



Indicators of hemeroby for the monitoring of landscapes in Germany



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ABSTRACT

The article discusses the concepts of “closeness to nature” and “hemeroby”, and outlines a method to establish two indicators of hemeroby. Until now Germany’s national land use monitoring systems have lacked an indicator to capture the naturalness respectively hemeroby of the landscape. Based on digital spatial data on land use (DLM-DE) and the mapping of potential natural vegetation, these indicators have now been estimated for the whole of Germany and illustrated cartographically. The indicators have been integrated into a land use monitoring system (IOER-Monitor). A hemeroby index that considers all hemeroby classes of a reference area (e.g. administrative unit and regular grid cell) is presented as well as an indicator named “Proportion of certain natural areas”. The results on hemeroby of several time-cuts can be used to estimate the cumulative impact of land use changes on the environmental status.

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Introduction

The sealing of surfaces and the intensification of land use around the world results in a decrease in nature accentuated surfaces. This undermines the preservation of biodiversity while potential landscape functions are also impaired, for example the attractiveness of the landscape for nature-based recreation (Dramstad et al. 2006).

For nature conservation, environmental planning and management information about the state of landscape is necessary and changes should be monitored. In accordance with Hellawell (1991) we regard monitoring as “intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from expected norm” (s.a. Dröschmeister 2000). Besides the regularly recording of land use data, an evaluation method and appropriate indicators are needed.

Existing national indicator systems reflect the development of land use mainly by describing changes in settlement and traffic areas (e.g. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2007; Federal Statistical Office of Germany 2012). However, these take no account of the quality of land use or how the landscape as a whole has changed. The indicators of hemeroby presented in this contribution should help to provide more informed answers to these questions. We also look at

whether the proposed indicators are suitable for a nationwide, regular monitoring scheme in Germany, specifically the IOER-Monitor (www.ioer-monitor.de) which looks at the settlement and development of open spaces. Furthermore, we discuss whether the changes in the landscape condition revealed by these indicators could serve as a basis for recommendations in the field of spatial planning.

Our objectives are in detail:

- the development of indicators of naturalness/hemeroby of landscapes;
- the evaluation of suitable databases;
- the evaluation of suitable reference units;
- and the integration of indicators of naturalness/hemeroby in a nationwide regular monitoring scheme.

Hemeroby and closeness to nature

The concept of hemeroby was originally developed for measuring human impacts on flora and vegetation. The term hemeroby, which was introduced by the botanist Jalas (Jalas 1955), is derived from the Greek words *hémeros* (tamed, cultivated) and *bíos* (life). Later this concept was applied on whole ecosystems (Blume & Sukopp 1976: p. 83; Sukopp 1972: p. 113ff). According to this, hemeroby can be understood as an integrative measure of the impact of all human intervention on ecosystems (Kowarik 1988; Sukopp 1976: p. 21).

In analysing current forms of land use in regard to human impact, hemeroby measures the distance between the current vegetation and a constructed final state of self-regulated vegetation in

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CONCEPT	CLOSENESS TO NATURE		HEMEROBY
PERSPECTIVE	historical perspective		'current' perspective
TIME REFERENCE	past		present
REFERENCE	primary natural vegetation	current vegetation	contemporary potential natural vegetation
EXAMPLE	riparian forest (through frequent inundation)	grassland (through river regulation and deforestation)	oak-wood (through irreversible groundwater lowering)

Fig. 1. Comparison of the concepts of closeness to nature and hemeroby.

Source: Stein and Walz (2012: p. 262), modified.

the complete absence of human intervention (so called potential natural vegetation (PNV)). Hence, it is as an inverse measure of the closeness to nature, if anthropogenic interventions are reversible (Kowarik 2006: p. 8). The concept of "closeness to nature", in contrast, takes the original natural vegetation as a reference (Kowarik 2006: p. 4, see Fig. 1). While the original natural vegetation represents the reconstructed vegetation which existed before the settlement of man, PNV describes the vegetation that would appear naturally if human impact is removed (Tüxen 1956). The concept of hemeroby looks at the current situation and, because it takes into account irreversible changes to the site in its reference to the PNV, describes the likely site potential (Jedicke 2003: p. 29). All in all, hemeroby and closeness to nature can be considered as two separate concepts to describe naturalness. Only if irreversible changes to the site happen, there will be different results.

In principle, the classification of closeness to nature or hemeroby can be made at the type level of habitat or land use classes (see also Kowarik et al. 2008: p. 76). For this purpose several scales of hemeroby can be found in the literature (Kowarik 2006: p. 9; Sukopp 1969: p. 363).

Mapping of hemeroby at regional and national level

The concept of hemeroby can be used to evaluate and compare landscapes. It enables an assessment and temporal comparison of landscape in which relative changes over time are more important than absolute values (Peterseil et al. 2004). Hitherto hemeroby has been mostly applied to smaller clearly defined areas, individual cities (e.g. Cscorba & Szabó 2009; Jedicke 2003; Kieser & Thannheiser 2001; Konnert & Siegrist 2000; Steinhardt et al. 1999) or regions (LfULG 2009; Schlüter 1992; Stein & Walz 2012). The concept has also been applied to the Federal Republic of Germany by using CORINE Land Cover data (Glawion 2002) to classify various land uses into spatial types and assigning a degree of hemeroby. Because of the underlying classification into only 16 spatial types and the relatively small scale, this mapping, while providing a general overview, is inappropriate for a more accurate calculation of spatial extent and thus the monitoring of local and regional developments.

For the European Union, Brentrup et al. (2002) have suggested to adopt the concept of hemeroby for analysis of the environmental impact of land use changes on the basis of bio-geographical regions. Only recently a proposal was presented for the integration of an indicator on naturalness into the agri-environmental set of indicators at the European level (Paracchini & Capitani 2011). Machado (2004) presented a well considered plan for the implementation of the concept of naturalness in the Galapagos Archipelago, the island of El Hierro and a section of the Canary Islands. A map of hemeroby for an entire country, in this case Austria, was created by the SINUS Project Team (Peterseil et al. 2004; Wrba et al. 2004) and Rüdiger

et al. (2012). Previously Grabherr et al. (1998) mapped the hemeroby of the Austrian forest ecosystems. In South Tyrol Tasser et al. (2008) determined hemeroby, among other indicators of biodiversity, on the basis of land use data and surveys of the vegetation. In the Chinese province of Shaanxi, Fu et al. (2006) have used the concept of hemeroby to assess the sustainability of agriculture in the local Loess hilly region.

Methods

Comparison of possible nationwide data basis

Suitable digital databases for a nationwide evaluation of hemeroby in Germany are the CORINE land cover dataset (EEA 2000), the Base-Landscape Model (Basis-DLM) of the Authoritative Topographic–Cartographic Information System (ATKIS) (Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany 2009) and the Digital Land Cover model for Germany (DLM-DE) (Arnold 2009) (see Table 1).

CORINE Land Cover (CLC) is a project of the European Commission for the uniform classification of the main types of land use and land cover in Europe. The digital, mostly automatic, mapping is based on 13 main classes, which are subdivided according to the type of land cover (in particular forms of agriculture) into 44 standard classes for the whole of Europe. Of these, 37 classes of land cover and use are found in Germany. To date three surveys have been carried out: for the years around 1990, 2000 and 2006. The lower limit for the detection of planar elements is a size of 25 hectares; for linear elements (e.g. watercourses) there is a minimum width of 100 m. In successive stages of data capture, changes of 5 ha and above have been recorded (Keil et al. 2010). Although CLC data has the advantage of European comparability, the low resolution of detection prevents a detailed assessment of hemeroby.

The Authoritative Topographic–Cartographic Information System (ATKIS) is a national standardised system of the Surveying Authorities of the States of the Federal Republic of Germany for the digital recording and display of information on the use and topography of the earth's surface in Germany. The Basis-DLM of ATKIS has the advantage that data is largely homogeneous for the entire country and regular updating is legally assured (Schumacher & Meinel 2009). In the basic update all objects are checked in a frequency of 3–5 years and adjusted for change. Particularly important topographic objects (especially in the field of transport) are updated every 3–12 months. Moreover, it is the latest and most detailed topographic spatial dataset covering the whole of Germany (Meinel 2009). The objects which are included (e.g. linear elements, such as roads, or planar, such as settlement areas, vegetation and water surfaces) are defined in an object catalogue, which includes more than 155 feature types with additional distinguishing attributes (Federal Agency for Cartography and Geodesy 2011). Regarding areas of

Table 1

Data sources for the calculation of landscape hemeroby.

Name	Scale	Legend	Latest data from	Updating	Coverage	Characteristics
<i>Land use/land cover</i>						
ATKIS Basis-DLM	1:25,000	More than 155 feature types, additional differentiation by further attributes	2012	>4 years	Germany	
DLM-DE	>1 ha	37 classes	2009	5 years (planned)	Germany	No linear elements
CORINE land cover	1:100,000	44 classes, of which 37 relevant to Germany	2006	6–10 years	Europe	
<i>Potential natural vegetation</i>						
Potential natural vegetation	1:500,000		2010	No updating planned	Germany	Reference data

open space the data is thematically rather less differentiated and also subject to the lowest frequency of update.

By contrast, the DLM-DE dataset offers vector data conforming to the standard European CORINE nomenclature. For the creation of the dataset appropriate land use classes were selected from ATKIS (99) and updated by the interpretation of remote sensing data (RapidEye; DMC – Disaster Monitoring Constellation, see www.dmcii.com). Furthermore, additional information was gained from topographic maps, digital orthophotos or older satellite images. The lower limit of detection is one hectare, which lies between ATKIS (0.1–1 ha) and CORINE (25 ha). Thus DLM-DE constitutes a more detailed and more topical dataset for Germany than CORINE. A first evaluation on the basis of data from 2009 was completed in 2011, and is available from the Federal Agency for Cartography and Geodesy (BKG). A continuous updating of DLM-DE is planned, probably in a 5-year cycle.

Adaptation of data basis

For the purposes of this study, the land use data from the “Digital Land Cover Model” (DLM-DE) was selected as it is more detailed and topical than ATKIS, particularly in the open space categories (forest, grassland). In addition, comparability to both CLC and ATKIS data is ensured. However, since the DLM-DE contains no linear elements, the buffered road and street network and the linear waterways from ATKIS were overlaid onto DLM-DE data. For the buffering of objects such as roads, main rural roads, rails and rivers, which are represented by linear vectors in the Basis-DLM, it was possible to make use of width values also contained in the ATKIS database. If no width data was available, a standard value was derived from related characteristics such as the number of lanes or tracks, or the type of road. Rows of trees and hedges as well as individual trees were disregarded.

Our research showed, that generalisations must be accepted, such as in the classification of forests. Thus the map of the potential natural vegetation (PNV) for Germany only exists at the scale 1:500,000 (BfN 2010). Despite this lack of detail, the database appears sufficient to examine the accordance of the forests of the DLM-DE with their location. We had to generalise the PNV into three classes because the forests of DLM-DE are mapped into three classes as well, while the geometry of the DLM-DE remains unaffected. At most, errors caused by the two different scales of DLM-DE and the PNV-map can occur in the case of fuzzy assignment of a hemeroby degree to objects at a border between different classes of potential natural vegetation. However, this affects only objects within different forest classes and natural forest-free sites.

Classification of hemeroby

A seven-point scale was used to classify land use by degree of hemeroby (Table 2). Such a scale is commonly adopted in the literature (Blume & Sukopp 1976; Glawion 2002; Marks & Schulte 1988)

and comparability with other studies is thus ensured. Any finer gradation of the scale of classification on the basis of the DLM-DE would in any case have no additional informational value since the differentiation of forests and open land in the data model is not adequate. For example it is not differentiated between extensive and intensive grassland.

The assignment of a land use class to a special degree of hemeroby respects the intensity, duration and range of human impact (Sukopp 1969). While for example residential areas are characterised by a high degree of soil sealing, which has high impacts on ecological function, and is mostly of long duration, agricultural

Table 2

Assignment of CORINE Land Cover classes (CLC) of the DLM-DE to degrees of hemeroby (compilation on the basis of Blume & Sukopp 1976; Glawion 2002; Marks & Schulte 1988; Rüdiger et al. 2012).

Degree of hemeroby	CLC-code and CLC-class of the DLM-DE	
1. Ahemerobic	332 Bare rocks	
– Almost no human impacts	335 Glaciers and perpetual snow	
2. Oligohemerobic	311 Broad-leaved forest	421 Salt marshes
– Weak human impacts	312 Coniferous forest (PNV)	423 Intertidal flats
	313 Mixed forest (PNV)	521 Coastal lagoons
	331 Beaches, dunes, sands	522 Estuaries
	411 Inland marshes	523 Sea and ocean
	412 Peat bogs	
3. Mesohemerobic	312 Coniferous forest (not PNV)	324 Transitional woodland-shrub
– Moderate human impacts	313 Mixed forest (not PNV)	333 Sparsely vegetated areas
	321 Natural grasslands	334 Burnt areas
	322 Moors and heathland	
4. β-Euherobic	141 Green urban areas	511 Water courses
– Moderate-strong human impacts	231 Pastures	512 Water bodies
	243 Land principally occupied by agriculture, with significant areas of natural vegetation	
5. α-Euherobic	142 Sport and leisure facilities	211 Non-irrigated arable land
– Strong human impacts	221 Vineyards	242 Complex cultivation patterns
	222 Fruit trees and berry plantations	
6. Polyherobic	112 Discontinuous urban fabric	133 Construction sites
– Very strong human impacts	131 Mineral extraction sites	
	132 Dump sites	
7. Metahemerobic	111 Continuous urban fabric	123 Port areas
– Excessively strong human impacts	121 Industrial or commercial units	124 Airports
– Biocoenosis destroyed	122 Road and rail networks and associated land	

Formula 1. Normalised area-weighted hemeroby index (a) and simple area-weighted hemeroby index (b).

(a) Normalised area-weighted hemeroby index (Steinhardt et al. 1999)

$$M_1 = 100 \sum_{h=1}^n \frac{f_n}{n} h$$

n – number of degrees of hemeroby (here: $n = 7$).

f_n – proportion of category n .

h – degree of hemeroby.

M – hemeroby index.

(b) Simple area-weighted hemeroby index

$$M_2 = \sum_{h=1}^n f_n * h$$

and forestry areas contain different intensities of use. Thus, for the classification of the hemeroby of forests and areas without any vegetation, an additional intersection with the “Potential natural vegetation” (PNV) was necessary. This required some analysis of the national map of PNV in the present scale of 1:500,000 (BfN 2010). Since forests cover 31.6% of Germany’s total land surface (see www.ioer-monitor.de), a realistic assessment of the human impact on forests was carried out. Forests and areas without vegetation were therefore classified by the extent of their deviation from the potential natural vegetation. A montane spruce forest in the high altitudes of the central uplands or a scree slope which accords closely with the typical PNV for such a site was assigned to a lower hemeroby degree (i.e. weaker human impacts) than a non-native coniferous forest in the lowlands or a human-made gravel surface. Areas that are without human impacts (Marks & Schulte 1988) are described as “ahemerobic”. As some degree of human impact exists almost everywhere due to supraregional pollution emissions and climate change, there should be practically no ahemerobic areas in Central Europe (Kowarik 2006). Therefore only potentially natural areas without vegetation (e.g. rock) were assigned to the “ahemerobic” degree (see also Paracchini & Capitani 2011, p. 8; Rüdiger et al. 2012). For the analysis, a semantic generalisation of the basic land use types of the DLM-DE (deciduous, coniferous and mixed forest and natural forest-free sites) was performed.

Indicators of hemeroby

With the help of the first proposed indicator at landscape level – the “hemeroby index” – the human impact for the individual territorial unit (e.g. a municipality) can be summarised and described, allowing us to compare different spatial units or, by using multiple time series, to document the development of hemeroby. To calculate the index, the area-weighted average of all hemeroby values of a landscape is calculated. Such a hemeroby index is already widely used, generally normalised to 100 (Formula 1a) (Frank et al. 2012; Fu et al. 2006; Steinhardt et al. 1999; Tasser et al. 2008). In our opinion the results are confusing, because for a seven-point scale the mean value can lie between 14.3 and 100. Such values are not as easy to interpret as the degrees of hemeroby shown in Table 2. Because of this, we simply calculated the area-weighted mean value of the degrees of hemeroby (Formula 1b).

The hemeroby index we present can have a value of between 1 and 7. The latter maximum value corresponds to a fully sealed area classified as metahemerobic, while the minimum value 1 describes an area which corresponds perfectly to the potential natural vegetation cover and thus is classified as ahemerobic.

For the purposes of nature conservation, however, nature-accentuated areas with a degree of hemeroby from ahemerobic to mesohemerobic are of special interest, because these are subject to little or infrequent human intervention. These include site-specific and non-native forests, woodlands and hedgerows, marshes and swamps. It is proposed to calculate the proportion of these

nature-accentuated areas to the reference area as a second separate indicator.

The method for calculating these two indicators was thoroughly tested in Saxony (see Stein & Walz 2012) and later adapted for nationwide calculations. Beside the simplification of the formula (see above) it proved necessary to keep the large amount of data to a manageable size. Thus unpaved roads and tree rows were ignored, since inclusion of these linear elements imposes a high computational effort. In addition, watercourses were not classified according to the water structure, but uniformly as β -euhemerobic (Marks & Schulte 1988; Steinhardt et al. 1999). Watercourses could indeed be distinguished by water policy or shipping category, but no national data is available for smaller waters.

Overall, for Saxony it has been found that the simplifications lead to a substantial acceleration in calculation without changing the results in any significant fashion (Stein 2011: p. 92). For example, disregarding tree lines and paths resulted in only a marginal change in the degree of hemeroby for most municipalities.

Reference units

Administrative units (municipalities) and regular grid cells were used as a means of spatial reference. While the land area of municipalities varies in size, and therefore the calculated indicators must always be considered as values relative to this area, the use of grid cell avoids the ambiguity of results based on different reference units. Moreover, the map representation provides a uniform level of detail, while the delineation at the level of local or county borders depends on the size of these units, resulting in a more or less detailed image. In addition, a comparison over time is often hampered by shifting administrative boundaries.

Grid maps are gaining in importance since Eurostat guidelines (European Commission & Eurostat 2005) and INSPIRE specifications (INSPIRE 2010) promote their use. Advantages are mainly their spatial and temporal comparability (without complicated conversions) compared to the exclusive use of administrative territorial units as a reference base (Wonka 2009).

Results

Classification of landscape hemeroby

Assigning degrees of hemeroby to the land use classes leads to a spatially explicit, detailed presentation of hemeroby (Fig. 2). The map sections, showing different regions in Germany, give an idea of the diversity of human impact on landscape. They also confirm the exact assignment of hemeroby to the various land use types.

Hereinafter indicator values are aggregated for spatial reference units.

Indicators of hemeroby and proportionate share of nature-accentuated areas

Although the strength of human impacts in a region can be determined in general from the hemeroby index, no information is given on the actual composition of the area out of single patches with different hemeroby degrees. For example, an index value of 3 will be obtained if the entire area of a municipality is mesohemerobic, but also if the municipality is equally composed of oligo- and β -euhemerobic areas.

On the one hand, the derived maps clearly show the distribution of municipalities with high proportions of nature-accentuated areas (Fig. 3, left). These are often located in upland and mountainous areas, but also on the coast and in the former glacial areas of the North German lowlands. On the other hand, the hemeroby index gives the average values for the municipalities (Fig. 3,

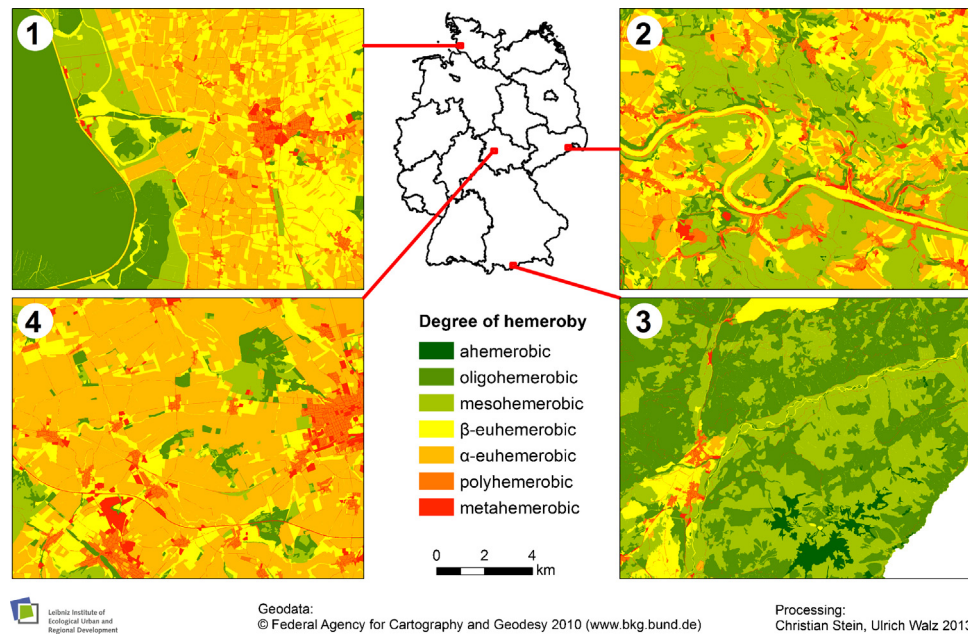


Fig. 2. Landscape hemeroby (sections from various landscapes: North Sea coast (1); Saxon Switzerland (2); Alps (3); and, Thuringian Basin (4)) (editors: C. Stein and U. Walz).

right). Here we particularly note municipalities with a high proportion of settlement areas, while intensively farmed areas such as the fertile plains with loess-rich soils (termed “Börden”) are also prominent.

A comparison of indicators between the federal states shows that those which contain mountainous areas (e.g. Rhineland-Palatinate, Hesse, Bavaria) have the largest number of municipalities showing especially low degrees of hemeroby and high shares

of nature-accentuated areas. But also Brandenburg, which in comparison to more densely populated (e.g. North Rhine-Westphalia) and agrarian states (e.g. Saxony-Anhalt) has a relatively small population and industrial density, shows a lower human impact.

It can be assumed that the average size of municipalities also influences the calculation of indicator values. Rhineland-Palatinate, in particular, is dominated by many small municipalities, leading to a much lower spatial generalisation of results. In larger

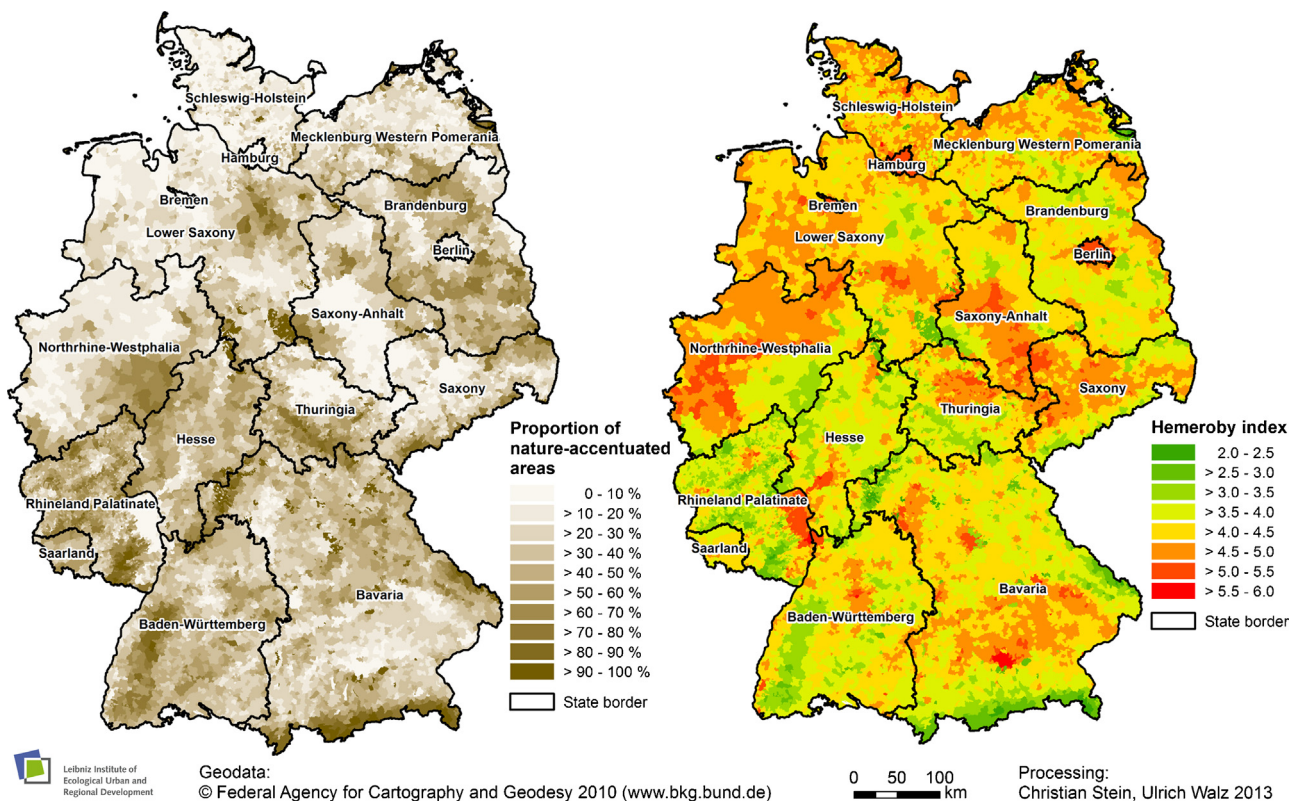


Fig. 3. Landscape hemeroby based on calculations for administrative units (municipalities) (left: proportion of nature-accentuated areas, right: hemeroby index) (processing: C. Stein and U. Walz).

Table 3

Proportion of nature-accentuated areas in the Germany's federal states (evaluation based on municipalities).

Germany's federal states	Proportion of nature-accentuated areas as % of total surface area									
	0–10%	>10–20%	>20–30%	>30–40%	>40–50%	>50–60%	>60–70%	>70–80%	>80–90%	>90–100%
Baden-Württemberg	1.3	7.4	20.8	27.3	18.8	10.2	7.2	3.4	3.0	0.6
Bavaria	5.2	13.0	22.7	22.0	15.6	7.8	3.7	2.4	3.2	4.5
Berlin	0	100	0	0	0	0	0	0	0	0
Brandenburg	7.1	8.9	18.9	16.7	20.1	11.2	11.7	4.9	0.4	0
Bremen	100	0	0	0	0	0	0	0	0	0
Hamburg	100	0	0	0	0	0	0	0	0	0
Hesse	2.6	5.1	13.4	24.4	25.3	17.8	7.3	2.3	0.3	1.5
Mecklenburg-Western Pomerania	14.6	33.6	21.1	11.5	7.3	5.7	3.4	1.9	0.5	0.4
Lower Saxony	19.1	29.6	21.8	14.0	6.1	2.8	2.2	1.1	0.9	2.4
North Rhine-Westphalia	15.3	37.1	13.6	8.7	7.6	8.9	5.9	2.8	0.0	0.0
Rhineland-Palatinate	10.2	5.7	11.9	15.3	18.7	12.9	11.4	8.4	3.8	1.6
Saarland	0	3.0	18.2	33.4	7.0	32.2	6.2	0	0	0
Saxony	17.9	22.9	20.6	11.9	9.0	7.3	4.1	4.1	2.1	0
Saxony-Anhalt	30.5	17.6	14.5	15.4	11.1	5.3	2.4	2.8	0.4	0
Schleswig-Holstein	45.4	29.7	14.5	6.0	1.6	0.7	1.0	0.1	0.1	0.9
Thuringia	19.4	10.2	14.0	18.5	12.8	10.0	6.3	5.6	2.7	0.3

municipalities, by contrast, the likelihood increases that the mean indicator value encompasses diverse land use types, such as areas in a more natural state (e.g. in the outskirts of settlements) alongside areas within the settlement itself which show a high degree of human impact. In addition, only one value is calculated for each municipal area. On this basis it is impossible to make a more refined analysis of indicators, and thus only one value can be generated for the city-states of Berlin and Hamburg (see [Tables 3 and 4](#)). In order to prevent the size of investigated areas from affecting the calculations and to allow further spatial differentiation below the level of municipalities, we also derived indicators on the basis of regular grid cells (see also [Fig. 4](#)).

Discussion

Why do we need further indicators?

Up to now the development of open space in Germany has been quantitatively evaluated within the National Strategy on Biological Diversity by means of an indicator on land consumption (increase in settlement and traffic areas) ([BMU 2010](#)). In this case the monitoring of change only takes account of the proportionate development of residential and traffic areas. This indicator describes the general development of land area for housing and transport. However, it provides no information on the forms of land use of areas which are negatively affected, and also gives no indication of how the state

of the landscape as a whole is changing in relation to the impact of other land use changes. In contrast, the hemeroby index covers the cumulative impact of such diverse land use changes. For example, if in addition to changes in settlement and transport areas, agricultural use has also undergone some form of transition (e.g. meadows transformed into arable land) then all these factors are reflected by the indicator. Compensatory measures are also taken into account. For example, if the consumption of land for new roadways is offset by reforestation measures elsewhere, these balancing factors will be incorporated in the hemeroby index ([Stein & Walz 2012](#)). There is a need for comprehensive and nationwide environmental indicators, e.g. for the assessment of the likely environmental effects of plans and programs like the German federal transport infrastructure plan ([Wende et al. 2004: p. 120](#)).

Furthermore, the hemeroby index allows conclusions on biodiversity. [Kowarik \(1988: p. 118\)](#) showed for West-Berlin that a low to moderate human impact promotes plant species richness, while a strong impact reduces the diversity of plants species. In mesohemerobic areas most plant species could be found. **With increasing human impact rare species are displaced and common plant species are promoted** ([Kowarik 1988: p. 138](#)).

Beyond this background, the two proposed indicators have different focal points: while at the municipal level the hemeroby index represents an average value of the human impact, the focus when looking at the proportion of nature-accentuated areas is on areas of value for nature conservation.

Table 4

Proportion of landscape hemeroby index classes in Germany's federal states (evaluation based on municipalities).

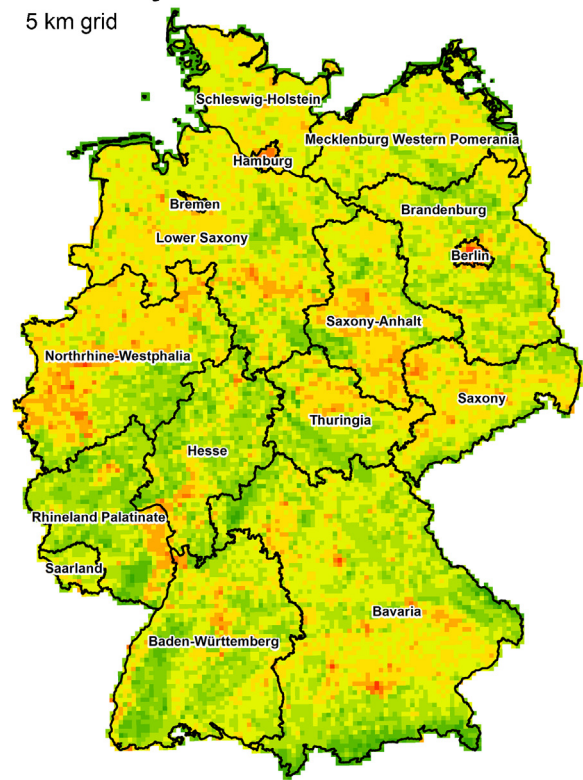
Germany's federal states	Proportion of landscape hemeroby index classes as % of the total surface area							
	2.0–2.5	>2.5–3.0	>3.0–3.5	>3.5–4.0	>4.0–4.5	>4.5–5.0	>5.0–5.5	>5.5
Baden-Württemberg	0	1.3	14.6	31.9	41.2	9.5	1.3	0.1
Bavaria	1.2	5.9	7.8	27.5	37.5	17.7	1.9	0.5
Berlin	0	0	0	0	0	0	100	0
Brandenburg	0.0	0.0	6.5	35.6	43.7	13.7	0.5	0.01
Bremen	0	0	0	0	0	21.0	79.0	0
Hamburg	0	0	0	0	0	0	100	0
Hesse	0	2.1	15.5	48.7	24.0	7.5	2.2	0.1
Mecklenburg-Western Pomerania	0.5	1.3	4.7	16.9	46.5	30.0	0.1	0
Lower Saxony	0.1	2.2	2.7	9.4	51.8	31.7	2.0	0
North Rhine-Westphalia	0	0	6.0	20.5	17.1	43.6	12.7	0.2
Rhineland-Palatinate	0.2	7.5	23.4	34.4	19.8	7.7	6.8	0.4
Saarland	0	0	0	24.6	67.5	7.9	0	0
Saxony	0	0.1	7.4	18.5	29.2	39.9	4.8	0
Saxony-Anhalt	0	0	5.8	15.3	37.7	34.0	7.1	0
Schleswig-Holstein	0.2	1.0	1.0	7.1	48.8	38.9	2.9	0.2
Thuringia	0.1	1.0	12.6	28.8	29.5	23.9	4.2	0

Proportion of nature-accentuated areas

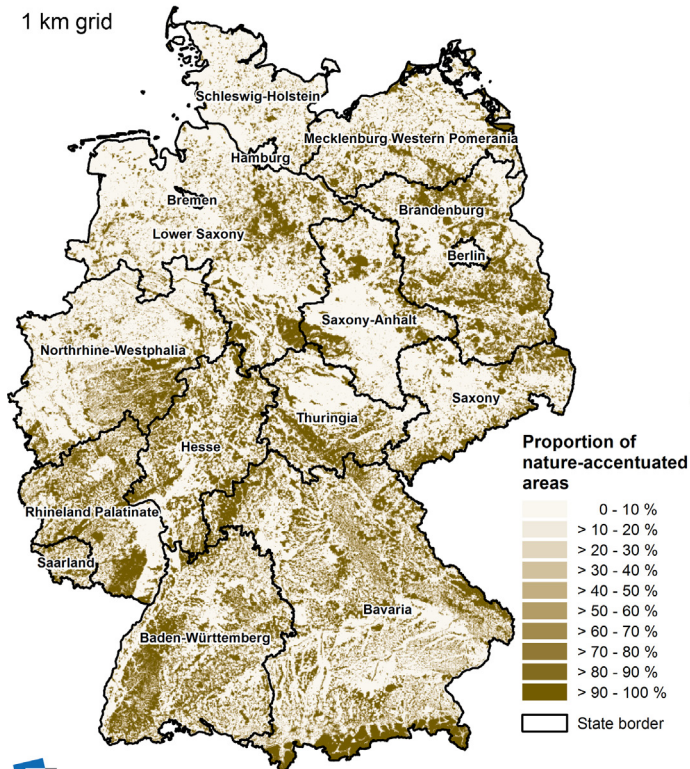
5 km grid

**Hemeroby index**

5 km grid



1 km grid



1 km grid

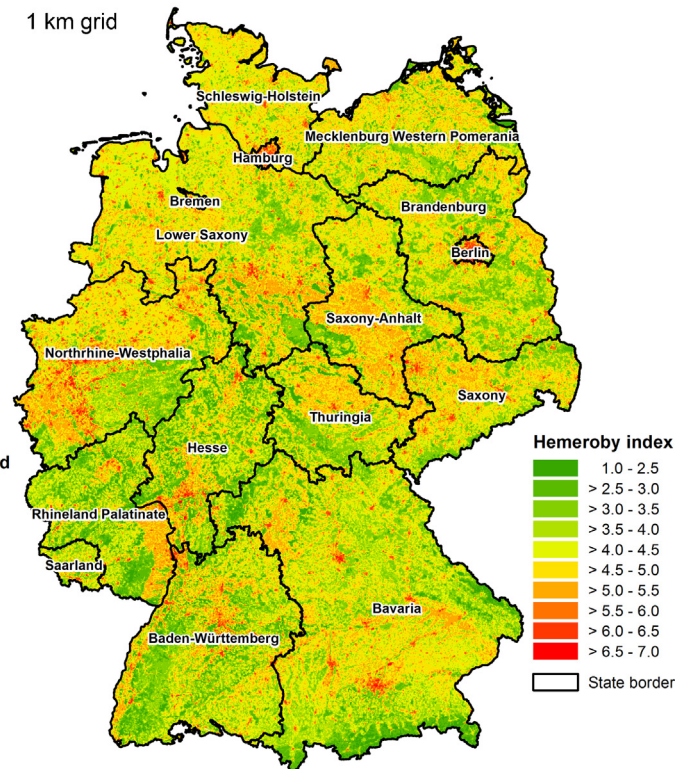


Fig. 4. Landscape hemeroby based on calculations for grid cells (left: proportion of nature-accentuated areas, right: hemeroby index; top: grid size of 5 km, bottom: grid size of 1 km) (processing: C. Stein and U. Walz).

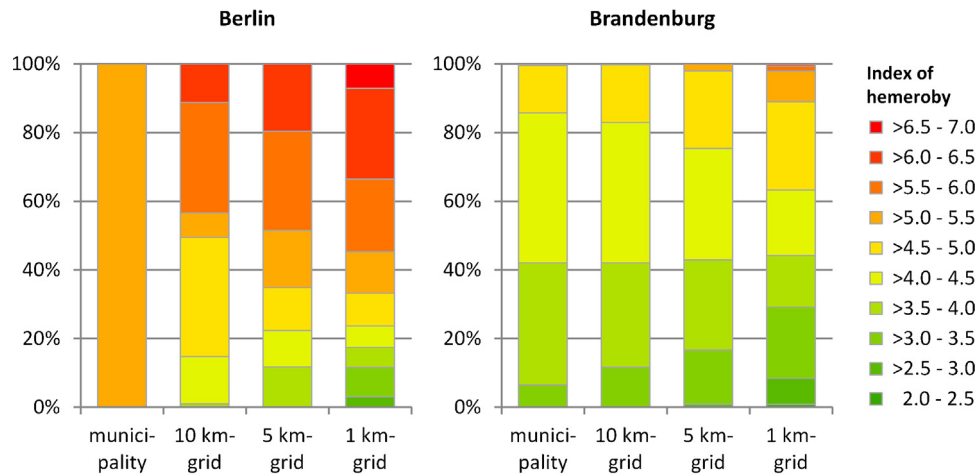


Fig. 5. Proportion of hemeroby index classes to total area, depending on the chosen reference unit (processing: C. Stein and U. Walz).

Comparison to other evaluations of hemeroby

In comparison to other evaluations of hemeroby in other regions, our method is based on assessment of land use units at the landscape level, while a lot of earlier studies are based directly

on vegetation data (Jansen et al. 2009; Klotz & Kühn 2002; Schlüter 1984). Instead of spatial types (Glawion 2002) or whole landscapes (Wrbka et al. 2005: p. 45), we classified detailed land use units. The advantage of our method is that the concept could be applied for larger regions, in our case the whole of Germany. Furthermore it is

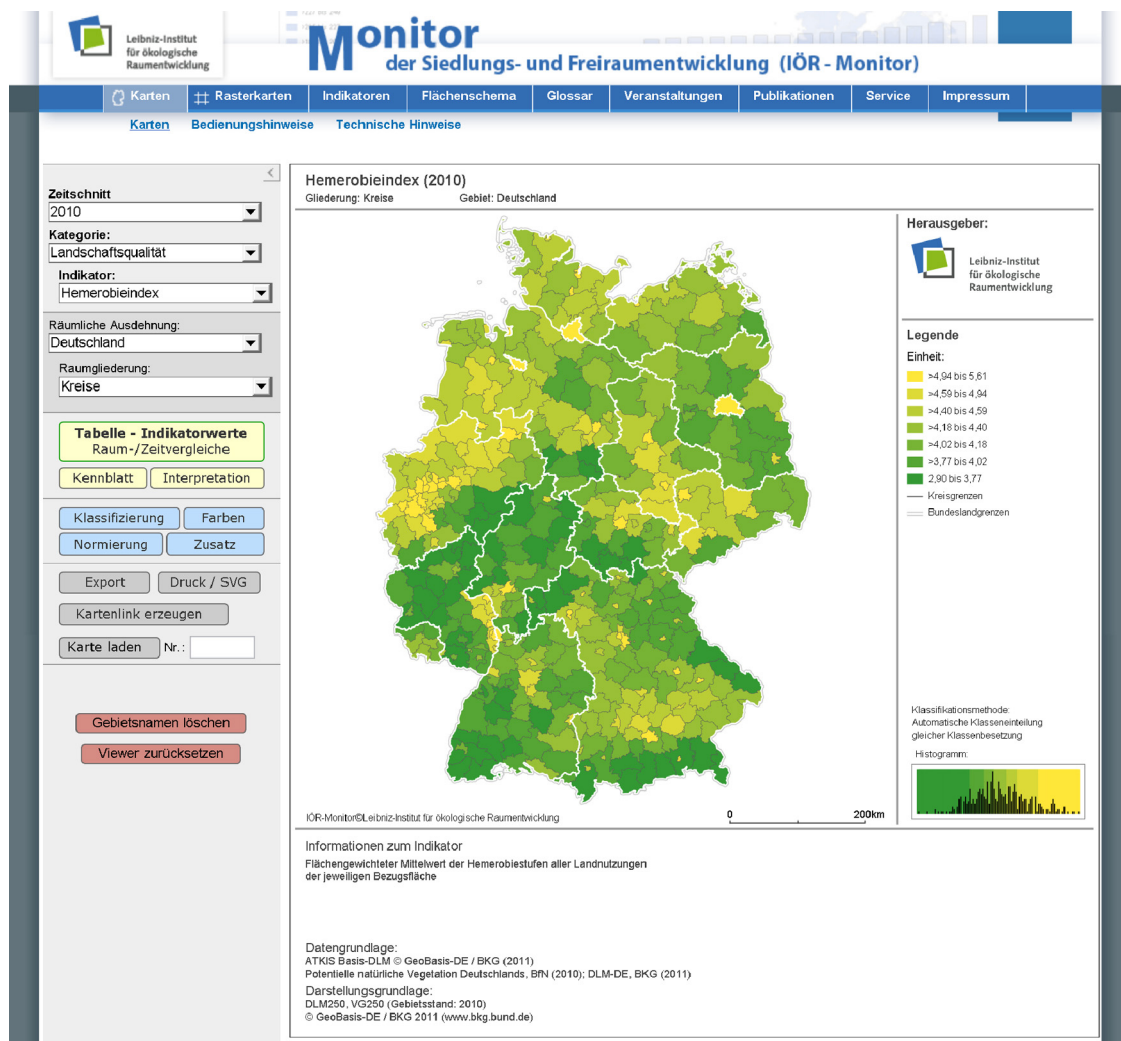


Fig. 6. Screenshot of the website on the landscape hemeroby index based on administrative units (district) within the IOER-Monitor of Settlement and Open Space Development, www.ioer-monitor.de.

easy to calculate and to understand, which is important for regular monitoring and the dissemination of the results to the public.

Earlier methods based on CORINE (25 ha) (Brentrup et al. 2002; Cscorba & Szabó 2009; Glawion 2002; Paracchini & Capitani 2011; Rüdisser et al. 2012) or maps of biotope types of federal states (LfULG 2009) are not useful for a detailed Germany-wide monitoring of hemeroby on the level of municipalities or grid cells. Main reasons are the coarse scale of data, the lack of coverage for the whole of Germany or that the regular repletion of data acquisition is not given. Therefore, we have developed a new method using DLM-DE (1 ha).

Problems of differentiation in forest and grassland

Although the DLM-DE is one of the most detailed datasets of land use for the whole of Germany, the modeling of forest and grassland is rather generalised. Yet in comparison to the Basis-DLM, forests in the DLM-DE are modeled at greater spatial detail and with more frequent updating. Nevertheless, forests are only classified as deciduous, coniferous or mixed forest, and there is no possibility of distinguishing between the different levels of intensity of grassland use. Here the mapping of biotope types could provide more accurate results. Unfortunately, such data is currently unavailable for the whole of Germany. A comparative calculation based on the biotope type mapping of Saxony from 2005 has shown that in the Basis-DLM, forests were generally evaluated as rather close to nature, while a higher degree of hemeroby was assigned to grassland (Stein 2011). This is because grassland in Basis-DLM is simply assumed to be intensively used grassland, while the lack of attributes to describe forests (such as age, structure of the stock and composition of species) prevent any conclusions being drawn on the type and intensity of forest use. It is therefore impossible, on the basis of the Basis-DLM or the DLM-DE, to assign, e.g. similarly aged monocultural forests of non-native tree species to the degree of β -euhemerobic. Consequently, site-adapted forests were categorised as oligohemerobic, non-adapted tree stocks as mesohemerobic forests and woodlands within settlements as β -euhemerobic.

Administrative units versus grid cells

The choice of reference unit greatly affects the calculation of indicators: the smaller the chosen grid, the more highly differentiated the resulting analysis. The information gain achieved if a uniform grid is applied instead of simply adopting standard municipal boundaries can be illustrated in the case of Berlin. At the municipal level, Berlin as a whole achieves a hemeroby index value of 5.28, and yet increased differentiation of results is already apparent when applying the 10 km grid (see Fig. 5). This effect occurs in all other federal states. Most importantly, application of a grid removes the influence of administrative unit size on results.

Nevertheless, the calculation of indicator values at the municipal level can be useful, especially in relation to spatial planning, which is usually based on administrative units. There is also no objection to their use for the periodic comparison of levels of development. As emphasised at the beginning, the temporal comparison is in the foreground in the evaluation of hemeroby. In any case, a 1 km grid should certainly be adopted if an analysis is required at a high degree of spatial differentiation. Nevertheless, since the hemeroby of landscape should be considered, grid sizes less than 1 km² seems less useful because otherwise nearly individual objects are mapped.

Conclusions and outlook

Our outcomes show, that it is possible to estimate and compare human impact on the landscape level for the whole of Germany at

different spatial and temporal levels of reference. With the DLM-DE and ATKIS a sufficient data base is available for regular monitoring of hemeroby at the landscape level. However, some generalisations are necessary, the results show that a German-wide monitoring will be able to represent changes in human impacts in sufficient accuracy and detail up to the levels of municipalities or 1 km grid cells.

We were also able to show, that the results could be integrated in a nationwide monitoring system. The calculated indicators of hemeroby for 2010 are freely available from the IOER-Monitor in the form of maps and tables (Meinel et al. 2013), and can be processed by any third party (see Fig. 6). With the delivery of the next actual dataset of DLM-DE in 2014 it will be possible to calculate a second time step. Therefore the main outcome of this research will be the establishment of a regular monitoring of hemeroby in Germany.

Indicators of hemeroby can be a meaningful supplement to information provided by other national indicator systems, e.g. the indicator “Species diversity and landscape quality” in the National Strategy on Biological Diversity (BMU 2010). While this indicator indirectly assesses the state of the landscape as a habitat based on the population sizes of 59 representative bird species, the concept of hemeroby evaluates the landscape state as a function of overall human impact.

Regarding the indicator on the development of settlement and traffic areas, e.g. of the National Strategy on Biological Diversity, valuable knowledge on land consumption can be obtained. The development of the share of nature-accentuated areas can indicate whether increasing utilisation of land for settlement and transport is mainly at the expense of more natural areas or those already under intensive use.

Human impacts on the landscape for each municipality, district or province could be monitored by examining the trends over time of hemeroby indices or the proportion of nature-accentuated areas. In combination with other indicators and parameters such as landscape fragmentation, the proportion of landscape and nature conservation areas or population trends of certain species, valuable insights can be gained on the development of open spaces. Other interesting questions could be examined, such as a potential association between the rehabilitation of endangered species and the hemeroby of the landscape.

Regular calculation of the presented indicators could make a significant contribution to the qualitative description of settlement and open space development in Germany. It would supply decision-makers and the interested public with detailed information on the changes taking place in landscapes, while at the same time highlighting the responsible use of open space. The indicators can reveal deficiencies within nature protection and landscape planning, pinpointing where measures to improve the condition of landscape are especially needed, while at the same time drawing attention to positive developments.

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