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Abstract	Rivers create landscapes with often unique characteristics that make them favorite areas for human recreation and aesthetic enjoyment. In general, water features such as rivers, lakes and the seashore are regarded as aesthetically particularly pleasing elements in our landscapes.

Assessing the Uniqueness of River Landscapes: The Lahn Case Study

Christian Albert, Jana Brenner, Johannes Hermes, Dominik Metzger and Julia Thiele

1 Introduction

Rivers create landscapes with often unique characteristics that make them favorite areas for human recreation and aesthetic enjoyment. In general, water features such as rivers, lakes and the seashore are regarded as aesthetically particularly pleasing elements in our landscapes (Thiele et al. 2019 based on Appleton 1975; Coss 1990; Ulrich 1993; Wherrett 2000; Schmitz et al. 2007; Howley 2011). Furthermore, river landscapes constitute important areas for recreational activities (Thiele et al. 2019 based on Raymond et al. 2009; Posthumus et al. 2010), thus providing an ecosystem service that positively affects human health and well-being (Hermes et al. 2018a; Chhetri and Arrowsmith 2008 von Haaren et al. 2014).

An important factor characterizing the recreational potential of landscapes is their visual character. The character or beauty of landscapes provides the backdrop against which all nature-based recreational activities take place. Studies of landscape character have defined three important criteria as particularly relevant, namely a landscape's diversity, its naturalness and its uniqueness (Hermes et al. 2018b), assuming that these three criteria combined describe a landscape's aesthetic quality or beauty. Assessing and evaluating the specific character of those riverside areas is a crucial aspect in developing spatial strategies for more sustainable river landscape development. Landscape diversity describes the pattern and composition or distribution of landscape features (see e.g. Ode et al. 2010). Naturalness is usually interpreted as "perceived naturalness" rather than actual naturalness (Tveit et al. 2006; Ode et al. 2009). Please note that the term uniqueness has been used here as it is widely applied in landscape aesthetic assessments and has also been adopted by the German Federal Nature Conservation Act as a reason for preserving nature for people (cf. BNatSchG §1 (1) 3). Landscape uniqueness is thus in line with the understanding of "locality" in

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this volume, following Prominski's (2016) definition as a place's specific character, which is continuously evolving in relation to its natural and cultural environment.

The third criterion, landscape uniqueness, finally, is often regarded as the most important determinant of landscape character (cf. Hoisl et al. 2000: 306) as it identifies the unique characteristics that make a landscape stand out and evoke identification, memorability and recognition among the local population and beyond. Landscape uniqueness can be defined as the rarity and historicity of landscape structure and elements (Hermes et al. 2018b). It contains the sub-indicators rarity of landscape types (cf. Gharadjedaghi et al. 2004), rarity of land cover types and elements that evoke uniqueness (Hermes et al. 2018b; Thiele et al. 2019).

The aim of this contribution is to demonstrate a method of assessing and evaluating this landscape uniqueness in terms of riverside areas. More specifically, we introduce a method for assessing this uniqueness in the River Lahn landscape, Germany, and compare the results with existing assessments of landscape uniqueness for German rivers in general. The Lahn case study has been selected due to issues of data availability and the familiarity of the research team with the case study area.

2 Case Study Region

AQ1 The Lahn River originates in the federal state of North Rhine-Westphalia and runs through Hesse and Rhineland-Palatinate before it flows into the River Rhine close to Koblenz, Germany. The study area selected for this contribution reaches from where the Lahn flows into the Rhine in the west up to the city of Giessen in the east. Along the river there are several towns, including Limburg an der Lahn, Wetzlar and Giessen.

According to the German classification of bodies of water, the River Lahn is categorized as a large upland river with large fluctuations in discharge and a very high habitat diversity (Pottgiesser and Sommerhäuser 2008; BfG 2019). The floodplains of the Lahn within the study area are considered "heavily" and "significantly" modified due to the historical transformation of the natural river course for urbanization and navigation reasons (Koenzen and Günther-Diringer 2009). This transformation in earlier periods included straightening and damming the river, resulting in numerous dams and locks (Guerrero et al. 2018). The floodplain in the study area is currently mainly used for grazing or cultivation, and the hillslopes are generally forested (Martin 2004).

The case study area consists of the Lahn River landscape between Giessen in the east, and the mouth of the Lahn at the River Rhine in the west (Fig. 1). The study area thus covers about 148 km of the Lahn River. The area studied in the following analysis considers the river course itself (about 602 ha), the recent floodplain area, understood here as the area within the one-hundred-year flood zone boundary (3239 ha), and the historical floodplain (1845 ha). In total, about 5686 ha are considered, which we herein refer to as the Lahn River landscape. This total study area predominantly

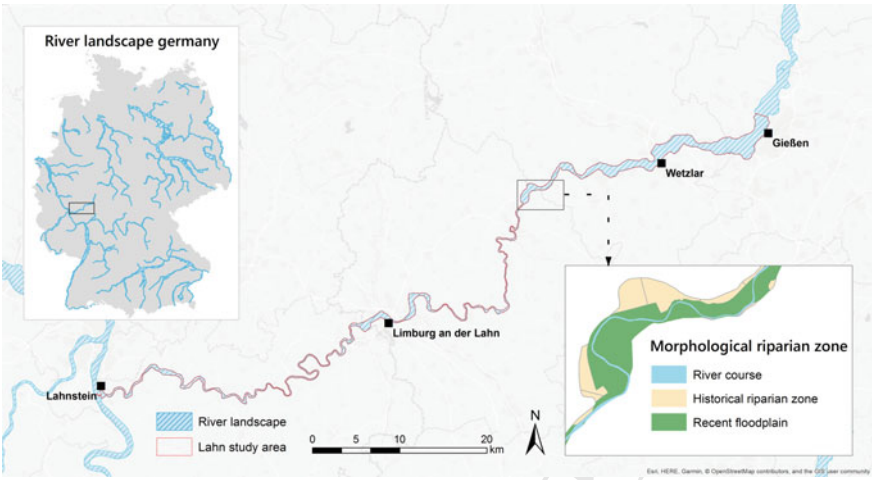

Fig. 1 The case study area of the River Lahn landscape (*Source* © Authors)

consists of agricultural areas (66.9%), followed by settlement and infrastructure (28.6%) and forests (1.7%) (BfN 2009).

Several initiatives are currently underway to address the ecological deficits of the Lahn River, to enhance its ecological quality and to better comply with the targets of the European Water Framework Directive, which requires member states to attain good ecological conditions in their rivers. For example, the integrated EU-LIFE project LiLa—Living Lahn is currently exploring strategies for enhancing the ecological status and improving the livelihoods of the users and stakeholders concerned (www.lila-livinglahn.de). The LiLa project is also considered a pilot case study for the development of such integrated concepts for future river landscape development for people and nature, and thus a good example of the German Federal Government's Blue Ribbon program, which aims at establishing new and sustainable perspectives for its river courses (BMUB and BMVI 2017).

3 Methods

Our research design consists of two steps. First, we extracted data on the uniqueness of the Lahn River landscape from a dataset developed by Thiele et al. (2019) relating to the visual attractiveness of rivers in Germany and based on a method developed by Hermes et al. (2018b). The dataset includes values for all three sub-criteria of uniqueness, namely the rarity of landscape types, the rarity of land cover types, and the presence of elements that give rise to uniqueness (Fig. 2).

Furthermore, the dataset includes a spatial representation of aggregated values regarding the study area's overall uniqueness. In order to best illustrate regional

Fig. 2 Three sub-criteria of uniqueness (*Source* © Authors)

differences, we normalized the scores between 0 and 100 obtained for uniqueness and its three sub-criteria and illustrated them in five classes using quintile distribution.

Second, we compared the mean scores attained for this case study area data with the respective results for the landscape uniqueness value of German river landscapes as a whole as assessed by Thiele et al. (2019). This comparison allows us more in-depth insights regarding the relative uniqueness of the Lahn River landscape with respect to German rivers in general.

Assessing the uniqueness in the Lahn Riverside area involved applying GIS procedures. The base data for the analysis was the landscape uniqueness assessment conducted by Hermes et al. (2018b) for the territory of Germany. Its resolution of 100 m-grid cells makes the data potentially useful even at landscape scales, albeit acknowledging scale-related challenges and considerations (see below and Thiele et al. 2019). The overall value for landscape uniqueness is calculated as the weighted sum of the three sub-indicators, i.e. each with the weight of 0.33 (Hermes et al. 2018b). To investigate the uniqueness of the region under investigation, we extracted the values for the riparian zones of the Lahn River according to Brunotte et al. (2009). This delineation of the case study region is the current standard approach to delineating river landscapes, and it enables comparisons with other river regions in Germany as conducted by Thiele et al. (2019). The results for the Lahn region are shown in maps for each sub-indicator and for the uniqueness in total (Fig. 3). The values are illustrated in five classes distributed between the highest and lowest values attained within the study area, and using quintiles to distinguish classes.

For the comparison with other riverside areas in Germany, the results of the assessment by Thiele et al. (2019) were used, who has investigated the landscape attractiveness values (including landscape uniqueness and its sub-criteria) for several river landscapes in Germany. The values from the Lahn River and the data obtained by Thiele et al. (2019) for other rivers can be compared, as both studies used the boundary delineation approach proposed by Brunotte et al. (2009), which includes the riparian zone and the historical riparian zone. Furthermore, both studies are based on the same method (Hermes et al. 2018b). The mean values of landscape uniqueness and its sub-indicators were calculated for each spatial zone of the River Lahn floodplain.

Fig. 3 Distribution of values obtained for landscape uniqueness and its sub-criteria in the River Lahn case study (*Source* © Authors)

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For comparison, respective mean values for river floodplains in Germany were taken from Thiele et al. (2019). The comparison allows insights regarding the specific uniqueness and locality of the Lahn River region.

4 Results

4.1 Spatial Distribution of Landscape Uniqueness Values

4.1.1 Values for Rarity of Landscape Types

The rarity of landscape types was evaluated using an existing classification of individual landscapes and landscape types (Hermes et al. 2018b). Within the study area the values for the rarity of landscape types range from 0 to 75.38, with a mean value of 30.03. Figure 3 (top map) displays the spatial distribution of the assessment values. Relatively speaking, very high scores are achieved in the surroundings of Limburg an der Lahn, while the values continuously decline upstream towards Wetzlar and Giessen. Furthermore, the mouth of the Lahn at Lahnstein also scores low values for rarity of landscape types.

4.1.2 Values for Rarity of Land Cover Types

For assessing the rarity of types of land cover, the proportional distribution of land use in Germany was analyzed first. Only land cover types that are found on less than three percent of the total area were considered rare. The indicator value represents the density of such rare land cover types (e.g. vineyards) in the Lahn River landscape (Hermes et al. 2018b). The resulting values range from 0 to 70.79, with their mean at 32. Figure 3 (second map) shows a rather scattered distribution of values along the Lahn, with a relatively high score near the Rhine.

4.1.3 Values for Elements Evoking Uniqueness

Assessing elements that evoke uniqueness relates to the occurrence of certain landscape elements, including natural or cultural monuments, historical elements or elements important for natural history. The mean value for this assessment in the Lahn study area is 18.71 with a range of values between 0 and 63.90. High values can be found in the surroundings of Limburg an der Lahn and in areas downstream as well as at the mouth of the Lahn on the Rhine (Figs. 3, third map, 4).

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Fig. 4 Exploring restoration activities and their positive effects on landscape uniqueness along the upper Lahn River (*Source* © C. Albert)

4.1.4 Overall Uniqueness in the Lahn Case Study

The overall landscape uniqueness values range from 0 to 64.81 in the study area, with a mean value of 31.66. Figure 3 (bottom map) shows that the highest values are achieved on the lower river course down to the Rhine. The area around Limburg an der Lahn has to be highlighted for its particularly high values. The upper part of the study area shows an increasing decline in the overall uniqueness from Wetzlar upwards.

4.2 Comparing the Uniqueness Values of the Lahn Case Study with German River Landscapes in General

The results of comparing the mean values for landscape uniqueness in the Lahn River case study with the values for other river landscapes in Germany are illustrated in Table 1. The mean values are given for landscape uniqueness and its sub-indicators both for the whole study area and for the river itself and for the parts of its floodplains according to Brunotte et al. (2009).

Overall, the mean values range substantially, with the greatest range to be found for the river landscapes as a whole (3.84–57.37). The mean landscape uniqueness value for the study area is slightly lower than for German river landscapes in general. However, the historical riparian zone in the Lahn case has a strikingly high mean uniqueness value, higher than other zones within the case study area, and a little higher than the mean of the historical riparian zone of German rivers in general.

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Table 1 Mean values of landscape uniqueness and (sub-)indicators for the Lahn River and other river landscapes in Germany (from Thiele et al. 2019, reference data in light grey) (mean values from the Lahn case study that are higher than the mean values for all German rivers shown in gree)

	River Lahn landscape				German river landscapes average (Thiele et al. 2019)			
Landscape uniqueness and sub-indicators	**Landscape uniqueness (in total)**	**River course**	**Recent floodplain**	**Historical riparian zone**	**Landscape uniqueness (in total)**	**River course**	**Recent floodplain**	**Historical riparian zone**
Landscape uniqueness	31.66	44.84	29.56	31.09	32.75	47.07	33.81	30.67
Rarity of land cover types	32	32.47	33.55	29.02	8.56	28.33	10.47	5.46
Uniqueness provoking elements	18.71	23.04	17.32	20.12	4.53	3.84	4.28	4.64
Rarity of landscape types	30.03	50.68	26.31	29.88	44.51	57.37	45.38	42.68

For every part of the floodplain investigated, the assessment of the Lahn shows significantly higher values regarding the sub-indicators of rarity of land cover types and elements evoking uniqueness in comparison with the river landscapes assessed by Thiele et al. (2019).

Rarity of land cover types is thus the sub-indicator with the highest value for the Lahn River region (scoring 32 for the whole study area). It is substantially higher than the corresponding value for all rivers in Germany (8.56).

Overall the values for the sub-indicator of elements evoking uniqueness are comparatively low. Rarity of landscape types represents the highest value within the study for German rivers, with a score of 44.51 for the whole study area compared with 30.03 in the River Lahn landscape.

5 Discussion and Conclusions

Mapping uniqueness in river landscapes is urgently needed both to emphasize their importance for the cultural ecosystem services 'aesthetics', 'recreation' and 'heritage' as well as to fulfil legislative frameworks and river landscape management strategies (e.g. the German Blue Ribbon program). It can also help highlighting the particularities and unique characteristics of landscapes, distinguishing them from similar ones especially when using comparative analyses as described here. This can usefully inform planning as well as regional marketing. Maps illustrate areas of high and low uniqueness and identify areas of particular importance for a landscape's unique character (Thiele et al. 2019). Thus, we would argue, depicting uniqueness encourages decision-making when taking into consideration a river landscape's beauty in planning restoration measures (Rodrigues 2015; Rabe et al. 2018). The public acceptance of restoration measures such as dike relocation or linking dead arms of a river could increase by demonstrating their local effect in maps using transparent and reproducible indicators (Daniel 1990). An indicator-based approach that includes existing spatial data is therefore a practicable approach towards integrating an assessment of uniqueness into planning processes.

Nevertheless, it could be argued that the choice of the sub-criteria and combining them in the assessment of overall uniqueness by equal weighting unduly influences the results. However, Rabe et al. (2018) demonstrate in their cultural ecosystem service evaluation that statistically significant differences between their expert-based model and evaluations from people who know an area could not be found. Also, the resulting maps seem to deliver a realistic reflection of the study area. Most people familiar with the area would for example agree with the lower values obtained for the dammed and straightened upper stretches of the Lahn River between Giessen and Wetzlar.

The sub-criterion 'rarity of land cover types' was evaluated on a national level. However, additional evaluations of rarity on lower levels could supplement this

assessment in a narrower context. Furthermore, a significantly above-average incidence of certain land cover types or any other notable deviation from average landscapes might give additional insights into a landscape's unique characteristics. Such evaluations would require detailed knowledge of the characteristics of an average German landscape and in-depth analysis of the deviations potentially evoking uniqueness.

The sub-criterion 'elements evoking uniqueness' was evaluated using the density of historical elements such as monuments, as such individual elements are often unique to a landscape and give rise to identification, memorability and recognition not only among the local population (Hermes et al. 2018b). Those elements were selected from the digital landscape model, a nationwide dataset from the 'Authoritative Topographic-Cartographic Information System' (ATKIS Basis-DLM). However, a local investigation was also able to integrate spatial data of local institutions in order to assess this sub-criterion more thoroughly. For example, a comparison of the number of monuments along the Bavarian Danube showed that the local spatial data set maintained by the Bavarian Federal Office for the Preservation of Monuments contains more monuments than the nationwide data set (Basis-DLM). Furthermore, local authorities and stakeholders should be able to provide valuable information about the actual relevance of individual elements for landscape uniqueness. While the collection and integration of respective data is time-consuming, it would help to overcome the inaccuracy of an expert estimation of relevance for uniqueness on the level of element types. We would therefore recommend using the local data set for an evaluation if no comparison with other river landscapes is to be made.

One important aspect of uniqueness that could not be assessed in the case study is a landscape's historicity (cf. Tveit et al. 2006). This refers to landscapes that have undergone only minor changes over time, typically for at least one generation (Nohl 2001). Such landscapes contain structures and elements that were more common in other landscapes as well and may evoke childhood memories of landscapes. The difficulty here is to find readily available digital data on historical land use, especially such that could be used for a comparative analysis between different landscapes. Still, historicity should be incorporated in assessments of landscape uniqueness where data is available, as it is a major determinant and such landscapes are typically highly valued.

It could be argued that assessments of uniqueness should also include intangible cultural heritage as proposed by Tengberg et al. (2012). Intangible cultural heritage is, for example, the cultural practice of special craft skills, which in turn are reflected in the materials used in the landscape and determine their unique character. In our assessment intangible heritage was excluded as it is not spatially determinable.

The aforementioned options for supplementing the assessment conducted here with local data and knowledge certainly have great potential for creating a deeper understanding of the characteristics of the Lahn River landscape. However, the uniqueness of a landscape is especially evident in its differences and peculiarities when compared to similar landscapes. Hence, the comparative approach presented here can give insights that an assessment only on the local level could not provide.

Appropriate landscape planning and governance can help sustaining and enhancing landscape uniqueness in the Lahn River landscape and thus its recreational quality. The approach shown here can usefully inform these processes. Moreover, mapping the benefits of management actions regarding landscape uniqueness can help in communication and in acquiring public support (Thiele et al. 2019 based on Gobster et al. 2007; BMUB and BfN 2014).

We identified two main aspects for further research. First, further research could develop enhanced ways for taking into account the demand for recreation and uniqueness by citizens and tourists (cf. Wolff et al. 2015) when planning river landscapes. In addition, future scholarship could investigate how more detailed and more accurate data could improve the assessment results without compromising the advantages of the comparative approach, for example if detailed habitat maps are widely available and constantly updated using remote-sensing approaches. Moreover, attention should be given to assessing effects on uniqueness by various river restoration options in order to conclude which measures protect uniqueness or affect it positively. Particularly challenging in this regard might be relations between uniqueness and historicity and how changes are perceived by the local population.

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Change italic to upright type	(As above)	
Change bold to non-bold type	(As above)	
Insert 'superior' character	through character or where required	or under character e.g. or
Insert 'inferior' character	(As above)	over character e.g.
Insert full stop	(As above)	
Insert comma	(As above)	
Insert single quotation marks	(As above)	or and/or or
Insert double quotation marks	(As above)	or and/or or
Insert hyphen	(As above)	
Start new paragraph		
No new paragraph		
Transpose		
Close up	linking characters	
Insert or substitute space between characters or words	through character or where required	
Reduce space between characters or words	between characters or words affected	