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Landscape functional mosaics

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Introduction

Every landscape has its own potential, which has to be determined in case of any kind of spatial planning meant to be environmentally friendly. Knowing the potential is also important during the evaluation of the effective or optimal land use. Any other way, planning and research will not produce realistic results. Numerous methods and tools can be applied for the evaluation of landscape structure and processes. Though, basically two approaches are accepted. On the one hand researchers might concentrate on spatial relationships and refer to the potentials of the landscape (Bastian, Schreiber 1999). On the other, if the operation and use of a given spatial unit are considered, one might end up in a functional landscape analysis. The functions are not only physical and natural categories, but they are able to also signify a certain type of potential. Most frequently landscape functions are defined as the pendants of landscape structure and landscape potential with an emphasis on functional and social relationships. To be aware of the landscape functions is crucial during management, thus planners must reveal these relationships if a well based project is expected. Besides, landscape functions have got an elementary role in determining environmental risk, too (Mezősi, Albrecht 2002).

The methods used for the spatial analysis of the landscape are well documented; the question of scale and structure is broadly discussed. Nevertheless, the spatial extension and hierarchy of landscape functions is somehow neglected in the literature. This is understandable, since the evaluation of functions as spatial mosaics raises a number of theoretical and practical questions. Some of these are as follows. How can be an integrated/aggregate value understood from the aspect of the basic functions? What are the limits of the theorem claiming that the analysis of functional mosaics must provide additional information on landscape quality and interactions?

The main goal of this paper is to explore the integrated value of functional mosaics; to evaluate their suitability for determining risk; and to asses the applicability of landscape metrics in the description of landscape functional mosaics.

Landscape functional mosaics

Functions in the landscape

Most of the interpretations agree that landscape functions can be divided into three thematic groups (deGroot 1992, Bastian, Schreiber 1999, Bastian, Steinhard 2002). These are: economic (e.g. renewable resources), ecological (e.g. resistance to soil erosion) and social (e.g. recreation). The quantitative description of the nearly three dozen of known landscape functions is not at all precise. During research, the most problem is caused by scale. Landscape functions can be grouped at least into two classes of scale, thus if the above mentioned thematic groups are considered too, then after all 1st order, 2nd order, 3rd order, main and subfunctions can be separated. If more functions are analysed during a research, it is very important that they are at the same hierarchical level. A further problem is that functions, having already an aggregate character (e.g. the erosional and recreational functions are determined by numerous factors), might show multiple combinations at almost each spatial units, and might mobilise various relationships and interferences.

Analysis of landscape mosaics

The major concepts of landscape ecology are based on the assumption that the patterns perceived in the landscape are in close relationship with ecological processes (Turner 1989). The mosaic character of the landscape and its features are well studied. It is also broadly accepted that the mosaic pattern is apparent regardless of scale (Forman 1995). Heterogeneity in the landscape appears in two ways. The first is the gradient change of an attribute in space. Gradients do not have borders and no patches can be realised in them, however they still represent heterogeneity (e.g. tropical rainforests, where changes can be considered continuous). Landscapes of this type are quite rare. The second form of spatial heterogeneity is represented by mosaic patterns. In this case attributes are spatially organised, they form aggregates, which can be delineated. Landscape mosaics may contain patches and corridors. This concept had set the base of the widely known patch-corridor-matrix model (Forman, Godron 1986) and lead to numerical description of patterns with the help of index-lists. Patches can be influenced by the heterogeneity of substrates, natural disturbances and anthropogenic effects. Landscape components and attributes can be arranged into a patch-corridor-matrix configuration.

The evaluation of the landscape, including statistical analyses too, is highly dependant on scale. Landscape patterns are studied at three levels: patch-level, class-level (patch type level) and landscape-level. Landscape indices are derived from the parameters defined for patches and patch types. Parameters are usually summed or averaged, though the algorhythm is frequently modified by different authors. Landscape indices can be interpreted not only as simple heterogeneity indicators, and class indices also represent more than just the fragmentation of the landscape. They are the measures of landscape pattern as a whole.

The Model of landscape functional mosaics

If landscape mosaics are defined as the aggregation of spatial patterns, landscape functional mosaics are then the aggregation of functional patterns, arranged in integrated spatial units. Different landscape functional mosaics can be created by focusing on different landscape functions during modelling. In contrary to the most approaches in the last decade, the term landscape metrics will be used in this study not only for land use or land cover. We apply landscape metrics for the description of spatial data and for mapping/assessing landscape functions. This results different levels of landscape metrics on the same cultural landscape.

The application of landscape metrics raises three major problems. The first is the integrated manner of functions, and as a consequence their interdependency. The second is the difference of scale. The content and extension of a so called main function, such as pedological function is very different from that of a subfunction, e.g. resistance to erosion. The third problem is the transfer of results (derived from the patch analyses of functional mosaics) to the practise of planning and management, and thus the way how functional values can be fitted to the existing landscape categories.

Methods

Landscape functions are scale dependent. The functional difference at the existing hierarchy levels can be determined, however, in order to exclude the serious problems originating from interdependency we applied homogenous categories. For the analysis the following landscape functions, representing the third hierarchical level, were selected: recreation, resistance to erosion, resistance to underground water and biomass production. The selection was made on the basis that these functions are the most important in determining environmental risk on the study areas.

Landscape functional mosaics were studied on a class-level. A major problem in this respect was the interpretation of the smallest geometry where landscape functional elements could be investigated (minimum element size was 500 m² and defined at a scale of 1:10.000). The methodological analysis was focusing on two test sites, each with an area of 50 - 100 km², situated in Germany and Hungary. The German site, Jesewitz, is characterized by a moraine landscape, and located north of Leipzig/Saxony. The Hungarian site is a part of the Lake Velence catchment and includes the lake itself. The surroundings of Jesewitz is characterised primarily by agricultural land use arable lands can be considered as the main land cover category. On the other hand, the Hungarian test site is characterised by combined land use and land cover (vineyard, recreation, agriculture).

Landscape metrics were applied on the patches of the above determined four landscape functions. Landscape potentials, described by Marks et al. (1992) gave the structural base of functions. Spatial units, fitting to the existing geotypes, were created this way. For example the resistance to erosion function is based on the resistance potential, which is dependant on the following factors:

- relief (the energy of overland flow is determined by slope length and angle),
- soil (physical soil type, humus-content, cobble-content),
- land use.

When calculating erosion probability, Marks et al. (1992) considered the same factors, and used a table form evaluation. In our study maps of physical soil types (9 categories), slope angle (11 categories) and land use (15 categories) were overlaid and intersected, in order to determine the basic units (approximately 800, representing nearly 70 classes) for which the likelihood of soil erosion was calculated. The EPIC method was used for this purpose, though Erosion 3D or any other Wischmeier-Smith based method could also be suitable. Units were evaluated one by one, and e.g. where erosion probability proved to be very slight the soil resistance function was considered unimportant. Patches were classified into 3 categories, and the spatial pattern of e.g. the soil resistance function was determined this way. Then the patterns were analysed on a patch-level, too, with the following metrics: Shape Index, Perimeter-Area ratio, Aggregation Index, Core Area Index, Proximity Index.

However, several problems have turned up during the aggregation at this hierarchy level namely the number of functions was highly influenced by the geometry of the patches. Thus landscape metrics were made only in case of the main landscape functions, otherwise several other functions should have been mathematically and statistically introduced. Another major question, worthwhile for further analysis, is how the interdependence between functions could be assessed and characterised.

First results

The data gained from the three base maps (fig. 1, 2, 3, 4) were organized in a database with a 160 row x 180 column setup. After overlaying the cell values of the different maps we have calculated the functional characteristics (e.g. likelihood for erosion), which may support decision making in the future. The patch values show that functions are usually of low spatial complexity (low perimeter-area ratio), they are diverse (low Shannon’s index) and fragmented (tab. 1, tab. 2).

It is hard to find a direct or visible relationship if the received metric values are compared to the patch-level values of ecological factors (e.g. the physical characteristics of soils). Nevertheless, the amount of available data is not enough for a statistical evaluation. Thus, for further analyses a larger pool of data would be necessary.

The question finally is: what additional means can landscape metrics provide for determining landscape functions and landscape potential, and how can changes be predicted in a cultural landscape? This predominantly depends on the possibility of projecting functional changes to the future. Regarding the Hungarian study area the extension of the nature protection function can be expected, which will decrease the weight of other functions (e.g. soil resistance), however, in the long run it may result an increase in the value of the soil productivity function. This may also mean that for instance in the case of the soil resistance function the measured Shannon index or the Perimeter-Area Ratio can decrease, referring to an increasing ecological stability.

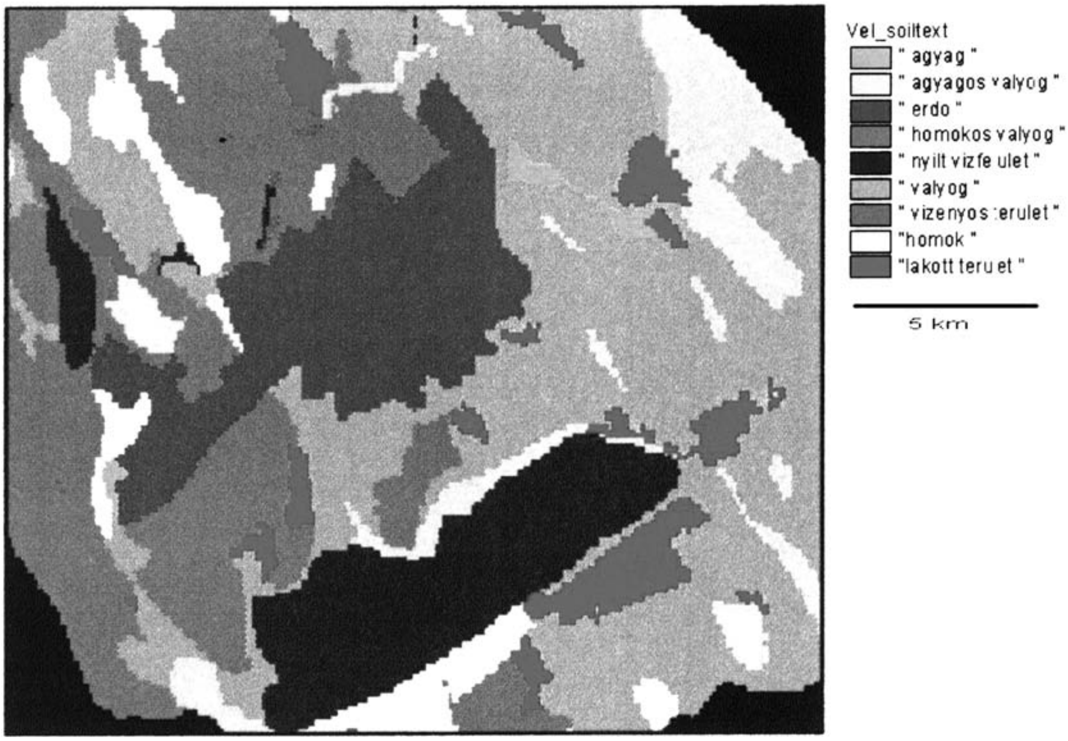

Fig. 1. Physical soils types

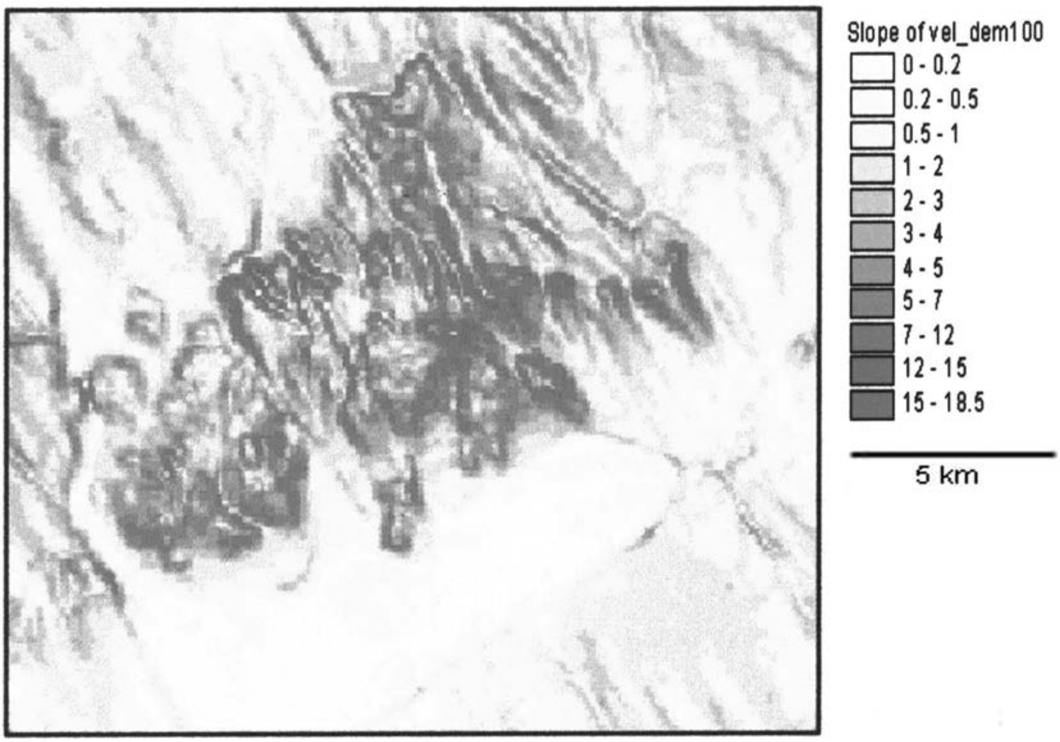

Fig. 2. Slope angle categories on the test area

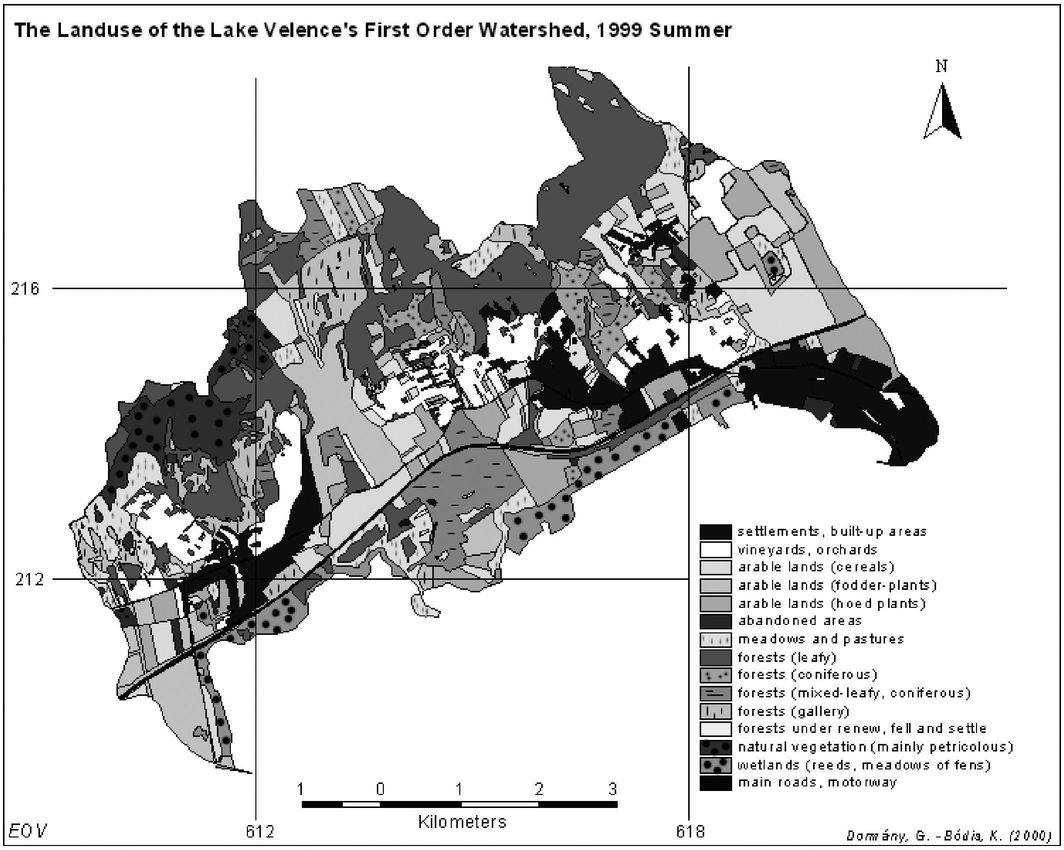

Fig. 3. Landuse map from 1999

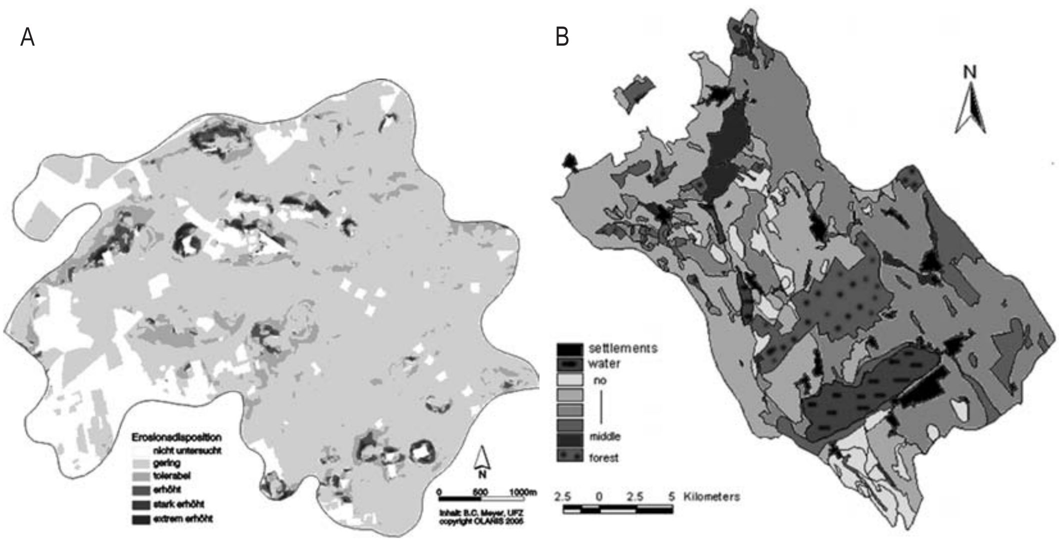

Fig. 4. Resistance to erosion on the study site (A - Test Area Jesewitz, Germany, B - Test Area Lake Velence, Hungary)

Table1. Calculated data for determining the functional pattern of the Test Area Jesewitz, Germany

	Function	Biopoly	Boden	Retention
Area	Number of parcels	1260	1407	6326
	Area (Class)	66461099,97	61149497,14	61270744,02
	Mean Patch Size	251327,68	409011,74	100858,37
	Patch Size stand. dev.	310474,94	988204,26	3419756,9
Edge	Total Edge	1013427,23	1596793,27	2519756,9
	Mean Patch Edge	4900,62	10485,47	3919,37
Diversity	Richenes	8	10	11
	Rel. richeness (%)	100	100	100
	Shannon's Diversity	0,683	1,72	1,721
	Shannon's evenness	0,328	0,747	0,718
	Dominance	1,397	0,583	0,677
	Number of classes (act.)	8	10	11
	Number of classes (pot.)	8	10	11

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Table 2. Calculated data for determining the functional pattern of the Test Area Lake Velence, Hungary

TYPE	AREA	AREA_ CPS	PERIM	PERIM_ CPS	PARA	PARA_ CPS	SHAPE	SHAPE_ CPS	CORE	CORE _CPS	PROX	PROX_ CPS
1	61.0	91.3043	8200.0	91.304	134.4262	4.3478	2.5625	91.3043	0.0	0.0	2.8889	52.174
1	94.0	95.6522	13800.0	100.000	146.8085	8.6957	3.4500	100.0000	0.0	0.0	1.7510	43.478
1	146.0	100.0000	13400.0	95.652	91.7808	0.0000	2.6800	95.6522	0.0	0.0	1.5192	39.130
2	377.0	97.6190	31600.0	100.000	83.8196	2.3810	4.0513	100.0000	0.0	0.0	2.1134	26.190
2	433.0	100.0000	21600.0	97.619	49.8845	0.0000	2.5714	97.6190	0.0	0.0	2.5989	33.333
3	3277.0	100.0000	142200.0	100.000	43.3933	0.0000	6.1826	100.0000	0.0	0.0	15.874	17.391