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EVALUATION OF QUALITY OF SEMI-NATURAL GRASSLANDS OF CENTRAL SERBIA UPON PHYTOSOCIOLOGICAL AND NUMERICAL ANALYSIS

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Abstract: The aim of this paper is to present a numeric-statistical model by which it is possible to evaluate the quality of the observed grassland upon floristic and vegetation assessment. Thanks to this new methodological approach, the impact of each individual plant species on overall quality of the grassland could be estimated. The main goal was to determine species which significantly determine the pastoral value of the grassland. The quality (pastoral value) of the grassland was calculated using the numerical values of quality index of each individual species of each relevé of the community. For testing this numerical method, the total of 11 relevés of 4 grassland communities of hilly-mountainous area of Mt. Kopaonik was used. Analyzed vegetation includes previously unpublished phytocenological relevés as result of our own field research. All analyzed relevés were obtained using the method of the Swiss-French phytocenological school. The results showed that the best and the worst quality were determined for the ass. *Festuco-Brometum erectii*, and the ass. *Nardetum strictae*, respectively. Species that highly contributed to good and bad quality of grassland were *Arrhenatherum elatius, Festuca rubra, Dactylis glomerata, Trifolium repens*, etc., and *Carduus alpestris, Hieracium hoppeanum, Ornithogalum umbelatum*, respectively

Key words: semi-natural grasslands, numerical index of grassland quality, numerical assessment of grassland quality, pastoral value, cluster analysis, multivariate analysis.

Introduction

Grasslands are one of the most important ecosystems. During the last century in developed countries their utilization shifted from weakly exploited areas into productive resources equal to any crop production (*Kemp and Michalk, 2007*). Considering their high distribution in Serbia, at about 1.4 million ha, grasslands have great importance both for grazing and biodiversity conservation, as indicated

that hilly-mountainous (semi) natural grasslands are the floristically richest vegetation units in the country (*Dajic Stevanovic et al., 2010*). Moreover, the most presented grassland communities of Serbia were also evaluated for high diversity and considerable stocks of medicinal and aromatic plants (*Dajić et al., 2000*).

Distribution, quality and botanical composition of pastures and meadows largely depend on the management, whereas excessive utilization, such as over-grazing and fertilization at one point, and abandonment from the other, cause dramatic effects on floristic and vegetation diversity (*Dajić Stevanovic et al., 2010*). Mt. Kopaonik, the largest in the central Serbia, is known for long tradition in use of semi-natural meadows and pastures, encompassing the height gradient between 450 and 2017 m a.s.l., above the upper forest zone, where form the final stage of vegetation formation. According to information gathered from local population, each of 11 studied grasslands was or is still used either for grazing or mowing. In order to evaluate the quality of meadows and pastures of the Mt. Kopaonik for forage production, researchers from the Institute for forage crops from Krusevac, Serbia, have been conducting numerous experiments starting from 1960's (*Đorđević and Radojević, 1968, Stošić 1973*), until today (*Lazarević et al., 2009*). The quality of grasslands was evaluated through chemical parameters of dry matter and botanical composition. Indirect evaluation of a grassland quality using pastoral value of each individual species was applied by different authors (*De Vries et al., 1942, with a scale of quality indices from 0 to10; Klapp et al. 1953, scale from -1 to 8; Jurko, 1990, scale from -3 to 5; Dajic Stevanovic et al., 2008, scale from -2 to 10, etc*). Upon application of numerical values as indicators of a quality of the grassland within its phytocoenological relevés, it is possible to obtain an indirect evaluation of the grassland quality and the impact of individual species on total pastoral value, which could facilitate decision-making in proper grassland's use, including application of various agricultural practices.

The aim of this study was the testing of numeric-statistical model applied on set of phytocoenological relevés of semi-natural grasslands of the Mt. Kopaonik to estimate the quality of each grassland community, as well as to evaluate the significance of particular species, mainly indicators of particular functional groups, within the total pastoral value of a community.

Materials and methods

The sampling of the phytocenological records was conducted in area of Mt. Kopaonik in central Serbia and was performed on 11 plant communities distributed at higher mountain zone, between 1400m and 1700m a.s.l. Phytocenological approach of Braun-Blanquet from 1964 was used, whereas species nomenclature followed "Flora of Serbia" (*Josifović*, *1970-1977*). The collected relevés belong to the following grassland communities: *Agrostietum vulgaris* (relevés no. 3,4,5,6 and 9 in Table 1.)*, Festucetum rubrae* (relevés no. 8 and 10 in Table 1.)*, Festuco-Brometum erecti* (relevés no. 7 in Table 1.) and *Nardetum strictae sensu lato*. (relevés no. 1,2 and 11 in Table 1.)

Table 1: 11 phytosociological relevés, and 24 of 37 species which number of occurrences are greater than in four relevés . Quality of each grassland (releve), the quality of each single species, influence of each species on grassland quality, membership of species to clusters are shown.

Species	Phytocenologicel relevés											The quality of species	Species impact on grassland quality											Average species impact	Cluster
	1	2	3	4	5	6	7	8	9	10	11		1	2	3	4	5	6	7	8	9	10	11		
Agrostis vulgaris	0	0	3	2	3	3	0	0	2	1	1	4	0	0	22	7.4	13	16	0	0	11	2.4	3.8	10.9	I
Arrhenatherum elatius	1	1	0	0	1	+	1	0	1	0	0	8	7.8	7.7	0	0	5.9	2.7	6	0	9.7	0	0	6.6	II
Festuca rubra	1	1	2	2	0	1	0	2	+	1	1	4	2.3	2.2	8.8	7.4	0	1.7	0	6.8	0	2.4	3.8	4.4	II
Dactylis glomerata	0	0	+	+	+	1	0	+	0	1	+	8	0	0	3.1	2.9	2.3	6.8	0	2.9	0	8.4	4.4	4.4	II
Trifolium repens	+	+	+	1	0	0	0	0	0	+	0	8	3.1	3	3.1	7.4	0	0	0	0	0	3.3	0	4	II
Anthoxanthum odoratum	1	1	+	+	0	+	0	0	2	1	+	4	2.3	2.2	0.9	0.8	0	0.7	0	0	11	2.4	1.5	2.7	II
Lathyrus pratensis	+	+	0	0	0	0	0	+	+	+	+	6	2	1.9	0	0	0	0	0	1.8	2.5	2.1	2.9	2.2	II
Trifolium alpestre	0	0	0	0	+	+	1	+	0	+	0	6	0	0	0	0	1.4	1.7	3.6	1.8	0	2.1	0	2.1	II
Lotus corniculatus	+	+	0	0	0	+	+	0	0	0	+	6	2	1.9	0	0	0	1.7	1.4	0	0	0	2.9	2	II
Briza media	0	0	0	0	+	0	0	1	1	1	+	4	0	0	0	0	0.6	0	0	1.8	2.9	2.4	1.5	1.9	II
Leontodon hispidus	1	1	0	0	1	0	+	0	0	0	+	4	2.3	2.2	0	0	1.5	0	0.5	0	0	0	1.5	1.6	II
Vicia villosa	0	0	0	0	1	1	1	0	+	1	0	4	0	0	0	0	1.5	1.7	1.3	0	1.1	2.4	0	1.6	II
Veratrum album	0	0	0	+	+	1	0	0	1	1	1	-2	0	0	0	-2.4	-2	-6	0	0	-7.2	-6.5	-7.4	-5.3	III
Hypericum maculatum	1	0	+	1	0	0	0	0	1	0	+	-2	-6.1	0	-2.3	-6.1	0	0	0	0	-7.2	0	-2.9	-4.9	III
Genista sagittalis	2	2	1	+	0	+	1	1	0	+	1	0	-12	-12	-3	-1.3	0	-1.4	-3.4	-3.8	0	-1.4	-3.7	-4.7	III
Hypericum perforatum	0	1	0	0	0	+	+	+	0	+	0	-2	0	-5.9	0	0	0	-2.4	-2.2	-2.6	0	-2.5	0	-3.1	III
Nardus stricta	2	2	0	0	0	0	0	0	0	0	2	2	0.1	-1.9	0	0	0	0	0	0	0	0	-1.9	-1.8	IV
Bromus erectus	0	0	+	+	0	+	1	0	0	+	0	4	0	0	1.1	0.7	0	0.7	1.5	0	0	0	0	1	IV
Carduus alpestris	0	0	R	R	1	+	0	1	1	0	0	0	0	0	-0.6	-0.7	-3	-1.4	0	-3.8	-3.8	0	0	-1.4	IV
Hieracium hoppeanum	1	1	+	+	0	0	1	0	0	0	+	1	-1.9	-1.9	-0.7	-0.8	0	0	-2.2	0	0	0	-0.7	-2.2	IV
Ornithogalum umbella.	0	0	0	0	+	+	0	+	+	0	+	0	0	0	0	0	-1.2	-1.4	0	-1.5	-1.5	0	-1.4	-1.4	IV
Silene sendtneri	+	+	R	R	+	0	+	+	+	+	+	0	-1.3	-1.3	-0.6	-0.7	-1.2	0	-1.3	-1.5	-1.5	-1.4	-1.4	-1.4	IV
Campanula abietina	+	+	1	1	+	0	0	0	0	+	0	1	-0.8	-0.7	-1.7	-2	-0.7	0	0	0	0	-0.8	0	-1.2	IV
Viola tricolor v.mac.	0	0	+	1	0	+	0	0	+	0	+	1	0	0	-0.7	-2	0	-0.8	0	0	-0.8	0	-0.7	-1.1	IV
Thymus pulegioides	+	+	0	1	0	0	0	0	+	+	+	1	-0.8	-0.7	0	-2	0	0	0	0	-0.8	-0.8	-0.7	-1	IV
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-1	IV
Grassland quality	**2.0**	**2.4**	**2.3**	**2.7**	**2.9**	**2.7**	**2.7**	**2.5**	**2.2**	**2.4**	**2.4**														

Values of species abundance (R, +, 1, 2, 3, 4 and 5) were transferred into its percentage equivalents (1, 2, 5, 17, 37, 62 and 87, respectively).

The quality of the grassland's species was assessed upon *Šoštarić-Pisarčić and Kovačević (1968)* by translating of their descriptive values into numerical system, and upon *Peeters and Dajić (2006)*. Such approach includes the scale from -2 to 10, with the lowest value for a poisonous plant and the highest for the best forage quality plant, respectively. Thus, each species of phytocoenological relevé was marked with number within this scale.

Based on the assessment of quality of individual species and abundance values, the overall quality of grassland (Q) was calculated by the following procedure: the number of species in observed grassland was indicated by n, species were marked with s_i ($i = 1, ..., n$). Value for land cover of the species s_i were indicated by c_i ($i = 1, ..., n$). The value for the quality of species s_i was indicated by q_i ($i = 1, ..., n$). Finally, the grassland quality was calculated by the following formula:

$$Q = \frac{\sum_{i=1}^{n} c_i \cdot q_i}{\max\left(\sum_{i=1}^{n} c_i, 100\right)}$$

where *max* denotes the larger of numbers $\sum_{i=1}^{n} c_i$ and 100. This way the division is done with the larger of those two numbers. For Q is $-2 \le Q \le 10$.

In addition to the overall quality of the grassland, the impact of individual species on its quality was calculated as well. The impact of species was calculated in two steps after determining the average total pastoral value of the grassland as described. The first step was to calculate the value of grassland quality without presence of the observed species. In the second step it was calculated the percentage of a change of grassland quality by removing the observed species.

If the grassland achieves a better quality by removing of the observed species, than that species has a negative impact. Otherwise, the observed species will exhibit a positive impact.

Such approach was modeled as follows:

Q_i marked the quality of the grassland generated by removing species s_i from phytosociological table. The impact of the species s_i was marked as I_i and calculated by formula:

$$I_i = \frac{Q - Q_i}{Q} \cdot 100$$

Based on the impact, the species were classified using k-means clustering method. By this method, a set of data (species) was divided into predetermined

number of clusters. In our analysis a set of species was divided into four clusters. In order to verify the validity of the results of cluster analysis, the principal component analysis (PCA) was also performed. PCA analysis was performed on species occurring at least in half of the total phyto-sociological records. These analyses were performed using the statistical package Statistica8 (*StatSoft, 2007*).

Results and Discussion

Phytocenological relevés were classified into the following associations: *Agrostietum vulgaris, Festucetum rubrae, Festuco-Brometum erecti and Nardetum strictae* (Tab. 1). In addition to coverage values of each individual species of the relevé, the quality value for each species is presented, as well as results for the quality of grasslands (Q), the impact on the quality of individual species on grassland (%), the average effect of the species calculated for all relevés, and species affiliation to particular cluster. Grassland quality is calculated using all species that occur in it. Of that number 37 species occur in four or more relevés, but 24 species are shown in Table 1. In Table 1, species *Nardus stricta* and *Bromus erectus* are also present as community edificator, although degree of their occurrence is less than four.

The obtained average values of the quality of individual grasslands ranged from 2 to 2.9. The lowest value was determined for the community *Nardetum strictae* **(**relevé no. 1 in Table 1), while the highest for the community *Agrostietum vulgaris* **(**relevé no. 5 in Table 1). Similar estimations for quality of these grasslands, but obtained upon measurements of yield of dry matter have been already reported (*Đorđević and Radojević, 1968*; *Peeters, 2004*).

Cluster analysis enabled grouping of species into four clusters (Tab. 1). The first cluster (Cluster 1) is made of only *Agrostis vulgaris* (the quality grade 4) as a species that has the greatest positive impact. Such high positive impact of a single species is here a consequence of its high coverage, since the quality index of the species is moderate. The second cluster (Cluster 2) consists of species *Festuca rubra* (4), *Anthoxanthum odoratum* (4), *Dactylis glomerata* (8), *Arrhenatherum elatius* (8), *Lathyrus pratensis* (6), *Trifolium repens* (8), *Briza media* (4), *Trifolium alpestre* (6) and others. These species with generally high marks for quality and significant abundance in the investigated associations have thus expressed the positive impact on the grassland quality.

The third cluster (Cluster 3) contains harmful and useless species which were abundant at surveyed sites, including *Genista sagittalis* (0), *Veratrum album* (-2), *Hypericum perforatum* (-2) and *Hypericum maculatum* (-2). The fourth cluster (Cluster 4) is made of species whose impact is more or less negligible, either due to their low abundance in the grasslands or due to their low quality value.

In case of the first grassland (relevé no. 1) whose quality was assessed as 2, it could be seen that obtained low quality value was depended mainly on high abundance of the *Hypericum maculatum* (lowering the average grassland quality for 6.1%) and *Veratrum album* (-12%), obviously having a negative impact on grassland quality (Tab. 1). However, in case of the fifth relevé, the contribution to general pastoral value was mostly depended on high proportion of *Agrostis vulgaris* (contributing for 13%) and *Arrhenatherum elatius* (5.9%), providing the highest determined grassland quality value (2.9).

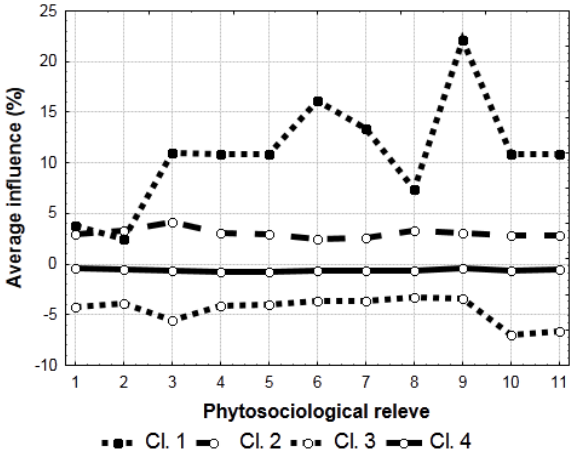

Figure 1: The average impact of the cluster members on each of the sites

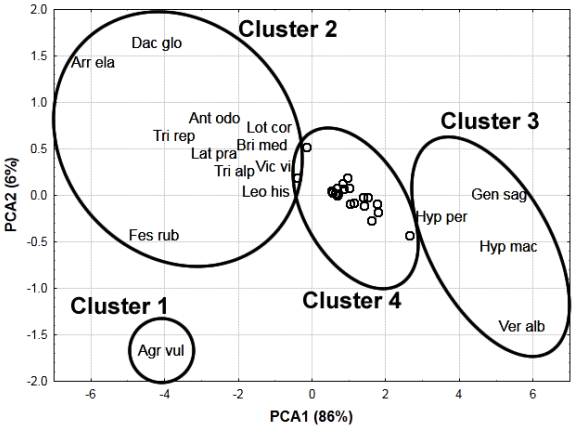

Figure 2: The principal components method. The names of species are presented by abbreviations, the first three letters of the name of the genus, the next three characters are the name of the species: Dac glo-*Dactylis glomerata*.Other names shown in Table 1.

Although communities with *Festuca rubra* i *Bromus erectus* are generally considered better, communities wih *Agrostis vulgaris* got here higher quality grade. It has appeared primarily due to high cover values of *Agrostis vulgaris*.

The average contribution of members of each cluster to the overall quality of the single grassland is presented (Fig. 1). Members of the first and the second cluster had, on average, a positive impact on each of the studied grasslands, while the impact of members of the third cluster was negative. The average impact of species of the fourth cluster was neither positive nor negative.

The results obtained using k-means clustering were confirmed using principal components analysis (PCA). It was shown that the first two axes cover 92% of the total variability of the data (Fig. 2). Species of a positive impact on the grassland quality are located on the left side, while species with a negative impact are grouped on the right side. Species that don't have a significant impact on the quality are located in the middle. The *Agrostis vulgaris,* which makes the cluster itself, is separated (lower left corner).

Conclusion

This paper presents a model for grassland quality estimation using numerical analysis approach in phytocenological data set. By this method, the evaluated quality of the studied grasslands of the Mt. Kopaonik ranged from 2 to 2.9. It was shown how each individual species contribute to the overall grassland quality upon its abundance and individual quality index. The classification method was assessed to identify the species that either increase or decrease the quality of the grassland in particular geographic region. Such modeling upon floristic composition and numerical analysis upon species abundance and individual quality index, it was possible to assess the value of grassland indirectly, which might be an useful approach for fast screening for sustainable livestock production.

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Procena kvaliteta polu-prirodnih travnjaka centralne Srbije korišćenjem fitocenoloških i numeričkih analiza

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Rezime

Travnjaci predstavljaju jedan od najznačajnijih prirodnih resursa; na teritoriji Srbije obuhvataju oko 1.400.000 ha. Koriste se kao izvor stočne hrane ali i kao resurs materija koje se primenjuju u farmaceutskoj industriji. Uzimajući u obzir njihov veliki značaj istraživanja na travnjacima u svrhu ispitivanja njihovog kvaliteta vrše se u Srbiji od 60-ih godina dvadesetog veka na ovamo. Cilj ovog rada je prikazivanje metode kojom se numerički ocenjuje kvalitet travnjaka, a pored toge se prikazuje i doprinos svake, pojedinačne vrste ukupnom kvalitetu. Doprinos vrste, koji je konkretan broj - pozitivan ili negativan, zavisi od njene pokrovnosti i numeričkog indeksa kvaliteta. Zahvaljujući dobijenim vrednostima doprinosa svake vrste kvalitetu izvršena je podela na klastere. To je najpre izvršeno metodom k-means clustering, zadata su četiri klastera, u prvom je samo jedna vrsta *Agrostis vulgaris*, u drugom su vrste koje pozitivno utiču na kvalitet, u trećem vrste koje negativno utiču na kvalitet a u četvrtom klasteru su neutralne vrste. Ova podela je proverena metodom glavnih komponenti, i na grafikonu je uočljivo razdvajanje vrsta na pomenute klastere.

Zahvaljujući ovoj metodi moguće je za kratko vreme dobiti podatke o kvalitetu nekog travnjaka i podatke o vrstama koje tu žive. Ti podaci o konkretnom travnjaku su dovoljni da se proceni njegova upotrebna vrednost kada je u pitanju stočarska proizvodnja a da se pritom izbegnu skupe hemijske analize.

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