Relationship between ecological indicators and soil properties (in case of a wetland)

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Abstract

Ecological indicators have been defined for higher plants. In theory with the use of these indicator values we can make predictions for the abiotic environmental factors based on cenological analysis. There are only few publications which have focused on validation of the published indicators. The scale dependence of these indices is poorly studied too. Present paper focuses on applicability of soil related ecological indicators in small scale studies. Three soil related indices were studied along a hydromorph toposequence, such as Simon's *W*, *R* and Soó's *N* values. Simon 's *T* value also was applied to compare applicability soil related ecological indicators with non-soil related ones for small areas. These values were determined on the basis of cenological measurement and compared with soil physical and chemical properties. Our results suggest that *W* values can be use only for small scale ecological indications.

Keywords: ecological indicator, physical and chemical properties, toposequence, water demand, nitrogen, pH, microclimate

Introduction

Development of soils is affected by several factors. Water and topography as primary environmental factors plays crucial role in soil development (Centeri, Cs. *et al*. 2009). Spatial differences of soil forming factors cause spatial heterogeneity of soil properties (White, R.E. 2006; Szabó Gy. and Czellér, K. 2009;

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Kertész, Á. *et al.* 2010). These phenomena affect on morphology and reflect in spatial distribution soil properties such as amount macronutrients (Sipos, P. 2004; Farsang A. *et al*. 2008; Kocsis, M. *et al.* 2008; Szabó, Gy. *et al*. 2008; Nagy. R. *et a*l. 2012) and organic matter (*OM*) decomposition and humification (Martins, T. *et al*. 2011; Alexis, M.A. *et al*. 2012). Since soil forming factors also have influence on vegetation, cenological properties of flora may have relationship with different aspect of the environment, theoretically.

As a result of floristic research, ecological indicators have been defined for almost the whole vascular flora (Soó, R. 1980; Simon, T. 1992). In theory with the use of these indicator values we can make predictions for the abiotic environmental factors based on cenological analysis (Csontos, P. 1984; Mjazovszky, A. *et al*. 2003; Szabó M. *et a*l. 2007).

As relevant differences may occur along hydromorph toposequences within small distances, changes in physico-chemical properties of the soil can be detected in a small area (Szalai, Z. *et al.* 2010; Varga, Á. 2010). These toposequences allow the validation of ecological indicator values. Present paper focuses on the reliability of the ecological indicators compared with soil properties.

Material and methods

Study area

The 8 ha *Mocsárrét* area located in the vicinity of Ceglédbercel is in the border of the Gödöllő Hills and the Pilis-Alpár Homokhát physical micro-regions *(Figure 1).* It belongs to the former floodplain of the Gerje Stream. The deepest parts of the Mocsárrét are willowy peat-bogs. The fens are differentiated from the sedgy meadows with a definite bench. The pasture-lands also differentiate definitely from the surrounding sandy steppes following a graduated elevation.

Sampling and measurements

Relationship between vegetation and soil properties were studied by Simon's *W* (water demand), *R* (soil pH) and Soó's *N* (soil nitrogen) values. Simon's *T* (Köppens's climate) value also was applied to compare applicability soil related ecological indicators with non-soil related ones for small areas.

Cenological properties of the Mocsárrét were studied by estimation of herbaceous vegetation cover along a 22 m transect. The estimation was carried out along a straight line using 22 neighbouring 1 x 1 m quadrates. The lowest and the highest ones are labelled by 0 and 22, the highest one. The quadrates

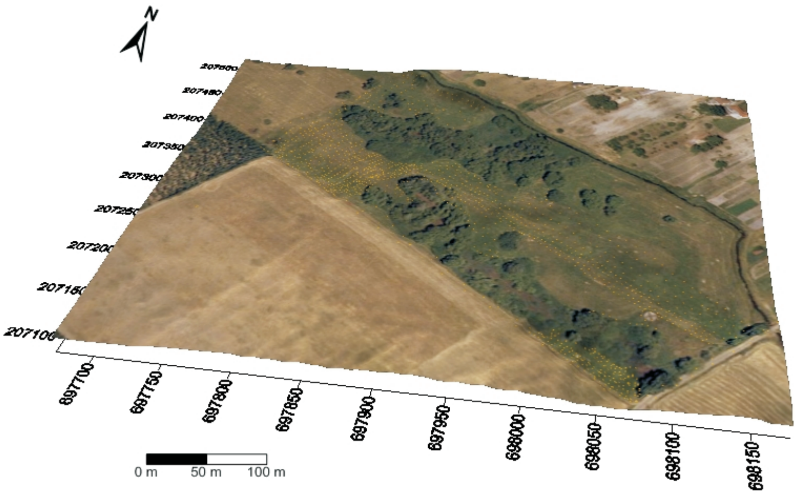

Fig. 1. Ortophoto combined DEM of study site

covered a whole hydromorphic toposequence beginning from the peat-bog to the dry lucerne area (sandy steppe). Species lists and cover estimations were carried out for each quadrats. Applied ecological indicators were assigned to each species from Hungarian Flora Database (Horváth, F. *et al*. 1995). The cover-weighed averages of values were used to the calculations.

Soil properties are studied by boreholes, which made by Edelman Auger. Drills were installed next to the quadrates and each of them reached the groundwater level. After the drilling, the depth of the groundwater level was measured in the borehole by tape-measure. Soil samples were taken and measured from the upper 25 cm densely rooted soil horizon.

Soil organic carbon (*SOC*) and total bounded nitrogen (*TN*) content were measured using NDIR/chemoluminescent analyser. Soil organic matter (*SOM*) content was calculated from the *SOC* values using a 1,72 multiplication factor. Humic compounds were characterized by Hargitai's *Q* value (Buzás, I. 1983). Soil pH was determined electrometrically from 1n KCl extract. $CaCO_3$ content was measured using Scheibler's method (Buzás, I. 1988). Texture of the mineral phase was defined with a laser diffraction particle sizer while the quality of the mineral phase was determined with an XRD (X-Ray Diffraction).

To compare soil data with ecological indicators soil pH values were converted to acidity ($cmol_+ \, kg^{-1}$) before regression analysis (to transform log scale to linear scale data). Ecological indicator values transformed from ordinal scale to interval scale data by Sneath and Sokal's method (Podani, J. 1997). The relationships were studied using linear regression and correlation coefficient.

Results

Morphological and mineralogical properties of soils

Along the 22 m toposequence SOM content doesn't change consistently with the decreasing water content. In the deepest point of the toposequence (0) starting soil type is peaty meadow soil-gleyic Phaeozem (pachic, arenic, calcaric), where the "*histic*" (H) horizon's thickness reaches 10 cm. Between the 0 and 1 quadrates soil type changes to calcaric meadow soil-gleyic Phaeozem (arenic, calcaric). This calcaric meadow soil is typical until highest point of the toposequence.

The mineral phase's texture sand content increases whilst silt and clay content shows a decreasing tendency starting from the lower endpoint to the upper one. Between the 0 and 1–5 quadrates there is a sudden change in the mineral phase ant this change appears in the herbaceous vegetation too. In the reed *quartz* and *calcite* are dominant, *smectite* is significant and only a little *feldspar* is present. The iron phase is traceable in the form of goethite for which refer reflections between 4.18 and 2.70 Å. Iron concretions and mottles are made of *poorly crystallized goethite*. Practically in the same level as the 0 quadrate lies the sedge dominated 1–5 quadrate. Their matrix consists of mainly quartz and calcite but smectites are also significant. The silt fraction contains little feldspar and amphibole. There is ferrihydrite in the matrix's iron-phase, it is shown by the elevated baseline with maximum values around 1.5 and 2.5 Å. In the iron concretions mineral phase the iron (III) is present mainly in the form of ferrihydrite and less poorly crystallized goethite (shoulder at the quartz's base, around 4.16 Å; weak peak at 2.69 Å). Dominant minerals of the soil matrix are also present in the iron concretions like quartz, calcite and feldspar. This alludes to the fact that iron-oxide concretions seceded around these mineral grains and incorporated them in the course of their growth. Advancing to the upper endpoint of the toposequence goethite becomes dominant in the iron phase again.

$CaCO_3$ and soil SOM contents also changes between the 0 and 1 quadrate. Further in the toposequence does not fall of $CaCO_3$, however quantity of SOM decreases continually. Condensation degree of humic acids degree increases steadily parallel with reduction of hydromorphy (*Table 1*).

Relationship between ecological indicators and environmental factors

From the reed (temporary open water surface) to the slightly elevating area headway of the lower water-demand plants can be observed to the expense of high water-demand (swamp) plants (ex. *Carex riparia*). The association at

Table 1. Chemical properties of topsoil (0–20 cm)

Indicator	0	1	2	3	4	5	6	7	8	9	10
SOM (%, m/m)	27.2	9.7	9.8	8.3	6.1	5.2	5	4.8	4.4	4.5	4.5
Q	0.34	0.32	0.42	0.45	0.46	0.45	0.43	0.51	0.49	0.48	0.48
TN (%, m/m)	0.26	0.08	0.19	0.25	0.28	0.26	0.23	0.21	0.2	0.21	0.19
C/N	60.7	70.3	29.9	19.3	12.6	11.6	12.6	13.3	12.8	12.4	13.7
$CaCO_3$ (%, m/m)	7.69	3.5	3.5	3.3	3.4	3.1	3.3	3.4	3.2	3.6	3.5
pH_{KCl}	7.81	7.81	7.8	7.78	7.81	7.8	7.72	7.65	7.65	7.52	7.54

Indicator	11	12	13	14	15	16	17	18	19	20	22	22
SOM (%, m/m)	4.6	4.3	4.1	3.8	3.2	2.8	2.2	1.9	2	2.1	2.1	2.1
Q	0.48	0.49	0.76	0.93	0.97	0.94	0.95	0.96	0.98	1.02	1.01	1.03
TN (%, m/m)	0.14	0.15	0.17	0.09	0.15	0.14	0.11	0.09	0.08	0.09	0.1	0.1
C/N	19.1	16.6	14.0	24.5	12.4	11.6	11.6	12.2	14.5	13.5	12.2	12.2
$CaCO_3$ (%, m/m)	3.6	3.5	3.7	3.8	3.8	4	4.2	3.7	3.5	3.2	3.0	2.9
pH_{KCl}	7.54	7.51	7.55	7.62	7.66	7.62	7.58	7.51	7.34	7.31	7.79	7.25

the top of the toposequence contains rather species of wet meadow (ex. *Festuca arundinacea*) as well as disturbance tolerating species of dry pasture-lands (ex. *Agropyron repens*). Average *W* value of the vegetation – calculated by the vegetation cover – decreases together with the reduction of water effect (*Figure 2)* while the trend line calculated by linear regression shows very weak connection (R^2 = 0.60) with the *T* values.

Total nitrogen content of the soil (*TN*) decreases towards the upper endpoint of the toposequence which is also followed by the *N* value (*Figure 3).* Although connection between *TN* and *N* value is "visible", the correlation coefficient between value pairs is very low (R^2=0.61).

Along with the drop of the water effect soil pH decreases from pH8.3 typical of $CaCO_3$ regulated wet systems to slightly alkali values typical of carbonated humic sandy soils. Correspondingly to the previous two ecologic indicator values Simon's *R* value shows a decreasing tendency also. However, there is no connection between alkalinity and its indicator value *(Figure 4).*

Albeit Simon's *T* value is primary for proving dissimilarities between Köppen's climatic zones (Csecserits, A. *et al.* 2009), we were curious if it could indicate microclimatic differences also. Accordingly to our expectations *T* values of the vegetation by the non-indifferent species do not show any distribution pattern *(Table 2).*

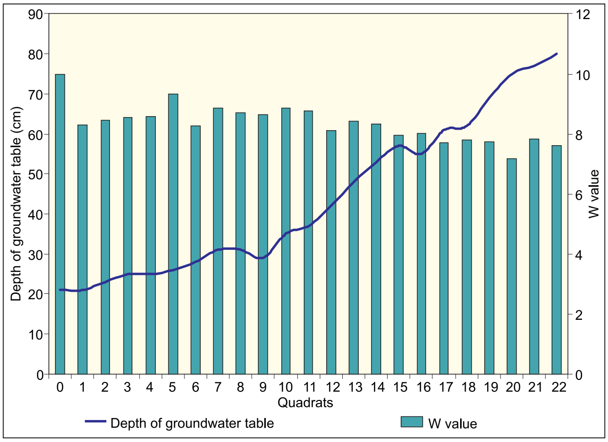

Fig. 2. Spatial distribution of *W* value along toposequence in relation to depth of groundwater table

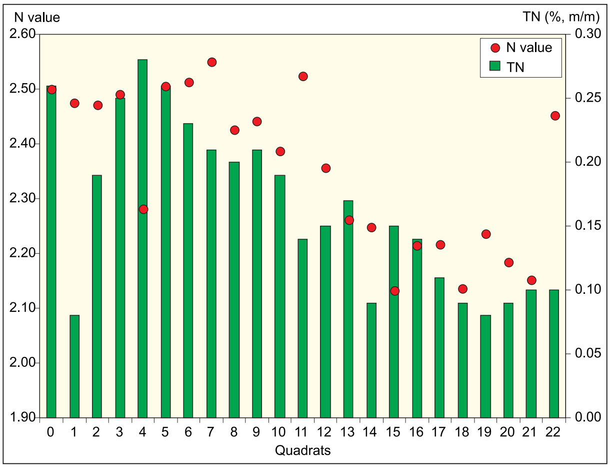

Fig. 3. Spatial distribution of *N* value along toposequence in relation to total bounded nitrogen (*TN*)

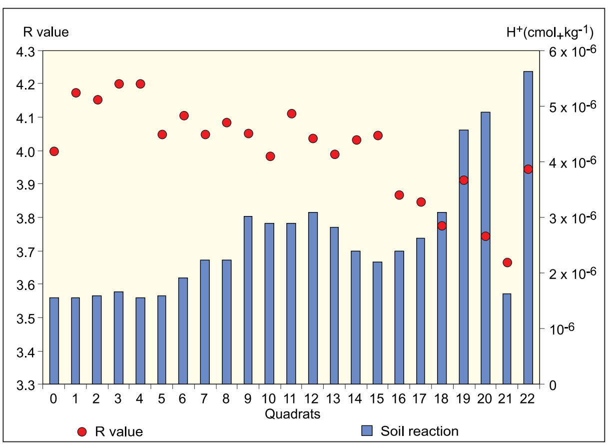

Fig. 4. Spatial distribution of *R* value along toposequence in relation to soil reaction

Table 2. Correlation between soil properties and ecological indicators on the basis of R^2

Soil properties	Simon's W value	Soó's N value	Simon's R value
Depth of groundwater table	0,63	–	–
Total bounded nitrogen	–	0,51	–
Soil reaction ([H^+] $cmol_+$ kg^{-1})	–	–	0,19
Soil reaction (pH)	–	–	0,20

Distribution of indifferent values

In case of all studied indicators there were some species which had 0 values. These species are not suitable for ecological indications. A question may arise as to whether there is any relationship between spatial distribution indifferent values and spatial distribution of soil pH *TN*, and hydromorphy (depth of groundwater table).

Indifferent species of studied indicators shows different kinds of spatial distribution *(Figure 5).* From the aspect of the water effect-indicating *W*

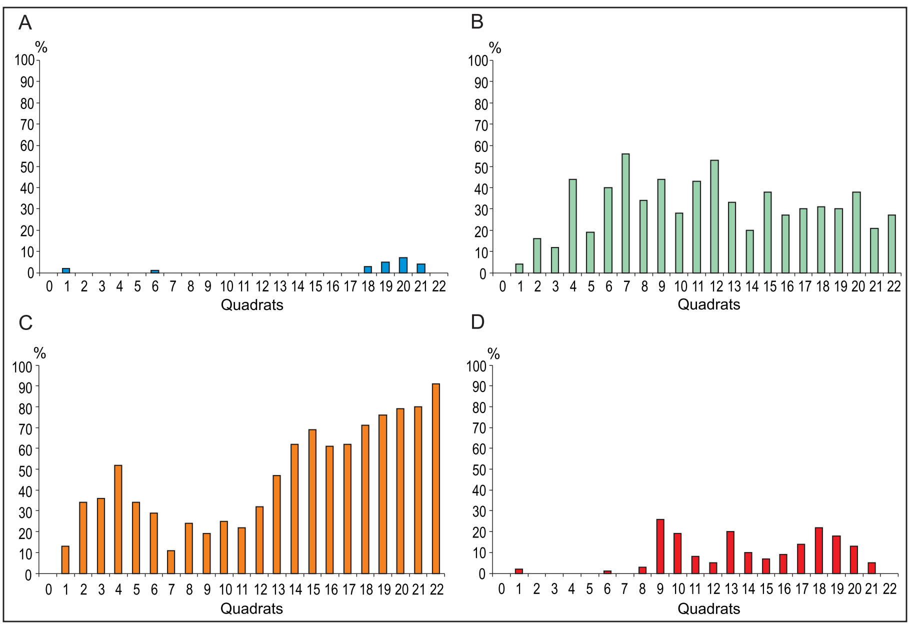

Fig. 5. Proportion of indifferent species within quadrats – A = *W* value; B = *N* value; C = *R* value; D = *T* value

value there were no indifferent species at the study area. This phenomenon supports the indicator's applicability. Species which didn't show an *N* value in the vegetation is negligible in the vicinity of the lower endpoint and that would be likely at the sandy steppe (if the natural vegetation could have been remained) above the upper endpoint of the toposequence, as well. Cover of the indifferent *N* value species exceeds 50% in the middle section.

Contrary with above *N* indicator, proportion of indifferent *R* values increases parallel with the depth of groundwater table. This reaches the 80% in the vicinity of the sandy steppe. However, climate indicator is not suitable for the indication of microclimatic differences, proportion of indifferent species shows similar spatial distribution as in case of water demand index.

Discussion

On the basis of correlation between indifferent species from the aspect of *R* value and soil reaction this indicator was not appropriate for ecological indication in our small scale study. This index is applicable for large differences, eg. acidic soils – slightly alkali conditions – sodic soils. Therefore multiplying sample numbers would not result a closer connection between the indicator and the pH value.

Relationship between *N* value and *TN* is also very poor, enlargement of the number of elements (studying several toposequences) would probably result a stronger connection. The most powerful connection is between the water demand and the *W* value. Here the connection between the water demand and the ecological index can be detected already through a few numbers of elements.

Studied soil related ecologic indices have formed two "groups", which are not sharply distinct, by their small scale applicability. Transition is graduated between the only regional and locally also adaptable indices.

In accordance with our expectations climate indicator *T* value out of the four ecological indices is not suitable for indicating microclimatic differences. The spatial distribution of indifferent climate indicators suggests that the site selection can be essential for such ecological studies which apply this indicator.

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