Ph.D. THESES

VEGETATION STRUCTURE AND EDAPHIC PROPERTIES OF GRASSLAND COMMUNITY BOUNDARIES

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Introduction

In the plant ecological texts there are no research results found on the detailed description of the vegetation pattern of the boundaries and boundary zones between the plant association patches. Although there are plenty of theoretical and review papers about the boundary zones and ecotones, the detailed description of the phenomenon can be found in very few papers only. However, the study of the neighbouring boundary zones, including the study of the spatial variation of species composition and the responsible abiotic and biotic constraints, can be important. The reason is that the boundary zone is the place of floristic and ecological changes. Consequently the study of boundary zones is important for nature and environmental protection issues. In protected areas the monitoring of vegetation, performed by vegetation mapping, is an important step towards the compilation of management plans at both the regional and association scale too. On the other hand, during vegetation mapping, when the mapper draws the boundaries of patches, it is important to know the location and size of boundary lines or zones between the patches, but the determination of these is not easy. The knowledge of the location and size of boundary zones is especially important in those areas which are affected by climate change, because past experience showed that due to environmental changes, the size and location of boundary zones may change.

The sandy and salt-affected grass associations of the southern region of the Great Hungarian Plain are much affected by climate change, and there are data available on these changes from the last twenty years. In the last two decades the drought and the continuously dropping level of the groundwater caused great changes in the Kiskunság sandy grass associations. Measureable changes have been shown in the size, shape and species composition of vegetation patches, and also transitional stands have appeared. Since the vegetation patches also change, the location and width of boundaries and boundary zones between them might also change. Due to further climatic changes, it can be expected that the width and the location of the boundary zones change, but so far there were no detailed studies on the vegetation boundaries in the sandy grass vegetation and their changes have not yet been described.

Recently much interest has been focused on the saline and sodic grasslands, because there is a tendency of decreasing soil salinity, mainly in the Kiskunság region and related to it the salt-affected vegetation is changing continuously. 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. From a vegetation ecologist’s point of view it is important to follow the seasonal changes in the vegetation boundaries and to reveal the strength of the relationships of the boundaries with edaphic parameters.

Objectives of the study

The objective of the dissertation is to study the location and extension of the boundaries and boundary zones in salt-affected and sandy grass associations with moving split window technique and to determine which edaphic background variables are responsible for the formation of the boundaries and boundary zones.

The answers were sought to the following questions:

1. What is the width of the boundary zone between stands, which belong to different association types, but have similar physiognomy along an elevation gradient?
2. How does the visually detected boundary coincide with the boundaries detected by moving split window technique?
3. In the case of sandy grassland and the salt-affected grass vegetation, what is the role of the strength of abiotic stress and the steepness of abiotic parameters for the statistical significance of the detection of boundaries and their width?
4. Is the location and width of boundary or boundary zone stable between the vegetation patches of sandy grassland of Bugac and the salt-affected grass vegetation of Csikóspuszta?

Materials and methods

1. Study sites

Four abiotically stressed study sites were selected, with differing stress factors. Consequently the intensity of the lateral changes of stress factors along the study transects is different in the four study sites. In the case of two study sites, the Felső-Bugac pasture and the Tanaszi-meadow the transition between neighbouring dry grass and mesophilous grass associations was studied, here the main stress factor the drought (edaphic shortage of soil moisture) was. In the case of the remaining two study sites, Miklapuszta and Csikóspuszta the main stress factor is the soil salinity. The Miklapuszta site also suffers from drought stress.

2. Vegetation sampling

Vegetation sampling was carried out in regular arrangement along transects. In each study sites transect(s) were delineated along elevation gradients in such a manner that the transects crossed two or more vegetation patches at right angle. Vegetation sampling was performed in micro-quadrats along the 15-30 m transects by recording presence/absence or by the estimation of percent plant cover. Out of the four study sites two were sampled once (Miklapuszta, Tanaszi-meadow), the other two sites (Bugac, Csikóspuszta) were characterized by seasonal samplings during two or five years performed at the same calendar times in order to assess the seasonal dynamics of boundary transitions.

3. Soil sampling and laboratory analysis

In the case of each study site, each micro-quadrat of the external row of one transect was sampled for soil (0-10 cm). Soil sampling was coincident with vegetation sampling.

The laboratory analysis of the soil samples was carried out according to Hungarian standard methods. The following parameters were determined: soil moisture content, aqueous pH, soil organic matter content, total nitrogen content. In the case of salt-affected soils also soluble sodium concentration and electrical conductivity (EC in 1:2.5 soil:water suspension) were measured.

4. Statistical analysis

4.1. Moving split window (MSW) technique

The moving split window technique was used to detect and characterise the boundaries between associations along the transects. As distance functions both the Squared Euclidean Distance function (SED) and the complement of Renkonen similarity index (DREN) were applied.

A “split window” with width matching the size of neighbouring quadrats (e. g. 25×25 cm) is superimposed the transect and the distance function was computed between the two halves of the window. Next the window is shifted to the next two neighbouring quadrats and the value of distance function is computed, after it the window is shifted further until the values of distance function are computed for each sampling point. The technique gives possibility for secondary sampling of the original data. It means that the width of the window can be increased to double, triple, multiple size, in order to perform a series of spatial analyses. This way the values of distance functions can be computed at several spatial scales along the transect. Since the technique is very sensitive for “noise”, that is random wobbling in the data the computation of distance functions performed at several spatial scales can minimize the noise. Values of distance functions is computed at half window widths ranging from one to 20. One half window width correspond to the size of the micro-quadrat which is applied in the given transect (10×10 cm, 25×25 cm, 10×20 cm, or 50×50 cm).

By plotting the computed value of distance function against the midpoint of windows, a “profile-diagram” is received, in which the significant peak is identified as vegetation boundary.

The significance of the peaks is tested with the Z-score transformation of the SED and DREN distance functions in order to solve the problem caused by the significance levels differing at the separate window widths. Z-score transformation means the standardization of distance functions, after which the values received at separate window widths can be averaged and the significance levels of peaks can be decided based on the averages.

Random reference is created with Monte Carlo simulation method: the population patterns are randomly shifted compared to each other, thus the distributions of the single populations remain unchanged. SED and DREN values are computed for each window position. Overall mean and standard deviation of distances are calculated after 1000 randomization, these are considered as expected values.

Expected means and standard deviations are computed for each window sizes. The differential profiles are then drawn from Z-scores averaged over several window sizes. The intercomparability of the results is assured by the averaging of enough windows to attain a half window of 2.5 m width in the case of every transect. The optimized average window width was determined by preliminary tests. 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 are also analyzed by MSW with the application of SED function, before the analysis they are standardized by the range. For the average Z-score profile diagram of abiotic parameters the same significance test is used as for the vegetation data.

4.2. Multivariate analyses (CA and CCA)

Direct gradient analysis was performed on the vegetation and soil data in order to reveal the relationship between the vegetation and soil variables and to find out whether the possible boundary zone and the neighbouring vegetation zone are distinct or not. Canonical correspondence analysis was performed on the above data by the software package SYNTAX 5.0. In those transects, in which there was no soil sampling the vegetation data were ordinated by correspondence analysis. For the ordination the local frequencies or the average cover percents of the species determined in one row of the transect were applied in SYNTAX 5.0.

4.3. Factor analysis

With the moving split window technique the transects were divided into several sections by the significant vegetation boundaries. In each section the relationship between the measured soil parameters (elevation, soil moisture, pH, soil organic matter, soluble sodium concentration, EC, total nitrogen content) and the local frequency values of plant species was studied with factor analysis with SPSS 11 software package.

4.4. Correlation between soil parameters

In each transect the Pearson correlation coefficient between the soil parameters were computed pair wise in order to reveal the extent of interdependence between them.

Results and discussion

1. Along an elevation gradient, between stands belonging to different association types, but having similar physiognomy either sharp boundary line or wider boundary zone can be formed.

1.1. In the case of **Bugac** transect ca. 5 m wide boundary zone was formed between the sandy pasture (association of *Potentillo arenariae-Festucetum pseudovinae* SOÓ (1940)) and dry Molinia sward (association of *Molinio-Salicetum rosmarinifoliae* MAGYAR ex SOÓ 1933). This boundary zone appears in one time vegetation sampling and also in the combined analysis of nine seasonal data series. The width of boundary zone is great compared to the 15-30 m average diameter of vegetation patches. The boundary zone shows the characteristics of ecocline, because in the boundary zone there is a continuous transition of abiotic properties and the vegetation is heterogeneous, it has a complex structure and great number of species.

1.2. In spite of the expectations based on the Bugac transect, there was a sharp boundary and not a boundary zone shown by MSW analysis in the transect of **Tanaszi-meadow**, where the spatial distribution of populations in the dune slope is continuous. Only in the case of one transect was there a significant boundary, where the elevation difference is the largest, between the Pannonic closed sand steppe (association of *Astragalo austriacae-Festucetum rupicolae* Soó 1957) and the calcareous purple moorgrass meadow (association of *Succiso-Molinietum* (Komlódi 1958) Soó 1969). Lateral changes of abiotic background gradients along the transect were not very steep, and according to the technical literature in such situations a wider boundary zone, ecoclin or continuous change would be expected.

1.3. There were sharp boundaries, each significant with the exception of one, shown by the moving split window technique between the salt-affected plant associations of **Csikóspuszta** transects. In a few cases the peaks of DREN distance function were higher than the peaks of SED function. This shows that in case of the associations composed of few species, the changes in species composition are more important than the changes in abundance. There were sharp and significant boundaries between the salt-affected and non salt-affected associations in both transects.

1.4. Almost in each case there were sharp boundary lines between the salt-affected plant associations, shown by the MSW technique in the **Miklapuszta** transects. Mostly only the values of DREN distance function reached the significant level. At the contact of the salt-affected and non salt-affected association patches (between the "Pannonic alkali hollow community" with the association of *Lepidio crassifolii-Puccinellietum limosae* Soó 1947 and "grassy saline puszta" with the association of *Achilleo setaceae-Festucetum pseudovinae* Soó1933 corr. Borhidi 1996) there were sharp, significant peaks shown by the MSW in all three transects. In contrast, there was a 1-2 m wide saline puszta (association of *Artemisio santonici-Festucetum pseudovinae* Soó 1933 corr. Borhidi 1996) patch described visually at the place of peaks in the field. The saline puszta patch appears in the slope of microerosional mound („szik padka"). The gentler the slope, the wider is the patch of saline puszta. The species distribution showed that there were species common for both associations in these patches, and additionally the *Artemisia santonicum* also appears. In the case of some patches there is continuous species turnover, the only constant species is *Artemisia santonicum*. It is the reason, why the boundary zone is located inside the saline puszta patch. The saline puszta patch could not be considered to be a separate association patch, because a) the MSW technique showed the boundary in the middle of saline puszta patch or at the boundary between the Pannonic alkali hollow community and saline puszta; b) the MSW technique did not show any boundary between the saline puszta and the grassy saline puszta; c) the CA analysis did not show a separate vegetation patch. The 1-2 m wide saline puszta patch formed between the Pannonic alkali hollow community and grassy saline puszta can be interpreted as an ecotone according to the concept of van der Maarel. The reason is that this patch is narrow, there are seasonal temporal changes in the abiotic properties (soil moisture, salt concentration), the number of species is low, it has only one or two characteristic species, and it is homogeneous with simple structure. The phenomena experienced in the salt-affected zonation are supported by the technical literature, since in most cases there were sharp boundaries described between the association patches of the zonation of salt-affected plant associations.

2. Width of the boundary or boundary zone formed between neighbouring plant associations depends on the abiotic stress. The greater the stress in the given vegetation type, the narrower and sharper are the boundaries. But there is a further factor which affects the width of boundary zones, the significance of MSW peaks and the spatial distribution of plant populations more than the abiotic stress: it is the steepness of the lateral change of the values of affecting and measured soil parameters. When the steepness of the lateral change is great, the boundary is sharp and linear. The higher is the number of the steeply changing parameters in the boundary zone and the steeper is the change in the values, the sharper, narrower and more significant is the resulting boundary. If not each parameter shows great steepness of lateral change, there is a less significant peak shown by MSW technique. This observation is typical for SED distance function, and not for DREN distance function, this latter being sensitive for species turnover. If the elevation slope is steep, but the steepness of the change of soil parameters is small, this situation can result in the formation of a boundary zone and can decrease the level of significance of the MSW peak. The reason is that the situation promotes the almost continuous turnover of species and that leads to the formation of a boundary zone. The results are not contradictory to the technical literature, but provide more accurate explanation for the phenomenon of boundary zone. The effect of abiotic environment on the width of boundaries was conceptualized by most researchers in general terms, like the sharp lateral changes of abiotic environment cause sharp and narrow boundaries, and in contrast the continuous changes of abiotic environment cause wider and more diffuse boundary zones of vegetation. The bulk of the results of the dissertation support this

statement, but the findings in the case of Tanaszi-meadow contradict to this, since in spite of a continuous change of soil parameters no boundary zone was found. When considering the steepness of the lateral change of soil parameters there is a clear explanation. At the boundary zone the steepness of the parameters is greater in the case of Tanaszi-meadow than in the case of Bugac transect, and this is the reason for the formation of boundary line between the two plant associations. Since not each soil parameter showed the same steepness at the boundary, both distance functions failed to show significant peaks. This a proof of a linear, but not sharp boundary.

3. Field observers do not always perceive the presence of a boundary or boundary zone. When, at the boundary of neighbouring association patches, the changes are greater in the abundance of species than in the species composition, it is difficult to visually perceive the boundary. On the other hand, if at the boundary the intensity of species turnover is greater than the changes in the abundance, or the two processes are of similar intensity, the possibility of easier accurate identification of the boundary line or boundary zone is given. In this latter case the appearance and spreading of one single population is enough for the safe detection of boundary. In the zonations of sandy grassland – marsh meadow (Bugac and Tanaszi-meadow transects) the lateral difference between visually detected and statistically proved (by the means of MSW technique) boundaries was much greater than in the case of salt-affected zonations. The reason for this is that in such vegetation, where there is a continuous turnover of species at the boundary of associations due to continuous, not very steep change of background parameters and a sharp boundary is not formed, the detection of boundary line or boundary zones is very difficult with field observation. In these situations an objective method, such as the moving split window technique is suggested for the detection of the boundaries.

4. Similarly to the temporal change of the location and width of boundaries between biomes, the results of the dissertation showed temporal changes of the width of boundary zones between the plant associations. Large seasonal shift of boundaries towards one or other vegetation patch was not found neither in the case of boundary zones or sharp boundary lines.

4.1. In the five year series of **Bugac** transect there is a series of small peaks merging into a large one, and it marks the boundary zone. The number and location of the double or triple peaks shown by moving split window technique, which mark the boundary zone does change seasonally. The peaks are not always significant. The width and sharpness of the boundary zone formed is fluctuating between 3 and 5 meters. The changes in the abundance of species was more important than the changes in the species composition for the resulting seasonal variation of the boundary pattern. There were no trend or cyclic changes found in the boundary zone structure when comparing changes between seasons (spring vs. autumn) or years. The changes in the width and significance of the boundaries is different for different years. Since the most important limiting factor for the plants living in the sandy grassland is the soil available water content, the rainfall distribution of the study periods is hypothesized to be the influencing factor of the changing boundary zone. This hypothesis was not tested in the dissertation.

4.1. There were no great temporal shifts in the position of MSW peaks in the **Csikóspuszta** transect. Only the significance of the peaks computed with both distance functions changed seasonally. The location of the boundary lines did not change during the two year study, a maximum of 10 cm shift was found in the data.

PUBLICATIONS

Publications related to the Ph.D. thesis:

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