West Hungarian University, Faculty of Forestry
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Ph.D. theses

CORRELATION BETWEEN SOIL PARAMETERS AND ECOLOGICAL INDICATOR VALUES ON THE BASIS OF FOREST HERBS

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INTRODUCTION

Concept of biological indication can be found in the literature in divers approaches. There are two essential different ways: indication in the range of environmental protection where cryptogams are used for revealing anthropogenous changes, and the general indication principle of P. JUHÁSZ-NAGY. A part of the last one is the phytoindication, which is a large scale conception including all methods for describing properties and processes in ecosystems by dint of behaviour their plant populations. These are firstly the indicator values for describing ecological behaviour of plant species in natural circumstances, furthermore scales for describing degradation and naturalness in ecosystems. Object of the dissertation are indicator values (also known by their German name *Zeigerwerte*), which are available for three scales for characterizing soil conditions of plant habitats: F = moisture, R = reaction (pH), N = nutrition.

The aim of this study was to check the rightness of indicator values in case of deciduous forest herbs and to answer the following questions:

- In which geographical and climatic borders are indicator values of these species valid?
- How can we compare different indicator value systems with different scales?
- Is it possible to create a measurable system by analyzing soil parameters, which allows a correction of indicator values of this species?
- If yes, can be drawn any conclusions for specifying other species ecological values without detailed survey?
- Is it possible and meaningful to analyze indicator values by statistical methods?

MATERIAL AND METHODS

The survey is based on data from 234 soil and plant samples collected in the growing season of the years 2003 - 2005 in the north-western part of Hungary. The soil samples had been analyzed 2004 – 2007 in the laboratory of the UWH Institute of Chemistry and Forest Site Sciences.

The selected species are forest herbs (*Buglossoides purpurocaerulea*, *Galium odoratum*, *Galium sylvaticum*, *Polygonatum multiflorum*, *Carex pilosa*). The sampling was carried out in different deciduous forest types. The sample plots were selected thus they represent both the range/assortment of forest associations in north-western Hungary and the association preferences of the given test species.

Fieldwork in each plot:

- Assessment of vitality of specimens (according to further morphological analysis)
- Co-occurrence of all other species (in 25 % of the plots as a species list)
- Composite soil sample taken directly from below the litter layer (0 – 10 cm)
- Undisturbed samples taken with 100 cm^3 metal cylinder (in 25 % of the plots for soil pore-size distribution measurement)
- Organic litter taken from 25 x 25 cm squares
- Humus form determination in the upper humuos layer (15 cm)

Laboratory analysis:

- pH(H2O): electrometrical, 1/2,5 soil/solution proportion
- pH(KCl): electrometrical, 1/2,5 soil/solution proportion
- y1 : hydrolytical acidity: from a Ca-acetate extraction
- y2 : exchangeable acidity: from a KCl-extraction
- Soil texture: fraction <2 mm, sedimentation and pipette method
- H% - humus content: wet digestion with Tyurin method
- AL- (easily) soluble phosphorus: ammonium-lactate from an acetic-acid extraction, using colorimetry
- AL- (easily) soluble potassium: ammonium-lactate, from an acetic-acid extraction, using AES
- Soil pore-size distribution measurement with the pF-method

RESULTS AND DISCUSSION

Vitality analysis

To analyze the vitality I've worked out independent scales in case of all 5 species, while specific literature data and methods are hardly available. The system, worked out to estimate the vitality of species can mentioned as a method-like experiment. I have compared the measurements with the bibliographical data of the standard flora. In the case of *Carex pilosa* I have pointed out, that the generative reproduction of the specie influenced more by the lighting, than the soil attributes and because of that I haven't took it into consideration. That surely affects the other plants, but not that significantly. It can be screened that there is a connection between the population vitality of calciphilous (e.g. *Buglossoides purpurocaerulea*) and calciphobous species (e.g. *Galium sylvaticum*). The most populations of *Buglossoides purpurocaerulea* are vital on lime soils, while on lime-deficient soils grow weakly. *Galium sylvaticum* shows opposite distribution (Figure 1.).

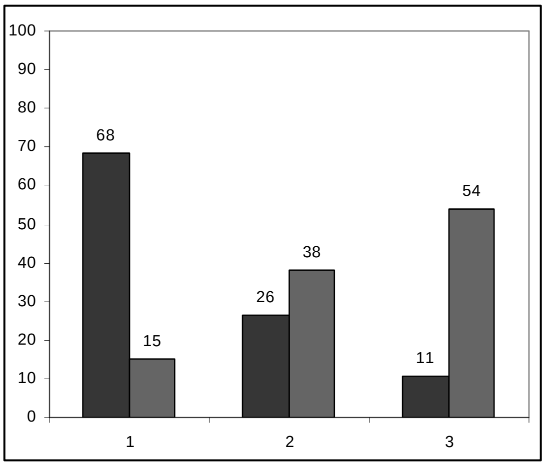

Figure 1/a. : The distribution of the vitality of *Buglossoides purpurocaerulea* by percentage on lime (right) and lime-deficient (left) soil. 1 – not vital, 2 – medium vitality, 3 – vital population

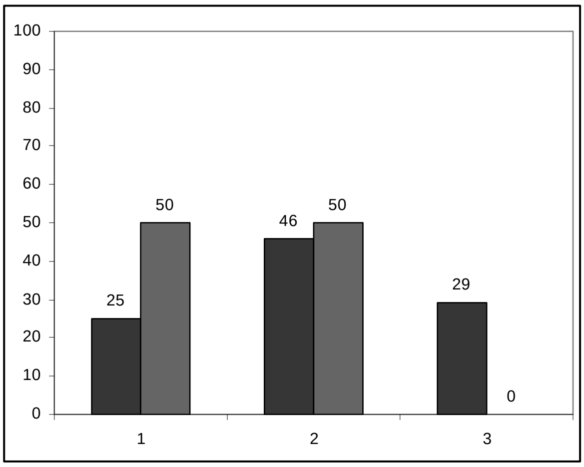

Figure 1/b. : The distribution of the vitality of *Galium sylvaticum* by percentage on lime (right) and lime-deficient (left) soil. 1 – not vital, 2 – medium vitality, 3 – vital population

Soil parameter analysis

Site conditions of *Buglossoides purpurocaerulea*

Respecting the physical properties of the soil, the species occurs on loamy soil on 77,5% of the 40 sample plots. The $pH_{(H2O)}$-values in the 63,4 % of the cases were in neutral (pH 6,5-7,5) category, 32 % of the samples occurred on acidic soil, and only 2 % on alkaline soil. 51% of the occurrence plots were under pH 7. Half of them connected to lime-deficient soil, the 30% of them were lime-rich and 20% of them contain little lime from those, which occurred on lime soil. 2/3 part of the occurrences connected to mull-, 1/3 part to moder humus, neglected part of them on raw humus, and the amount of humus in 17,5% of the cases can be classified into weakly humic, 42% into humic and 40% into humus-rich, humuos or organic soil category. This species do not occur on mildly humic soils. Regarding the nutrient supply in 73% of the sample plots, the soil's complete nitrogen amount were high and in 27% of them were medium-supplied. The phosphorus and potassium distribution were nearly normal, drawn somehow towards the nutrient-deficient (left) site, the most of the sites are medium-supplied.

Site conditions of *Galium odoratum*

Regarding the physical properties of the soil, 72% of the 73 sample plots are in loamy soil, the other 30% sand,-sandy loam or clayey loam soil in circa equally ratio. The pH (H_2O) values range from 4,2 to 7,7, two maximums can noticed in their distribution in the acid (34 %) and in the neutral (25%) province, which are only some percentage higher, than those samples in mildly acidic and mildly alkaline provinces. The occurrence rate of severely acidic category is 5%. 66 % of the occurrences is under pH 7, these sites contain no lime, while ca. third of the sample plots contains, from that 20 % much, 13 % little. On most of the sample plots (61%) the dominant humus form is the mull, about 30% of the plots can be characterized by moder humus, raw humus occurs sometimes. The distribution of the humus-content is nearly regular, the maximum of it is in humuos and humus rich categories, containing the 75% of the samples. In case of the nutrient supply in 85% of the sample plots, the soil's complete Nitrogen amount was high and 15% of them were medium-supplied. The phosphorus and potassium distribution were nearly regular, drawn somehow towards the bell curve-graph giving nutrient-deficient site, most of the sites are medium-supplied.

Site conditions of *Galium sylvaticum*

In 51 % of the 47 sampling sites *Galium sylvaticum* occurs in loam texture soil. To a lesser extent there are samples from sandy and sandy loam soils (15 and 17 %) and from clay and clay loam soils (15 and 2 %). The $pH_{(H2O)}$-values in 59,5 % of the cases were in acidic category, 15 % of the samples occurred on mildly acidic soil, and 23 % on neutral soil. Only 1 sample falls under the intermediate, mildly alkaline category. Only 14 % of the samples contain a large amount lime, 6 % contain few. 80 % originate from lime-free soils with pH value under 7. On the strength of humus forms 51 % of the samples prefer moder, and 47 % of them prefer mull, while 3 % occur on row humus. The humus contents of the sampling sites are generally high, with nearly normal distribution. 80 % of the sites has humus-rich soil, 11 % of them has humus or organic soil, while the rest 9 % of the samples has moderate humus content. This species cannot be found in humus-deficient site. Corresponding with the high humus content 71 % of the sampling sites possess good, and 26 % of them moderate nitrogen-supply. In case of potassium 50 % of the samples belong to the category of moderate potassium amount. The others contain lesser, 8 % of them are from soils of extremely poor potassium content. In the respect of the phosphorous content, medium values are typical (93 %).

Site conditions of *Polygonatum multiflorum*

In nearly 80 % of the 50 sampling sites *Polygonatum multiflorum* occurs in loam texture soil. There are samples from sandy and sandy loam soils to a lesser extent (8 and 10 % respectively). Only a minimal portion of the specimens was collected from clay and clay loam soils (1-1 sample). pH spectrum of the sampling sites ranges between 4,2 and 7,5. Distribution of the samples according to the pH value shows double maximum, at the acidic (34%) and the neutral (46 %) category. 14 % of the samples falls under the intermediate, weakly acidic category, whereas 6 % into the strong acidic category. *Polygonatum multiflorum* does not exist by pH value higher than 7,5, which regard as alkaline from pedology point of view. Consequently 60% of the samples originate from lime-free soils with pH value under 7, 20 % of them contain a large amount lime, as well as 16 % of them contain few. On the strength of humus forms 75% of the samples prefer mull, and 25% of them prefer moder. This species does not occur on row humus. The humus contents of the sampling sites are generally high. 57 % of the sites has humus-rich soil, 8 % of them has humus or organic soil. Only one sample originates from humus-deficient site, while the rest 42 % of the samples has moderate humus content. Corresponding with the high humus content 91 % of the sampling sites possess good, and 9 % of them moderate nitrogen-supply. *P. multiflorum* does not exist in nitrogen-deficient soil. In the respect of the phosphorous content, relatively high values are typical, cannot be found in phosphorous-deficient soil, 13 % of the samples contains small quantity of phosphorous, while 11% contains a large amount. Other samples possess moderate or good phosphorous quantity. In case of potassium most of the samples belong to the category of moderate potassium amount, the others contain lesser. Negligible percentage of the samples derives from potassium-rich sites, while 8 % of them are from soils of extremely poor potassium content.

Results of pF-measurements

The pF-curves for undisturbed soil samples collected from the upper soil of the growth area of the 5 selected plant species are presented in Figure 2.

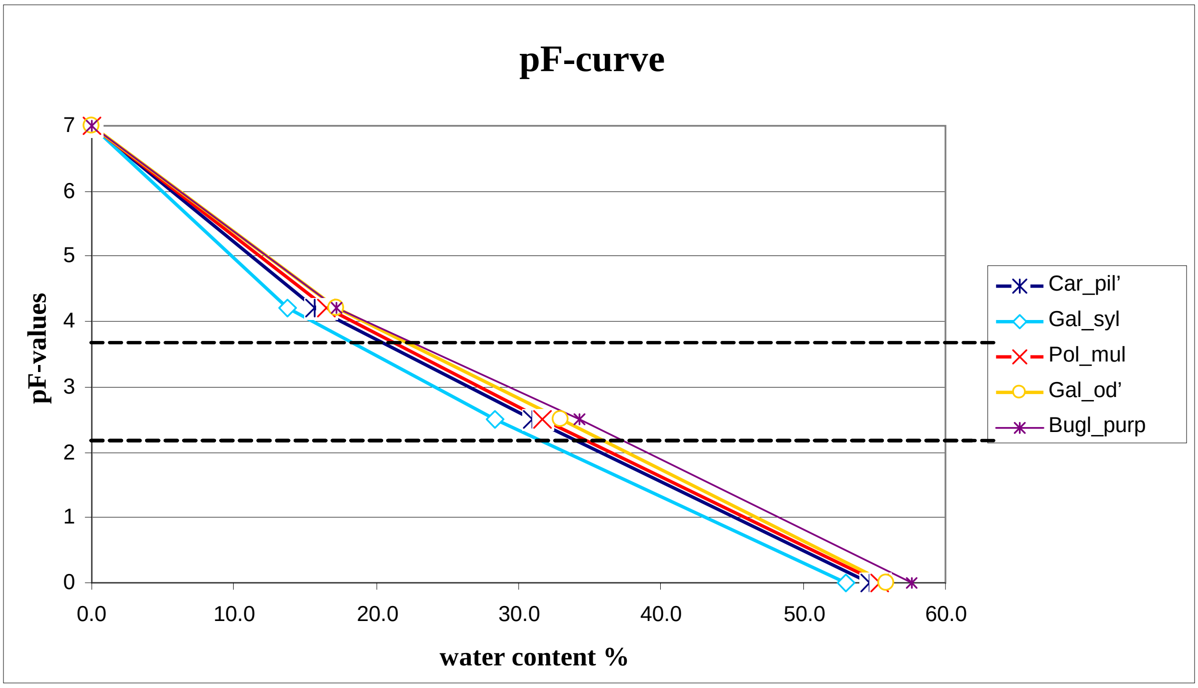

Fig. 2.: The relationship between matrix potential and water potential of the upper soil representative for the growing area of 5 plant species

The pF-curves are quite similar for all the five species. Water is drawn from the soil evenly throughout the whole domain of the matric potential between the status of full saturation and oven dried soil. This shape of curve is characteristic for loams. Hydrology of these types of soil layers is optimal for plant growth because of good infiltration of the precipitation into the soil and their ability to store proper amounts of available soil water. Based on the pF-measurements, the soil pore-structure was determined for the sites of the 5 plant species, shown in Figure 3.

According to the pF-curves, average soil pore-structure is quite similar for all five growing areas. The plant available water is stored in 13,8-17,1% of the soil volume. The range of the capillary pore space storing this available water is quite small, differences in the length of time period, in which trees, herbs and grasses can take up water from this pore space, are not bigger than 2 days.

The total pore space tells us more about the aeration of a soil. The sites of *Galium sylvaticum* showed less total pore space than the soils of the other four other species, which could indicate the ability of *Galium sylvaticum* to growth on soil with a poorer aeration.

Summarizing the results of the pF-measurements, all the five selected plant species are growing on loamy soils with a good hydrology and aeration. Differences of the extent of the growing area of these plants are probably not depending on this soil property.

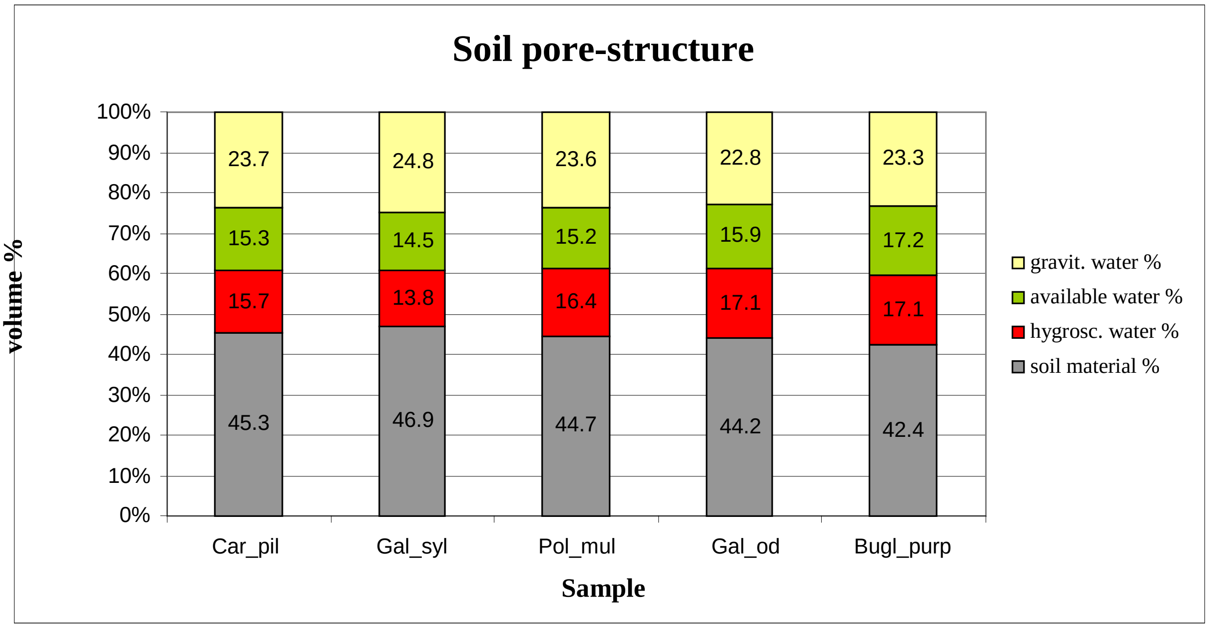

Fig. 3.: Soil pore-structure representative for the growth-area of the five selected plant species

Means of ecological indicator values

On the evidence of the group median of indexes connected to all the species of the species-list being at our disposal from the sample plots, I have represented on diagram index-spectrum of the site a given species. After I have searched correlation of indexes with the matching measured ecological factor. During the comparison at first, I have used the Borhidi-system as a base, while it is valid for the whole country and flora. Than as I forest plants I've compared them with the values of the Zólyomi-list and the Ellenberg numbers (valid for the western part of Europe). As an example I give the results of the analysis made on the sites of *Buglossoides purpurocaerulea*.

Sites of *Buglossoides purpurocaerulea*

On the grounds of the mean values of all the species W-number that occurs on the sites of blue gromwell, 91% of the species is 5, as mesic site indicator, belonging to the group of species, that are absent from wet and often desiccating habitats. It's not matching with the Borhidi-classification (WB 4), by him the species belongs to drought tolerants that sometimes occur in mesic soil. Compared with Zólyomi-system the behaviour is the same. The 73% of the sample plots has WZ-index 5 that shows unambiguously mesic site circumstances, like the former classification. Index 5 matches with Ellenberg-classification. The difference can have more causes. First of all, we have to search causes in the distribution of the species. On West-Transdanubia the occurrence of the species is sporadic, in our mountains of middle height, frequent. The Borhidi- and Zólyomi-classification use the whole country as a base, while on the research area probably the less typical habitats of the species are dominant.

On the grounds of the mean values of R-number of all species, 73% of the sample plots has index 7. These are the mildly acidic-mildly alkaline site indicator species, which never occur on acid site. In this case Borhidi classifies them one category higher, into category 8, „usually lime indicator". In Zólyomi-list the species classified into category 5, species occur in lime, alkaline soil, while in case of the West-Transdanubian occurrences, only 9% of the samples belong into the category 5, while fifty-fifty of the rest 91% of the samples shared between category 3 and 4. So in the research area it can be classified to species group that occurs on mildly acidic, neutral soil. Ellenberg's R-index is 7, so it matches with the West-Transdanubian data. The cause of the differences can be the same that was explained in connection with the W-index.

On the ground of the N-index 46% of the sites of the species are medium supplied, 36% a bit more nutrient-supplied and just 9% of them matching with the index 4 of Borhidi, which means the species that occur usually nitrogen-deficient areas. Ellenberg classified it into category 4 as well. The cause of differences may be explained by plant physiology processes. The nutrient intake for plants is more difficult on acid soil, both in the case of the ions flowed in by diffusion, and intaked by active transport. Acid pH-value of the soils can be compensated by abundant nutrient-supply. As I suppose, the species cannot exist on areas having the same pH-value, but nutrient-deficient areas. The relative rarity of the species on the research area also confirm this theory.

NEW SCIENTIFIC RESULTS

1. It is established that in the respect of the categories, classified species and permeability the indicator value systems applied in Europe are corresponding to each other. Although in the view of classified species no correlation concerning all the systems can be determine, classifications of the scales valid for the same geographic regions are similar (regarding the differences of the category definitions).
2. For the five studied species vitality scale on the strength of specific, ecomorphologic and biometric characteristics were created. By the help of this scale I displayed, that the site spectrum evaluated by presence-absence can be significantly refined. For example in contrast of our previous knowledge *Buglossoides purpurocaerulea* many cases occur in lime-deficient soils, but there is an unambiguous positive correlation between the lime content of the soil and the vitality of the population.
3. I also affirmed that in the success of the evaluation of vitality beside the soil parameters, light as ecological factor plays a significant role.
4. Detailed description based on measured data of the ecological behaviour of the five examined plant species widen our former knowledge, and also makes more precise the conditions of the occurrences of these species in the studied area, and explain the differences from the occurrences found other parts of the country as well.
5. It is also stated that the indicator values are valid for larger area than the research field. Sampling sites belong into the same geographic regions within the territory of the northwest Transdanubia, therefore form a homogeneous collection from ecological indicators point of view.
6. Analyzing the area of the studied species and the phytogeographic borders of this region in connection with my own data, it can be proved that the purposes, had been prepared during the creation of the indicator values, can be achieved. The purpose was to form an indicator value system applicable for the great geographic units of Europe. There may be differences because of the extrazonal or edaphic characteristics of a certain site, or the position of a given species within its whole range.
7. The main question on which my researches are based is whether can be defined a site correlation system of numerical values by analyzing site parameters which facilitate to make more precise the ecological indicator values. To this question, I have to answer no. By instrumental measures under the present technical conditions is impossible to detect

the complex network of the countless site correlation. At the same time a systematic and numerous sample collections by strictly the same methods can be applied – with a special regards – in the perfection of the values of the indicators.

8. It is also confirmed that neither the measuring results of the indicators nor the measuring results of the site parameters are independent of themselves, thus their correlation must be considered during the evaluations. Besides it is essential to take into account of the whole species list of a certain sampling site.

9. Further result is the discussion of the question of the so-called calciphilous and calciphobous species. Evaluating from pedology point of view, there are no or small number calciphilous species existing in closed forest, while the upper 10 cm of the forest soils normally do not contain lime. It is especially valid in case of the calciphilous *Buglossoides purpurocaerulea*. Its occurrences in west Transdanubia cannot be found on lime-rich sites, but it generally exists in nutrient-rich soils.

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