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RIPARIAN TALL HERB FRINGE COMMUNITIES IN A SMALL LOWLAND RIVER VALLEY: SPECIES-ENVIRONMENT INTERACTIONS

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SYNOPSIS

This work was aimed at exploring habitat conditions of the communities from *Convolvuletalia sepium* order (the class *Arthemisietea*) and at analysing environmental effects on their species composition. The study was conducted in the River Piaśnica valley (northern Poland). The materials analysed consist of 39 phytosociological relevees carried out in 2009 using the classic Braun-Blanquet technique, and supplementary habitat data (e.g., geomorphology, distance from the riverbed, soil moisture content, pH, water regime, land use type, anthropogenic effects). The CANOCO 4.5 for Windows software was used to perform DCA, and then CCA to explore relationships between species composition and habitat variables. In addition, stepwise selection of environmental variables was applied and the Monte Carlo permutation test.

INTRODUCTION

Nitrophilous fringe communities of herbaceous flora (the order *Convolvuletalia sepium*, the class *Arthemisietea*) which grow along lowland water courses are a natural component of a typical riparian landscape and are protected by the EU Habitat Directive (Code 6430-3). Physionomically, those communities are made up by lush, multilayered herb assemblages and the *Convolvuletalia* consisting of tall perennials and creepers. The communities in question usually occupy narrow, 1-2 m wide patches forming between riparian rushes, willows and alder carrs as well as between rushes and other fringe or meadow herbs. They occupy sites which are periodically or episodically flooded, with fertile, nitrogen- and moisture-rich soils (Kopecký, 1985; Brzeg, 1989; Borysiak & Wiszniewska, 1990; Borysiak, 1994; Matuszkiewicz, 2002; Mróz, 2004). In Poland, those interesting and floristically diverse plant communities are still poorly known. No relevant habitat survey has been conducted so far.

This work was aimed at exploring habitat conditions of riparian herbaceous communities and at analysing environmental effects on species composition of those communities. The study was conducted in the River Piaśnica valley, the Piaśnica being a small, lowland river in northern Poland.

The 28.6 km long Piaśnica rolls through two Pomeranian Province counties: Wejherowo and Puck (54°49'1''N; 18°6'16''E). The river originates in a small nameless lake in the Las Wejherowski (Wejherowo Forest), NW of the village of Kąpino (2.5 km SW of Wejherowo). It flows along a narrow valley among the Darżlubska Primaeval Forest to enter, as the Piaśnica Górna, the Lake Żarnowieckie (7.5 km long) in its southern part and to leave the lake, via a weir in the lake's northern part as the Piaśnica Dolna. Downstream of Żarnowiec, the river becomes a part of a system draining the northern part of the Kashubian Proglacial Valley (the so-called Przymorskie Błota Plain) to discharge into the Baltic Sea W of the village of Dębki. A nature reserve, the 'Piaśnickie Łąki', has been set up at the site of the Piaśnica's discharges into the Baltic to protect the Pomerania's best preserved fragment of *Molinia* meadows located in a fork formed by the Piaśnica and its palaeomeanders. The diverse mosaic of non-forest and forest vegetation (the latter made up mostly by birch-oak woods) favours the presence of numerous vascular plants, rare in the region and even in Poland. The Piaśnica catchment covers about 310 km^2 and extends over a part of the Żarnowiecka Plateau and the Słowińskie Coast (Kondracki, 2000).

MATERIALS AND METHODS

The materials analysed consist of 39 phytosociological relevees carried out in 2009 using the classic Braun-Blanquet technique, and supplementary habitat data. The site of each relevee was recorded on a 1:10000 topographic map and located with a GPS receiver. Six environmental variables were used in the analysis: (1) geomorphology, a nominal variable with three classes: flat; undulating; slope; (2) distance from the riverbed, measured in the meters; (3) soil moisture content, scored on a five-point scale: 1 (dry); 2 (fresh); 3 (moist); 4 (marshy); 5 (with standing water); (4) water regime, a nominal variable with two classes: water seepage; drainage ditch; (5) land use type, a nominal variable with five classes: transport; tourism; meadows and pastures; deciduous forests; coniferous or mixed forests; (6) anthropogenic effects, a nominal variable with five classes: tramping or weeding; mowing or grazing; drainage; fertilisation; litter or rubble dumping. Habitat conditions were determined also by collecting soil samples for physical and chemical assays for pH (in 1M KCl solution), loss on ignition, to approximate the soil organic matter content, i.e., to determine whether the soil tested is: 1 (mineral, loss on ignition 0-10%), 2 (mineral-organic, 10-20%), 3 (organic, 20-100%), organic carbon and nitrogen contents, with a Costech CHNS analyser and biologically available forms of P, K, and Mg.

The CANOCO 4.5 for Windows software (Ter Braak & Šmilauer, 2002) was used to perform detrended correspondence analysis (DCA) with which to calculate the length of the environmental gradient and to explore variability of species distribution along environmental gradients. In addition, forward selection of environmental variables was applied; the variables were checked for the strength of their association with species diversity of the samples. The Monte Carlo permutation test was used to address statistical significance of relationships between species composition of the samples and the individual environmental variables (Borcard et al., 1992). A direct gradient analysis (canonical correspondence analysis, CCA) was performed to explore relationships between species composition and statistical significant habitat variables. CCA cannot directly cope with ordinal variables such as moisture and loss on ignition, so they must be treated as quantitative or nominal variables (Ter Braak, 1987). In this work, moisture and loss on ignition were treated as a quantitative variables. Nominal variables were arranged in present/absent data matrix. The Braun-Blanquet coverage scale was replaced by a nine-score ordering scale (r – 1; + - 2; 1 – 3; 2 – 5; 3 – 7; 4 – 8; 5 – 9).

Names of species were reported after MIREK et al. (2002), bryophytes – OCHYRA et al. (2003), syntaxa – BRZEG and WOJTERSKA (2001).

RESULTS AND DISCUSSION

The fringe communities in moist and wet habitats of the Piaśnica valley develop usually in a complex of riparian forest complexes and alder carrs; more seldom are they found in willow shrubberies and *Molinia* meadows (within the 'Piaśnickie Łąki' nature reserve). In the vicinity of the Piaśnica's discharge to the Baltic, underneath a canopy of a deformed *Salicetum albo-fragilis* riparian forest, a single *Soncho palustris-Archangelicetum litoralis* R.Tx. 1937 patch was encountered. The patch was partly destroyed by tourists staying on the nearby beach. The assemblage in question is associated with weakly saline water of coastal reservoirs, but usually lacks obligate halophytes and only exceptionally contains other brackishwater species (Piotrowska, 1974). The assemblage's physiognomy is determined by 2.5 m high stems of *Angelica archangelica* subsp. *litoralis*. In addition, the patch examined showed a substantial coverage of *Urtica dioica*, *Calystegia sepium*, and *Galium aparine*. Lack of halophytes may be explained with low concentration of chlorides in the mouth section of the Lower Piaśnica. The Baltic

Sea has not influenced water salinity since the Żarnowiec pumped-storage power plant was constructed (Cieśliński, 2008).

The *Urtico-Convolvuletum sepium* Görs et Th. Müller 1969 was one of the commonest assemblages of riparian herbaceous plants. The best-developed patches were found in the downstream reaches of the river, on mineral, weakly acidic to acidic soils; more seldom, the soils supporting the assemblage were mineral-organic and organic. The assemblage consists of lush stands of *Urtica dioica*, penetrated by the abundant *Galium aparine* and *Calystegia sepium*. The relatively stable components of the assemblage in the area include the meadow species: *Vicia cracca*, *Filipendula ulmaris* and *Lysimachia vulgaris*. Some patches, dominated by *Urtica dioica*, lacking *Calystegia sepium* and with abundant *Galium aparine* were impoverished forms of the assemblage and were classified as *Urtica dioica*-community (Table 1).

The Piaśnica valley was equally frequently found to support the *Eupatorietum cannabini* R.Tx. 1937 assemblage, usually occurring as small (8-15 m^2) patches. The assemblage usually developed in gaps within carrs and riparian forests, particularly in the vicinity of water seeps, on organic and mineral-organic soils. The dominant *Eupatorium cannabinum* was accompanied by the creepers *Galium aparine* and, more seldom, *Solanum dulcamara* as well as by *Urtica dioica*, *Carex acutiformis*, *Scirpus sylvaticus*, *Filipendula ulmaria*, *Lysimachia vulgaris*, *Galium palustre* and *Mentha aquatica*. In addition, the area was found to support the *Epilobio hirsuti-Convolvuletum sepium* Hilbig, Heinrich et Niemann 1972 as well as two assemblages dominated by *Galeopsis speciosa* and *Rubus idaeus*, the phytosociological affinity of which requires further study. Both species as regarded as edificators of forest clearing communities of the class *Epilobietea*. However, the patches studied were clearly associated with the presence of the river, their floristic composition including species belonging to the characteristic combination of the *Convolvuletalia*, i.a., *Galium aparine*, *Urtica dioica*, *Phalaris arundinacea*, *Elymus repens*, *Carex acutiformis*. Mentioned patches were classified as *Rubus idaeus*-community and *Galeopsis speciosa*-community (Table 1).

Ordination analyses were initiated by calculating the length of the environmental gradient, represented by the first ordination axis, to explore the data structure and to select an appropriate analysis. The gradient was 4.361 SD long, which is indicative of a unimodal data structure: distribution of the species constituting the set analysed follows a full Gaussian spectrum. Such a gradient justified application of DCA, a technique recommended for application at gradients higher than 4 SD (Jongman et al., 1995).

As the first ordination axis eigenvalue was 0.582, the gradient it represented significantly discriminated between the species of the set under study. The second axis eigenvalue was closed to the threshold value of 0.5, which means the environmental gradient represented by the axis was fairly important as well (Table

2). However, interpretation of environmental gradients represented by the two axes, based only on the occurrence of species in the ordination space, is difficult (Fig. 1). Other workers, too, found it difficult to interpret pronounced but complex gradients (Økland, 1990; Lorens, 2001).

Results of CCA were similar: eigenvalues of the first two axes were high. Results of the significance test for the first CCA axis point out to a strong, significant ($p = 0.002$) environmental gradient producing variations in the species' occurrence. Results of the second test, too, demonstrate a significant relationship between the species' occurrence and gradients represented by the canonical axes (Table 3).

Results of forward selection of environmental variables and the Monte Carlo permutation test demonstrated as few as 8 out of 22 environmental variables to be significant ($p \leq 0.05$) in explaining the variability in the species' occurrence. The area's geomorphology produced no significant effects on the species diversity in the samples. Similarly, no significant effect was exerted by the distance of the patches examined from the river channel. On the other hand, the water regime and the soil moisture associated with it proved significant. Of the different land use forms, tourism, transport and meadow management only were found to produce marked effects on the vegetation variability. Meadow mowing, drainage and littering turned out to be the anthropogenic effects most important for differences in the species' occurrence (Table 4).

After obtaining the results of forward selection new CCA analysis was performed for 39 samples and 8 statistical significant environmental variables (Table 5). The total inertia (sum of all eigenvalues) was 6.960; the variation in the occurrence of the species explained by the canonical axes (sum of all canonical eigenvalues) was 2.355. An appropriate calculation (2.355/6.960 x 100%) showed the environmental variables used in the ordination to explain about 33.8% of the total variation in the data (variability in the species' occurrence).

The longest vectors in the CCA ordination plot (Fig. 2-3) were those of soil moisture, drainage, meadow mowing or grazing, and headwater seepage. Consequently, those environmental variables can be regarded as fairly important for shaping the variability in the species' occurrence in the area. The environmental variables producing short vectors were less important. In addition, the diagram shows soil moisture variability to be most tightly associated with the first ordination axis, whereas drainage was most related to the second one, because the smaller the angle of a vector relative to an ordination axis, the stronger the association between the vector and the axis. This is also confirmed by correlation coefficients of associations between environmental variables and sample indices calculated as weighted mean indices (in the inter-set correlation): along the first ordination axis gradient, the highest correlation between environmental variables and sample locations was produced by soil moisture; drainage produced the highest correlation along the second axis, whereas litter dumping and biologically available Mg correlated most tightly along the third and fourth axes, respectively (Table 6).

As indicated by the directions of the vectors in the ordination plot, soil moisture increases from left to right, drainage increasing from the bottom to the top. The habitats characterised by the presence of headwater seepages featured the highest frequency and coverage of the mosses *Climacium dendroides*, *Cratoneuron filicinum*, and *Mnium hornum* and the vascular plant species *Valeriana dioica*, *Mentha aquatica*, *Cardamine amara*, *Crepis paludosa*, *Myosotis palustris*, *Galium palustre*, *Solanum dulcamara*, and *Eupatorium cannabinum* (Fig. 2). The species mentioned occurred on the soils characterised by the highest moisture content. That part of the plot contained also a half of the patches of the *Eupatorietum cannabini*, the wet form of assemblage (Fig. 3, samples 4-5, 7, 9, 13-14). The left-hand side of the plot shows a cluster of fresh soil species, including, i.a., *Anthriscus sylvestris*, *Galeopsis bifida*, *Geum urbanum*, *Holcus lanatus*, *Glechoma hederacea*, and *Ballota nigra*. The meadow species that requires mowing, e.g., *Molinia caerulea*, *Thalictrum flavum*, *Gladiolus imbricatus* are placed in the bottom left-hand corner of the plot. That part of the ordination space features the patches found in the 'Piaśnickie Łąki' nature reserve, hence the high proportion of the *Molinia* meadow species (Fig. 2). In addition, it should be emphasised that the upper portion of the plot groups patches of the assemblages dominated by *Rubus idaeus* and *Galeopsis speciosa*; their location relative to the drainage vector indicates the habitats of those assemblages to be most transformed by draining operations. The highest number of samples representing the *Urtica dioica*-community clusters near the centre of the ordination plot, which may mean indirect preferences with respect to or neutrality towards those environmental variables (Fig. 3). SZOSZKIEWICZ (2004) in his work also showed, that most of terrestrial communities of river valleys were quite neutral along identified environmental gradients, and only a few of them indicated apparent preferences against environmental conditions.

CONCLUSIONS

Ecological interpretation of vegetation variability is complicated, due to a great number of environmental factors and the complex character of their influence. The relationships between the vegetation and environmental variables and the species' responses to changes in the intensity of those factors were described with CCA. The usage of this technique allows to select the most important parameters determining the variability of vegetation. The floristic variability of the riparian herbaceous plant patches examined resulted from both natural and anthropogenic environmental factors. Soil moisture proved to produce the strongest environmental gradient differentiating between the samples and species of the set examined. Habitat

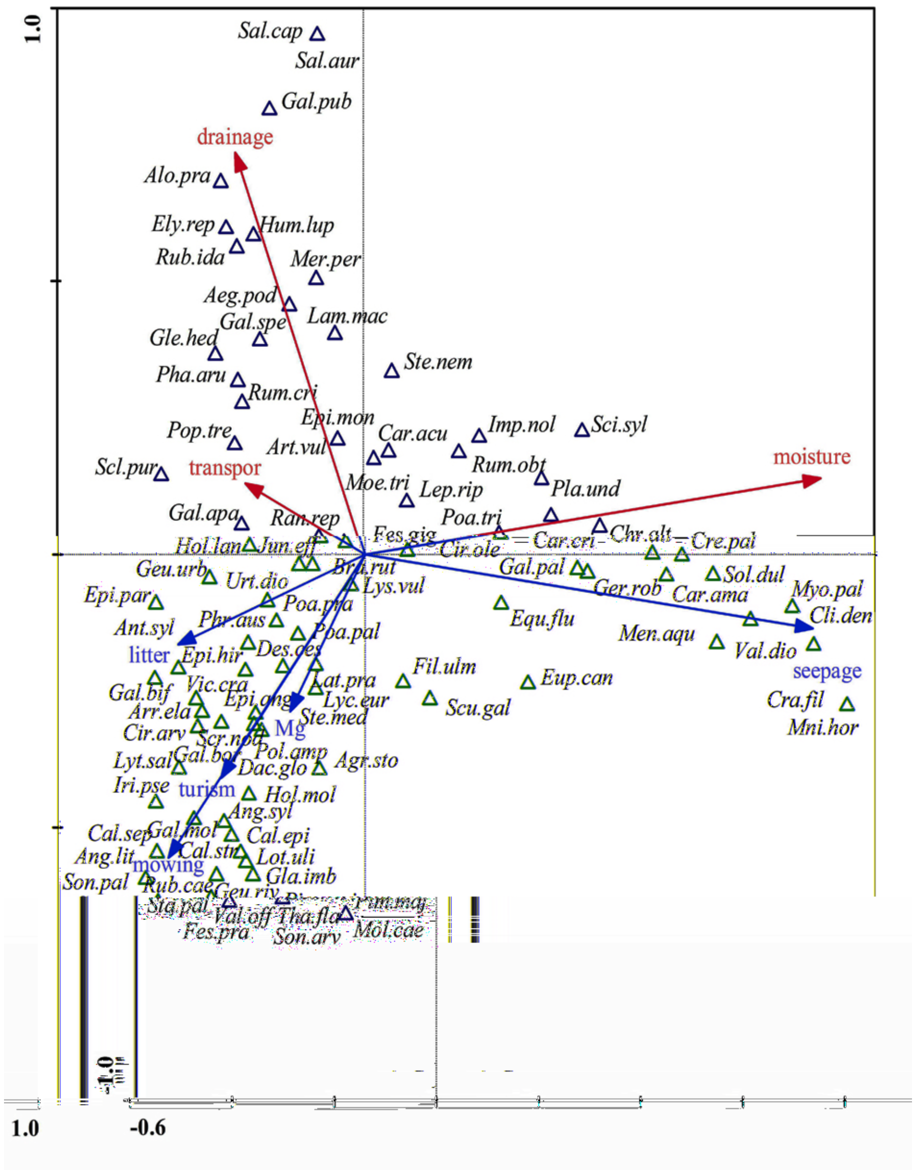

Figure 2: CCA ordination diagram with species (triangles) and environmental variables (arrows). Full names of environmental variables are given in Table 4. The names of species are in the abbreviated form originating from the first three letters of Latin generic and species name, e.g. Gal.pub = *Galeopsis pubescens*. To increase the ordination plot legibility, the names of sporadically occurring species, i.e., those found only once or twice and at a minimum coverage, were removed. Any ordination space location-based inference on their preferences would not have been reliable anyway.

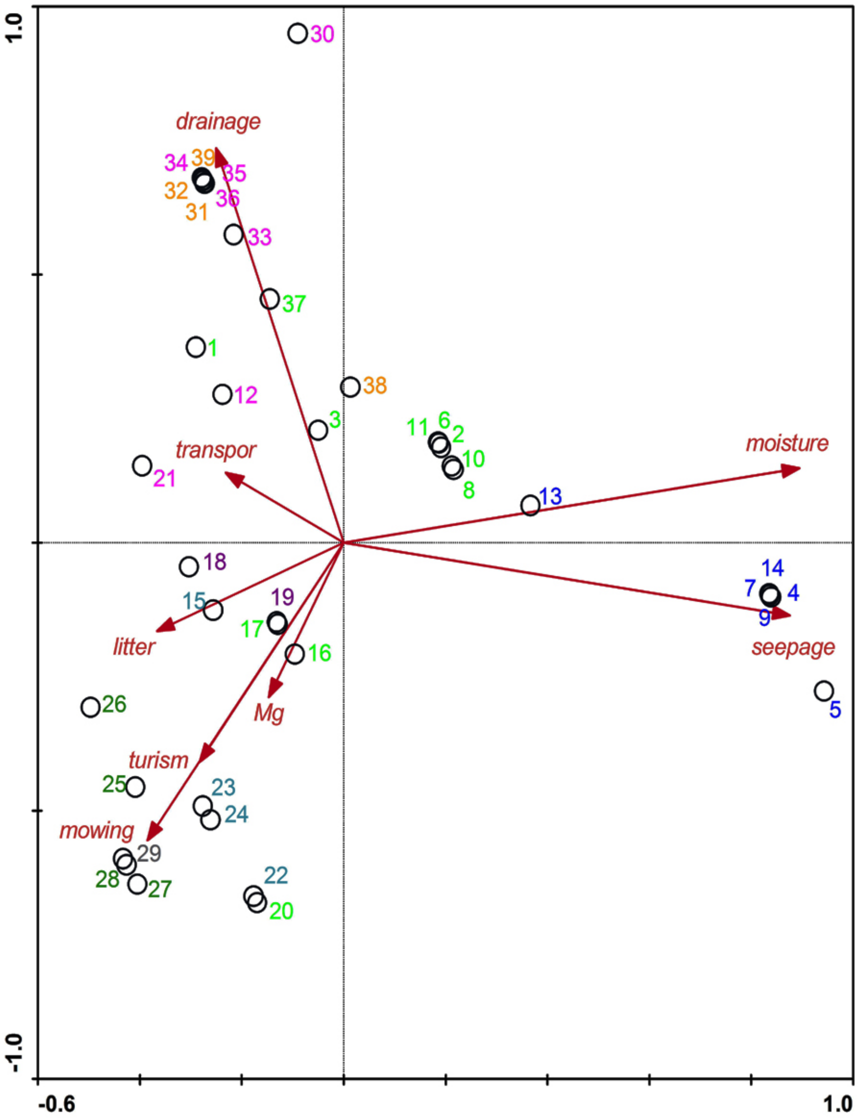

Figure 3: CCA ordination diagram with samples (points) and environmental variables (arrows). Full names of communities with samples numbers are given in Table 1. Full names of environmental variables are given in Table 4.

Table 1: Classification of 39 phytosociological relevees (samples) representing *Convolvuletalia sepium* order (class *Artemisietea*) in Piaśnica river valley.

Plant community	Phytosociological relevees (samples)
Soncho palustris-Archangelicetum litoralis	29
Eupatorietum cannabini	4-5, 7, 9, 13-15, 22-24
Urtico-Convolvuletum sepium	25-28
Urtica dioica-community	1-3, 6, 8, 10-11, 16-17, 20, 37
Epilobio hirsuti-Convolvuletum sepium	18-19
Rubus idaeus-community	12, 21, 30, 33-36
Galeopsis speciosa-community	31-32, 38-39

Table 2: Summary of DCA results for 39 samples and 151 species.

Axes	1	2	3	4
Eigenvalues	0.582	0.472	0.287	0.206
Lengths of gradient	4.361	3.976	2.775	2.701
Cumulative percentage variance of species data	8.4	15.1	19.3	22.2
Sum of all eigenvalues (Total inertia)	6.960			

Table 3: Summary of Monte Carlo test for 39 samples, 151 species and 23 environmental variables.

Test of significance of first canonical axis	Eigenvalue = 0.556
	F-ratio = 1.389
	P-value = 0.0020
Test of significance of all canonical axes	Trace = 4.607
	F-ratio = 1.424
	P-value = 0.0020

Table 4: Forward selection results for 39 samples, 151 species and 23 environmental variables. Red colour indicate statistical significant environmental variables.

No	Variable	Conditional Effects		
		LambdaA	P	F
1.	soil moisture content	0.47	0.002	2.70
2.	drainage	0.38	0.002	2.21
3.	mowing or grazing	0.32	0.002	1.93
4.	water seepage	0.26	0.002	1.61
5.	turism	0.24	0.016	1.52
6.	litter or rubble dumping	0.25	0.024	1.54
7.	transport	0.23	0.006	1.50
8.	biologically available Mg	0.21	0.042	1.34
9.	distance from riverbed	0.19	0.056	1.31
10.	geomorphology: slope	0.18	0.150	1.19
11.	deciduous forests	0.19	0.126	1.22
12.	coniferous forests	0.19	0.114	1.28
13.	organic C content	0.18	0.120	1.25
14.	meadow and pastures	0.17	0.208	1.16
15.	biologically available K	0.17	0.234	1.16
16.	biologically available P	0.15	0.312	1.09
17.	geomorphology: flat	0.16	0.306	1.11
18.	tramping or weeding	0.14	0.574	0.94
19.	soil organic matter content	0.13	0.602	0.90
20.	N content	0.13	0.620	0.91
21.	soil pH (in KCl)	0.15	0.456	1.00
22.	fertilisation	0.12	0.724	0.81

Table 5: Summary of CCA results for 39 samples, 151 species and 8 statistical significant variables.

Axes	1	2	3	4
Eigenvalues	0.534	0.469	0.306	0.258
Species-environment correlations	0.972	0.974	0.952	0.957
Cumulative percentage variance of species data	7.7	14.4	18.8	22.5
Cumulative percentage variance of species-environment relations	22.7	42.6	55.5	66.5
Sum of all eigenvalues (Total inertia)	6.960			
Sum of all canonical eigenvalues	2.355			

Table 6: CCA results for 39 samples, 151 species and 8 statistical significant variables: inter-set correlations of environmental variables with axes. Red colour indicate the highest correlation between environmental variables and sample locations.

No	Variable	Axis 1	Axis 2	Axis 3	Axis 4
1.	soil moisture content	0.8705	0.1353	-0.1735	0.0595
2.	biologically available Mg	-0.1426	-0.2808	-0.1436	0.4509
3.	water seepage	0.8523	-0.1322	0.0776	0.1275
4.	transport	-0.2250	0.1267	-0.3689	0.3390
5.	turism	-0.2750	-0.3989	0.5771	-0.4414
6.	mowing or grazing	-0.3749	-0.5415	-0.6650	0.1607
7.	drainage	-0.2436	0.7169	-0.1145	-0.2071
8.	litter or rubble dumping	-0.3568	-0.1610	0.7448	0.2618

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