COMMUNITY BOUNDARIES AND EDAPHIC FACTORS IN SALINE-SODIC GRASSLAND COMMUNITIES ALONG AN ELEVATION GRADIENT

M. Zalatnai, L. Körmöczi and T. Tóth

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Abstract. In the characteristic saline-sodic grassland of Miklapuszta a 15 m transect with 30 cm elevation difference was delineated. After the survey of 150×6 micro-quadrates and soil sampling in each 10 cm interval, the vegetation boundaries and soil-plant relationships were studied with moving split window (MSW) and correlation techniques.

Our objective was to test how precisely can the visible boundaries of the community patches distinguished during field observation coincide with the boundaries determined by MSW from the vegetation and soil data. Data showed that the best coincidence of the boundaries was in the depression, the most saline and sodic part of the transect. The interpreation of the data supported the hypothesis, that the higher the soil salinity and sodicity, the better is the coincidence of the vegetation and soil section boundaries.

Keywords: moving split window, environmental gradient, soil parameters, solonchak-solonetzic soil

Nomenclature: Borhidi (2003) for coenotaxa.

Abbreviations: MSW – moving split window, SED – Squared Euclidean Distance, DREN – complement of Renkonen similarity index, EC – electrical conductivity

M. Zalatnai, L. Körmöczi, Department of Ecology, University of Szeged, Közép fasor 52. H-6726 Szeged, Hungary; e-mail: zalatnai@bio.u-szeged.hu; **T. Tóth**, Research Institute for Soil Science and Agrochemistry of the Hungarian Academy of Sciences, Budapest

Introduction

Zonation along elevation gradients is one of the basic features of vegetation distribution (Whittaker 1975). The zonation of plant community patches and the establishment of their boundaries are generally closely related to the edaphic factors (Begon *et al.* 1986, van der Maarel 1976). Sharp vegetation boundary occurs between the communities of edaphic grasslands at those places where there are abrupt changes in edaphic parameters, and the boundaries are wider if the variation of edaphic parameters is gradual (Hobbs 1986, Begon 1986).

In the case of saline areas the spatial pattern of the vegetation is often micromosaic-like and the zonation appears at small distances due to the strong ecological stresses of soil salinity, sodicity, alkalinity and waterlogging/drought (Bodrogközy 1965, 1970, Tóth *et al.* 1991, Tóth and Rajkai 1994). The variation of the above edaphic parameters is often abrupt at small distances, which is highlighted by the vegetation boundaries (Zalatnai and Körmöczi 2004).

In Hungary, a country with a wide range of soil conditions, there are large areas covered by natural and semi natural grassland vegetation (Fekete and Varga 2006). Recently much interest has been focused on the saline and sodic grasslands (Molnár and Borhidi 2003), because there is a tendency of decreasing soil salinity (Harmati 2000) and changing vegetation in the central part of Hungary (Molnár and Borhidi 2003). A range of techniques is being tested for monitoring the changes, such as satellite imagery and aerial photos for detecting shifting boundaries of microerosional mounds (Rakonczai and Kovács 2000). From a vegetation ecologist's point of view it is important to follow the temporal changes in the vegetation boundaries in those saline grasslands and to reveal the strength of the relationships of the boundaries with edaphic parameters.

There are several methods for the examination of vegetation boundaries (Kent *et al.* 1997, 2006, Fortin and Dale 2006). We applied moving split window (MSW) boundary analysis that was used first by soil scientists (Webster 1973) and recently is applied by ecologists to detect ecotones and landscape boundaries from one and two dimensional data sets (Johnston *et al.* 1992.) and in two publications we already tested the methods in fine-scale studies (Zalatnai and Körmöczi 2004, Körmöczi 2005).

In this paper we described the soil-plant relationships and the establishment of their boundaries in the zonation of saline-sodic grassland communities along an elevation gradient.

Our basic questions were:

1. Do the boundaries of the vegetation units, visible in a field observation, coincide well with the boundaries determined by MSW from the vegetation and soil data?

2. How strong is the relationship between the elevation and the dependent edaphic parameters and the establishment of community boundaries?

3. Does increasing soil salinity level result in sharper boundary between vegetation patches?

Materials and methods

Study region

The sampling region was Miklapuszta, the largest alkali habitat complex of the Danube-Tisza interfluve region; it belongs to the territory of the Kiskunság National Park, Hungary. The area is a mosaic complex of the patches of diverse halophytic habitats, such as salt marshes, saline meadows, alkali bare hollow communities and saline puszta (Horváth 1997). It is situated in the middle of the Danube valley, its total area is 6241 ha. The climate of the region is continental, with mean January temperature of –1.4, mean July temperature of 21.8 °C, and mean annual temperature of 10.7 °C. Mean annual precipitation is 577 mm. It was the former floodplain of the river Danube which was built up in the middle Pleistocene by gravel and sandy gravel sediments. Later, silt and clayey silt layers were deposited above the fluvial sand in the Holocene and then these silt and clayey silt deposits have become salt affected in large areas in the Danube valley (Pécsi 1967).

Sampling site

The sampling site was located in the south-west part of the area, near Felsőerek village (N 16° 36' 25" E 19° 05' 40").

It is dominated by solonchak and solonchak-solonetz soil types (Pécsi 1967) covered with different types of halophyte vegetation and meadow chernozem soil at higher elevation with glycophylic vegetation. The erosion activity of the former inundations and the water resulting from snow melting formed diverse microtopography. The erosion of the nonsaline A horizon and the high level of ground water resulted in varied environmental conditions due to the different surfaces of steps ("szik banks") characterised by distinct soil types, salt content, water supply and alkalinity. This special geomorphological formation has received already much attention by Strömpl 1931, Tóth 2001, Kovács *et al.* 2006. Due to the varied effects of the diverse environmental conditions, the plant communities are distributed in a zonation-like manner along the elevation, salt accumulation and soil water supply gradients (Horváth 1997).

In higher terrains *Achilleo setaceae-Festucetum pseudovinae* Soó 1933 corr. Borhidi 1996 association forms large stands (Horváth 1997). It is a species-rich, dry, slightly salt affected pasture; its soil type is meadow chernozem with higher salinity in greater depth below the zone of the roots, characterized by thick nonsaline A horizon (approx. 30 cm) and neutral soil reaction.

The characteristic association of the slopes and microerosional plateaus of "szik banks" is *Artemisio santonici-Festucetum pseudovinae* Soó 1933 corr. Borhidi 1996 (Horváth 1997). It is characterized by thin nonsaline A horizon (approx. 10 cm) and saline B horizon, slightly alkaline soil reaction, and extreme unbalanced water supply. The soil type is meadow solonetz. The vegetation is composed of halotolerant species. Here the stands are small and they have strongly transitional character.

At the foot of the slopes, at the lowest elevation where the A horizon is completely eroded, the plants can survive on the hard, saline B horizon under extreme habitat conditions where the salts accumulated close to the surface of the soil because of the high level of groundwater. Its soil type is solonchak, the soil reaction is alkaline. This vegetation zone is characterized by the halophyte and species poor *Lepidio crassifolii-Puccinellietum limosae* Soó 1947 association (Horváth 1997).

In the lowest depressions, small stands of *Agrostio-Caricetum distantis* Rapaics ex Soó 1938 are located on slightly solonchakized meadow soils (Horváth 1997). The soil reaction is slightly alkaline.

The soil surface is covered with shallow water in the spring period and can be wet during summer as well.

Vegetation sampling

We established a fine scale contiguous belt transect perpendicular to an ephemeral streamlet. Four different plant communities could be identified along the transect where the elevation, the level of salt accumulation and water content of the soil constituted the background gradients (Fig. 2). The communities were the following: *Achilleo-Festucetum pseudovinae* on higher elevation, on the szik bank, *Artemisio-Festucetum pseudovinae* on the slopes of the szik bank, *Agrostio-Caricetum distantis* in the lowest and wetter part of the depression and *Lepidio-Puccinellietum limosae* at the foot of the slope in the drier part of the depression (Fig. 2, Table 1).

Vegetation and soil samples were taken in regular arrangement. The transect was 15 m long and the largest elevation difference was 30 cm.

The transect consisted of 150×6 contiguous micro-quadrats, 10×10 cm size each. Presence/absence data of the plant species were recorded in the quadrats once in May of 2001. The location of the vegetation patches and boundaries were also observed visually along the transect.

Soil sampling and laboratory analysis

Soil sampling was done at the time of the vegetation relevés in regular arrangement. Samples were collected from the centre of the outermost quadrats of each row from 0-10 cm depth. Laboratory analysis of the soil samples was carried out according to Buzás (1988).

Soil pH was measured in 1:2.5 soil:water suspension with a glass electrode after 12 hour equilibrium time. Soil organic matter content was measured with spectrophotometer after wet oxidation by potassium dichromate and sulphuric acid. Na^+ ion content was measured in 1:5 soil:water suspension with flame photometer. Electrical conductivity (EC) was measured in 1:2.5 soil:water suspension with conductometer (WTW multi 340i).

Statistical analysis

First the presence/absence values (zero or one) of plant species were summed in the six microquadrats perpendicular to the main axis of the transect at each 10 cm interval, resulting in local frequency values ranging from 0 to 6 for each species. We used these local frequency values in moving split window and multivariate analyses.

The distribution of each species was visualized along the transect from these frequency values (Fig. 1).

The moving split window technique (Webster 1973, Ludwig and Cornelius 1987, Johnston *et al.* 1992) was used to detect and characterise the boundaries between associations along the transect. Squared Euclidean Distance function (Brunt and Conley 1990) and the complement of Renkonen similarity index given by

$$DREN_{jk} = 1 - \sum_{i=1}^{n} \min \left\{ \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, \frac{x_{ik}}{\sum_{i=1}^{n} x_{ik}} \right\}$$

(n: number of species, x_{ij}: frequency of species i in quadrat j, x_{ik}: frequency of species i in quadrat k) was used to compare the two halves – j and k – of the window. (For the detailed description of the methods see Zalatnai and Körmöczi 2004, Körmöczi 2005.). The same boundaries can be obtained by both functions but SED results in sharper peaks and it is more sensitive to differences in species abundance than DREN whereas DREN is more sensitive to differences in species composition than SED (Körmöczi 2005). We used both functions to make clear which factor is decisive in the development of the boundary zone in the transect.

Plotting the average Z-score transformed values of the SED function vs. window midpoint position results in a profile diagram where a significant peak is identified as a vegetation boundary. We computed the values of the function in several scales (half window sizes) from 1 to 20. In our case the half window size 1 means a 25 cm segment of the transect.

The significance of the peaks was tested with the Z-score transformation of the squared Euclidean distance values (Cornelius and Reynolds 1991, Hennenberg *et al.* 2005). Z-score transformation is given as:

$$Z = \frac{d_{i,k} - \bar{d}_{exp.,k}}{SD_{exp.,k}}$$

where $d_{i,k}$ is the SED value for the i^{th} window midpoint position for k half-window size, $\bar{d}_{exp.,k}$ is the overall mean SED value from randomized data for k half-window size (expected mean), and $SD_{exp.,k}$ is standard deviation of SED values from randomized data for k half-window size.

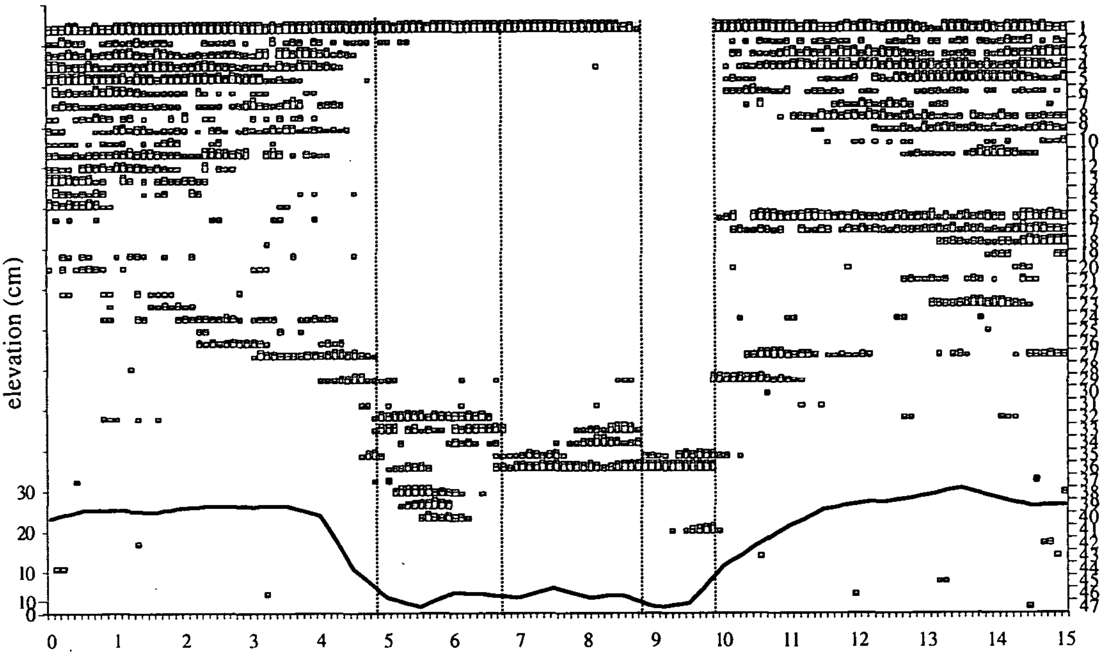

Figure 1. Spatial distribution of local frequency of the plant populations along the transect. The broken lines sign the boundaries revealed by MSW analysis, elevation is also indicated. The plant species are marked by numbers:
1. *Festuca pseudovina*, 2. *Ornithogalum umbellatum*, 3. *Cynodon dactylon*, 4. *Achillea setacea*, 5. *Medicago falcata*, 6. *Potentilla arenaria*, 7. *Vicia angustifolia*, 8. *Koeleria cristata*, 9. *Thymus glabrescens*, 10. *Plantago lanceolata* 11. *Galium verum* 12. *Carex liparicarpos*, 13. *Stipa capillata*, 14. *Centaurea pannonica*, 15. *Bromus inermis*, 16. *Cerastium semidecandrum*, 17. *Erophila verna*, 18. *Arenaria serpyllifolia*, 19. *Poa angustifolia*, 20. *Veronica prostrata*, 21. *Fragaria viridis*, 22. *Gypsophila muralis*, 23. *Chrysopogon gryllus*, 24. *Euphorbia cyparissias*, 25. *Plantago media*, 26. *Botriochloa ischemum*, 27. *Agropyron repens*, 28. *Scabiosa ochroleuca*, 29. *Artemisia santonicum*, 30. *Plantago maritima*, 31. *Podospermum canum*, 32. *Lotus corniculatus*, 33. *Aster tripolium*, 34. *Carex stenophylla*, 35. *Lepidium crassifolium*, 36. *Puccinellia limosa*, 37. *Bromus mollis*, 38. *Agrostis stolonifera* 39. *Juncus gerardii*, 40. *Hordeum hystrix*, 41. *Camphorosma annua*, 42. *Leontodon autumnalis*, 43. *Medicago minima*, 44. *Asperula cynanchica*, 45. *Veronica spicata*, 46. *Salvia pratensis*, 47. *Carduus nutans*.

Random reference was made with Monte Carlo method: the population patterns were randomly shifted compared to each other (Horváth 1998), thus the distributions of the single populations remained unchanged. SED or DREN values were then computed for each window position. Overall mean and standard deviation of distances were calculated after 1000 randomization, these are considered as expected values. Expected means and standard deviations were computed for each window sizes. The differential profiles were then drawn from Z-scores averaged over 1 to 20 half-window sizes.

As the distribution of the expected mean is very close to normal distribution, Z-scores greater than 1.65 are considered significant at 5% probability level and Z-scores greater than 1.28 are considered significant at 10 % probability level.

The measured abiotic parameters (elevation, pH, organic matter, Na^+ ion content, EC) were also analyzed by MSW with the application of SED function, before the analysis they were standardized by the range. For the average Z-score profile diagram of abiotic parameters the same significance test was used as for the vegetation data.

Pair-wise correlations were computed between the measured abiotic parameters (elevation, pH, organic matter, Na^+ ion content, EC) with SPSS 11 program package to reveal their interdependence.

Finally, in the five vegetation sections separated by MSW (Table 2), we examined the relationships between the above abiotic parameters and the local frequency values of plant species via factor analysis (Tóth *et al.* 1995, Boeye and Verheyen 1994). In each section we computed with exploratory PCA the first factor from the abiotic parameters and with a separate computation the first factor from the frequency values of the plant species in the same section. Than in each section we computed the

Pearson-correlation coefficient between the respective first factors of abiotic parameters and of the local frequency values of plant species. SPSS11 program package (Howitt and Cramer 2002) was used in factor analysis and computing correlation coefficients.

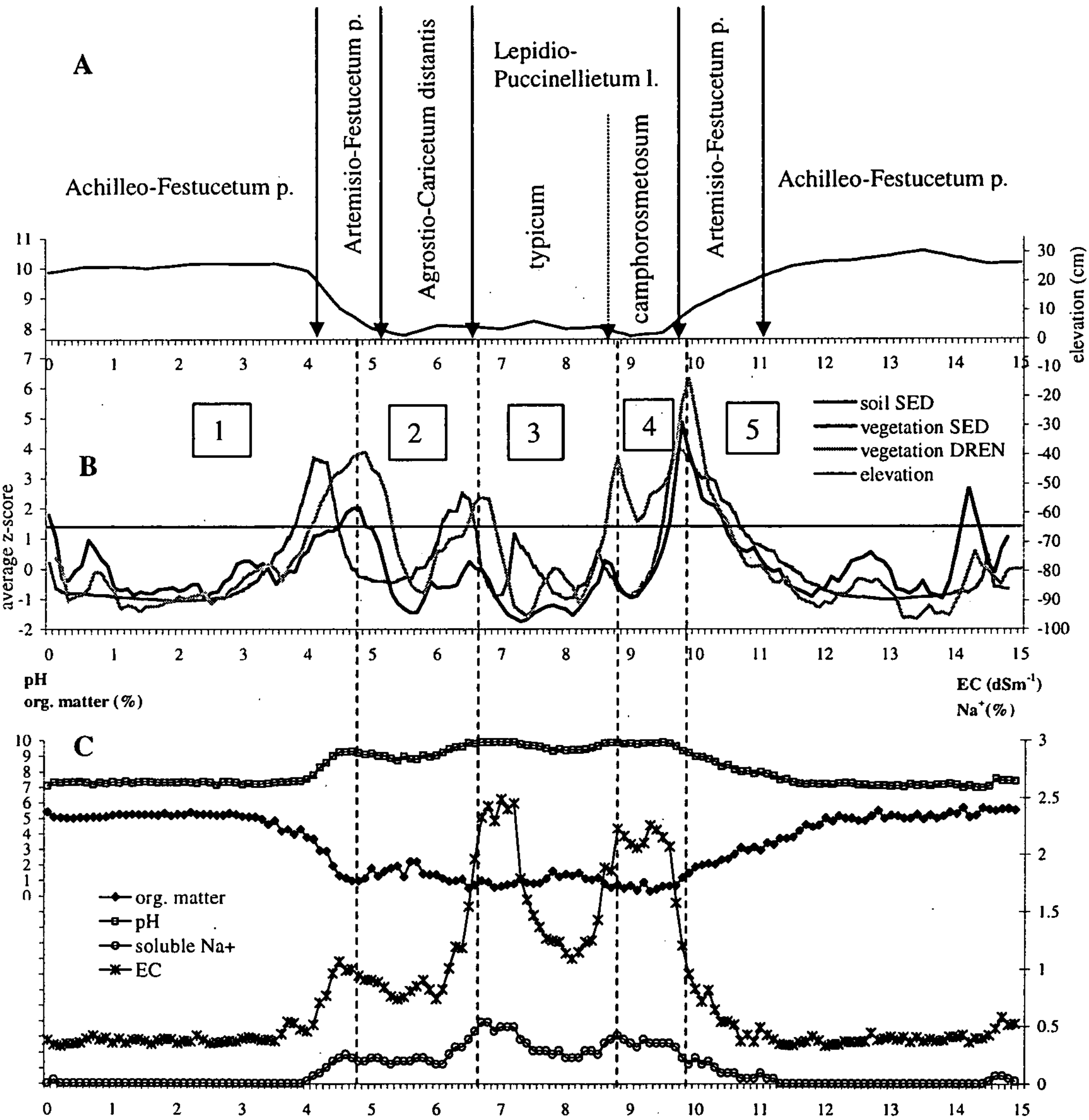

Figure 2. A: The spatial distribution of the community patches along the transect and the elevation profile of the transect. Arrows sign the visual boundary of the communities **B:** Average Z-score profile diagrams of vegetation (with SED and DREN functions) and soil factors (with SED function) obtained by MSW along the transect. Z-scores are averaged over 1-20 half window sizes. **C:** Changes of the abiotic parameters (pH, Na ion content, EC, organic matter content) along the transect. The broken lines sign the boundaries revealed by MSW analysis.

Results

The distribution of the populations along the transect

Individuals of 47 plant populations occurred along the transect local frequency distribution of which is presented in Fig. 1.

The populations correspond well with the five community patches. The separation of the patches is clear, the spatial distribution of only few species overlap in certain degree.

MSW analysis

In the case of the vegetation data four sharp peaks appeared on the average Z-score profile with DREN function and five sharp peaks appeared with SED function (Fig. 2.B). The shape and the location of four peaks with both functions coincided well and separated the vegetation into five section, these sections were referred in Table 2. At 14.5 m only SED function reaches a significant peak but it is rather close to the end of the transect thus cannot be considered.

Table 1. The spatial distribution of the community patches along the transect by visual observation

Achilleo-Festucetum pseudovinae	0-4.2 m, 11.1-15 m
Artemisio-Festucetum pseudovinae	4.2-5.2 m, 9.8-11.1 m
Agrostio-Caricetum distantis	5.2-6.6 m
Lepidio-Puccinellietum typicum	6.6-8.7m
Lepidio-Puccinellietum camphorosmetosum	8.7-9.8

Table 2. Vegetation sections along the transect made by MSW

1.	2.	3.	4.	5.
0-4.8 m	4.8-6.7 m	6.7-8.9 m	8.9-9.9 m	9.9-15 m

All of the DREN peaks were significant but only two SED peaks were significant. Since the saline grasslands generally have few species, the values of the SED function were low. Therefore we consider vegetation boundary where DREN or both functions have significant peak.

The location of the peaks coincided in three cases with the visual boundary of the community patches (Table 1, Fig. 2.A,B) but the peak at 4.8 m is located between the two visual community boundaries.

In the case of the soil parameters, the MSW analysis showed three marked significant peaks. The peak at 9.9 m coincided well with the peaks of the vegetation data but in the position of 4.2 and 6.5 m the peaks of soil and vegetation data were in 60 cm and 20 cm distances, respectively.

The peak at 4.2 m coincided well with the visual boundary of community patches.

Soil conditions

Changes in the values of pH, electrical conductivity, soluble Na^+ ion content and soil organic matter content were plotted against the relative elevation (Fig. 2.C) along the transect. pH was neutral (approximately 7) on the szik banks. The soil reaction of the slopes was slightly alkaline (between 7 and 9 pH) and that of the depression was strongly alkaline (between 9 and 10 pH). Soluble Na^+ ion content was zero on the top of the szik bank, on the slopes and on the depression it ranged from 0 to 0.6%. The values of the electrical conductivity were low on the top of the szik bank (between 0.3 and 0.5 dS/m), and ranged from 0.5 to 1 dS/m on the slopes and from 1 to 2.5 dS/m in the depression depending on the elevation. The organic matter content was high on the top of the szik bank, it changed between 5% and 6 %, between 2% and 4% on the slope, and between 0 and 2% in the depression depending on the elevation.

Organic matter content values positively correlated with the elevation: they were high on the top of the szik bank and decreased continuously on the slopes until reaching a minimum at the depression. pH values showed large variation along the transect and closely correlated with either electrical conductivity or Na^+ ion content. pH, Na^+ ion content and electrical conductivity correlated negatively with the elevation, their values were low on the top of the szik bank and increased continuously on the slopes until reaching their maximum at the depression.

Table 3. Pair-wise correlations between the measured abiotic variables.

	organic matter	pH	EC	soluble Na
elevation	0.961**	-0.970**	-0.820**	-0.910**
organic matter	-	-0.977**	-0.831**	-0.912**
pH		-	0.891**	0.959**
EC			-	0.959**

** Correlation is significant at the 0.01 level (2-tailed).

The pair-wise correlations were significant ($p<0.01$) between the measured abiotic parameters, indicating that the saline-sodic grassland had very strong organization (Table 3). Elevation is the most important factor with respect to the soil properties, as all other variables depend on it. Therefore the correlation between each pair of variables is statistically significant. It is the salt accumulation that primarily depends on the elevation increasing with the decrease of relative height, and therefore there is a negative correlation between these two variables. Electrical conductivity depends basically on the Na^+ ion content, therefore the higher the Na^+ ion content the higher the EC is. pH depends on the salt content in this soil which contains dominantly sodium-carbonate. The higher the Na ion content the less the microbial activity and plant biomass are, that is to say soil organic matter content. Therefore there is a negative correlation between soil pH, EC, and Na^+ ion content and soil organic matter, and there is a strong positive correlation between the elevation and soil organic matter. This pattern is also strongly affected by the water supply: precipitation water regularly accumulates in the depression.

Table 4. Pearson correlations between the first factors of the measured abiotic parameters and those of the frequency values of plant species in the five sections of the transect.

	1	2	3	4	5
	0-4.8 m	4.9-6.7 m	6.8-8.9 m	9-9.9 m	10-15 m
Correlation coefficient	-0.685	0.533	-0.569	-0.859	-0.814
Level of significance	0.01	0.01	0.01	0.01	0.01

The results of the factor analysis showed that in the five vegetation sections separated by MSW the correlation coefficients were significant ($p<0.01$) between the first factors of the soil parameters and those of the abundance values of the plant populations (Table 4). The strongest correlation in absolute value was found in the fourth and the fifth sections where the peaks in the average Z-score profile were the highest between the fourth and fifth section (Fig. 2.B).

Discussion

The closest coincidence (less than 10 cm horizontal difference) of the visible boundaries and the boundaries determined by MSW from the vegetation and soil data was at 10 m between the *Lepidio-Puccinellietum limosae camphorosmetosum* and *Achilleo-Festucetum pseudovinae* (sections 4 and 5). Between these two sections each MSW peaks (DREN, SED, soil data) were significant and their positions were the same. In these two sections the correlation was the largest (Table 4) between the first factors of the local frequency of plant populations and those of the soil parameters, therefore it can be stated that the species composition and the variation of the species composition strongly dependent on abiotic conditions in this section. Inside both sections the horizontal change of the values of the soil parameters were the highest (Fig. 2.C) and the species composition changed with the continous change of the soil parameters by the transect (Fig. 1).

Between sections 3 and 4 (boundary of the two subassociations of *Lepidio-Puccinellietum limosae*) the visible vegetation boundary and MSW peaks of DREN and SED coincided, although the peak of SED was not significant because of the low species number (4-5 species). The MSW peak of soil data was not significant because the rate of change in the values of soil parameters was low and the elevation difference was small too.

Between the sections 2 and 3 (boundary of the *Agrostio-Caricetum distantis* and *Lepidio-Puccinellietum limosae*) the visible vegetation boundary and the MSW peaks of DREN and SED coincided, although the peak of SED was not significant because of the low species number (4-5 species). The MSW peak of soil data did not coincide well with the MSW peaks of DREN and SED, there was 30 cm lateral difference. Although the elevation difference was small, the rate of lateral change in the values of EC and Na ion content was high, consequently the MSW peak of the soil data was significant.

Between sections 1 and 2 (inside the community of *Artemisio-Festucetum pseudovinae*) the visible vegetation boundary, the MSW peaks of DREN and SED and the MSW peak of soil parameters did not coincide. The DREN and SED peaks were formed in the middle of *Artemisio-Festucetum pseudovinae* community patch and the MSW peak of the soil parameters coincided with the visible boundary of *Achilleo-Festucetum pseudovinae* and *Artemisio-Festucetum pseudovinae*. Inside the area of *Artemisio-Festucetum pseudovinae* there is an abrupt change in the elevation and soil parameters and they have intermediate values between the szik bank and the depression, thus they indicate environmental conditions in which the characteristic species of the two vegetation patches co-occur and *Artemisia santonicum* occurs only here (Fig. 2). Zalatnai and Körmöczi (2004) had similar result in the same sampling site. According to their explanation this 1 m wide vegetation zone cannot be considered as a distinct community here, but this patch should be considered as an ecotone (van der Maarel 1990).

There is a similar situation in the other slope of the szik-bank with *Artemisio-Festucetum pseudovinae*, between 9.9 and 11 m, where the visible boundary between *Artemisio-Festucetum pseudovine* and *Achilleo-Festucetum pseudovinae* could be justified with neither MSW analysis nor multivariate methods (Zalatnai and Körmöczi 2004). There was not large difference in the species composition between *Artemisio-Festucetum pseudovinae* and *Achilleo-Festucetum pseudovinae,* except the occurrence of *Artemisia santonicum*. In the patch of *Artemisio-Festucetum pseudovinae* the rate of change of soil parameters was large, although the alteration in elevation and soil parameters were gradual.

There was a significant SED peak at 14.5 m, but it was not considered a boundary, because there was not significant change in the species composition nor in the edaphic parameters. At this location a small depression was formed, where EC and Na^+ ion content became larger, but not each soil parameters changed. The vegetation highlighted this small variation at this point and some species disappeared (*Chrysopogon gryllus*, *Galium verum*), whereas other species appeared (*Plantago lanceolata*, *Agropyron repens*) and the abundance of certain species changed (*Cynodon dactylon*, *Thymus glabrescens*, *Arenaria serpyllifolium*) and all these changes resulted in the increase of the values of SED function.

Our results showed that the boundaries determined by MSW from vegetation and from soil parameters were coincident precisely only in one case. In the other three cases the MSW peaks of soil parameters were situated in the graph (Fig. 2.B) prior to the peaks of the vegetation data, the difference between the two kinds of peaks were 20, 30 and 60 cm, respectively. This was caused by the fact that the vegetation boundary (both visual and MSW determined) was situated where the values of the soil parameters reached their local maxima or minima and remained at those values throughout the given section. On the contrary the MSW boundaries of the soil parameters appeared, where the rate of horizontal change in the values of soil parameters was the largest. This means that the vegetation boundaries were formed at the point where the soil parameters remained unchanged and not in the section of the change. It seems that the vegetation follows with a delay the horizontal changes of the soil parameters. At the point where the MSW peaks of the vegetation and of soil data coincided precisely each soil parameters showed intense and simultaneous changes.

The establishment of the vegetation boundaries was strongly influenced by soil parameters as shown by the correlation values (Table 2) which are not smaller than those reported by Tóth *et al.* 1995 in saline grasslands. The elevation has determining role in the variation of edaphic parameters and the zonation of the vegetation patches. In the depression small elevation differences resulted in a change of species composition (Fig 2.A,B). The reason for it was that the limiting effect of the high soil salt content in the depression was influenced by the temporal waterlogging resulting from differences of the elevation. We concluded that the higher the soil salinity, the stronger is the role of elevation in the separation of vegetation patches (Tóth and Rajkai 1994).

Conclusions

The differences between the species composition of community patches and the position of the community boundaries can be explained principally by the elevation differences and the related variation in salinity, sodicity and alkalinity along the transect.

The salinity, sodicity and the rate of change in edaphic parameters are the most important factors behind the coincidence of the visual vegetation boundaries and MSW boundaries of vegetation and soil parameters. The larger the salinity, sodicity and the rate of lateral change of edaphic parameters along the transect, the better is the coincidence of this three types of boundaries.

The narrow community belts of *Artemisio-Festucetum pseudovinae* have special state here because neither MSW nor multivariate methods could separate these as independent community patches. According to our earlier and recent results, these narrow vegetation zones should be consider rather ecotones than independent community patches.

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