belonging to the alliance *Festucion vaginatae* (Pannonian sandy dry grasslands). This is at the same time a priority habitat of the European Union: 6260 = * Pannonic sand steppes (European Commission 2013). In the following, we give some first insights into synthaxonomy, species richness patterns and species-area relationships of these grasslands in Serbia. At the same time, our contribution can be seen as an "appetizer" to attend next year's EDGG Field Workshop in Serbia, where many more and diverse grasslands will be studied by an international expedition team (see Vrahnakis et al. 2013; Biurrun et al. 2014).

Study area

The sampling took place on an open sand dune 3 km northeast of the village Deliblato, Vojvodina, Serbia (44.86457° N, 21.05903° E, precision: 10 m, elevation: 142 m a.s.l.) on 6 June 2015. This dune belongs to the Special Nature Reserve "Deliblato Sands" (Deliblatska peščara). This Special Nature Reserve is a unique geomorphological and biogeographical phenomena and one the largest inland sand dune systems in Europe. It is located in South-Eastern Banat, in the northern Serbian province of Vojvodina. The protected area spreads over 34,829 ha (348 km²) in southeast-northwest direction. It is characterized by specific geological structure – thick layers of silica-carbonate sand originating from the Pleistocene (Butorac et al. 2002). The wind *Košava* has shaped an impressive and unique dune relief, with altitudes between 70 and 200 m.

The unusual relief and soil substrates, with a moderate continental climate and the absence of surface waters has caused the formation of diverse specialised phytocoenoses. The specificity of the Deliblato Sands is sandy open and forest-steppe vegetation, but also wetlands and aquatic vegetation on the banks of the Danube. As the largest oasis of sands in the Pannonian Basin, the Special Nature Reserve "Deliblato Sands" is an important center of biological diversity of Europe and the most important sand-steppe area in Serbia. First fragments of this area were protected in 1912, while the Nature Reserve was founded in 1977, and transformed into a Special Nature Reserve by the Government of the Republic of Serbia in 2002. The Deliblato Sands are also Important Bird Area (since 1989).

The Deliblato Sands are an example of a large and long-term human commitment to overcoming natural processes, which he caused by irrational management of natural habitats in the past. Almost 150 years ago, this commitment was reflected in the actions of preventing the movement of sand mass from the Deliblato Sands to the fertile agricultural soils of the surrounding Pannonian Basin. However, today more than half the surface of the Deliblato Sands is overgrown with planted forests of *Robinia pseudoacacia* and pines. Afforestation, changes in the water regime and the lack of management in the protected areas of sand and steppe allowed the expansion of shrub vegetation and further succession, which led to the reduction in numbers or even regional extinction of typical steppe and sand species.

Methods

One square plot of 100 m² was delimited in a homogenous part of the vegetation, following the modified version of Dengler (2009b) by Turtureanu et al. (2014). We recorded complete species composition (vascular plants, terricolous bryophytes and lichens) with the any-part system (see Dengler 2008) for two nested-plot series in the NW and SE corner for areas of 0.0001, 0.001, 0.01, 0.1, 1 and 10 m² as well as for the whole 100 m². Species cover (in %) was estimated for the two 10-m² plots, where also environmental parameters were assessed and a mixed soil sample of the uppermost 10 cm drawn for soil analyses (pH in water, skeleton).

The species composition was compared with lists of diagnostic species provided from both regional and supraregional sources to find the proper syntaxonomic placement to allow a placement in the syntaxonomic system. The species richness data for the seven different grain sizes were compared to literature data and used to construct a species-area relationship, as power-law function in the linearized version ($\log_{10} S \sim \log_{10} A$, where S is the species richness and A the area in m²; Dengler 2009a). The vegetation-plot data (RS01) are stored in and available from the *Database Species-Area Relationships in Palaearctic Grasslands* (GIVD ID EU-00-003; Dengler et al. 2012b) and in the *Balkan Dry Grassland Database* (GIVD ID EU-00-013; Vassilev et al. 2012).

Fig.1: Sampled 100-m² biodiversity plot (RS01), belonging to the allliance *Festucion vaginatae* near Deliblato, Vojvodina. Below two aspects of the community with some typical species. Left: *Stipa borysthenica*, *Festuca vaginata*, *Astragalus onobrychis*; right: *Koeleria glauca*, *Artemisia campestris*, *Euphorbia seguierana* and *Dianthus gigantiformis* (Photos: J. Dengler, 2015/06).

Results and discussion

Syntaxonomy

There is a broad agreement that the perennial-dominated grasslands of base-rich sands from the Pannonian Basin belong to the alliance *Festucion vaginatae*. However, regarding the placement of this alliance into the syntaxonomic system, opinions diverge from subordinating it to the *Festuco-Brometea* (e.g. Mucina & Kolbek 1993; Aćić et al. 2015), or the *Koelerio-Corynephoretea* (e.g. Borhidi 2003) or placing it into a class of its own, *Festucetea vaginatae* (e.g. Stanová 1995; Sanda et al. 2006; Chytrý 2007). However, these treatments usually just follow their national traditions, without statistical evaluation at national or supra-national level. By contrast, J. Dengler compiled an extensive set of synoptic tables of all dry grassland classes across Europe to evaluate their floristic relationships (unpublished; but see selected results in Dengler 2001, 2003), according to which the connection of the *Festucion vaginatae* to the class *Koelerio-Corynephoretea* is largely predominant, and neither a subordination to the *Festuco-Brometea*, nor a class of its own seem to be justified.

Within the *Koelerio-Corynephoretea*, the *Festucion vaginatae* belongs to a group of closely related syntaxa on base-rich, very dry and very nutrient-poor sands under subcontinental to continental climate. Three

vicariant alliances with perennial tussock grasses can be distinguished, *Koelerion glaucae* (Germany, Poland, Czech Republic, N Ukraine, countries surrounding the Baltic Sea), *Festucion vaginatae* (Pannonian Basin) and *Festucion beckeri* (S Ukraine), plus one or two pioneer alliances, dominated by annuals (*Sileno conicae-Cerastion semidecandri*, *Bassio laniflorae-Bromion tectorum*). The three "perennial" alliances are dominated by the tussock grasses *Koeleria glauca* and *Stipa borysthenica* (throughout most of the range) and by various vicariant species of *Festuca ovina* agg., mostly from Ser. *Psammophilae*, namely *F. polesica*, *F. psammophila*, *F. tomanii* (*Koelerion glaucae*), *F. vaginata*, *F. wagneri* (*Festucion vaginatae*) and *F. beckeri* (*Festucion beckeri*). Despite the stands of these three alliances are floristically, physiognomically and ecologically very similar, this has hardly ever been reflected in syntaxonomic classification, probably because most researchers did not know this community type throughout its entire range. Only Dengler (2001, 2003, 2004) proposed to join all four to five alliances in one order, which according to priority rules then should be named *Sedo acris-Festucetalia* Tx. 1951 nom. invers. propos. (for nomenclature, see Dengler et al. 2003), of which *Festucetalia vaginatae* Soó 1957 would become a younger syntaxonomic synonym. Note that originally the *Festuco-Sedetalia acris* also contained an alliance of meso-xeric sandy grasslands (*Armerion elongatae*), which now normally is placed into a separate order (*Trifolio arvensis-Festucetalia ovinae*) together with other meso-xeric sandy grasslands of Europe (e.g. Schaminée et al. 1996; Dengler 2004; Pedashenko et al. 2013).

The stands in Vojvodina confirm the placement into the *Koelerio-Corynephoretea* because diagnostic species of that class clearly prevail over those of the *Festuco-Brometea* (Table 1). They are particularly similar to the association *Jurineo-Koelerietum glaucae* of the Upper Rhine Valley (Korneck 1974), which have been visited during the European Dry Grassland Meeting 2015 (Becker & Becker 2015). Important joint taxa are *Koeleria glauca*, *Euphorbia seguierana*, *Alyssum montanum* subsp. *gemlinii*, *Artemisia campestris*, *Cerastium semidecandrum*, *Bassia laniflora*, *Galium verum*, *Cynodon dactylon, Fumana procumbens* and the dominant species of the cryptogam layer, *Syntrichia ruralis* agg., while the genera *Festuca*, *Jurinea* and *Silene* are represented by vicariant species (*Festuca tomanii*, *Jurinea cyanoides* and *Silene conica* in the Upper Rhine Valley vs. *F. vaginata*, *F. wagneri*, *J. mollis* and *S. subconica* in Vojvodina).

In the past (Stjepanović-Veseličić 1956, 1957, 1979; Parabućski et al. 1986), fescue sandy grassland communities in Serbia had been defined by their

Table 1.: Vegetation table of the two 10-m² plots in the NW and SE corner of the 100-m² biodiversity plot. Performance of species is given in percentage cover. Species are grouped into the following functional-taxonomic groups: VW = vascular plant, wood; VG = vascular plant, graminoid, VL = vascular plant, legume, VF = vascular plant, other forb, B = bryophyte, L = lichen. Character and differential species are

		Subplot	NW	SE
		Land use	no	no
		Aspect (°)	135	-
		Inclination (°)	1	0
		Microrelief (cm)	10	4
		pH (H_2O)	8.23	8.15
		Soil texture class	Sand	Sand
		Skeleton content of the soil (%)	0.0	0.0
		Cover vegetation (%)	85	92
		Cover herb layer (%)	60	60
		Cover cryptogam layer (%)	55	70
		Cover litter (%)	50	NA
		Species richness (total)	**29**	**26**
		Species richness (vascular plants)	26	24
		Species richness (non-vascular plants)	3	2
Alliance: *Festucion vaginatae*				
C	VG	*Festuca vaginata*	1.5	5
C	VG	*Festuca wagneri*	.	15
C	VF	*Centaurea arenaria*	2	.
C	VF	*Trogopogon floccosus*	0.1	.
C	VG	*Bromus squarrosus*	.	0.02
D	VG	*Festuca rupicola*	3	15
D	VG	*Carex liparocarpos* subsp. *liparocarpos*	5	8
C	VF	*Fumana procumbens*	5	4
D	VG	*Cynodon dactylon*	5	.
D	VF	*Erysimum diffusum*	.	0.02
Order: *Sedo acris-Festucetalia*				
C	VF	*Euphorbia seguierana*	20	8
C	VG	*Koeleria glauca*	3	5
C	VG	*Stipa borysthenica*	5	2
C	VF	*Bassia laniflora*	0.01	0.1
C	VF	*Silene subconica*	0.01	0.01
C	VF	*Alyssum montanum* subsp. *gmelinii*	.	0.02
D	VG	*Poa bulbosa*	2	1
Subclass: *Koelerio-Corynephorenea*				
C	VF	*Cerastium semidecandrum*	1	1
Class: *Koelerio-Corynephoretea*				
C	B	*Syntrichia ruralis* agg.	25	25
Joint species of the classes *Koelerio-Corynephoretea* and *Festuco-Brometea*				
D	VF	*Artemisia campestris*	10	5
D	VF	*Galium verum*	.	1
D	L	*Cladonia pyxidata* agg.	0.05	.
Class: *Festuco-Brometea* and subordinate units				
	VG	*Botriochloa ischaemum*	25	7
	VF	*Jurinea mollis*	0.5	0.1
	VF	*Scabiosa ochroleuca*	0.2	0.3
	VF	*Thymus pulegioides subsp. pannonicus*	0.5	.
	VF	*Dianthus giganteiformis*	0.2	.
	VF	*Allium flavum*	0.1	.
Other companion species				
	B	*Tortella tortuosa*	30	45
	VF	*Minuartia verna*	3	5
	VF	*Crepis foetida* subsp. *rhoeadifolia*	1	0.2
	VF	*Minuartia glomerata*	1	0.2
	VF	*Echinops ritro* subsp. *ruthenicus*	0.5	0.3
	VF	*Clinopodium acinos*	0.5	.

Table 2: Maximum richness values found in this study (RS) compared to the documented maximum richness values in European grasslands (EU).

Plot size [m²]	RS all species	RS vascular plants	EU vascular plants	Ratio RS / EU	Country	Alliance	Reference
0.0001	3	1	7	14%	Ukraine**	*Agrostio-Avenulion schelliae & Stipion lessingianae*	Kuzemko et al. (2014)
0.001	4	2	12	17%	Sweden*	*Filipendulo-Helictotrichion*	van der Maarel & Sykes (1993)
0.01	8	6	25	24%	Estonia*	*Filipendulo-Helictotrichion*	Kull & Zobel (1991)
0.1	14	12	43	28%	Romania*	*Cirsio-Brachypodion*	Dengler et al. (2012a)
1	23	20	82	24%	Czechia	*Cirsio-Brachypodion*	Chytrý et al. (2015)
10	29	26	98	27%	Romania*	*Cirsio-Brachypodion*	Dengler et al. (2012a)
100	38	35	133	26%	Czechia	*Cirsio-Brachypodion*	Chytrý et al. (2015)

geographical origin and distribution: *Festucetum vaginatae deliblaticum* Stjepanović-Veselčić 1953 (Deliblato Sands), *Festucetum vaginatae danubiale* Soó 1929 (sandy areas near Subotica), *Festucetum vaginatae kladovense* Stjepanović-Veselčić 1956 and *Festucetum vaginatae ramo-požežense* Stjepanović-Veselčić 1956 (on sands in Eastern Serbia), but these names are all illegitimate according to Art. 34a of the International Code of Phytosociological Nomenclature (ICPN; Weber et al. 2000).

According to Stjepanović-Veselčić (1956), sand vegetation of Deliblato Sands and the sands of eastern Serbia can be grouped into a single community *"Alyseto-Festucetum vaginatae"* Stjepanović-Veselčić 1956. As Aćić et al (2014) indicated, according to the ICPN, this original name must be orthographically corrected to *Alysso gmelini-Festucetum vaginatae* Stjepanović-Veselčić 1956.

If we consider the high coverage of such species as *Botriochloa ischaemum*, *Euphorbia seguierana*, *Artemisia campestris*, *Syntrichia ruralis* agg. and *Tortella tortuosa*) as well as the relief position (plateau between the slopes of the dunes), we can accept the proposal of Stjepanović-Veselčić (1979) for segregation of a subassociation defined by mosses. It should be noted that typical species of pioneer, mobile sands (*Festuca vaginata*, *Koeleria glauca*) under such conditions lose vitality and are replaced by *Artemisia campestris*, *Botriochloa ischaemum* and later *Stipa borysthenica*. In this subassociatoin, the sand is less exposed to the wind, it is stable and thus conditions are created for further succession towards steppe vegetation of the *Festucion valesiacae* (*Festuco-Brometea*), which indeed occupied some nearby patches that were even more stable, more humus rich and probably also richer in fine-soil fractions.

In the past (Stjepanović-Veselčić 1956, 1957, 1979; Parabućski et al. 1986), fescue sandy grassland communities in Serbia had been defined by their geographical origin and distribution: *Festucetum vaginatae deliblaticum* Stjepanović-Veselčić 1953 (Deliblato Sands), *Festucetum vaginatae danubiale* Soó 1929 (sandy areas near Subotica), *Festucetum vaginatae kladovense* Stjepanović-Veselčić 1956 and *Festucetum vaginatae ramo-požežense* Stjepanović-Veselčić 1956 (on sands in Eastern Serbia), but these names are all illegitimate according to Art. 34a of the International Code of Phytosociological Nomenclature (ICPN; Weber et al. 2000).

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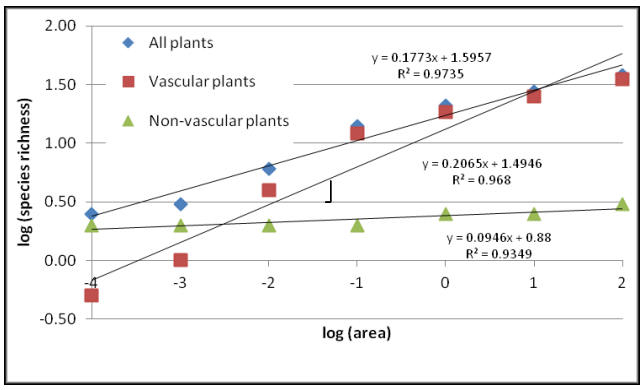

Fig. 2 Species-area relationships in double-log representation for the averaged richness values of both corners together

Species-area relationships

With a *z*-value of 0.177 (Fig. 2), our stands are more homogenous (have less species turnover or lower beta-diversity) than most other European dry grasslands, for which *z*-values of 0.193–0.249 (Dengler 2005) and 0.174–0.278 (Dengler & Boch 2008) are reported. As frequently reported (Dengler & Allers 2006; Hopp & Dengler 2015 in this issue), also in our case the *z*-value of the vascular plants alone (0.207) was much higher than that of the non-vascular plants (0.095).

Outlook

This short article provides, based on a single "EDGG biodiversity plot", a first glance at the scale- and taxon-dependent phytodiversity patterns of the grasslands in Serbia. However, the country has a very diverse dry grassland vegetation (Aćić et al. 2015), so that similar studies in other grasslands types and regions of the country appear promising and important to understand how small-scale biodiversity patterns emerge and are maintained, what the average richness values are and where maximum richness values can be found. Here the next EDGG Field Workshop, scheduled for summer 2016 in Serbia, provides the opportunity to get involved in these baseline studies. Details on the Field Workshop (dates, prices, itinerary, registration) will be published in this or the next issue of the EDGG Bulletin.

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Stipa borysthenica. Photo: A.Kuzemko