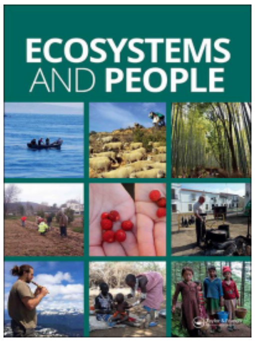

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RESEARCH

Spatially assessing unpleasant places with hard- and soft-GIS methods: a river landscape application

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ABSTRACT
This paper explores the visual, acoustic and olfactory impairments to landscape aesthetic quality in a river landscape case study, using hard- and soft-GIS approaches. The research objectives are (1) to develop a model that localizes the spatial distribution of areas likely perceived as unpleasant and assesses the intensity of visual, acoustic and olfactory impairments in those areas by using a hard-GIS method, and (2) to test the statistical validity of the model based on results gained from a soft GIS method. The case study area is the Lahn river landscape, Germany. Results show a substantial share of the study area affected by modelled impairments, especially areas close to urban environments and along rivers. The area affected by impairments is highest for visual (91%), followed by acoustic (84%) and olfactory factors (54%). However, impairment intensities are greatest for acoustics (30% of study area) and visual (18%). Soft-GIS data tests revealed statistical defensibility of modeled impaired areas. The results highlight the importance of disaggregate analyses of impairments and can provide information on suitable locations for interventions to minimize impairments. Combining hard-GIS with soft-GIS methods may contribute to the credibility, relevance and legitimacy of scientific findings for planning processes and decision-making.

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Lahn river; hesse; landscape aesthetics; landscape character; impairments; geographic information system

1 Introduction

The aesthetic quality of landscapes, understood here as their capacity to fulfill human aesthetic needs and desires (Carvalho Ribeiro et al. 2019), directly affects people's health and well-being. Contact with and activities in nature and landscapes are associated for example with improved physical health, faster recovery from stress and mental fatigue, and more positive emotions (e.g. Kaplan 2001; Kahn et al. 2008; Abraham et al. 2010; Russell et al. 2013). The societal demand for recreational opportunities in high aesthetic quality landscapes constantly rises in developed countries (MEA 2005; Guo et al. 2010). Hence, expected impairments of such landscapes are often met with public resistance (Gobster et al. 2007; Daniel et al. 2012). Given its significance for human well-being, landscape planning has been assessing landscape aesthetics for decades as relevant information for understanding the current condition of landscapes and to devise appropriate measures for sustainable landscape development for people and nature (cf. Bishop and Hulse 1994; Ervin and Steinitz 2003, von Haaren 2004; Gobster et al. 2019). Methods for spatially assessing landscape aesthetic quality are diverse and can comprise two general types. First, so called 'hard-GIS' or 'user-independent' methods assess the physical appearance of a landscape based on a combination of spatial indicators (Carvalho Ribeiro et al. 2019), such as landscape diversity, uniqueness and naturalness, sometimes with several sub-indicators. Such methods assume that people's appreciation of landscape aesthetics is related to landscapes' physical attributes, which allows for mapping based on geographic data (De Vries et al. 2007), and thus aesthetic appreciation can be aggregated and generalized and treated as an objective information. Hard-GIS methods often assess values based on expert knowledge or literature analysis and refer to general landscape preferences. The methods thereby present an efficient way to deliver assessments of entire study areas, but are unable to capture the transactional process between an individual and a place. Second, 'soft-GIS' or 'user-dependent' methods directly ask people for their individual perceptions and try to extrapolate from the individual responses. In contrast to hard-GIS methods, user dependent methods assume that landscape and its change is perceived subjectively by the individual (Stedman 2016) and landscape character is not solely inherent in the physical landscape, but a product of mind (Lothian 1999). Soft-GIS applies participatory mapping methods, such as Public Participation GIS (PPGIS). They have shown

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Supplemental data for this article can be accessed here.

successful to assess perceptional information of citizens or soft-GIS data (Kahila and Kyttä 2009) and to be potentially useful for planning practice (Ives et al. 2015). Yet, the application of soft-GIS methods required substantial financial, technical and intellectual resources (Kahila-Tani et al. 2019).

Landscape aesthetic quality has been predominantly spatially assessed at a regional scale based on indicators such as diversity, naturalness and uniqueness (Hermes et al. 2018; Carvalho Ribeiro et al. 2019). These indicators are also endorsed for landscape planning by the German Federal Nature Conservation Act (BNatSchG 2009).[1] Focusing on areas of high aesthetic quality and using only these indicators as a basis for landscape planning implies the risk that only areas important for conservation are identified, but locations with a high potential for improvements that are highly affected by aesthetic impairments are neglected. However, approaches are missing for the spatial assessment of existing impairments of landscape aesthetic quality planning and management.

Impairments of the aesthetic quality can be of three different kinds – visual, acoustic and olfactory impairments (Porteous 1982; Swanwick 2002). Visual quality of the landscape can be seen either objectively, as judged by experts or subjectively, as perceived by its user (Lothian 1999; Vouligny et al. 2009). Visual disturbances can be of various kinds, ranging from single point structures such as wind turbines through linear elements (e.g. roads and railways) to large structures such as industrial facilities, power plants, or mining sites (LANA 1996; Köppel et al. 1998; Nohl 2001; Gerhards 2002; Meyer 2003; Rodrigues et al. 2010). In contrast to visual qualities, acoustic characteristics are largely overlooked in landscape aesthetics research (Liu et al. 2014). Acoustic impairments are caused by anthropogenic noise, especially from traffic (Esswein & Schwarz von Raumer 2004; MVI-BW 2013). The most neglected sensory quality is smell, yet it is used for an indicator of bad water quality (Lee & Lee 2015). Annoying smells from landfills, purification plants or industrial processes cause olfactory impairments (ARGE 1994; BMU 2002). All three impairment types negatively influence people's perception and experience of landscapes and reduce the benefits people get from recreational activities. Yet, despite the importance of each of the sensory qualities for landscape experience, there is no study assessing them jointly.

Therefore, the aim of this paper is to explore the visual, acoustic and olfactory impairments to landscape aesthetic quality in a river landscape case study, using both a hard- and a soft-GIS approach. More specifically, the objectives are (1) to develop a model that localizes the spatial distribution of areas likely perceived as unpleasant and assesses the intensity of visual, acoustic and olfactory impairments in those areas by using a hard-GIS method, and (2) to test the validity of the model based on results gained from a PPGIS survey.

Using soft and hard-GIS methods allows to take into account both an objective expert-based point of view and complement it with a subjective approach. We use the concept of unpleasant places, understood here as perceived negative qualities of a place, such as traffic noise, perceived insecurity or poor environmental qualities (Kyttä et al. 2013; Raymond et al. 2016) as common denominator to compare the results of hard-GIS method and soft-GIS approach. Hard-GIS model uses determinants of acoustic, olfactory and visual impairments and according distance-to-source values to identify such unpleasant places. We compare the results from hard-GIS method with data from an online PPGIS survey in which respondents marked places they perceived as unpleasant.

2 Case study area

The research was focused on a case study area in the Lahn river landscape which is in the center of the federal state of Hesse, Germany. The study area is limited by a 5 km buffer to both sides of the river. This buffer size was used to integrate the maximum number of points located by the residents in the PPGIS study. Previous effort on limiting the study area to the morphological floodplain would have substantially reduced the number of points. This area includes a part of the river used as federal waterway for navigation. Containing two of the biggest cities of Hesse, Gießen and Wetzlar, the area forms part of the center of middle Hesse (HLUG 2013). The whole study area covers about 297 km^2 and reaches from the city of Wißmar in the north-east to the city of Solms in the south-west. The Lahn river and its river landscape are the main focus of this research.

Apart from the urban areas of the two cities in the center of the case study area, the land use is mainly characterized by woodland, especially at the edge of the area, agricultural land and a fair number of industrial sites and facilities as well as traffic facilities (see Figure 1).

3 Methods

3.1. Research design

The research design consists of two steps to be seen in Figure 2. The first step comprises the approach to modelling the spatial distribution of three different impairment types that identified in the literature as key factors for creating an unpleasant surrounding in the landscape.

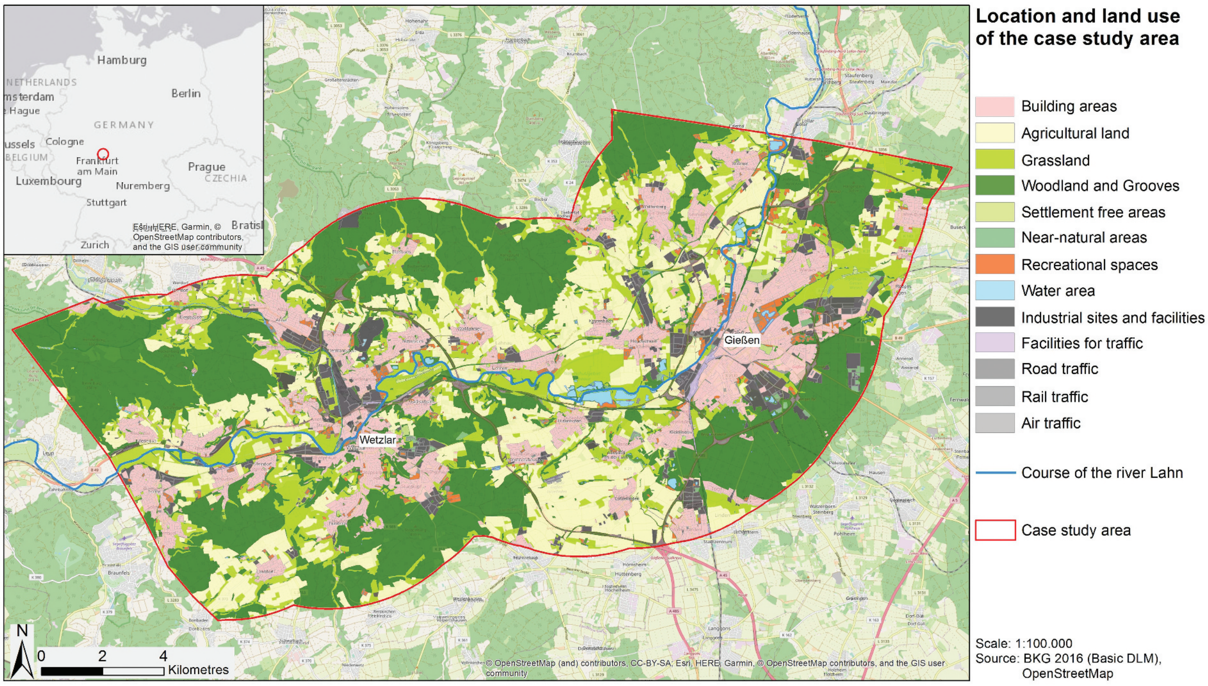

Figure 1. Location and land use of the case study area including the cities Gießen and Wetzlar.

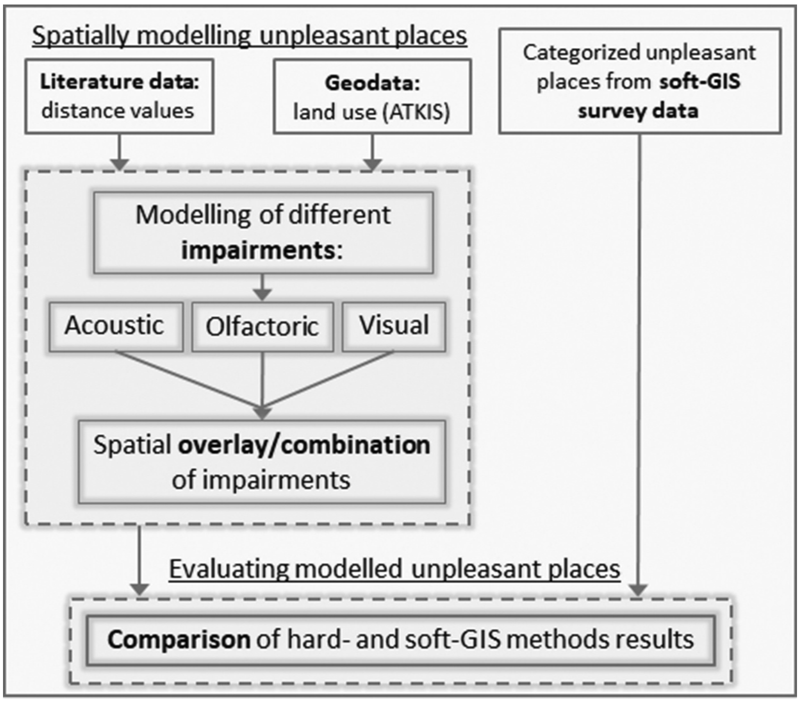

Figure 2. Research design with two steps to modelling and evaluating unpleasant places.

These impairments are assembled of multiple determinants which provoke either acoustic, olfactory or visual disturbances. With the creation of a spatial overlay of the determinants of each impairment type the areas with the heaviest impairments could be located. Later on, these heavily impaired areas of all three impairment types were joined together in order to model unpleasant places inside the case study area.

The second step consists of a statistical evaluation of the spatial accuracy of the modelled unpleasant places based on the consideration of independent data. The modelled data is compared to independent data of unpleasant places that were marked by inhabitants of the region in an online survey.

3.2. A hard-GIS approach to spatially modelling unpleasant places

To conduct the first step of the research design, two different types of input data are needed: First, information on structural determinants, such as motorways and landfills, and the respective threshold values based on reviewed literature, and secondly, geodata on land use which was derived from a Digital Basic Landscape Model (BKG 2016) to apply literature findings to the case study area (Figure 2).

Distance values stem from various literature sources. Where possible, we used administrative regulations such as the German 'technical instructions for protection against noise (TA Lärm)', or administrative guidelines and conventions – e. g. for landscape plans or the intervention regulation – that are often derived from them. In other cases, we used literature suggesting approximate distances in which the negative impairment (acoustic, olfactory or visual) of the single determinants could be perceived (Table 1). These impairment areas of the determinants of unpleasant places were then applied to land use data concerning the study area. After preparing the geodata based on the determinants for acoustic, olfactory and visual impairments, we created three matrices to evaluate the impact values against each other. Finally, a GIS software (ESRI ArcGIS version 10.5) was used to analyze and visualize the resulting impairment areas of all determinants.

Each determinant is categorized into one, or sometimes more than one, of the three impairment types acoustic, olfactory and visual. In the following table it is shown, which determinants are relevant for each of the impairment types, which distance value was assigned to them through literature research and which sources were used.

The determinants most liable for an acoustic impairment in the case study area are all types of streets, especially motorways, federal highways and state roads, railways, strip mining, industrial sites and facilities and recreational spaces (Bayrisches Landesamt für Umweltschutz 2003; Esswein and Schwarz 2004; MVI-BW 2013).

An olfactory impairment is mainly caused by landfills and purification plants, as well as industrial sites and facilities, masts and chimneys, motorways and federal highways (ARGE 1994; BMU 2002).

The determinants with the heaviest visual impacts are especially landlines but also motorways, federal highways and state roads, as well as railways, construction sites, solar plants and industrial sites and facilities (LANA – Länderarbeitsgemeinschaft Naturschutz, Landschaftspflege und Erholung 1996, Köppel et al. 1998, Nohl 2001, Gerhards 2002, Meyer 2003, Rodrigues et al. 2010). Larger areas of arable land can be perceived as visually unpleasant. Yet well-structured arable landscape with many different attractions for the human eye is not seen as an impairment (Nohl 2001; Wöbse 2002; Wojtkiewicz and Heiland 2012).

Most determinants, such as motorways, cause more than one impairment. This is due to different types of the perception that are affected by the determinants. A street for example can exude noise, an unpleasant smell and can also affect the visual quality of a surrounding. Moreover, arable land was only considered as a structural determinant when the covered area was larger than three hectares and there were no visual interruptions like hedges or groves.

To account for the fuzziness of the perception of the unpleasantness of a place, every determinant in each of the impairment types has a maximum impact value attached that will be categorized into five impairment classes (from very high to very low impairment) in the according matrices (see Appendices 1–3). The

Table 1. Determinants of acoustic, olfactory and visual impairments and according distance values taken from literature data.

	Acoustic impairment		Olfactory impairment		Visual impairment	
Determinants of impairment	Distance value	Literature	Distance value	Literature	Distance value	Literature
Motorways	1800 m	1), 2)	250 m	4)	500 m	6), 7)
Federal highways	800 m	2)	150 m	4)	500 m	6)
State roads	330 m	2)	75 m	4)	500 m	6)
District roads	210 m	2)	50 m	4)	300 m	6)
Municipal roads	90 m	2)	50 m	4)	300 m	6)
Facilities for traffic	90 m	2)	25 m	4)	150 m	6)
Other traffic related areas	90 m	2)	25 m	4)	150 m	6)
Railways	1200 m	2)	-	-	500 m	6)
Construction sites	90 m	2)	50 m	4)	500 m	7), 8)
Landfill	90 m	2)	500 m	5)	300 m	6), 9)
Purification plant	90 m	2)	500 m	5)	300 m	6), 9)
Strip mining	300 m	3)	-	-	300 m	6), 9)
Solar plants	-	-	-	-	500 m	7), 10)
Landlines	-	-	-	-	1000 m	7)
Industrial sites and facilities	500 m	2)	250 m	4)	500 m	6)
Masts and chimneys	-	-	250 m	4)	450 m	11), 7)
Arable land ≥ 3 ha	-	-	-	-	300 m	6), 9)
Recreational spaces	200 m	2)	-	-	-	-

1) Esswein and Schwarz (2004), 2) MVI-BW (2013) 3) Bayrisches Landesamt für Umweltschutz (2003) 4) ARGE (1994) 5) BMU (2002) 6) Köppel et al. (1998) 7) Gerhards (2002) 8) Meyer (2003) 9) Nohl (2001) 10) Rodrigues et al. (2010) 11) LANA – Länderarbeitsgemeinschaft Naturschutz, Landschaftspflege und Erholung (ed.) (1996)

categorization is dependent on the determinant with the highest impact, i.e. highest distance value. For example: the acoustic impairment from a motorway, which is the strongest emitter of noise, can be heard up to a distance of 1800 m. This distance is divided into five equidistant classes. All other emitters are assigned to those classes according to their impact in relation to the strongest emitter. The underlying assumption is that the impairment intensity at the given maximum distance is similar over all emitters, whereas there are large differences between them directly at the source. Accordingly, state roads, with a maximum distance of 330 m, are categorized into the two lowest classes. The maximum impact values of all impairments can be seen on the right site of the matrices in blue (see Appendices 1–3). We chose a simplified linear distribution for the distance values of each impairment category, as it was the most suitable for the modelling process in this research.

The model of the propagation of the impairment categories is processed with the help of a GIS software. It results in isophones (one up to five, depending on the categories) for each feature available in the considered determinants. Based on these assignments, it is possible to combine all of the different determinants for one impairment type into a resulting impairment raster showing the intensity of the impairment in five classes (one very low: dark green to five very high: red). To do so, all determinant raster sets for one impairment type were combined and each cell of every raster was compared to the overlying cells. Each cell contains one of the category values from 0 (no class assigned) to 5 (very high impairment). During the comparison, the highest value is chosen and written into the resulting impairment raster.

After this step, the three considered impairment types need to be combined in order to model the unpleasant places in the case study area. Doing so, the generated results were analyzed and the three highest categories (3-medium, 4-high, 5-very high) of each impairment type were chosen for further processing, because a perceivable impairment is most likely in the areas of these categories. Then, a joined map was created by combining each of the highest three categories of the three impairment types into one category. Each cell of the three impairment raster sets now contains either a 0 or a 1, indicating either no heavy impairment (0) or a medium to very high impairment (1). In the next step these three resulting impairment raster sets were merged into one overall impairment raster showing the number of perceivable impairments. The raster cells were therefore added up so that the resulting raster contains values from 0 (no heavy impairment) up to 3 (all three impairment types are heavily perceivable).

In general, it can be said that the more impairments there are at a location, the higher the probability of an unpleasant place.

3.3. A soft-GIS approach to evaluate and amend the model

To evaluate the findings of the model used for the localization of areas with acoustic, olfactory and visual impairments that represent unpleasant places, we tested results from the model against independent data from an online PPGIS survey by using inferential statistics (ordinal logistic regression).

The online survey was conducted in the Lahn region using a PPGIS method in the summer of 2017. In a random sampling effort, 3000 residents of 13 communes adjacent to river have been invited via post mail, including a reminder post card. The relation to the river and the main topics were introduced at the first survey page 'The river landscape of the Lahn is a central component of the landscape in Middle Hessen. What places are important and meaningful? How is the river and its shores used for different activities? Are there any unpleasant or problematic places?'. On a separate place, respondents were asked to locate on a map their unpleasant places and specify their experience by selecting one or more perceived problems and unpleasant experiences (PPUE) and/or adding another reason ('Which of the unpleasant experiences do you associate with this place?'). Within the study area 90 respondents located 113 unpleasant places. To align with Hard-GIS model, the PPUE were categorized into the three impairment types acoustic, olfactory and visual. Some unpleasant experiences, such as 'the atmosphere is unpleasant' have been assigned to more than one impairment type. This categorization resulted in 90 unpleasant places. Some (23) unpleasant places were assigned to PPUEs that did not relate to the impairment types.

For statistical evaluation we used an ordinal logistic regression analysis from the R package 'MASS' (Cran 2019). The odds were estimated that unpleasant places from the model and survey data are located in the same area. Regression coefficients were determined and then the odds ratios as well as the percent change in the odds for a one unit increase in the independent variable were derived in accordance with Blissett (2017). The same statistical method was used to evaluate the combined model of unpleasant places including a spatial overlay of all three impairments (with the three highest categories). Further details are explained in Appendix 4.

4. Results

4.1. Spatial distribution of modelled unpleasant places

4.1.1. Acoustic impairments

Acoustic impairments exist in a large part of the case study area with about 30% of the areas evaluated as highly to very highly impaired (see Figures 3a and Figures 4). Particularly affected is the eastern part of the case study area. Most of the acoustic impairment is caused by the motorway and the railway which run all across the case study area. The modelling results show that the remaining three categories are not as prominent. Noteworthy is only the medium level of acoustic impairment that covers 17% of the case study area and can be perceived in higher distances to streets and railways. The remaining categories one and two are evenly distributed throughout the case study area and reach further into the surrounding and more away from the river.

4.1.2. Olfactory impairments

Olfactory impairments are distributed rather uniformly regarding the different impairment categories throughout the case study area (Figure 3b). In contrast to acoustic impairments that are present in about 84% of the area, olfactory impairments are available only in 53% of the area (see Figure 4). Furthermore, areas of very high impairment intensity are present in only a few spots towards the center of the eastern part of the examined area. It covers about 1% of the area and is solely based on landfills and purification plants. The same findings apply to the second highest category that is only present around the described spots. Most of the case study area is of only low olfactory impairment. We can trace this back on the occurrence of many determinants for an olfactory impairment that only occur in this category (e.g. construction sites, streets, etc., see Appendix 2). Overall, a slightly higher concentration of impaired areas exists in the eastern part of the case study area around the city Gießen.

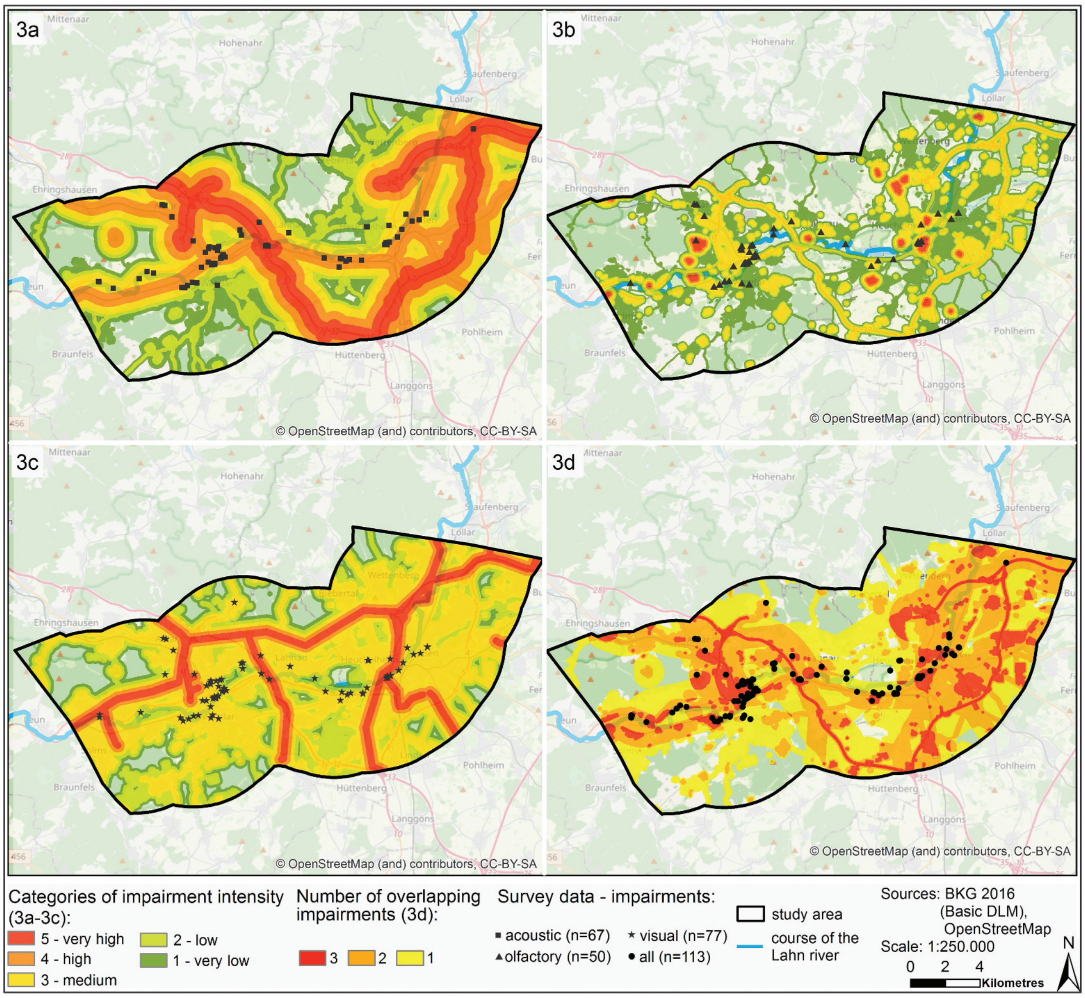

Figure 3. (a-d): Resulting maps for the spatial modelling of impairments and unpleasant places: 3a: Modelled areas with acoustic impairments and appropriate survey data, 3b: Modelled areas with olfactory impairments and appropriate survey data, 3c: Modelled areas with visual impairments and appropriate survey data, 3d: Modelled potential unpleasant places based on all impairments and appropriate survey data.

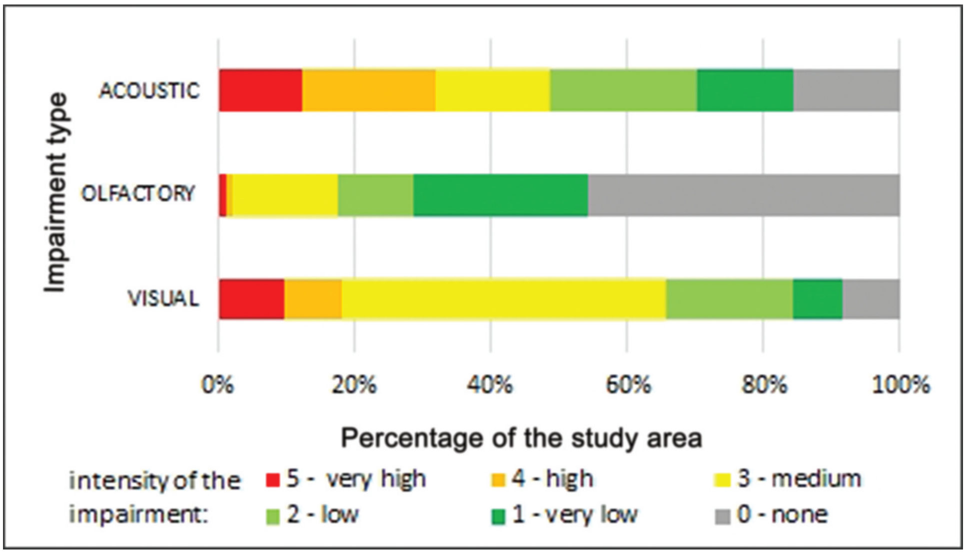

Figure 4. Percentage of the case study area which is covered by the five classes of Impairment intensity of all three impairment types.

4.1.3. Visual impairments

Visual impairments are ubiquitous in the case study area (see Figure 3c), with only 8,5% of the study area not affected by any of the visual impairments (see Figure 4). Very high (about 10% coverage) and high intensity (about 9% coverage) visual impairments are present in places throughout the entire case study area, bur mostly concentrated along the route of landlines. Medium intensity of visual impairments is common, with a presence in about 48% of the case study area and relating to the respective impact distances considered (see Appendix 3).

Low visual impairments are present in about 19% of the case study area (see Figure 4), especially in the southern part with greater distances to the river.

4.1.4. Potential unpleasant places

The spatial overlay of the modelled areas with a medium to very high intensity of impairment from all three impairment types shows an agglomeration of areas that are impaired by all three impairment types around the vicinities of the two cities Wetzlar in the western part of the case study area and Gießen in the eastern part of the case study area. Another agglomeration proceeding along the pathway of the motorway and the federal highway was discovered. Towards the easternmost part of the case study area multiple smaller scaled impairment areas of all three types could be located. Especially around the Lahn river in the western part of the case study area these small scaled areas of all three impairment types are present as well.

The comparison between the previous maps (Figure 3a–c) and map 3d emphasizes that the majority of the areas that are impacted by two impairment types are caused by an acoustic and a visual impairment. An olfactory impairment almost exclusively exists when the other two impairment types are spatially present as well.

4.2. Unpleasant places

Overall, unpleasant places are not distributed evenly across the case study area (Figure 3d) but cluster around the two larger cities in the east (Gießen), the west (Wetzlar), and the course of the Lahn river. Furthermore, many of the places are located inside build-up areas and around industrial facilities as well as the bigger streets. Only a few unpleasant places are located at the edges of the study area and further away from the river.

An overview of the number of sites chosen as unpleasant paces for visual, acoustic or olfactory reasons as well as other unpleasant experiences is provided in Table 2. The summary also includes some the survey response options. The summary illustrates that visual and acoustic impairments are most often associated with unpleasant places (77 and 67 sites, respectively) while olfactory impairments account for only 50 sites.

4.3. Interactions between impairments and unpleasant places

Results from the ordinal logistic regression showed that acoustic impairment from survey data (as opposed to areas without acoustic impairment) is associated with a 97% increase in the odds of being covered by unpleasant places from the model (t-value of 1.865, p-value of 0.063, see Table 3). The odds that olfactory impairments from survey data were located

Table 2. Perceived unpleasant experiences categorized into the three impairment types and other experiences. Note: as some experiences, such as 'atmosphere is unpleasant' were assigned to more than one impairment, the total N does not add up to 113 as presented in Figure 3d.

	Sensory impairments			
Category	Visual	Acoustic	Olfactory	**Other unpleasant experiences**
Survey response options	• Atmosphere is unpleasant • The scenery is not attractive • The location is crowded • The water quality is poor • It is full of garbage	• Atmosphere is unpleasant • The location is crowded • The location is noisy	• Atmosphere is unpleasant • It is full of garbage • The location smells	• I feel that I do not belong there • Temporary inaccessible due to flooding • Certain groups of people or use of methods bothers me • Use of the location requires a membership to an association/club • The location lacks necessary equipment, services, safety structures, routes, etc. • I have been harassed or discriminated against • Environmental protection or other administrative rules restrict use of location
N	77	67	50	23

Table 3. Output of the ordinal regression. The table shows the regression coefficients with their values, standard errors, t values, odds ratio, percent change in the odds for a one unit increase in the independent variable, and p-values for three different regressions of impairments from the model and survey data.

Impairments (model and survey data)	Value	Standard error	t-value	Odds ratio	Percent change in the odds	p-value
Acoustic model ~ survey	0.676	0.363	1.865	0.676	96.6	0.063
Olfactory model ~ survey	0.841	0.358	2.352	0.841	131.9	0.019
Visual model ~ survey	0.325	0.475	0.684	0.325	38.4	0.495

Table 4. Output of the ordinal regression. The table shows the regression coefficients with their values, standard errors, t values, odds ratio, percent change in the odds for a one unit increase in the independent variable, and p-values for one regression of the combined model of unpleasant places (including all three impairments) and the impairments from the survey data.

Impairments (combined model and survey data)	Value	Standard error	t-value	Odds ratio	Percent change in the odds	p-value
Acoustic	0.935	0.3915	2.3881	2.5472	154.7	0.0174
Olfactory	0.4051	0.457	0.8864	1.4994	49.9	0.376
Visual	0.0386	0.4865	0.0794	1.0394	3.9	0.9368

in the same area of unpleasant places from the model were 132 times higher as opposed to areas without acoustic impairment from survey data (t-value of 2.352, p-value of 0.019), this coefficient was statistically significant at the 5% level. For areas of acoustic impairments from the survey, the odds of being located in areas of acoustic impairments from the model were 38 times that of areas without acoustic impairments from the survey (t-value of 0.684, p-value of 0.495).

Furthermore, results from the evaluation of the combined model of unpleasant places including all three impairments (with the three highest categories) showed that the highest coefficients for the odds of spatial concordance of model and survey data could be found for acoustic impairments (154%), followed by olfactory (50%) and visual (3%) (see Table 4).

By spatially comparing the combined model with survey data the following pattern could be identified (see Figure 3d): In the city Wetzlar and west of Wetzlar most of the modelled data matched with the survey data (57%: 64 unpleasant places in total of which 58% acoustic, 52% olfactory, 69% visual). All of the underlying areas in this region are marked by a medium to a very high impairment and additionally in most of them all three impairment types can be perceived. The rest of the unpleasant places from the survey data are primarily distributed along the course of the Lahn river (42%). It is very prominent that most unpleasant places are present in areas specified as very heavily impaired by the model (43%). Only three unpleasant places towards the center of the case study area were lying outside of the modelled potential unpleasant places. The affected area is declared as a nature reserve and is therefore not as heavily impaired. However, if the modelled single impairments are reviewed as well, we can say that these unpleasant places are present in areas with a modelled low visual impairment and a low to very low acoustic impairment.

5. Discussion

The presented results show that large parts of the case study area in the Lahn river landscape are affected by the modelled acoustic, olfactory and visual impairments. Especially the areas around the two big cities Gießen and Wetzlar and the near surrounding of the Lahn river are heavily affected by the three impairments. The edges of the study area are however mostly unaffected by our modelling results. Testing these results based on independent survey data showed high odds that impairments and ultimately unpleasant places estimated by models match with those identified in the survey. Particularly, for the olfactory model we could find statistical evidence (p-value = 0.019) that modelled olfactory impairments occur in the same areas as identified in the survey.

The modelling results for acoustic, olfactory and visual impairments show varying spatial patterns, thereby reemphasizing the importance to include multiple sensory aspects in aesthetic quality assessment (Porteous 1982). Visual impairments can be found in 91% of the total area, whereas acoustic impairments impact 84% and olfactory impairments 54%. Yet, looking at the impairment intensities, the highest categories (high and very high intensity) cover the largest area for acoustic impairments (30% of the study area) followed by visual (18%) and olfactory (2%). Taking the specific example of a road, it means that even when the road is not well visible anymore the noise can still be heavily perceptible. Jeon and Jo (2020) show that there is a strong interaction of audio and visual information and that in combination they best performed to explain soundscape and landscape components, such as pleasantness or naturalness.

In this study we have shown that all three impairment types overlap in the immediate surroundings of the large river Lahn which dominates and characterizes the landscape. This calls for attention, as blue spaces have shown to be positively associated to mental health (Gascon et al. 2017) and to lead to higher momentary subjective wellbeing than urban fabric or indoor environments (MacKerron and Mourato 2013).

This apparent contradiction could be explained by the presence of a four-lane road right next at the southern shore following the river path. The finding highlights the importance to consider impairments in the analysis of aesthetic quality of the landscape. While approaches that not consider impairments and focus on positive aesthetic factors might have led to misleading high values for aesthetic quality of the landscape, the inclusion of impairments in general and sensory impairments in particular allows researchers and planners to see the nearby road as well, especially if acoustic and olfactory impacts are strong as well.

6. Conclusions

The modelling applied here can be useful for landscape planning practice. By using hard-GIS approach to model impairments, indications of potentially unpleasant places can be generated. This information can form the basis for more in-depth, and eventually more focused, survey-based investigations of actual perceived unpleasant places. In addition, the information can provide planners important information on where interventions are needed if the perceived quality of places for citizens should be enhanced. The results show by what types of impairments and in which intensity an area is affected by acoustic, visual and olfactory impairments. This information is not directly evident from assessments of the aesthetic quality of landscapes commonly found in landscape planning. Planners can use this information, supplemented by spatial assessment of the demand for areas suitable for recreation, to develop targeted measures aimed at reducing impairments and thereby increasing recreation opportunities (Albert et al. 2019). Potential measures can then focus on minimizing the sources of impacts (for example suggestions to lower speed limits on roads to reduce acoustic impacts) or on amending existing impacts, for example by planning wide-enough tree corridors along roads to reduce noise propagation. Further research may focus on testing the modelling approach in other regions, and by testing it together with planners, stakeholders and decision-makers in practice.

Hard- and soft-GIS methods can be seen as complementary approaches. As demonstrated in this study, soft-GIS methods can be used to verify and complement hard-GIS methods, but also hard-GIS methods can provide basic information for subsequent in-depth survey-based investigations of actual perceived unpleasant places as discussed above. Results have shown that not only experiences associated to sensory dimensions led participants to locate an unpleasant place. Personal emotional experiences, such as sense of belonging or undesirable incidences, a lack of accessibility and safety, and social experiences, such as feeling bothered by other people, contributed as well to perceived unpleasant places. This is in line with previous studies, which found that various factors, such as noise, scariness, restricted access or unattractiveness, contributed to perceived place dissatisfaction (Tyrväinen et al. 2007; Kyttä et al. 2013; Raymond et al. 2016).

Combining hard-GIS methods with soft-GIS methods brings together 'hard' objective, register-based geodata with 'soft', subjective, experiential survey data and contributes to credibility, relevance and legitimacy of scientific findings for planning processes and decision-making (Kyttä 2011; Durham et al. 2014). Therefore, utilizing both hard-GIS and soft-GIS methods and exploiting their complementary features helps to build a bridge between research and practice, between various professionals in the planning process, and between planning practices and inhabitants' unique experiences of everyday life (Kahila and Kyttä 2009).

However, implementing hard-GIS and soft-GIS methods has inevitable limitations (Spiegelhalter and

Riesch 2011; Brown and Fagerholm 2015; Burkhard and Maes 2017). When assessing the impairments in the case study area, the land use data was connected to selected literature data. The distance values we used are conservative estimates commonly used in landscape planning in Germany. We argue that these conservative estimates are adequate for the field of application outlined above. They could be refined using more advanced modelling and using additional data. The biggest improvement might be gained from incorporating visibility analyses based on a digital surface model (relief and height of buildings and vegetation) to determine the areas actually impacted by visual impairments (compare e.g. Hernández et al. 2004). But the propagation of noise and smells could be modeled more accurately, too. This should lead to a more realistic representation of the on-site situation and to stronger correlations between modeled impairments and surveyed unpleasant places. These improvements, however, require more advanced modelling, more data, and empirical foundations, which are not always as readily available as land use data and conservative estimates. Hence, each step towards a more realistic representation of the actual on-site situation is a step towards less practicability, and time and cost efficiency for assessments on broader scales. We would suggest incorporating such advanced modeling, complemented by on-site surveys, when planning and allocating measures as outlined above for areas preselected based on our results.

With regards to the comparison between the modelling results and the survey data, a few issues can be noted. To evaluate the aesthetic quality model, the survey data on PPUE had to be categorized in the three impairment types, leading to three potential shortcomings. First, the PPUE survey question was not design to be categorized into impairment types, and thus the choice of statements, which was unequally distributed between the types may have influenced the results. Second, the breadth of PPUE had been reduced offering less detail on what exactly the perceived impairment of that place was. Third, some of the PPUEs did not fit into the categories provided by the aesthetic quality model (see Appendix 5). This did not only reduce the number of points, but also misses another dimension of aesthetic quality. Kyttä et al. (2013) have shown that negatively perceived places are strongly related with factors describing social life, such as insecurity or bad reputation. Integrating more cognitive aspects indeed could further enhance the technocratic and expert based approach of landscape assessment (Dakin 2003).

Note

1. http://www.gesetze-im-internet.de/bnatschg_2009/

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References

Abraham A, Sommerhalder K, Abel T. 2010. Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. Int J Public Health. 55 (1):59–69. doi:10.1007/s00038-009-0069-z.

Albert C, Boll T, Haus P, Hermes J, von Haaren C. 2019. Measures for landscape aesthetics and recreational quality. In: von Haaren C, Lovett AA, Albert C, editors. Landscape planning with ecosystem services. Theories and methods for application in Europe. 1st ed. 2019. Dordrecht: Springer Netherlands; Imprint: Springer (Landscape Series, 24; p. 381–388.

ARGE. 1994. ARGE Eingriff-Ausgleich NW – entwicklung eines einheitlichen Bewertungsrahmens für straßenbedingte Eingriffe in Natur und Landschaft und deren Kompensation. Endbericht: Düsseldorf.

Bayrisches Landesamt für Umweltschutz. 2003. Anforderungen zum Lärmschutz bei der Planung von Abbauflächen von Kies, Sand und anderen Bodenschätzen.

Bishop I, Hulse D. 1994. Prediction of scenic beauty using mapped data and geographic information systems. Landsc Urban Plan. 30(1–2):59–70. doi:10.1016/0169-2046(94)90067-1.

BKG. 2016. Bundesamt für Kartographie und Geodäsie, Digital Basic Landscape Model, Basic DLM © GeoBasis-DE / BKG (2016).

Blissett R. 2017. Logistic regression in R. [Accessed 2020 Jan 12]. https://rpubs.com/rslbliss/r_logistic_ws

BMU. 2002. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit – erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz. (Technische Anleitung zur Reinhaltung der Luft – TA Luft).

BNatSchG. 2009. Bundesnaturschutzgesetz vom 29. Juli 2009 (BGBl. I S. 2542), das zuletzt durch Artikel 5 des Gesetzes vom 25. Februar 2021 (BGBl. I S. 306) geändert worden ist.

Brown G, Fagerholm N. 2015. Empirical PPGIS/PGIS mapping of ecosystem services: a review and evaluation. Ecosyst Serv. 13:119–133. doi:10.1016/j.ecoser.2014.10.007.

Burkhard B, Maes J, Eds. 2017. Mapping ecosystem services. Advanced Books. Ispra, Italy: Joint Research Centre. doi:10.3897/ab.e12837.

Carvalho Ribeiro S, Schroth O, Konkoly-Gyuró E, Hermes J, Boll T, Haaren C. 2019. Landscape aesthetics capacity as a cultural ecosystem service. In: Haaren C, Lovett A, Albert C, editors. Landscape planning with ecosystem services. Theories and methods for application in Europe. 1st ed. Dordrecht: Springer Netherlands; Imprint: Springer (Landscape Series, 24); p. 221–252.

Cran. 2019. Package 'MASS' version 7.3-51.5. [Accessed 2020 Jan 12]. https://cran.r-project.org/web/packages/MASS/MASS.pdf

Dakin S. 2003. There's more to landscape than meets the eye: towards inclusive landscape assessment in resource and environmental management. Can Geogr. 47:2. doi:10.1111/1541-0064.t01-1-00003.

Daniel TC, Muhar A, Arnberger A, Aznar O, Boyd JW, Chan KMA, Costanza R, Elmqvist T, Flint CG, Gobster PH. 2012. Contributions of cultural services to the ecosystem services agenda . Proc Natl Acad Sci U S A. 109(23):8812–8819. doi:10.1073/pnas.1114773109.

De Vries S, Lankhorst JR-K, Buijs AE. 2007. Mapping the attractiveness of the Dutch countryside: a GIS-based landscape appreciation model. For Snow Landscape Res. 83:43–58.

Durham E, Baker H, Smith M, Moore E, Morgan V. 2014. The BiodivERsA stakeholder engagement hand-book. Paris: BiodivERsA. Accessed April/2018. Available from. http://www.biodiversa.org/706/download

Ervin S, Steinitz C. 2003. Landscape visibility computation: necessary, but not sufficient. Environ Plann B Plann Des. 30(5):757–766. doi:10.1068/b2968.

Esswein H, Schwarz VR. 2004. Darstellung und Analyse der andschaftszerschneidung in Bayern Teil 2: Lärmbelastung Endbericht. Im Auftrag des Bayerischen Landesamt für Umweltschutz, 21 S.

Gascon M, Zijlema W, Vert C, White MP, Nieuwenhuijsen MJ. 2017. Outdoor blue spaces, human health and well-being: a systematic review of quantitative studies. Int J Hyg Environ Health. 220(8):1207–1221. Elsevier GmbH. doi:10.1016/j.ijheh.2017.08.004.

Gerhards I. 2002. Die Bedeutung der landschaftlichen Eigenart für die Landschaftsbildbewertung dargestellt am Beispiel der Bewertung von Landschaftsbildveränderungen durch Energiefreileitungen – freiburg i. Br. Institut für Landespflege. 2002(Culterra 33):225 S.

Gobster PH, Nassauer JI, Daniel TC, Fry G. 2007. The shared landscape: what does aesthetics have to do with ecology? Landscape Ecol. 22(7):959–972. doi:10.1007/s10980-007-9110-x.

Gobster PH, Ribe RG, Palmer JF. 2019. Themes and trends in visual assessment research: introduction to the landscape and urban planning special collection on the visual assessment of landscapes. Landsc Urban Plan. 191: S. 103635. doi:10.1016/j.landurbplan.2019.103635.

Guo Z, Zhang L, Li Y, Romanuk TN. 2010. Increased dependence of humans on ecosystem services and biodiversity. PLoS ONE. 5(10):10. doi:10.1371/journal.pone.0013113.

Hermes J, Albert C, Haaren CV. 2018. Assessing the aesthetic quality of landscapes in Germany. Ecosyst Serv. 31:296–307. doi:10.1016/j.ecoser.2018.02.015.

Hernández J, García L, Ayuga F. 2004. Assessment of visual impact made on the landscape by new buildings: a methodology for site selection. Landsc Urban Plan. 68:15–28. doi:10.1016/S0169-2046(03)00116-6.

HLUG. 2013. Hessisches Landesamt für Umwelt und Geologie. Umweltatlas Hessen – ein Angebot des Hessisches Landesamt für Naturschutz, Umwelt und Geologie. Allgemeine Daten: bevölkerung. [Accessed 2020 Jan 12]. http://atlas.umwelt.hessen.de/servlet/Frame/atlas/allg_dat/bevoelk/bevoelk_txt.htm

Ives CD, Biggs D, Hardy MJ, Lechner AM, Wolnicki M, Raymond CM. 2015. Using social data in strategic environmental assessment to conserve biodiversity. Land Use Policy. 47:332–341. doi:10.1016/j.landusepol.2015.04.002.

Jeon JY, Jo HI. 2020. Effects of audio-visual interactions on soundscape and landscape perception and their influence on satisfaction with the urban environment. Build Environ. 169:106544. doi:10.1016/j.buildenv.2019.106544

Kahila M, Kyttä M. 2009. SoftGIS as a bridge-builder in collaborative urban planning. In: Geertman S, Stillwell J, editors. Planning support systems best practice and new methods. The geojournal library. Vol. 95. Dordrecht: Springer; p. 389–411. doi:10.1007/978-1-4020-8952-7_19.

Kahila-Tani M, Kytta M, Geertman S. 2019. Does mapping improve public participation? Exploring the pros and cons of using public participation GIS in urban planning practices. Landsc Urban Plan. 186:45–55. doi:10.1016/j.landurbplan.2019.02.019.

Kahn PH, Friedman B, Gill B, Hagman J, Severson RL, Freier NG, Feldman EN, Carrère S, Stolyar A. 2008. A plasma display window?-The shifting baseline problem in a technologically mediated natural world. J Environ Psychol. 28(2):192–199. doi:10.1016/j.jenvp.2007.10.008.

Kaplan R. 2001. The nature of the view from home. psychological benefits. Environ Behav. 33(4):507–542. doi:10.1177/00139160121973115.

Köppel J, Feickert U, Spandau L, Straßer H. 1998. Praxis der Eingriffsregelung. Schadenersatz an Natur und Landschaft? Ulmer (Stuttgart): UTB.

Kyttä M. 2011. SoftGIS methods in planning evaluation. In: Hull A, Alexander ER, Khakee A, Woltjer J, editor. Evaluation for participatory and sustainable planning. Routledge; p. 334–354. doi:10.4324/9780203813485.

Kyttä M, Broberg A, Tzoulas T, Snabb K. 2013. Towards contextually sensitive urban densification: location-based softGIS knowledge revealing perceived residential environmental quality. Landsc Urban Plan. 113:30–46. doi:10.1016/j.landurbplan.2013.01.008.

LANA – Länderarbeitsgemeinschaft Naturschutz, Landschaftspflege und Erholung (Hrsg.). 1996. Methodik der Eingriffsregelung. Gutachten zur Methodik der Erfassung, Bewertung und Beschreibung von Eingriffen in Natur und Landschaft, zur Bemessung von Ausgleichs- und Ersatzmaßnahmen sowie von Ausgleichszahlungen. Teil III: Vorschläge zur bundeseinheitlichen Anwendung der Eingriffsregelung nach § 8 BNatSchG. – Stuttgart (LANA-Schriftenreihe Heft 6).

Lee L-H, Lee Y-D. 2015. The impact of water quality on the visual and olfactory satisfaction of tourists. Ocean Coastal Manage. 105:92–99. ISSN 0964–5691. doi:10.1016/j.ocecoaman.2014.12.020.

Liu J, Kang J, Behm H, Luo T. 2014. Effects of landscape on soundscape perception: soundwalks in city parks. Landsc Urban Plan. 123:30–40. doi:10.1016/j.landurbplan.2013.12.003.

Lothian A. 1999. Landscape and the philosophy of aesthetics: is landscape quality inherent in the landscape or in the eye of the beholder? Landsc Urban Plan. 44 (4):177–198. doi:10.1016/S0169-2046(99)00019-5.

MacKerron G, Mourato S. 2013. Happiness is greater in natural environments. Glob Environ Change. 23 (5):992–1000. doi:10.1016/j.gloenvcha.2013.03.010.

MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and human wellbeing. Synthesis. Vol. 10. Washington (DC): Island Press; 137.

Meyer J. 2003. Städtebau – ein Grundkurs. W Kohlhammer GmbH Stuttgart. 229(S). doi:10.1007/978-3-322-99792-0.

MVI-BW. 2013. Ministerium für Verkehr und Infrastruktur Baden-Württemberg (Hrsg.), Städtebauliche Lärmfibel. Hinweise für die Bauleitplanung – Stuttgart; p. 197 S.

Nohl W. 2001. Landschaftsplanung: Ästhetische und rekreative Aspekte – patzer Verlag. Berlin-Hannover: 248 S.

Porteous D. 1982. Approaches to environmental aesthetics. J Environ Psychol. 2(1):53–66. doi:10.1016/S0272-4944(82)80005-4.

Raymond CM, Gottwald S, Kuoppa J, Kyttä M. 2016. Integrating multiple elements of environmental justice into urban blue space planning using public participation geographic information systems. Landsc Urban Plan. 153:198–208. doi:10.1016/j.landurbplan.2016.05.005.

Rodrigues M, Montañés C, Fueyo N. 2010. A method for the assessment of the visual impact caused by the large-scale deployment of renewable-energy facilities. Environ Impact Assess Rev. 30(4):240–246. doi:10.1016/j.eiar.2009.10.004.

Russell R, Guerry AD, Balvanera P, Gould RK, Basurto X, Chan KMA, Klain S, Levine J, Tam J. 2013. Humans and nature: how knowing and experiencing nature affect well-being. Annu Rev Environ Resourc. 38(1):473–502. doi:10.1146/annurev-environ-012312-110838.

Spiegelhalter DJ, Riesch H. 2011. Don’t know, can’t know: embracing deeper uncertainties when analysing risks. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 369 (1956):4730–4750. doi:10.1098/rsta.2011.0163.

Stedman RC. 2016. Subjectivity and social-ecological systems: a rigidity trap (and sense of place as a way out). Sustain Sci. 11(6):891–901. doi:10.1007/s11625-016-0388-y.

Swanwick C. 2002. Land Use Consultants. Landscape character assessment. Guidance for England and Scotland. Edinburgh: Countryside Agency, Cheltenham and Scottish Natural Heritage.

Tyrväinen L, Mäkinen K, Schipperijn J. 2007. Tools for mapping social values of urban woodlands and other green areas. Landsc Urban Plan. 79(1):5–19. doi:10.1016/j.landurbplan.2006.03.003.

von Haaren C. 2004. Landschaftsplanung. Stuttgart:Verlag Eugen Ulmer; 527 S.

Vouligny É, Domon G, Ruiz J. 2009. An assessment of ordinary landscapes by an expert and by its residents: landscape values in areas of intensive agricultural use. Land Use Policy. 26(4):890–900. doi:10.1016/j.landusepol.2008.10.016.

Wöbse HH. 2002. Landschaftsästhetik – Über das Wesen, die Bedeutung und den Umgang mit landschaftlicher Schönheit. Stuttgart: Verlag Eugen Ulmer ; p. 304 S.

Wojtkiewicz W, Heiland S. 2012. Landschaftsverständnisse in der Landschaftsplanung. Eine semantische Analyse der Verwendung des Wortes „Landschaft“ in kommunalen Landschaftsplänen. Raumforschung und Raumordnung. 70(2):2012. doi:10.1007/s13147-011-0138-7.