Topic 3

Planning Tools

Ecosystem modelling based on holistic and reductionistic measures in nature conservation planning in urban areas

Alicja SUDER

Zusammenfassung
Dieser Beitrag präsentiert die Ergebnisse einer Vegetationsbewertung in einer mittelgroßen Stadt. Zur Analyse von Vegetationsstrukturen und -funktionen auf einer Patch- und Landschaftsebene sowie zur Prüfung ihrer Anwendbarkeit in der räumlichen Planung und zur Vegetationsüberwachung in städtischen Gebieten werden holistische sowie reduktionistische Ansätze angewandt.

Schlüsselwörter: holistische und reduktionistische Ansätze, Vegetation, Landschaft, Naturschutz in städtischen Gebieten

Abstract

This paper presents the results of vegetation valuation occurring in a medium-sized town, based on holistic and reductionistic approach to recognize vegetation structure and functioning at the patch and landscape levels and to explore their applicability in spatial planning and vegetation monitoring in urban areas.

Key words: holistic and reductionistic approaches, vegetation, landscape, nature conservation in urban areas

1. Introduction

Nowadays the majority of people live in urban areas, thus urbanization is considered as one of the processes which significantly contribute to ecosystem change on the Earth. Human impact on flora and vegetation appears by their qualitative and quantitative changes such as the size of species pool and the variability of species traits, caused by selection pressure as well as their spatial transformations, resulting from different availability of habitats and their spatial arrangements. Reductionistic approaches do not recognize complexity of the landscape features and various factors which govern them, using a single measure i.e. naturalness which is very general and difficult to apply in nature conservation practice in a changeable environment. Although holistic approaches assume more detailed measurement of features of a set of landscape components, they take into account dynamic aspects of ecosystem functioning as a reference measure of vegetation structure rather then the characteristic species composition. The reason is that nature conservation in urban areas is claimed to be different from traditional approaches, because less emphasis is placed on rare species or habitats and considerable weight is given to the values and benefits of urban wildlife to local people. Consequently, vegetation is assessed on the basis of self-organizing theory and diversity-stability models which join the requirements of biodiversity preservation with human economics and human perception of landscape in spatial planning (HEARNSHAW 2005 et al.). As a result, the exploration of social preference play important role during compilation of spatial management plans and tools of social influence to enhance those activities which favour the maintenance of species and ecosystems.

Numerous ecological theories which explain in different ways the complexity of ecosystem structure and functioning, are applied in nature conservation practice, then ecological indicators become a specific conservation value of ecosystems. Consequently, nature conservation based on the information theory give a higher value to ecosystems composed of many elements (species), in contrast to community ecology background which weights the importance of information included in the natural systems. The maintenance of high species richness without community context requires enlargement of green areas in parallel with constant human interference in condition of shortage surface within towns and their expansion into adjacent areas. Because of such a reason, the preservation of rare ecosystems in regional scale within urban areas and species diversity (β) connected with them gain primary importance.

The methodical aspect of preservation state in ecosystems' modelling is an assumption of their intrinsic dynamics, determined by the size of ecological niches of constituent species which is described in conservative terms (correlative models) or adaptation (models based on functional traits and species response to environmental conditions) as well as ecological niche dynamics resulting from genetic variability. Dependently on the measurement scale, species diversity is shaped by microhabitat conditions and the area size (α diversity) but also depends on the average value of environmental parameters and species interactions (β diversity) at the community level. Regardless of established model (additive or multiplicative) the both aspects of species diversity determined γ diversity according to the following formulas: $\alpha + \beta = \gamma$; $\alpha \times \beta = \gamma$, respectively. As a result one may distinguish two kind of habitat heterogeneity: those, resulting from microhabitat diversity and habitat area (α) and those related to habitat feature (β). Both components are influenced by spatial factors, defined by neighbourhood and distance between patches (meta-communities) as well as the history of land use (temporal structure) (ANDERSON 2011 et al.). Although the increment of both components of natural system diversity at the landscape level, their influence on species composition within plant communities is different. The maintenance of stable ecosystem, it means capable to independent functioning is the basic goal of nature conservation, thus estimation of preservation state and the direction of ecosystem change within commune town, which was the main goal of undertaken studies, were done based on characteristic species composition. The supplementing and more detail inside into community structure based on functional diversity of constituent species enhances the power of ecological forecasting of ecosystem change, incorporating demographic features and neighbouring vegetation in ecosystem modelling (TILLMAN 1994). As the basis of this study, I assumed, that demographic processes and species interactions modified by the method and intensity of land management play an important role in structuring vegetation within particular quarters (local scale) but spatial features affect on vegetation variability at the town scale.

2. Methods

The basic aim of this compilation was to valuate vegetation within commune town – Trzebinia, located in the southern part of Poland, on the border of the Silesian Upland (the northern part) and Krakowsko-Częstochowska Upland (smaller, southern part). The town is distinguished by the long-standing industrial tradition, started at the beginning of the XIII-th century, when the first zinc and lead mines were established and the pick of development in the second part of XX-th century when three coal and one dolomite mines, refinery, ironwork, power plant and many light industry were functioned. Nowadays, the distribution of different economic branch within this urban area is presented in Fig. 1.

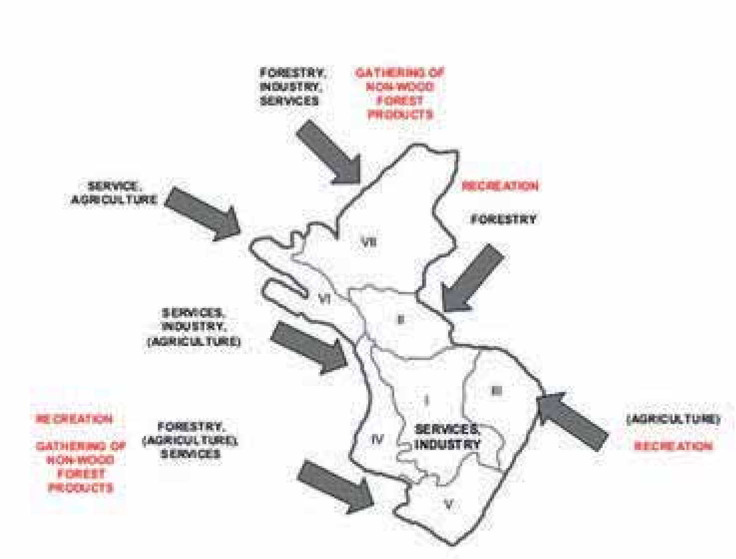


Fig. 1: Location, division and the way of management of investigated area (Coordinates: 50° 09' N; 19° 28' S; Altitude: 315 M)

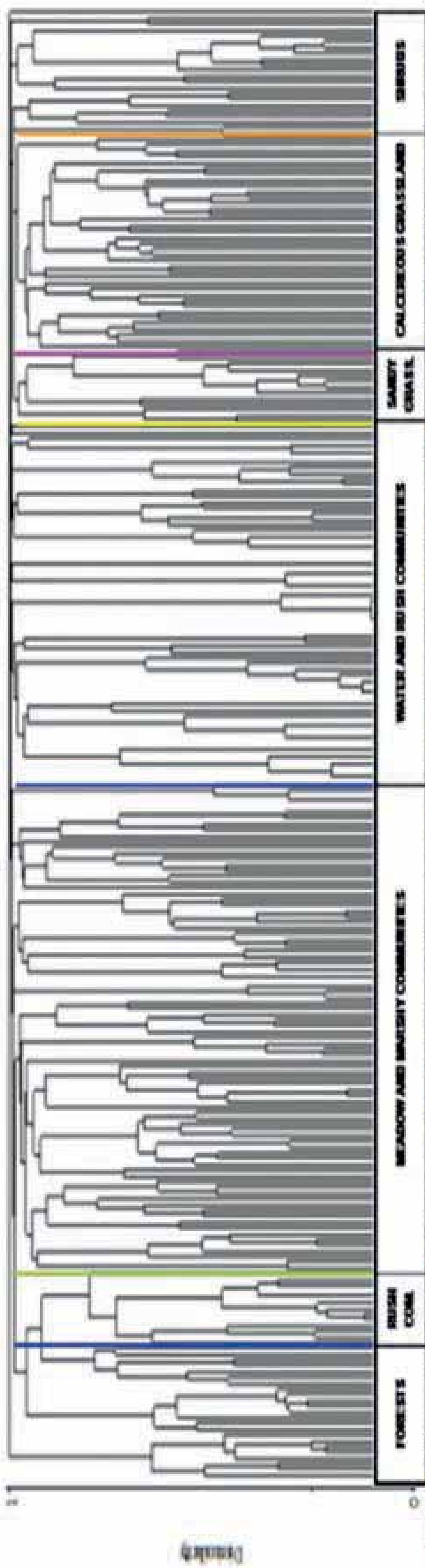
To identify plant communities, flora and vegetation inventory was done according to Braun-Blanquet approach. Based on the data set of 225 vegetation samples (preferential sampling procedure) and hierarchical clustering (presence/absence data – Jaccard formula, abundance data – Ruzicka formula, UPGMA) 52 plant communities were distinguished. Cophenetic correlation was calculated to compare the accuracy of classifications with the ordination results (PODANI 2001). Based on the land use forms, appointed by the index of built-up areas, vegetation cover as well as dominating type of economy, the town area was divided on seven quarters which partially are consistent with the administrative division. The calculated Simpson diversity index for vegetation within each distinguished part of town was correlated with scores of PCA (for binary data). However, the obtained results showed lack of significant correlation between environmental gradient and species diversity within town centre which might be the result of spatial effect and strong dependability of Simpson index on evenness model, thus this part of analysis was omitted in this compilation.

To estimate the magnitude of environmental influence on preservation state of plant communities, including the length of spatial gradient, raster map was done (municipality order, "Proglob" company) which covered the whole town area. Vegetation cartography was done based on aerial photo and remote sensing data. Vegetation sampling was conducted using stratified random sampling procedure. Preferred method of ecosystem management in relation to expected benefit of local society from natural resources was investigated on the basis of revealed preferences. The estimation of landscape fragmentation was done by calculating aggregation index for distinguished vegetation patches, scaled to value I – IV (range from small to high fragmentation) (URBAŃSKI 2008). The spatial and habitat gradients resulting in different species turnover were investigated using non-metric multidimensional scaling (NMDS, Bray-Curtis formula) and detrended correspondence analysis (DCA). The values of component scores of two DCA axes were correlated with the values of ecological indicators for species (ZARZYCKI 2002 et al.) and scaled distance between vegetation samples using multiple regression analysis to label gradient into ordination axes. Constrained canonical correspondence analysis (CCA) was applied to reveal the influence of spatial and habitat gradients on vegetation groups (forests, meadows, grasslands and bushes). To forecast the direction of species composition change during secondary succession on non-managed grasslands, functional diversity indices were calculated (LEPˇS 2006 et al.; SCHLEUTER 2010 et al.) in parallel with modelling of distinguished as the important species traits using minimum spanning tree (MST) (PODANI 2001). All analyses were done in SYN-TAX, Statistica, ArcGIS software.

3. Results

Vegetation of commune town is composed of 52 natural and semi-natural plant communities representing water, rush, marshy, xerothermic and sandy grasslands, bushes and forest patches listed in Fig. 2. Species richness is more diversified along environmental gradients (the range of dissimilarity: min. = 0.0047, max. = 0.9892 level for dendrogram based on presence/absence data), however less connected with habitat features (cophenetic correlation = 0.7960) suggesting the significance of spatial effect in shaping diversity of vegetation patches. Changeability of species abundance is lower (the range of dissimilarity is more narrow as follows: min. = 0.6349, max = 0.9973 level for dendrogram based on quantitative data) but strongly correlated with habitat characteristics (cophenetic correlation = 0.9783).

Flora analysis revealed the occurrence of 642 taxa of vascular plants, among which 16.2% is *anthropophyta*, most commonly *ergasiophygophyta* (39.6%) and *agriophyta* (30.2%). Nitrophilous species are the most numerous among the habitat groups (18.7%), in contrast with the groups of water plants (1.7%) and heath or species-poor *Nardus* grassland (2.5%). 38 species of town flora are protected under Polish law and 84 taxa are locally endangered which together constitute about 19% of overall town flora. Within particular quarters the distribution of historic-geographical groups is not uniform, revealing the greatest percent of alien species (including cultivated ones) within I and V quarters as a result of their introduction by landscape architects, private persons or foresters.



1. Lemnetum gibbae	*Alliance:*	*Lemnion gibbae* R.Tx et A. Schwabe 1974 in R.Tx. 1974
2. Potametum lucentis	*Alliance:*	*Potamion* Koch 1926 em. Oberd. 1957
3. Potametum natantis	*Alliance:*	*Nymphaeion* Oberd. 1953
4. Myriophylletum verticillati		
5. Hottonietum palustris	*Alliance:*	*Hottonion* Segal 1964
6. Ranunculetum fluitantis	*Alliance:*	*Ranunculion fluitantis* Neuhausl 1959
7. Scorpidio-Utricularietum minoris	*Alliance:*	*Sphagno-Utricularion* Mull et Gors 1960
8. Community with Juncus bulbosus		
9. Scirpetum lacustris	*Alliance:*	*Phragmition* Koch 1926
10. Typhetum angustifoliae		
11. Sparganietum erecti		
12. Eleocharitetum palustris		
13. Equisetetum limosi		
14. Phragmitetum australis		
15. Typhetum latifoliae		
16. Glycerietum maximae		
17. Cicuto-Caricetum pseudocyperi	*Alliance:*	*Magnocaricion* Koch 1926
18. Iridetum pseudacori		
19. Caricetum acutiformis		
20. Caricetum paniculatae		
21. Caricetum rostratae		
22. Caricetum appropinquatae		
23. Caricetum gracilis		
24. Phalaridetum arundinaceae		
25. Community Ranunculus sceleratus – Rorippa palustris		
26. Diantho-Armerietum	*Alliance:*	*Vicio lathyroidis-Potentillion argenteae* Brzeg et Wojt. 1996
27. Filipendulo-Geranietum	*Alliance:*	*Filipendulion ulmariae* Segal 1966
28. Aegopodio-Petasitetum hybridii		
29. Selino-Molinietum	*Alliance:*	*Molinion caeruleae* W Koch 1926
30. Cirsietum rivularis	*Alliance:*	*Calthion palustris* R. Tx 1936 em Oberd. 1957
31. Scierpetum sylvatici		
32. Epilobio-Juncetum effuse		
33. Equisetetum palustris		
34. Community with Deschampsia caespitosa		
35. Mentho longifoliae-Juncetum effusi	*Alliance:*	*Agropyro-Rumicion crispi* Nordh. 1940 em R.Tx 1950
36. Arrhenatheretum elatioris	*Alliance:*	*Arrhenatherion elatioris* Koch 1926
37. Holcetum lanati		
38. Thalictro-Salvietum pratensis	*Alliance:*	*Cirsio-Brachypodion pinnati* Hadac et Klika 1944 em Krausch 1961
39. Origano-Brachypodietum pinnati		
40. Community with Sanguisorba minor		
41. Community with Bromus inermis		
42. Community with Coronilla varia – Origanum vulgare		
43. Valeriano-Caricetum flavae	*Alliance:*	*Caricion davalianae* Klika 1934
44. Community with Equisetum variegatum		
45. Community with Menyanthes trifoliata		
46. Rhamno-Cornetum sanguinei	*Alliance:*	*Berberidion* Br-Bl (1947)1950
47. Ribeso nigri-Alnetum	*Alliance:*	*Alnion glutinosae* (Malc. 1929) Meijer Drees 1936
48. Community with Calla palustris		
49. Leucobryo-Pinetum	*Alliance:*	*Dicrano-Pinion* Libb. 1933
50. Fraxino-Alnetum	*Alliance:*	*Alno-Ulmion* Br-Bl et R.Tx 1943
51. Community with Equisetum telmateia		
52. Carici-Fagetum	*Alliance:*	*Cephalanthero-Fagenion* R. Tx. 1955

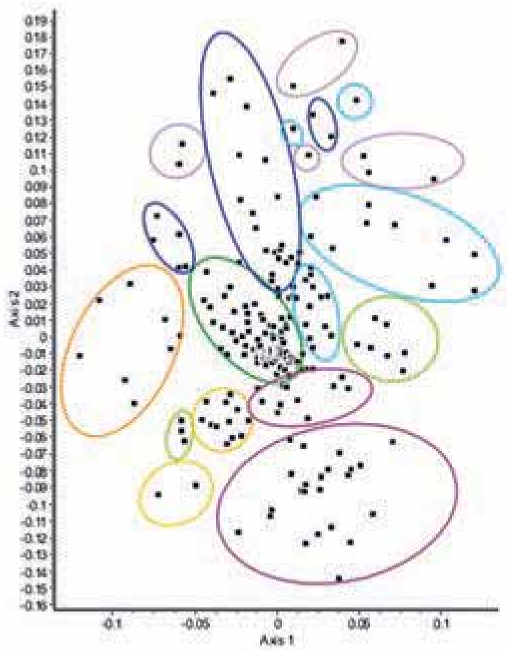
Endangered (EX), vulnerable (V), rare (R) and least concerned (I) species in regional scale (The Silesian Upland)

Fig. 2: Unconstrained classification of vegetation samples (abundance data) done within the patches of natural and semi-natural plant communities in the town area.

Among 96 protected and rare species within town quarters, three were found only on secondary habitats and one – *Epipactis helleborine* – classified as characteristic for the common beech forests does not show any habitat preference. The high value of species diversity index for the town centre is due to high portion of alien species, but species richness of IV-th part is connected with habitat heterogeneity. The low value of species diversity index in the area of VII-th quarter results from habitat homogeneity and low variability of plant communities, mainly composed by coniferous forests.

The changeability of species composition along gradients suggest the primary role of habitat humidity and distance in shaping the vegetation structure as well as secondary significance of habitat acidity, which may be related to calcium carbonate content or habitat fertility (Fig. 3). However within particular town quarter, the length of environmental gradients determining species diversity and turnover was created by humidity and management.

The influence of spatial and habitat effect on species composition among particular type of habitat (forests, meadows, grasslands and bushes) is not equal. Taking into account habitat age and the way of ecosystem management as well as spatial effect (neighbourhood) in constrained ordination (CCA), species diversity of forest communities is mainly shaped by humidity gradient thus environmental filtering strongly prevail, in contrast with meadows and grassland whose community composition is determined by spatial effect, most probably as a result of the abandonment of mowing practice.



Pearson correlation coefficient p<0.0001)	DCA axis 1	DCA axis 2	R2	R2
Environmental parameters				
I. SOIL CONDITIONS				
HUMIDITY	0.83*	0.002ns	0.72	0.29
TROPHY	-0.25ns	-0.10ns	0.84	0.19
ACIDITY	-0.17ns	0.31*	0.76	0.27
II. SPATIAL CONDITIONS				
DISTANCE (scaled)	-0.71*	0.47*	0.57	0.43

Fig. 3: Ordination of vegetation samples along environmental gradients (NMDS, DCA – correlation of component scores for two axes with environmental data in multiple regression analysis)

The highest concentration of not-mown grassland patches was found within the III-th quarter. Incorporating their spatial contact with vegetation of former arable lands, dominated nowadays by *Solidago sp.* patches and classifying vegetation according to their species traits at the community level (MST), the most probable direction of grassland change is their transformation into monoculture built by *Solidago sp.* population or bushes communities (Fig. 4).

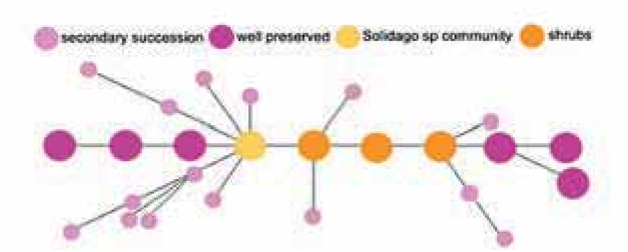


Fig. 4: Minimum spanning tree of vegetation samples based on important traits for secondary succession in unmanaged grasslands

4. Conclusion

Vegetation of commune town, explored during this study, shows high variability and diversified preservation state. The habitat patches with regional importance in terms of conservation value are concentrated within the II-nd and the IV-th quarter. However, local society does not recognize the whole potential and value of some ecosystems thus the abandonment of grassland management prevail which has primary importance in grassland maintenance.

The phenomenon of rare species occurrences on secondary habitats as well as the lack of habitat preference of such an taxa which is classified as diagnostic species, suggest the need of further investigation of their adaptations in broader scale (across climate and human impact gradient) to estimate the scale and magnitude of this effect, to enhance the forecasting of species composition change and mean time to extinction of populations as well as create the adaptive maps.

Balancing the scale of human impact on natural habitats to preserve ecosystem values and to provide healthy environment for people is the core issue of modern spatial planning. The maintenance of ecosystem remnants is more effective strategy from ecological and economic perspectives then habitat creation. Therefore, the preferences of local society, including inspiration for economic development should be weighted by the value and the level of ecosystem vulnerability in broader, it means a regional scale.

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Contact of the author:

Alicja Suder
Department of Ecology, Faculty of Biology and Environmental Protection
University of Silesia
Bankowa St. 9
40-032 Katowice, Poland
a_suder@interia.eu

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