Landscape as an Area as Perceived by People: Empirically-based Nationwide Modelling of Scenic Landscape Quality in Germany

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Abstract: Nation-wide standardized scenic quality data is necessary to allow for the assessment of landscape impacts in the Strategic Environmental Assessment of national grid expansion planning. In this paper, we present an approach of GIS-based scenic quality modelling based on empirical data gathered using online visual landscape assessment surveys. Based on a representative sample of over 800 photographs covering the variety of German landscapes, and using the scenic quality ratings of over 3,500 respondents, a scenic quality model explaining 64 % of the variance in scenic quality ratings could be developed. This model then was applied to the entire territory of Germany, providing the first nation-wide scenic landscape quality dataset.

Keywords: Scenic quality assessment, online survey, GIS-based modelling, visual landscape quality

1 Introduction

The ambitious energy transition in Germany does not only require the constantly increasing rollout of renewable energy production facilities such as wind turbines, photovoltaic installations and biogas plants, but also a massive expansion of the national high-voltage transmission grid. The latter is required due to the overproduction in the wind-rich north and the overconsumption in the south which is rich in population and industry. The national development plan for the grid expansion requires a Strategic Environmental Assessment (SEA), which according to the SEA Directive and its national implementation in the Environmental Impact Assessment Act shall contain an analysis and assessment of "the likely significant effects on the environment, including issues such as […] landscape" (SEA DIRECTIVE 2001).

Whereas numerous published methods exist to assess scenic quality on a local or regional scale (cf. ROTH 2012, ROTH & BRUNS 2016), there are only few approaches to assess scenic landscape quality on a federal state level (ROTH & GRUEHN 2005, 2012, ROSER 2011) and none covering the whole of Germany.

Thus, so far, reliable and valid data on scenic quality on a national level, based on a consistent methodology, and data meeting a common standard does not exist. Federal state data or data from regional landscape planning also cannot be used due to different methods applied, different age and evaluation scales. Therefore, as scenic landscape quality is often neglected in

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these planning processes. In order to fill this gap, the Federal Agency for Nature Conservation started a project to provide an empirically-based nation-wide scenic quality assessment that can be used for national planning procedures as a basis to include landscape quality into the weighing of environmental factors in SEA. The scenic quality assessment criteria of visual diversity, landscape character and scenic beauty, as mentioned in the Federal Nature Conservation Act had to be separately modelled and assessed in this research project. In the following paper, we will focus on the scenic quality assessment.

2 Data and Methods

The assessment of scenic qualities based on empirical visual landscape assessment (using photographic stimuli) and GIS data, that are combined in a statistical model which then is subsequently applied to the area of investigation has been done before (e. g. BISHOP & HULSE 1994, PALMER & LANKHORST 1998, HUNZIKER & KIENAST 1999, BISHOP et al. 2000, ROTH & GRUEHN 2005, 2012, ROSER 2011). In contrast to existing methods, because of the large area of investigation (> 380,000 km²), a specific concept of sampling photographic stimuli had to be developed. In order to cover the variety of German landscapes, we selected 30 test areas, each around 150 km^2 in a two-way stratified sample using both the natural landscape classification of Germany (MEYNEN & SCHMITHÜSEN 1953-1962) and the landscape types defined by GHARADJEDAGHI et al. (2004). Whereas the natural landscape classification is mainly based on topographic features, the landscape types also represent cultural factors such as human land uses, settlements, etc. This sampling procedure ensured to cover different regions (from the North and Baltic Sea coast to the Alps) and different amounts of human interference in the landscape (from nearly-natural high alpine landscapes, semi-natural forests, agricultural areas and settlements to industrial areas and mining landscapes). In these 30 test areas, a photographic documentation of characteristic landscapes was conducted from May till August 2016, in order to provide a set of stimuli for empirical landscape quality assessment that covers diversity of German landscapes. In total, out of more than 10,000 photographs, 822 photographs were selected by a group of experts. These photographs then were implemented in an online visual quality assessment survey, following the methodology proposed by ROTH (2006). By cooperating with an online research panel (SoSci Panel), we could involve a set of respondents that is diverse regarding its socio-demographic composition, which is a necessary prerequisite in order to generalize from the sample towards the general public.

All photos were geo-tagged right on site when they were taken, and in addition to the position of the camera, the field of view (i. e. focal length) and the horizontal direction of the view were recorded. Then, using GIS-based visibility analysis on the national digital elevation model (ATKIS-DGM 10) with 10 m horizontal resolution, the viewsheds for each photograph could be calculated. Within these viewsheds, existing land uses, landscape elements and landscape metrics were then measured for several distance zones, as listed in table 1. These parameters were then used as potential regressors in regression analysis to model the scenic qualities perceived by the participants, based on landscape elements within the viewsheds of the vistas.

Table 1: Distance zones used in the viewshed analysis

zone	from distance	to distance
1 (foreground)	0 m	500 m
2 (near mid-ground)	500 m	2,000 m
3 (far mid-ground)	2,000 m	5,000 m
4 (background)	5,000 m	10,000 m
near view	0 m	2,000 m
far view	2,000 m	10,000 m

Once the scenic quality models have been established, the relevant indicators, i. e. regressors, were calculated nation-wide, based on a 1x1 km² grid, which represents the immediate foreground named "zone 1" in table 1. Using focal statistics in ArcGIS, these calculations were not only done for each cell, but for all distance zones mentioned in table 1 for and around all 387,000 cells within Germany. After this dataset has been established, the regression model could be applied to the entire territory of Germany, and visual landscape quality maps were produced.

3 Results

During the two months field time, more than 3,500 participants took part in the survey and over 44,000 complete landscape assessments (according to the three criteria mentioned initially) were collected.

By asking for the postal code, the participants could be geo-located without compromising privacy regulations. Correlation analysis of the distribution of participants over the 16 federal states showed a representative distribution in comparison with the total population distribution (Pearson's $r = 0.963$, $p < 0.001$).

In total 17 regressors were included in the model consisting of terrain (2), positively valued land uses (5), impacting land uses and infrastructure (9) and hemeroby (1). These regressors are listed in table 2, including the zones where they were calculated, the non-standardized beta coefficients and the standardized beta coefficients. In total the model explains 64 % of the variance in scenic beauty ratings.

Table 2: Variables used as regressors in the linear regression model for scenic quality

no.	regressor variable	Zone	non-standardized beta coefficient	standardized beta coefficient
1	constant	/	7,109	
2	relative relief 1 (absolute value)	0 to 2,000 m (near view)	+ 0,002	+ 0,171
3	relative relief 2 (absolute value)	2,000 to 10,000 (far view)	+ 0,001	+ 0,185
4	lake, ocean, river (percentage of view)	0 to 500 m (foreground)	+ 0,008	+ 0,152
5	orchard (percentage of view)	0 to 10,000 m (complete view)	+ 0,031	+ 0,096
6	forest (percentage of view)	0 to 10,000 m (complete view)	+ 0,005	+ 0,088
7	natural grassland (percentage of view)	500 to 2,000 m (near mid-ground)	+ 0,025	+ 0,083
8	heathland (percentage of view)	0 to 500 m (foreground)	+ 0,017	+ 0,068
9	hemeroby (average value)	0 to 500 m (foreground)	- 0,317	- 0,200
10	road density (m/km²)	0 to 2,000 m (near view)	- 0,0001	- 0,189
11	arable land (percentage of view)	0 to 10,000 m (complete view)	- 0,010	- 0,187
12	industrial, commercial and traffic infrastructure 1 (percentage of view)	0 to 500 m (foreground)	- 0,019	- 0,187
13	industrial, commercial and traffic infrastructure 2 (percentage of view)	500 to 2,000 m (near mid-ground)	- 0,018	- 0,106
14	industrial, commercial and traffic infrastructure 3 (percentage of view)	2,000 to 5,000 m (far mid-ground)	- 0,011	- 0,065
15	transmission line density (m/km²)	0 to 5.00 (foreground)	- 0,0001	- 0,101
16	sport and recreation area (percentage of view)	0 to 5.00 (foreground)	- 0,019	- 0,077
17	sparse vegetation (percentage of view)	500 to 2,000 m (near mid-ground)	- 0,205	- 0,075
18	wind turbine density (no./km²)	0 to 10,000 m (complete view)	- 0,588	- 0,071

Figure 1 shows an example of the resulting scenic beauty map of Germany. Dark blue represents high scenic beauty values, followed by green, yellow indicates medium values and orange, followed by red represents low scenic beauty.

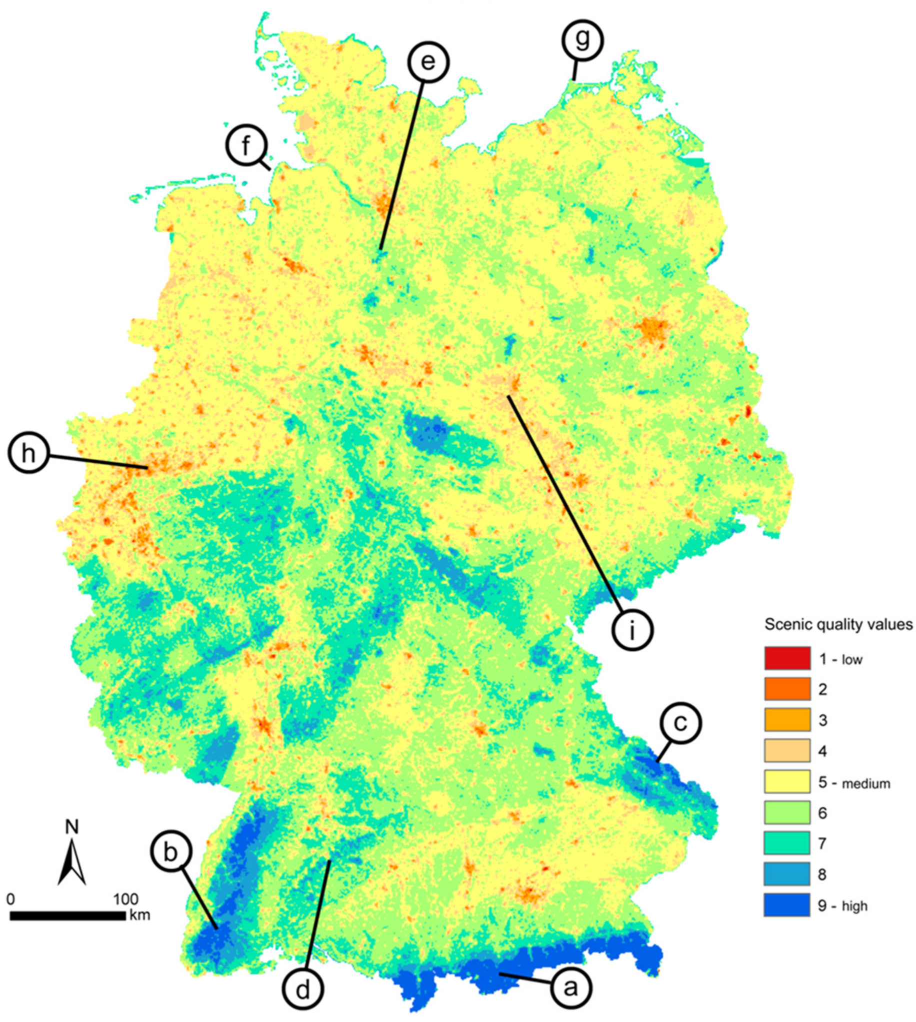

Fig. 1: Scenic beauty map of Germany, based on linear regression analysis with 17 regressors

The map in figure 1 shows the dominating positive influence of terrain and water, and the strongly negative influence of traffic infrastructure, arable land, and industrial/commercial areas. The alps in the very South (a), the Black Forest in the South-West (b) and the Bavarian Forest in the South-East (c) are characterized by steep terrain, (semi-)natural landuses like forests and meadows, and vernacular architecture with a generally relatively low presence of intensive human interference (see figures 2 and 3).

Fig. 2: Alpine landscape (a in map)

Fig. 3: Black Forest landscape (b in map)

Specific landscape features such as the escarpment of the Swabian Alb (d) or the heathland in the Lüneburg Heath (e) were among the top-rated photos in the online survey and also reached scores distinctively higher than their surroundings.

Fig 4: The escarpment of the Swabian Alb (d in map)

Fig. 5: Heathland in the Lüneburg Heath (e in map)

Landscapes dominated by water, such as the coastal landscapes of the North Sea (f) or the Baltic Sea (g) did not reach top scores in the online scenic quality assessment, but ended up in the range of 7 to 8 both in the online survey and in the GIS model.

Fig. 6: North Sea coast (f in map)

Fig. 7: Baltic Sea coast (g in map)

Hemeroby as a complementary term to naturalness, based on the national hemeroby dataset provided by the Leibniz Institute of Ecological Urban and Regional Development also proved to be relevant predictor of perceived scenic beauty. Thus, both urban landscapes, especially those dominated by industrial or commercial buildings like the one in the Ruhr area (h), and intensively farmed unstructured areas, especially those with additional technical infrastructure such as transmission lines or wind turbines, e. g. in the Magdeburg Börde (i) scored low both in the empirical assessment and in the resulting GIS model.

Fig. 8: Industrial area in the Ruhr area (h in map)

Fig. 9: Intensive agriculture with little landscape structure (i in map)

4 Discussion

One could argue that the high scenic quality landscapes and the very low scenic quality landscapes as illustrated in figures 2 to 9 could be identified without the elaborative online survey and GIS modelling, which is partially true. On the other hand, a valid differentiation of scenic quality for all the landscapes in between would not have been possible without a solid empirical basis and a validated GIS model.

In terms of the generalizability of the results, we are very confident that both from the sample of areas used to set up the visual stimuli for the online survey and from the characteristics of our sample of respondents, we reached a critical level of representativeness. As has been described above, the two-way stratified sampling procedure for the test areas in conjunction with an expert-based photographic sampling and expert-based photo selection for the online survey made sure that the variety of German landscapes is represented in the sample. As the sample of respondents is covering all age classes from 11 years to 80 years, gender-balanced, representatively distributed in the country and representing both lay people (around 70 %) and landscape experts (around 30 %), limits of studies that generalize from student samples to the general public (which has been criticized by ROTH 2006 and 2012) could be overcome.

Another potential point of criticism is that a model covering such a wide variety of landscape classes should incorporate some kind of regionalization or classification of different landscape types. We investigated whether a regionalization of for example relative terrain range in a particular area (relief energy) would improve the explained variance of the scenic quality model, but that was not the case. A regionalization in terms of developing several sub-models for different geographical areas was not in the scope of the research, as comparable scenic quality assessments according to a standardized model and scale were the main intention of the project presented.

Compared with past modelling approaches, the results presented in this paper extend past studies in several ways: (1) taking in to account the large area of investigation and the impossibility of detailed mapping of landscape elements, the model quality of $r^2 = 0.64$ can be considered very high. (2) In terms of the empirical basis, the study presented is the largest scenic quality survey that has ever been carried out in Germany. (3) Based on national datasets of standardized GIS data, the scenic quality models developed are the first nation-wide dataset considering visual landscape quality that is both based on a representative empirical basis and consistent across federal states and natural regions.

5 Conclusion and Outlook

With the approach presented, it is possible to produce nation-wide standardized data on scenic quality that are not based on normative expert views, but on a representative empirical basis. Thus, scenic quality is modelled in a way that represents the landscape perception of the general public, which is in line with the landscape definition of the European Landscape Convention (COUNCIL OF EUROPE 2000). Using the dataset presented, a method for visual sensitivity analysis and landscape conflict assessment will be developed that can be used in national planning procedures for high-voltage grid lines.

Future work will be directed towards validating the results of the study presented. This can be done using external data such as the scenic quality assessments that exist for singular federal states. In addition to that, a validation of the linear regression model using a bootstrapping method with only part of the online survey data feeding into model generation and the rest used to test the accuracy of the prediction.

In conclusion, we hope that by overcoming methodological difficulties and closing data gaps that in the past led to a non-representation of scenic qualities in environmental assessments for electricity transmission infrastructure, we can contribute to a better consideration of landscape in these procedures. Ultimately, we hope that this will lead to better planning and a higher acceptance of infrastructure that is critical for a successful energy transition in Germany.

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