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Larger Gradients of Abiotic Factors Result in More Vegetative Zones in Salt-Affected Habitats

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ABSTRACT

Data of 11 transects were collected from the literature in order to find an answer to the question: what is the most important factor that determines the number of zones in a transect? From collected data on transect length, elevation, soil salinity and soil pH, the gradients of these parameters were calculated between the highs and lows of the transects. The number of vegetative zones per unit transect length showed a very strong correlation (significant at 0.01 level) with every studied gradient. The strongest correlation was shown by the pH gradient with r = 0.991, because of the toxicity of sodium carbonate, being responsible for the high pH values in the affected soils. Although the studied database is rather heterogeneous, the tendencies are very clear. For a comparison of the effect of separate abiotic factors on the number of vegetative zones per unit transect length, more detailed analysis with a larger number of transects (with similar length and elevation) is necessary.

Keywords: elevation, pH, salinity, zonation

INTRODUCTION

In spite of decades of recent conceptual development in vegetation science, the contrasting approaches of either communities or gradually changing species composition is still the focus of theoretical studies (Austin 2005). Soil science, focusing on pedons that cover a given land surface and not on individual plants, which sometimes have a point distribution, has similar discussions, but in general has reached a compromise of using classification for dividing the land surface into distinct classes of soil (Krasilnikov *et al*. 2009). In other words, the constraint of managing pieces of land biases soil scientists to prefer classes to points. The reason for the parallel concepts in the two disciplines could be the parallel development of soil and vegetation cover.

The general equation of Jenny (1941) describing the formation of soils as Soil = f (climate, organisms, parent material, topography, time) was adopted for vegetation, in the same form by Austin (2005). Ironically it is a group of salt-affected soils (Keren 2010; Levy 2010), which can be treated in an agricultural context without mentioning soil classes for two reasons: (i) the features of these soils are determined by their specific chemical properties and (ii) the management of these soils depends on the magnitude of particular properties, which are best shown on isoline maps and not on soil class maps. Similarly to current developments, the study of soil-plant relationship earlier was typically carried out utilizing soil classes, but often lacks such classes at present (Pennings and Moore 2001).

In contrast to agronomy, in ecological studies the concept of communities provides a frame for soil-vegetation investigations. The objectives of this study were to analyse the effect of soil properties and other abiotic factors on the zonation of vegetative stands. We focus on the issue of the number of vegetative zones, which appear in a transect. The basic question is: what is the most important factor that determines the number of zones in a transect?

Our hypothesis was the following: specific combinations of abiotic factors result in specific vegetative stands.

Our working hypotheses were the following:

1) The larger the number of combinations of abiotic factors, the larger is the number of occurring specific vegetative stands. Here the possible abiotic factors are temperature (cold-hot), watertable depth (shallow-deep), watertable salinity (great-small), soil salinity (great-small), soil alkalinity (great-small), soil sodicity (great-small), soil moisture content (great-small), soil texture (clay-sand), elevation (low-high).
2) The stronger is the gradient of abiotic factors in a segment perpendicular to the zonation borders, the narrower is the transition zone between the vegetative zones. This hypothesis has been set and verified by Zalatnai (2008).
3) The larger is the number of abiotic factors operating inside the area, the larger is the number of vegetative zones.

The stronger the gradient and the larger the number of abiotic factors, the larger is the number of vegetative zones and the narrower is the zone and the transitional zone.

MATERIALS AND METHODS

Transects 1-11 (**Table 1**) were selected from the literature for this analysis. The main requirement for the transects was to have the following minimum data: plant zonation information, elevation, length and soil salinity. Only transects showing a constant rise/drop were selected. The different salinity related parameters were transformed into electrical conductivity of the saturation extract according to Richards (1954). A short description of the transects shown in **Table 1** and **Figs. 1-4** follows.

Inland transects

Transect No. 1. from Zalatnai (2008), "First transect" was described at Miklapuszta (46° 36' 25" N, 19° 05' 40" E) (Hungary) on fluvial alluvium (texture was gravel-sand and clay-silt) with 'Solonchak', 'Solonchak-solonetz' and 'Chernozem' soil types in a treeless, halophyte vegetation.

Transect No. 2. from Zalatnai (2008), "Second transect" was described at Mórahalom (46° 11' 15" N, 19° 52' 37" E) (Hungary)

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Research Note

Table 1 The measured and derived parameters of the 11 studied transects.

Code of transect#	Number of Zones	Length of transect						pH	Zones/Length	Elevation/Length gradient	Salinity/Length gradient	pH/Length gradient	Sum of gradients	Affecting factors
	vegetative unit	m	at low	at high	at low	at high	at low	at high	/m	n.a.	dS/m	/m		
1	6	15	0	0.27	2	16.7	7	9	0.4	0.018	0.978	0.133	1.129	Salinity, sodicity, pH, soil water retention, waterlogging
2	2	20	0	0.8	4.6	2	8	8	0.1	0.04	0.134	0	0.174	Salinity, soil water retention
3	4	30	0	0.8	10	5.3	7	7	0.133	0.027	0.156	0	0.182	Salinity, sodicity, pH, soil water retention, waterlogging
4	4	400	0	3	15	0.5	8.2	6.9	0.01	0.008	0.035	0.003	0.047	Chemical composition, seasonal dynamics of soil solution, salinity, dynamics of groundwater, flooding period
5	8	2480	9.4	10.2	35	2	7	6.8	0.003	0	0.013	8.06E-05	0.014	Salinity, waterlogging
6	4	30	0	2	13.5	85	7.7	8.7	0.131	0.066	2.346	0.032	2.443	Soil moisture, soil chemistry, texture soil minerals
7	3	225	0	3	130	180	7	7.3	0.013	0.013	0.222	0.001	0.237	Soil redox potential, salinity, sulphide concentration
8	6	200	3	4	116	71.5	8	8.3	0.03	0.005	0.223	0.002	0.229	Flooding period, salinity, minimum Ca/Na ratio, mean SAR
9	5	45	3	5	10.9	13.9	9.3	8	0.111	0.044	0.067	0.029	0.3	Flooding period, salinity, minimum Ca/Na ratio, mean SAR
10	4	70	95.7	96.2	8.6	0.67	9.8	8	0.057	0.008	0.114	0.025	0.148	Salinity, sodicity, pH, soil water retention, waterlogging
11	4	3	0	1	24.9	8.9	10	7.9	1.333	0.333	5.333	0.693	6.36	Differences in relative elevation, salinity

#Data were collected from the following publications **1**: Zalatnai (2008) 1st transect; **2**: Zalatnai (2008), 2nd transect; **3**: Zalatnai *et al.* (2008); **4**: Cantero *et al.* (1998); **5**: Vince and Snow (1984); **6**: Brotherson (1987); **7**: Mathijs *et al.* (1999); **8**: Alvarez Rogel *et al.* (2001), 1st transect; **9**: Alvarez Rogel *et al.* (2001), 2nd transect; **10**: Tóth *et al.* (2009); **11**: Mile *et al.* (2001)

on sand dunes formed on fluvial alluvium with 'Meadow', salt-affected soils with loamy texture in a steppe grasslands - salt marsh transitional area.

Transect No. 3. from Zalatnai *et al.* (2008) was described at Csikóspuszta (46° 17' 21" N, 20° 38' 8" E) (Hungary on gravelly/ sandy fluvial alluvium with 'Chernozem', 'Meadow solonetz' soils in loess grassland, salt–affected grassland, salt marsh/meadow vegetation.

Transect No. 4. from Cantero (1998) was described in Cordoba province (Argentina). The area is characterized by fluvial paleoactivity, and interconnected lagoons. Soil types are Typic Natraquoll, Typic Natraqualf and Typic Duraqualf. Water table oscillates yearly. Vegetation is 'meadow' grassland, and salt marsh.

Transect No. 6. from Brotherson (1987) was described at the west bank of Utah lake (USA). The soil texture is silt dominated. Vegetation is halophyte grassland, like annual saltgrasses, alkali-grasses, saltgrass-forb, and typical saltgrasses.

Transect No. 10. from Tóth *et al.* (2006) was described at Apaj (Hungary). The sandy salt-affected soils are covered by salt-affected grassland vegetation.

Transect No. 11. from Mile *et al.* (2001) was described at Pétery lake (Hungary). Periodically waterlogged micro-relief is typical here, hence vegetation is composed of various salt-affected grasslands, with sharp boundaries.

Seashore transects

Transect No. 5. from Vince and Snow (1984) was described at Sustina River Alaska, (61° 15' N 150° 30' W) (USA). Soil layers of silt and peat alternate. Vegetation is mudflat, and sedge marsh.

Transect No. 7. from Mathijs (1999) was described at Gazi bay (4° 25' S, 39° 50' E) (Kenya). Soil type changes form dark grey coloured muddy soil, with loam texture, to a sandy light textured soil along the transect. Vegetation is mangrove forest.

Transect No. 8. from Alvarez Rogel (2001), was described at the La Mata lagoon (38° 02' 00" N, 0° 40' 35" W) (Spain) originally as "Transect 1". Along the transect ochric and mollic epipedon was found, with $CaCO_3$ increasing with depth. Soil texture was silty-loam. Vegetation is halophyte grassland.

Transect No. 9. was described by Alvarez Rogel (2001), as "Transect 2" in the original publication, but compared to their "Transect 1" had different texture, sand.

Each transect was tabulated between the lowest (minimum elevation) and highest (maximum elevation) points. The corresponding variables, such as length of the transect, the number of vegetative zones, salinity and pH were tabulated between these extreme points.

The hypotheses were tested by correlation analysis, using the Pearson correlation coefficient. For each calculation (or each figure), the individual transects provided one pair of observations, resulting in a sample size of 11. The number of zones per length of transect (for Transect No 1 it was 6/15, see first line of **Table 1**) was correlated with derived variables, such as the elevation gradient, the salinity gradient, the pH gradient and the sum of these three gradients (see **Table 1**). Gradients were calculated analogous to slope: the rise was divided by the transect length. For example elevation gradient for Transect No 1 was calculated as (0.27-0)/15, see first line of **Table 1**.

RESULTS AND DISCUSSION

Table 1 shows the basic measured parameters of the transects together with the derived ones. Since the most important question was how frequently do the vegetative zones follow each other, the main 'dependent' variable was the number of zones per unit length of the transect. This variable, although it seems to be suitable, has some drawbacks, which are enumerated below.

Firstly, the length of the transects depends very much on the overall scale of the studies. This scale is sometimes not evident from the publications, which focus on the relationship between vegetation and soils. Typically, ecological or restoration, management studies use larger transects and floristic and pedological studies use shorter ones. An example is the case of the four Hungarian studies. Transect No 11 focussed on coenological assessment of natural salinization. Transects Nos 1 to 3 were surveyed for studying the vegetation boundaries. Transect No 10. was sampled for de-

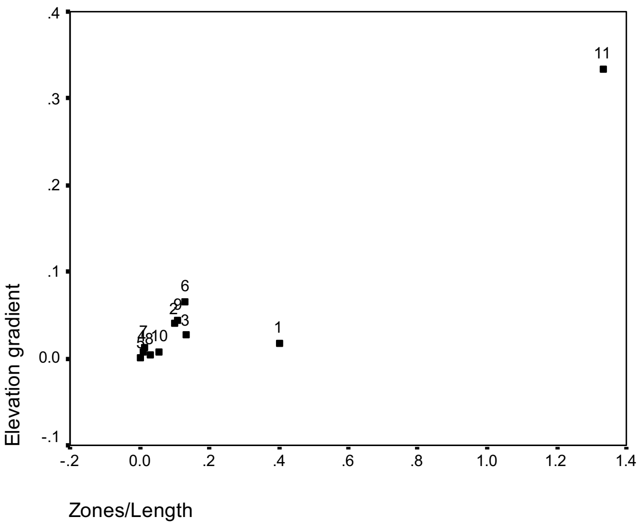

Fig. 1 Relationship between the elevation gradient and the number of zones per unit length of the transect. Labels refer to individual transects as shown in **Table 1**. The correlation coefficient is 0.954 (significant at 0.01).

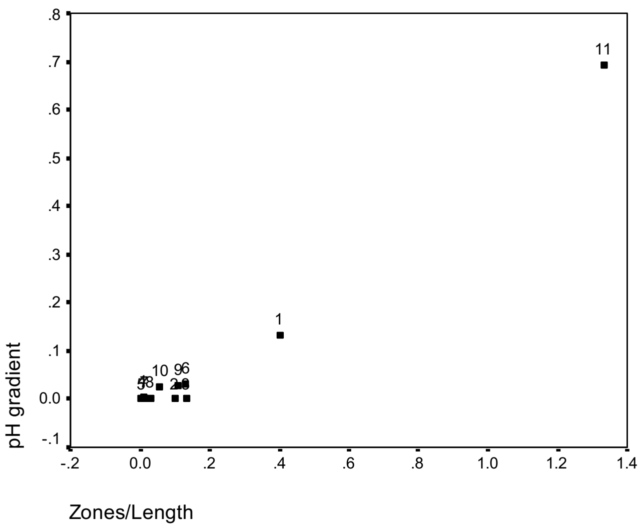

Fig. 3 Relationship between the pH gradient and the number of zones per unit length of the transect. The correlation coefficient is 0.991 (significant at 0.01).

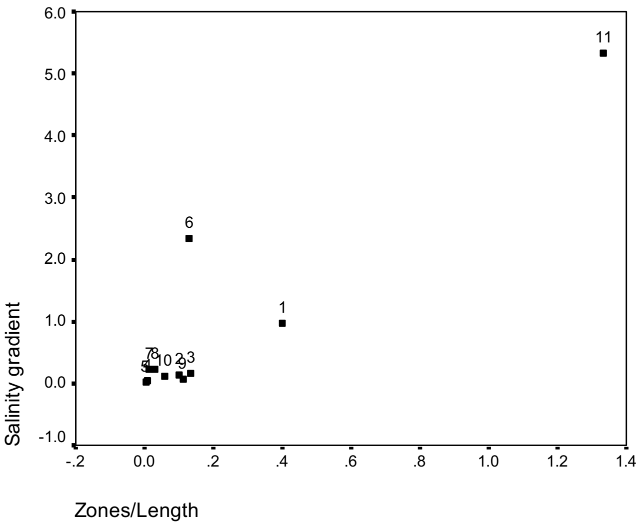

Fig. 2 Relationship between the salinity gradient and the number of zones per unit length of the transect. The correlation coefficient is 0.920 (significant at 0.01).

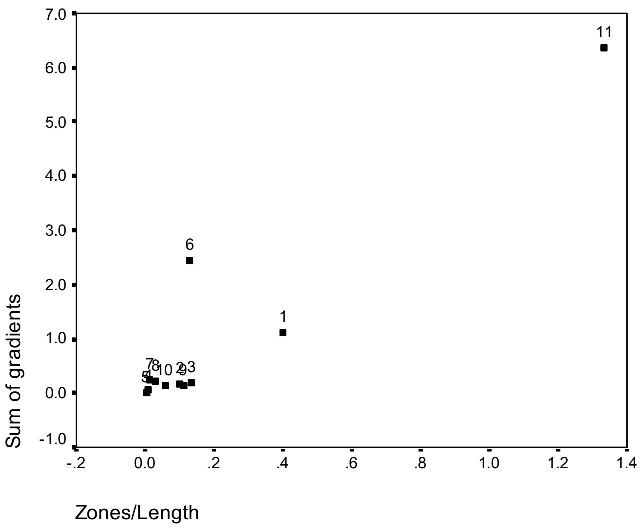

Fig. 4 Relationship between the sum of elevation, salinity and pH gradient and the number of zones per unit length of the transect. The correlation coefficient is 0.938 (significant at 0.01).

monstrating the usefulness of five different geoelectric field instruments.

Secondly, the number of the vegetative zones depends very much on the objectives of the studies. For management and restoration, typically fewer zones are distinguished than for floristic and pedological studies. As an example, it was a very important issue to distinguish as many zones as possible in the Transects 1-3, resulting in a detailed zonation.

Figs. 1-4 show the relationships between the calculated gradients and the number of vegetative zones per unit transect length. The elevation is a variable, which does not have a direct affect on the vegetation, but includes the complex effects of other variables. In the case of salt-affected habitats, the most important of these variables is wetness/waterlogging, but sedimentation is also important. Based on the circumstances and the selection of the transects, higher elevation can be linked to lower or to higher salinity.

Fig. 1 shows that there is a very strong correlation between the gradient in the elevation and the number of zones per unit length. The scatter of the points is dominated by Transect No 11, which was surveyed in the most alkaline environment. Being also the shortest, it had a very remarkable effect on the scatter and the overall correlation coefficient.

Fig. 2 shows the effect of salinity gradient on the number of zones per unit length of the transect. All three outstanding points in the upper part belong to active and ancient lakeside sites. Salinity has very strong physiological effect, but it has somewhat weaker correlation with the number of zones per unit length than the elevation gradient had.

As **Fig. 3** shows, the strongest correlation with the number of zones per unit length was shown by the pH gradient. High pH values are closely related to the presence of salts that show alkaline hydrolysis. The most characteristic such salt is sodium carbonate, typical for the Hungarian Plain, where Transect Nos 1 and 11 were described. Since carbonate is toxic, its strong effect on the number of zones was expected.

In order to check the hypothesis of the effect of combined abiotic factors, the scatter of the summed gradient values (elevation+salinity+pH) with the number of zones per unit length is shown in **Fig. 4**. The correlation coefficient is not higher than those shown in **Figs. 1-3** and the pattern is very much similar. There is no evident improvement in the correlation with the number of the zones per unit length as the result of summing the gradients.

Although the studied database of 11 transects is rather heterogeneous, the tendencies are very clear. This assessment is the first step towards more detailed evaluations. For a comparison of the effect of separate abiotic factors on the number of vegetative zones per unit transect length, more detailed analysis with a larger number of transects (with similar length and elevation) is necessary. Therefore the database of transects will be enlarged. Subsequent evaluations will diverge based on the inland/seashore character of the transects.

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