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H. Herbst, M. Förster, B. Kleinschmit
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Contribution of landscape metrics to the assessment of scenic quality – the example of the landscape structure plan Havelland/Germany

H. Herbst*, **M. Förster, B. Kleinschmit**

Department of Geoinformation Processing for Landscape and Environmental Planning,
Technical University of Berlin, Straße des 17.Juni 145 (EB 5), 10623 Berlin, Germany. helge.herbst@tu-berlin.de

* Corresponding author

Abstract

The scenic quality of a landscape is a natural resource that is to be preserved according to German and international law. One important indicator for the evaluation of this value is the structural diversity of the landscape. Although *Landscape Metrics* (LM) represent a well-known instrument for the quantification of landscape patterns, they are hardly used in applied landscape and environmental planning. This study shows possibilities for the integration of LM into a commonly used method to assess scenic quality by the example of a Landscape Structure Plan. First results indicate that especially *Shannon's Diversity Index* and *Edge Density* are suitable to achieve an objective evaluation of the structural diversity as indicator for scenic quality. The addition of qualitative parameters to the objective structural analysis is discussed. Moreover, the use of *landscape scenery units* and raster cells as basic geometry has been compared. It shows that LM can support the evaluation of the aesthetic quality in environmental planning, especially when integrated into commonly used evaluation methods.

Keywords:

scenic quality, landscape metrics, structural diversity, landscape planning, evaluation methods, landscape structure plan

1 Introduction

The usefulness of Landscape Metrics (LM) for practical environmental planning has been examined and confirmed in various studies (Blaschke 2000, Botequilha Leitão & Aher 2002, Kleinschmit & Walz 2006, Lang & Blaschke 2007). Through quantitative measures, partially subjective evaluation methods can be more objective and reliable, working procedures can be accelerated. Walz (2001), Augenstein (2002), and Botequilha Leitão et al. (2006) specifically pointed out the advantages of LM for quantifying structural aspects of the landscape's scenic quality. In the practical landscape planning, however, LM are hardly used. This is because the meaning and relevance of indices and the possible enhancement of evaluation methods are often not plausible to the planning expert (Gustafson 1998, Botequilha Leitão & Aher 2002, Lipp 2006).

The German Federal Nature Conservation Act (FNCA) indicates the preservation and development of *diversity, unique character*, and *beauty* as well as the recreational potential of the landscape as objectives for nature conservation. In the German tradition of landscape planning these qualities of landscape are commonly referred to as "landscape scenery" or "scenic beauty". These terms, as well as "aesthetic potential", are used synonymously in this paper. On the European level the European Landscape Convention confirms landscape quality as one essential basis for cultural and social identity (CoE 2000), and in many European countries there is a tradition of assessing and preserving the aesthetic potential of the national landscapes (see Visual Diversity 2005, Palmer & Lankhorst 1998, Angilieri & Toccolini 1993). Over the last decades, motivated through several laws in the 1960's and 70's concerning scenic beauty, there have been intense research and planning efforts on the field of assessing aesthetic quality of landscapes in the USA as well (USDA 1995, Daniel 2001).

Especially in the German and English speaking countries, many different methods for the assessment of scenic quality were developed (Roth 2006, von Haaren 2004, Steinitz 1990, Hunziker & Kienast 1999, Palmer & Hoffman 2001). Authors from other European countries often base their research on those methods (e.g. Arriaza et al. 2004, Real et al. 2000, Angilieri & Toccolini 1993). There are mainly two approaches to the topic: on the one hand there is the objective/expert approach which focuses on the composition of the landscape and the configuration of its elements as formal design parameters. On the other hand there is the subjective/perception-based approach which analyses the preferences of those who view and experience landscape, usually presenting photographs (Daniel 2001, Augenstein 2002). Both approaches accept the premise that aesthetic quality of a landscape derives from an interaction between landscape features and perceptual/judgemental processes of the human viewer (Daniel 2001). Hence an assessment of the scenic quality in an area can therefore base on an analysis of landscape pattern and structuring elements. The influence of certain patterns and elements on scenic quality can be found in the results of perception-based research. Over the last decades there were several attempts to quantify landscape features in order to assess scenic quality (e.g. Shafer & Brush 1977, Bishop & Hulse 1994, Hunziker & Kienast 1999, Augenstein 2002, Roth & Gruehn 2006), some of which also use Landscape Metrics.

Considering this background, it was the objective of the study to investigate how LM could be integrated into frequently used evaluation methods using Geographic Information Systems (GIS) and if supposed improvements, (i.e. more objectivity, reliability and acceleration of the working process) could be achieved. As a standard tool of German landscape planning, the Landscape Structure Plan (LSP) of the county Havelland (Landkreis Havelland 2003) served as an example. The LSP is a typical medium-scale product of the German landscape-planning hierarchy. The objective of this plan is the sustainable development of a region, taking into account the environmental interests. In order to develop requirements and measures of nature conservation and landscape management, the existing and anticipated status of nature and landscape is assessed.

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This study demonstrates a methodological framework for the evaluation of the aesthetic potential as a selected landscape function. For a more general review of the use of LM for abiotic and biotic landscape functions in regional planning see Herbst et al. (2007).

2 Study area

The area selected for this case-study is the county Havelland, a rural district in the northeast lowlands of Germany. The study site situated in the western part of the Federal State of Brandenburg covers an area of 1,717 km² and is a typical agriculturally dominated region (Fig. 1). It is used less intensively and shows a varied small-scale landscape structure with many nature reserves. The area is characterized by a high portion of grasslands (27 %) in comparison to the Federal State of Brandenburg (14 %). Agricultural land covers 30 % (Brandenburg: 35 %) of the surface. The share of forests (35 %) corresponds to the state average. The landscape is characterized by the riparian floodplains of the lower Havel and its tributaries. According to Zebisch et al. (2004), the biodiversity of the area is relatively high compared to the state average. The portion of semi-natural biotopes reaches values over 80 % in the nature protection areas, especially along the Havel with high biotope varieties. The relief is rather flat with few noticeable elevations between 50 and 100 m. Anim. 1 gives an impression of different scenes in the study area. The LSP for this study site was finished in 2003. However, it has not been proven by the administration until now (2008). Therefore, at the moment no requirements and measures stated in the plan have been put into practice.

Figure 1. Location of the study area within the State of Brandenburg.

3 Data and method

The utilization of LM was based on the evaluation methods of the original LSP (Landkreis Havelland 2003). Thus relevant work procedures of the originally published plan were examined for the suitability of LM. Since the LSP uses standardized evaluation methods, validity and acceptance of the results within environmental agencies were assumed. In the original LSP, the scenic quality of the landscape was mainly evaluated by using qualitative (visual-aesthetic) assessment methods. However, for the evaluation criteria which could be assigned to structural factors, newly quantified LM-based evaluations were substituted with those in the original LSP. All qualitative assessment-criteria remained unchanged. The results of the method with integrated LM were compared to the original evaluation of the LSP. Differences in the results were quantified and the reasons explained by visual examination of those areas in the database. As data basis, a Digital Biotope Mapping (scale 1 : 10,000) in vector format, a Digital Elevation Model (DEM – grid size 50 m) and data of the original evaluation of the LSP were available.

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Animation 1: Different scenes in the study area (Sources: Uehlein 2006, Förster 2006); a) diverse riparian landscape, b) medium-structured grassland, c) extensive arable land with typical coniferous forest, d) extensive grassland and mixed forest, e) drainage canal in intensive grassland.

Evaluation method of the original LSP

The evaluation method of the original LSP is based on *landscape scenery units* (LU) as input geometry for assigning values of different scenic quality. Those units are defined as homogeneous fields of similar visual experience of the landscape. They have an average size of 3.6 km². The delineation of LU was carried out manually with the help of visually perceptible space edges such as forest borders, the topography, or different forms of land use (e.g. arable land/grassland). Fig. 2 offers an overview of the biotope structures of the study area and shows the LU (black lines). Within these units, the included biotope structures were evauated according to the three main criteria defined by the FNCA, namely *diversity*, *unique character* and *naturalness.*[2]

2 The evaluation criterion beauty was replaced by the term naturalness. Beauty cannot be evaluated objectively. Therefore, the factor is commonly substituted (e.g. Adam et al. 1986). Naturalness refers to the impression of a human viewer that the current appearance of nature could have developed without anthropogenic influence (Landkreis Havelland 2003).

The evaluations of these attributes were averaged equivalently with one another to a total result (1 = very high value, to 5 = very low value).

Most of the structural parameters which can be quantified with LM were found in the criterion *diversity*. It is determined by the sub-criteria *variety of vegetation*, *variety of relief*, *variety of waterbodies*, and *variety of land use*. Nevertheless, in the original LSP these parameters were evaluated qualitatively and manually rather than quantitatively. *Variety of vegetation* and *variety of land use* were determined by simply ranking the different biotope types (e.g. coniferous forest – low, deciduous forest – high). In the case of several different biotope types and/or structuring elements the values could be increased. *Variety of relief* was classified from 'no relief/plain' to 'intense topography/several steep slopes (>8%)', and *variety of waters* was ranked from 'occurrence of no waters' to 'occurrence of still waterbodies'. No concrete numbers (except steep slope), amounts or densities were given.

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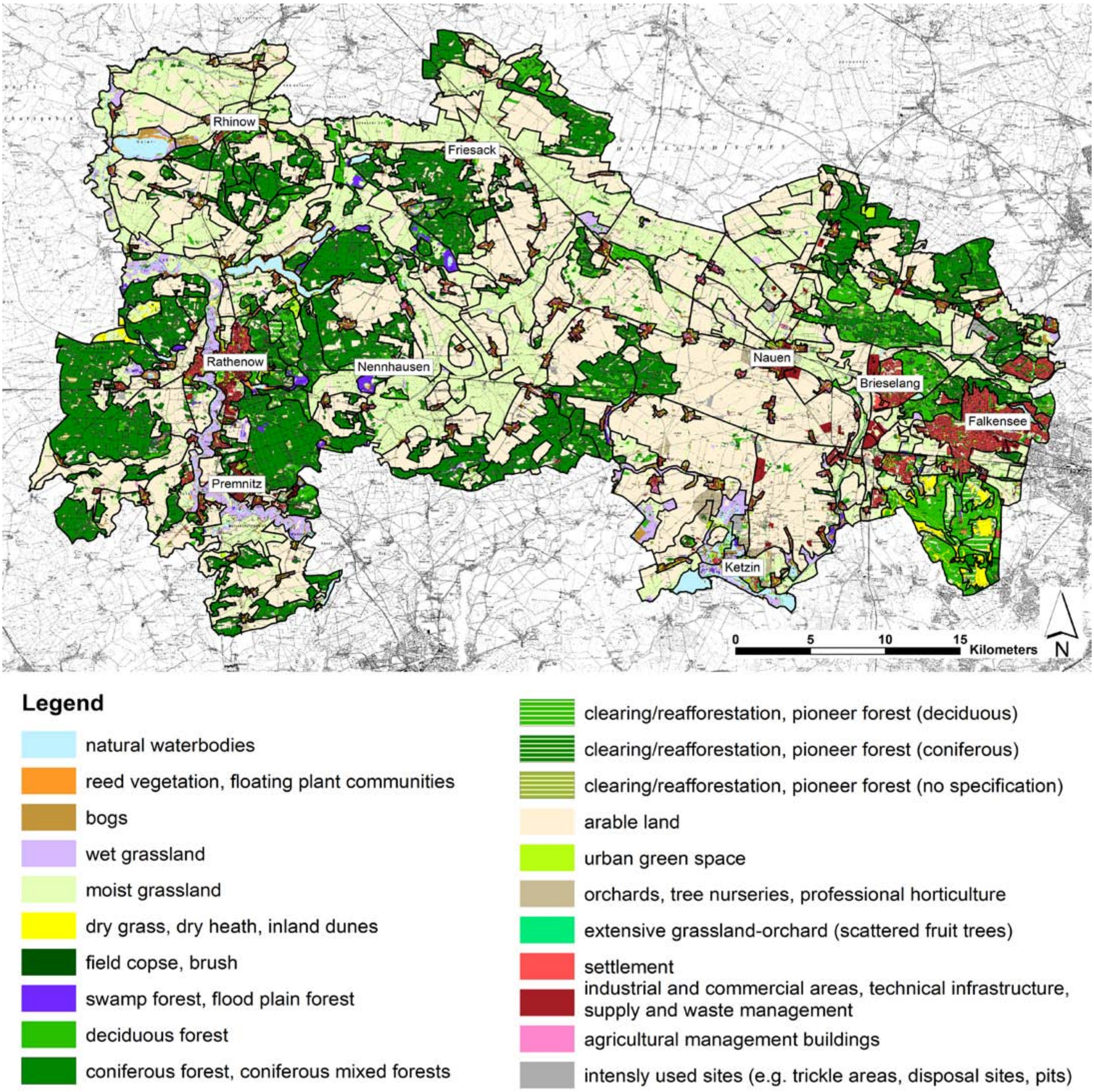

Figure 2. Land use, vegetation structure, and landscape scenery units (black lines) in the county Havelland, (source: Color-Infrared-Biotope-mapping: MLUV[2] Brandenburg/Landkreis Havelland 2003, topographic information: LGB BB 2002).

2 MLUV: Ministerium für Ländliche Entwicklung, Umwelt und Verbraucherschutz, Ministry of Rural Development, Environment and Consumer Protection

For the main criterion *naturalness*, biotope types were also ranked according to qualitative parameters (see Bierhals et al. 1986), while the factor *unique character* was evaluated on the basis of the land-use changes over the last 50 years (e.g. changing forest into arable land gets very low values). However, the area of the LU occupied by one of the given classes was used for the evaluation.

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Table 1. Quantification of the evaluation criterion diversity with LM.

Variety of Vegetation		Variety of Waterbodies	
Parameter	Landscape Metric	Parameter	Landscape Metric
Number and Distribution of Biotope-types	Shannon Diversity Index (SHDI)	Density of Natural Waterbodies	ED (standing waterbodies) ED (rivers and streams)
Structural Richness	Edge Density (ED)	Density of Artificial Waterbodies	½ ED (canals and drainage canals)
Occurrence of Structuring Elements	ED (Line Elements)		

Evaluation method of the LSP with the usage of LM

The structural diversity of a landscape is a substantial quality criterion for the factor landscape scenery within the LSP. Parameters which affect the structural diversity of a landscape are the number and distribution of different land uses and biotope structures, the structural richness of the landscape mosaic, the relief, and the occurrence of waters and other structuring elements (e.g. hedges) which can all be quantified with LM (Walz 2001, Augenstein 2004, Syrbe 2005, Lang & Blaschke 2007).

The diversity of land-use types can be determined with *Shannon's Diversity Index* (SHDI, Shannon & Weaver 1949), which quantifies number and distribution of different classes in the area of investigation. Structural richness can be located with *Edge Density* (ED), which measures the density of edges between different classes (e.g. border between arable land/pasture, pasture/forest) per unit area. The density of structuring linear elements such as hedges or tree rows can be measured as well. ED is also useful for the detection of the density of waterbodies. In this case, the lengths of rivers and drainage canals and the riparian zones of standing waters are measured. Since natural waters (lakes, rivers, brooks) have a higher aesthetic value than man-made structures (e.g. drainage canals) (see Steinitz 1990, Bishop & Hulse 1994), the values for anthropogenic influenced waters were weighted with a factor of 0.5.

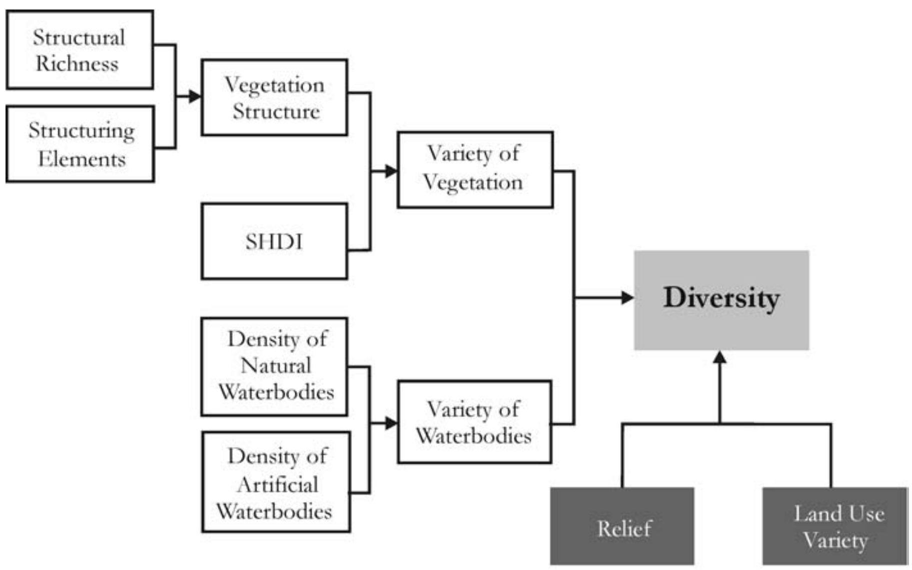

Figure 3. Aggregation scheme for the criterion *diversity*. White boxes are newly calculated with LM, while dark grey boxes are values from the original LSP.

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Table 1 shows the method of quantification of landscape *diversity*. LM were used for the evaluation of the sub-criteria *variety of vegetation* and v*ariety of waterbodies*. The values for *variety of relief* and *variety of land use* were derived from the original LSP. Within the parameter *variety of vegetation*, SHDI and ED (*structural richness*) were calculated over all of the 20 existing biotope and land use types, except settlements. All the other parameters, as can be seen, were calculated for a choice of landscape elements. The sub-parameters were ranked in a five-step scale and then aggregated. For the criterion *variety of vegetation*, the results for *structural richness* and occurrence of structuring elements were averaged. In a second step, this result was again averaged with the value of SHDI. The values for *density of waterbodies* were summed up. Finally, the newly calculated values for *variety of vegetation* and *variety of waterbodies* were combined with the values for *relief* and *land-use variety* from the original LSP into a total value for *diversity* (see Fig. 3).

Raster-based evaluation method

In most federal states of Germany the LSP has to be updated regularly (von Haaren 2004). Therefore, manually defined *landscape scenery units* (LU), as used in the LSP Havelland, are only partially suitable because of delineation updates required for each monitoring step. Thus, an alternative evaluation method, established by Marks et al. (1989) was applied. This method is based exclusively on structural parameters and utilizes raster cells as standard geometry.

For the evaluation of scenic quality, the study area was divided into 500 x 500 m raster cells. Within these cells, the *edge effect* of the biotope structures can be determined as indicator for structural diversity. Therefore, the edge length (*Total Edge*, TE) of defined borders of vegetation types (e.g. forest edges) was calculated. Furthermore, the length of edges of waterbodies was derived. Similar to the approach with LU, artificial waterbodies were weighted with a factor 0.5 in order to differentiate them qualitatively from natural waters. Tab. 2 shows the biotope structures used for the assessment of the *edge effect*. As further criteria the relief energy derived from the average slope of the DEM and the value of the land-use types are determined within the raster cells. The value for different land uses in a raster cell as qualitative parameter was transferred from the evaluation rule of Marks et al. (1989).

Table 2. Evaluation of the *edge effect* (altered according to Marks et al. 1989).

Biotope structures	Total edge	Value
Vegetation (Edge of woodlands, Edge of groves, tree rows, hedges)	< 200 m	Very low (5)
	200 – 600 m	Low (4)
	600 – 1200 m	Medium (3)
	1200 – 2000 m	High (2)
	> 2000 m	Very high (1)
Waterbodies (Riparian zones,Brooks, (Drainage) canals (x 0.5))	< 100 m	Very low (5)
	100 – 300 m	Low (4)
	300 – 600 m	Medium (3)
	600 – 1200 m	High (2)
	> 1200 m	Very high (1)

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4 Results

The results of the original LSP and the LSP with LM were intersected to illustrate the differences (see Fig. 4). Areas with the value „- 1“ were evaluated with LM one evaluation stage lower, „0“ means no changes in the results, and „1“ displays evaluation results with LM one evaluation stage higher. 426 of altogether 474 LU were assigned to the same value. The similarity of the results supports the validity of the LM method. Investigating the differently classified units, a trend to lower evaluations with the LM-based method can be recognized: 32 units obtain a lower value, 16 units are assigned to a higher class.

To explain these general divergences, sample LU were selected and examined visually, the values for the sub-parameters in the original method and after use of LM compared. The reason for most “higher” evaluations can be found in the parameter *variety of vegetation*. Especially the values of the SHDI are decisive for the class changes. For these LU there were frequent increases of two evaluation stages. In the visual comparison of such units several biotope types could be identified, which were also relatively regularly distributed within the LU (see Anim. 2a). Obviously, in the LSP low values were assigned to the predominant urban green spaces. The large water surfaces were not included in the evaluation. However, the diverse landscape pattern and the high incidence of water in this LU are indicators for a high aesthetic potential. LU with the main land-use type grassland were often assigned to medium values in the LSP, whereas the calculations with the LM method resulted in low values. In these areas, few land-use types which are relatively widespread occur. Therefore, biotope variety (SHDI) and structural richness (ED) result in low values. The internal biotope-quality, which was not considered with LM, might be the reason that in the original LSP evaluation the value for grassland is assig-

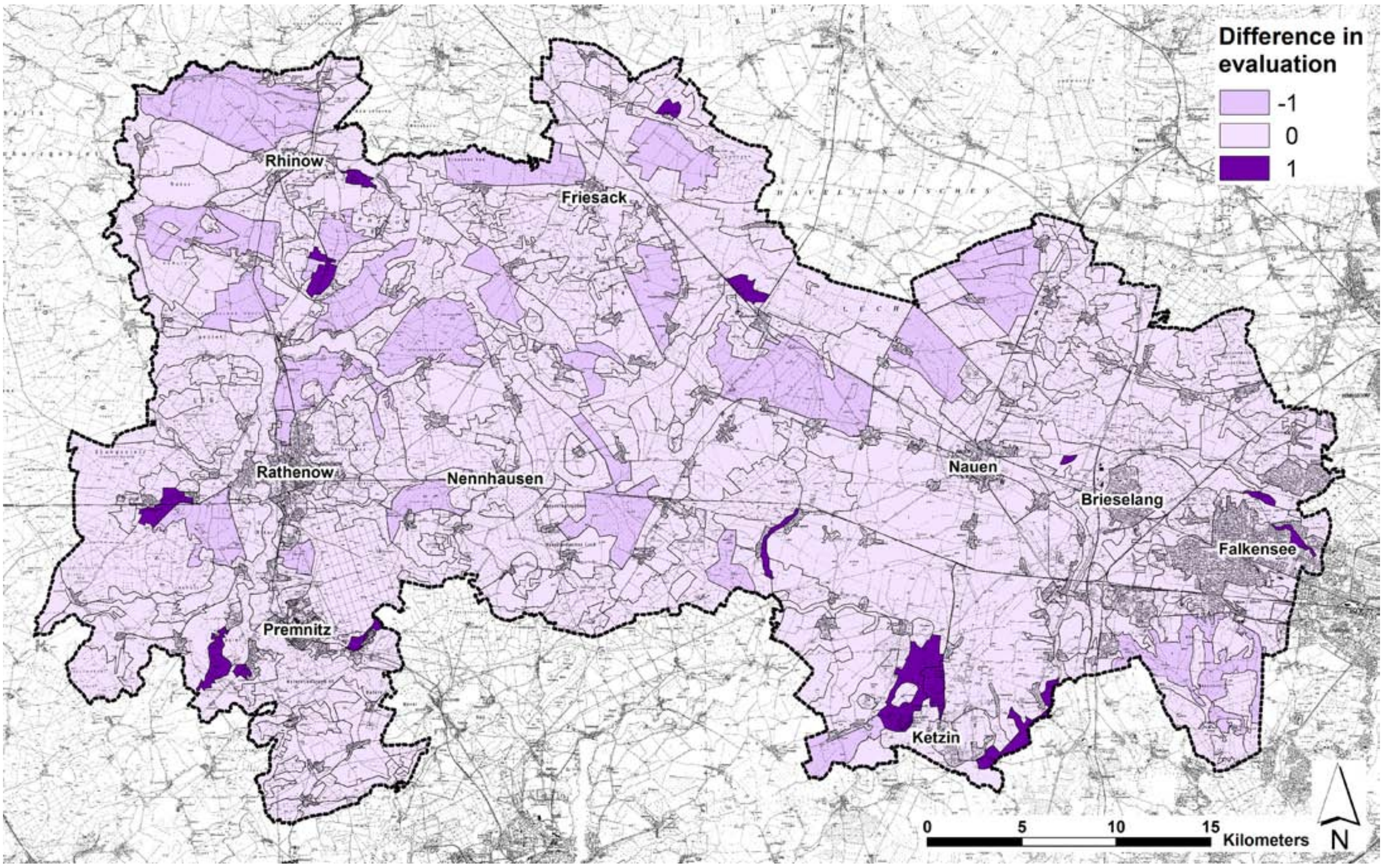
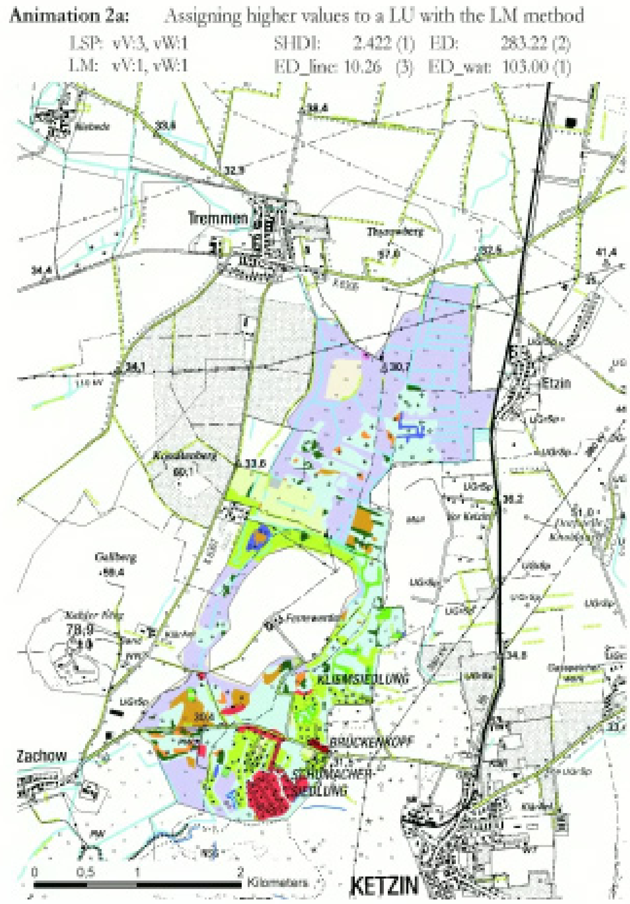


Figure 4. Comparison of the evaluation of LU in the original LSP with the usage of LM.



Animation 2. Polygonal patterns of biotope structure with linear elements (blue: linear water bodies; green, dotted: hedges, tree rows). vV: variety of vegetation, vW: variety of waterbodies, SHDI: Shannon Diversity Index, ED: Edge Density (structural richness), ED_line: density of structuring elements, ED_wat: density of waters (edges).

ned to medium values, although an in-field assessment of every piece of pasture is rather improbable. Moreover, grassland areas in the Havelland region are often characterized by drainage canals. Due to the weighting with the factor of 0.5, their influence on the value for the *variety of waterbodies* is reduced (see Anim.2b). Evaluations were also "lower" in units with forest. Those areas are often characterized by little structural richness and few line elements leading to small diversity values from the structural point of view. The biotope-internal structure as well as the general higher value of a forest for the recreational use is considered. Exemplarily, a LU with coniferous forest is displayed (Anim. 2c). Additionally there are two small standing waters in this LU. From the quantitative perspective, a low amount of regularly distributed land-use type can be found. Moreover, the edge length of the waterbodies is only small. Both the forest structures and the occurrence of waters were assigned to medium values in the LSP. Hence, the LU in the original LSP obtained a higher value than with the evaluation with LM. Therefore, the absence of linear elements connected with little structural richness resulted in low values for the criterion *variety*. Another reason for different results is the higher evaluation of standing waterbodies by the original LSP. The value of standing waterbodies originates not only from its shoreline, as ED determines, but also from the water's surface and quality. Thus, for woodlands and standing waterbodies, a qualitative weighting, as for artificial running waters, could obtain a more accurate result.

Comparison of calculating LM in landscape scenery units and raster cells

The calculation of landscape metrics in LU proved problematical. The LU in the LSP were manually digitized; consequently, the borders of the units are often not congruent with biotope borders (see Fig. 5). This affects the results of the calculation, e.g. the number of classes for calculating SHDI. Moreover, the structural diversity within a LU is normalized, since certain structural characteristics of the landscape are aggregated to a unit. Thus, a structural selection takes place while digitizing the LU, leading to a double assessment if structure parameters are determined again within these units.

The calculation of LM in raster cells offers the possibility to avoid the problems mentioned above. Fig. 6 shows the results of the evaluation of the scenic quality for the district Havelland according to the methodology of Marks et al. (1989) in comparison to the original method of the LSP. Due to the smaller geometric resolution of the raster cells (0.25 km² in comparison with 3.6 km² for LU) a more differentiated picture appears than with the evaluation in LU. The natural structures (e.g. the river Havel and the floodplains, arable land) are distinguished more clearly. Moreover, the settlements (not evaluated) cover smaller areas, since the classification refers exclusively to sealed surfaces. Urban green spaces, such as parks and other open spaces for recreation are more highly evaluated. Tab. 3 compares the evaluation of scenic beauty in the LSP and in raster cells (RC) on the basic geometry of the RC. Due to the higher amount of investigation units (13.025 RC vs. 474 LU) a more differentiated evaluation is possible for the RC-based method. Nevertheless, for the medium evaluation classes (2-4) a high agreement of the results can be found. A high amount of units (41.6 %) were assigned to the same value. Most of the other units were evaluated either one stage lower or higher. The higher amount of cells assigned to the classes 2 and 4, compared to the LU-method, indicate a higher variation and differentiation of the results of the RC-based method. Nevertheless, the LU-based method tends to evaluate areas with extreme low values (especially 5), while the RC-based method assigns more cells to good evaluations (especially 1). Many areas that were not evaluated before (settlements) were assigned to a distinct value based on RCs. Therefore, the amount of cells valued 0 is very high (1.339) for the LU-based method. The high agreement with the more manually derived evaluation of the LSP confirms the significance of the results of the raster-based method. Because of the smaller number of evaluation parameters and the simple structure of the investigation units (raster cells), the method can be realized very efficiently in a GIS.

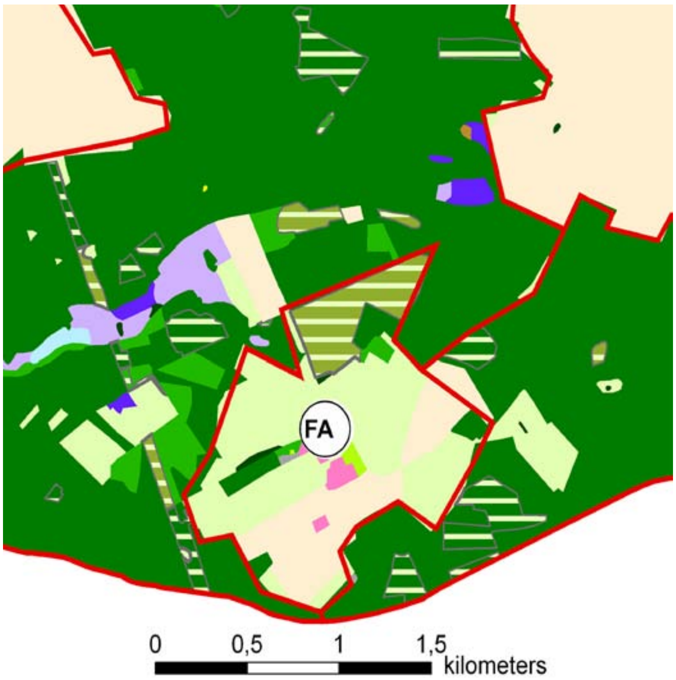


Figure 5. Inaccurate delineation of *landscape scenery units.*

Discussion

The basic statement of landscape ecology that there are close relationships and interactions between landscape pattern and ecological processes and functions is also valid for the aesthetic potential of a landscape. The methods used in this study rest on the assumption that the biophysical features of the lands-

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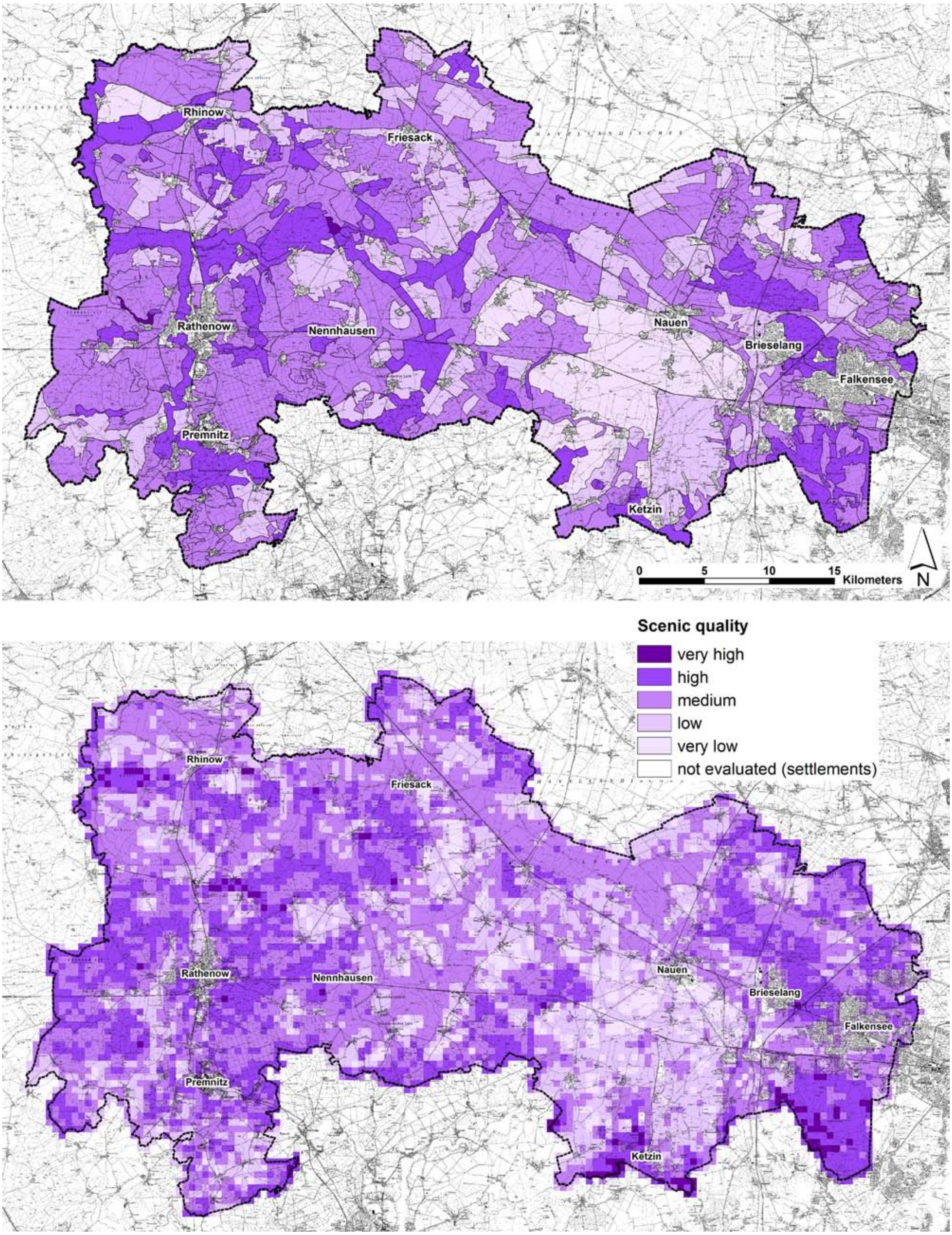

Figure 6. Comparison of the evaluation method in the LSP (top) and according to Marks et al. 1989 (bottom).

Table 3. Comparison of different evaluations in Raster Cells (RC) and LU.

	Count LU	1.339	26	2.238	5.799	2.710	913
Count RC	**Scenic Quality**	**0**	**1**	**2**	**3**	**4**	**5**
164	**0**	**93**		8	24	25	14
164	**1**	6	**1**	96	54	4	3
3.018	**2**	147	17	**977**	1.563	259	55
5.692	**3**	484	8	891	**3.032**	1.085	192
3.426	**4**	531		247	1.050	**1.134**	464
561	**5**	78		19	76	203	**185**
13.025							

cape are the basis for the perception of landscape aesthetic quality. The *psychophysical perception-based method,* for instance, systematically relates biophysical features of the landscape to the perceived visual landscape quality (Daniel 2001). Other studies have shown that the quantitative analysis of landscape elements relevant for the aesthetic perception closely correlate with the results of perception-based surveys (Bishop & Hulse 1994, Palmer & Lankhorst 1998, Hunziker & Kienast 1999, Roth & Gruehn 2006).

The relevance of *Shannon's Diversity Index* for evaluating the aesthetic potential of landscape was shown by Hunziker & Kienast (1999) and Augenstein (2002), the use of Edge Metrics was recommended by Roth & Gruehn (2006). This study confirms that *Shannon's Diversity Index* and *Edge Density* are suitable for an objective evaluation of the structural diversity of a landscape. Equal values are assigned to equal structural environments. Different evaluations of identical natural conditions as occurring in a manual method can be avoided by quantifying actual patterns in the map.

However, qualitative characteristics like biotope-internal structure and especially valuable components as an important river are not automatically considered by the use of LM. Weighting factors for certain biotope structures could improve the general result. Furthermore, the use of linear elements as indicators for higher scenic quality has to be implemented carefully. Linear elements often originate from drainage canals as a result of melioration measures especially in less structured areas. That shows that their appearance not necessarily indicates a high aesthetic value. On the other hand, the absence of linear structures, canals as well as hedges and tree rows, within woodland decreases the value of these units considerably. The question what landscape features have what influence on visual landscape quality is, therefore, an important one and is often discussed in literature. It is a well known fact that water has a positive effect on scenic beauty (Steinitz 1990, Bishop & Hulse 1994, Real et al. 2000) whereas artificial elements (as are canals) have a negative influence (Steinitz 1990, Real et al. 2000). Angileri & Toccolini (1993) state in a similar study in a quite similar study area that 'the presence of large numbers of canals of various dimensions […] helps to interrupt the monotony of single-crop landscape, enriching it with the contrast these make against the profile of the flat land'. The weighting of artificial linear elements with a negative factor, thus, seems to be an adequate method to represent the actual influence of those features on the aesthetic perception of real landscapes.

Steinitz (1990), as well as Hunziker & Kienast (1999), show that people appreciate forested areas only to a certain degree. Palmer & Lankhorst (1998) state that the initial introduction of small amounts of landscape objects creates a positive effect, which was one of their predictors of a landscape's identity. It can be assumed, therefore, that missing linear elements in woodlands under the given method lead to a realistic assessment of the aesthetic potential of such areas.

Although other studies use landscape scenery units as basic geometry (e.g. Angilieri & Toccolini 1993) the calculation of LM in LU proved to be difficult. The significance of the indices decreases because of the pre-

Table 4: Comparison of different evaluation methods for scenic beauty.

Method	Investigation Units	Criterion	Quantification/ Evaluation	+/-
Original LSP	Landscape scenery units	Diversity (vegetation, relief, water bodies, land use) Unique character (land-use change over 50 years) Naturalness (ranking of biotope types)	Relief: assessment of altitude diversity, (manually/visually) Water bodies: density of water bodies (no concrete numbers, manually/visually) Vegetation and land use: qualitative values Proportion of types of change Proportion of types of naturalness	+ good transfer of the requirements of the law (FNCA) + based on established scientific methods - relatively time-consuming - relatively subjective evaluation of the criteria due to visual interpretation of digital map
LSP + LM	Landscape scenery units	Variety of vegetation Variety of waterbodies + variety of relief and land use + unique character and naturalness from LSP	Diversity (SHDI), Structural richness (ED), Structuring elements (ED) Density of edges and linear elements (ED + weighting factor) As original method (see above)	+ efficient evaluation of relevant structural parameters + objective through measuring actual elements in the map - inaccuracy through calculating in LU
Marks et al. 1989	Raster cells (500x500 m)	Edge effect of selected vegetation Edge effect of waterbodies Relief energy Value of land-use types	Total Edge in Raster cells (TE), partially weighted Average slope of DEM Area weighted qualitative values	+ easy to use, transparent approach + objective through measuring actual elements in equal investigation areas + better knowledge about distribution of scenic quality - size of raster cells crucial - no good comparison with other landscape functions

selection of certain land-use types. Moreover, double evaluations can occur. In addition, the manual delineation of the boundaries leads to inaccuracies (compare previous section and Fig. 6). From the monitoring point of view the necessity of updating the landscape units due to land-use changes could cause substantial expenditures. The evaluation in raster cells proved to be an option to the use of *landscape scenery unit*s.

Many instances found in literature that use GIS and structural analysis also use raster cells as basic geometry (Palmer & Lankhorst 1998, Real et al. 2000, Augenstein 2002, Roth & Gruehn 2006). It increases the objectivity due to the equal basic geometry and creates a higher differentiation. With the available data (Biotope Mapping, DEM), the raster-based evaluation can be accomplished very efficiently. For monitoring reasons, the use of raster cells as basic geometry would lead to simplification since no new reference areas must be determined. Structural changes can effectively be determined with the parameters used. Tab. 4 sums up the results of this study by comparing the different investigation methods.

Conclusion

Altogether l*andscape metrics* are a useful tool for the assessment of landscape functions like scenic quality in environmental planning. They can be integrated well into the usual evaluation methods and improve them through objectification and acceleration of the working process. Most evaluation methods for scenic quality acknowledge the influence of certain patterns and structuring elements in the landscape and then quantify them to differentiate the study area. Once it is clear which elements and structures are meaningful, these can easily and objectively be quantified with landscape metrics. Since structural diversity proved to be a main quality criterion for scenic beauty, SHDI and ED are very effective measures to assess this natural value. These metrics are easy to understand and therefore suitable for every planner working with GIS. As investigation units we suggest raster cells since they are more easy to delineate and thus very effective for monitoring purposes. Moreover, calculating LM in raster cells is more precise and objective. The presented method is very efficient in terms of time and computational resources which shows the improvements that LM can bring to working processes in environmental planning.

An interesting new aspect of using LM is the integration of the 3rd dimension into the indices as Hoechstetter et al. (2008) showed in their work. The usage of 3D-landscape metrics would improve the significance of the results of structural analysis because 'real' surface is measured not only the area seen from above. Especially the component of relief, which is an important parameter for aesthetic quality, could be integrated into the objective structural analysis for assessing scenic quality. Assessing the scenic quality of a landscape is only one of many possible applications of LM. Other landscape functions that have to be evaluated in Regional Planning, e.g. habitat quality for wildlife, also base on specific pattern of the landscape mosaic. Diversity and structural richness of a land-use pattern, isolation and connectivity are decisive parameters for the habitat quality for the wildlife and assessing biodiversity in an area. Further studies should focus on the practicability of scientific methods on quantifying these parameters for the use in practical environmental planning. In the German speaking area there are several initiatives suggesting indicators (see Kiel & Albrecht 2004, Lipp 2006, Herbst et al. 2007). Thus, developing a core set of practical metrics for usage in landscape planning, as proposed by Botequilha Leitão & Aher 2002, would help to integrate this tool in 'everyday life' planning.

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References

Adam, K.; W. Nohl & W. Valentin 1986. Bewertungsgrundlagen für Kompensationsmaßnahmen bei Eingriffen in die Landschaft. MURL Nordrhein-Westfalen. Düsseldorf.

Angileri, V. & A. Toccolini 1993. The assessment of visual quality as a tool for conservation of rural landscape diversity. Landscape and Urban Planning 24, 105-112.

Arriaza, M.; J.F. Cañas-Ortega; J.A. Cañas-Madueño & P- Ruiz-Aviles 2004. Assessing the visual quality of rural landscapes. Landscape and Urban Planning 69, 115-125.

Augenstein, I. 2002. Die Ästhetik der Landschaft. Ein Bewertungsverfahren für die planerische Umweltvorsorge. Weißensee Verlag. Berlin.

Augenstein, I. 2004. Über die Eignung von Landschaftsstrukturparametern zur Bewertung des Landschaftsbildes. In: U. Walz; G. Lutze, A. Schultz, R.-U. Syrbe (eds.): Landschaftsstruktur im Kontext von naturräumlicher Vorprägung und Nutzung, 223-236.

Bierhals, E.; H. Kiemstedt & S. Panteleit 1986. Gutachten zur Erarbeitung der Grundlagen des Landschaftsplans in Nordrhein-Westfalen – entwickelt am Beispiel „Dorstener Ebene“. Institut für Landschaftspflege und Naturschutz, Universität Hannover.

Bishop, I.D. & D.W. Hulse 1994. Prediction of scenic beauty using mapped data and geographic information systems. Landscape and Urban Planning 30, 59-70.

Blaschke, T. 2000. Landscape Metrics: Konzepte eines jungen Ansatzes der Landschaftsökologie und Anwendung in Naturschutz und Landschaftsforschung. In: Archiv für Naturschutz und Landschaftsforschung 39, 267-299. Harwood Academic Publishers.

Botequilha Leitão, A. & J. Aher 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning 59, 65-93.

Botequilha Leitão, A.; J. Miller; J. Ahern & K. McGarigal 2006. Measuring Landscapes – A Planner's Handbook. Island Press. Washington.

CoE (Council of Europe) 2000. Text of the European Landscape Convention and its explanatory report in English. http://conventions.coe.int/Treaty/Commun/QueVoulezVous.asp?NT=176&CM=8&CL=ENG. (Date: 23.05.2008)

Daniel, T.C. 2001. Wither scenic beauty? Visual landscape quality assessment in the 21st century. Landscape and Urban Planning 54, 267-281.

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: What is the state of the art? Ecosystems 1, 143-156.

Herbst, H.; M. Förster; U. Uehlein & B. Kleinschmit 2007: Verwendbarkeit von Landschaftsstrukturmaßen als Bewertungsinstrument in der Landschaftsrahmenplanung. In: J. Strobl; T. Blaschke & G. Griesebner (eds.): Angewandte Geoinformatik 2007. Beiträge zum 19. AGIT Symposium Salzburg. 4.-6. Juli 2007. Wichmann. 234-239.

Hoechstetter, S.; Walz, U.; Dang, L.H. & N.X. Thinh 2008. Effects of topography and surface roughness in analyses of landscape structure – A proposal to modify the existing set of landscape metrics. Landscape Online 3, 1-14.

Hunziker, M. & F. Kienast 1999. Potential impacts of changing agricultural activities on scenic beauty – a prototypical technique for automated rapid assessment. Landscape Ecology 14, 161-176.

Kiel, S. & K. Albrecht 2004. Großräumige Landschaftsbewertung mit landscape metrics im Praxistest – Ein Methodenvergleich. In: J. Strobl, T. Blaschke, G. Griesebner (Eds.): Angewandte Geoinformatik 2004. Beiträge zum 16. AGIT-Symposium Salzburg. Herbert Wichmann Verlag. Heidelberg

Kleinschmit, B. & U. Walz (eds.) 2006. Landschaftsstrukturmaße in der Umweltplanung - Beiträge zum Workshop der IALE-AG Strukturmaße. Berlin: TU Berlin. 19, 1-3.

Landesbetrieb für Landesvermessung und Geobasisinformation Brandenburg (LGB BB) 2002. Topografische Karte im Maßstab 1:50.000 (TK 50).

Landkreis Havelland 2003. Landschaftsrahmenplan Landkreis Havelland. Band II: Bestand und Bewertung. GfU (Gesellschaft für Umweltplanung, Forschung und Beratung). Berlin.

Lang, S. & T. Blaschke 2007. Landschaftsanalyse mit GIS. Ulmer Verlag. Stuttgart.

Lipp, T. 2006. Landschaftsstrukturmaße in der Landschaftsplanung – Aufgaben, Rahmenbedingungen, Perspektiven. In: Kleinschmit, B. und Walz, U. (eds.) 2006: Landschaftsstrukturmaße in der Umweltplanung - Beiträge zum Workshop der IALE-AG Strukturmaße. Berlin: TU Berlin. 19, 18-29.

Marks, R.; M.J. Müller; H. Leser & H.-J. Klink 1989. Anleitung zur Bewertung des Leistungsvermögens des Landschaftshaushaltes. Forschungen zur deutschen Landeskunde. Band 229. Zentralausschuss für deutsche Landeskunde. Trier.

Palmer, J.F. & J. R.-K. Lankhorst 1998. Evaluating visible spatial diversity in the landscape. Landscape and Urban Planning 43, 65-78.

Palmer, F.P. & R.E. Hoffman 2001. Rating reliability and representation vlidity in scenic landscape assessments. Landscapeand Urban Planning 54, 149-161.

Real, E.; C. Arce & J.M. Sbucedo 2000. Classification of landscapes using quantitative and categorical data and prediction of their scenic beauty in North-Western Spain. Journal of Environmental Psychology 20, 355-373.

Roth, M. 2006. Landschaftsbildanalyse - Landschaftsbildbewertung. Entwicklungsgeschichte eines Planungsinstruments. In: Eisel, U. & S. Körner (Eds.): Landschaft in einer Kultur der Nachhaltigkeit - Band I: Die Verwissenschaftlichung kultureller Qualität. Arbeitsberichte des Fachbereichs Architektur - Stadtplanung - Landschaftsplanung, Heft 163. Infosystem Planung. Kassel, 47-65.

Roth, M. & D. Gruehn 2006. Die Bedeutung von Landschaftselementen für das Landschaftserleben. In: Kleinschmit, B. und Walz, U. (eds.) 2006: Landschaftsstrukturmaße in der Umweltplanung - Beiträge zum Workshop der IALE-AG Strukturmaße. Berlin: TU Berlin. 19, 155-169.

Shafer, E.L. & R.O. Brush 1977. How to measure preferences for photographs of natural landscapes. Landscape Planning 4, 237-256.

Shannon, C. & W. Weaver 1949. The mathematical theory of communication. Univ. Illinois Press. Urbana

Steinitz, C. 1990. Toward a sustainable landscape with high visual preference and high ccological integrity: the loop road in Acadia National Park, U.S.A. Landscape and Urban Planning 19, 213-250.

Syrbe, R.-U. 2005. Methodisch differenzierte Bewertung des Landschaftsbildes mit Hilfe von Strukturmaßen. „Dynamik der Landschaftsstruktur" – Workshop der IALE-D Arbeitsgruppe Landschaftsstruktur am 3.6.2005 in Leipzig.

US Department of Agriculture Forest Service (USDA) 1995. Landscape Aesthetics: A Handbook for Scenery Management. Agriculture Handbook No. 701. USDA Forest Service, Washington, DC.

Visual Diversity 2005. Visual Diversity - Landscape scenery as a subject of socio-cultural appraisal and sustainable development in rural Eastern Europe. International symposium from Oct. 17-19 2005. Muencheberg, Germany. www.visualdiversity.net. (Date 07.03.2009)

Von Haaren, C. 2004. Landschaftsplanung. Verlag Eugen Ulmer. Stuttgart.

Walz, U. 2001. Charakterisierung der Landschaftsstruktur mit Methoden der Satelliten-Fernerkundung und der Geoinformatik. Logos Verlag Berlin

Zebisch, M.; F. Wechsung & H. Kenneweg 2004. Landscape response functions for biodiversity – assessing the impact of land-use changes at the county level. Landscape and Urban Planning 67, 157-172.

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