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Measurement and modelling of aesthetic landscape values

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Abstract: The paper gives an outline of several landscape preference studies considering different landscape types which have been carried out at Dortmund University of Technology within the last couple of years. Scenic quality to a considerable extent depends on the provision of landscapes with specific land use types, such as forests or agricultural landscapes. The paper focuses on two examples from Germany on federal state level, Saxony and Mecklenburg-Western Pomerania, where aesthetic landscape values were modeled on the basis of empirical surveys, and digital landscape data. The surveys carried out among inhabitants of different parts of Germany, questioning about demographic factors (e.g. sex, age, school and professional qualification, importance of nature and environment, frequency of outdoor trips) as well as different scenic qualities such as variety, uniqueness and beauty of different landscape types. The paper explores various factors to account for variability in preference judgements for particular landscape scenes. Variance is examined and discussed in relation to the level of preference/scenic quality, in relation to possible group differences, and in relation to landscape ecological factors, e.g. vegetation type on different levels of phytosociological hierarchy. Besides, potential impacts of climate change as well as modification of land management methods are discussed.

Key Words: Landscape Aesthetics; Landscape Preferences; Scenic Quality Assessment

Introduction

Under conditions of growing severe global ecological problems, it may be surprising to some to read an article on “measurement and modelling of aesthetic landscape values” in an ecological journal. Hence, we should raise the question “What reasons make it necessary to deal with the aesthetic dimension of landscapes?”.

1. The aesthetic dimension of landscapes is an important emotional factor for many people including ecologists as well as non ecologists concerning their relationship to landscape issues.
2. The aesthetic dimension has been implemented in environmental legislation (EIA, SEA, Landscape Planning) since decades.
3. There is still much research needed to discover how landscape elements or landscape metrics determine aesthetic landscape values.

Another problem is linked with the question “What is the content of aesthetic landscape values and how can they be measured?”

The word “aesthetics” is deduced from the ancient greek term ‘aisthesis’, which means perception. Hence, aesthetics refers to the way how humans perceive natural and cultural phenomena. Aesthetic landscape values or ‘scenic value’ comprise perceived visual criteria, such as variety, uniqueness, beauty or naturalness of natural and cultural landscapes. They can be measured at least on an ordinal scale level by means of survey techniques (Roth & Gruehn 2005; Roth 2006).

Materials and Methods

The methods applied in our research are theoretically based on the psychological-phenomenological approach according to Nohl (2001). This approach comprises the real landscape (on an object level), the viewer (on a subject level) as well as the scenic landscape quality as an interface between real landscape and viewer (on an image level; figure 1). According to Nohl (2001), scenic quality can be described as aesthetically-symbolically interpreted appearance of landscape. Since ratings of single viewers to a large extend reflect subjective experiences, expectations, visions etc. we use large random samples (n ≥ 100) to avoid biases.

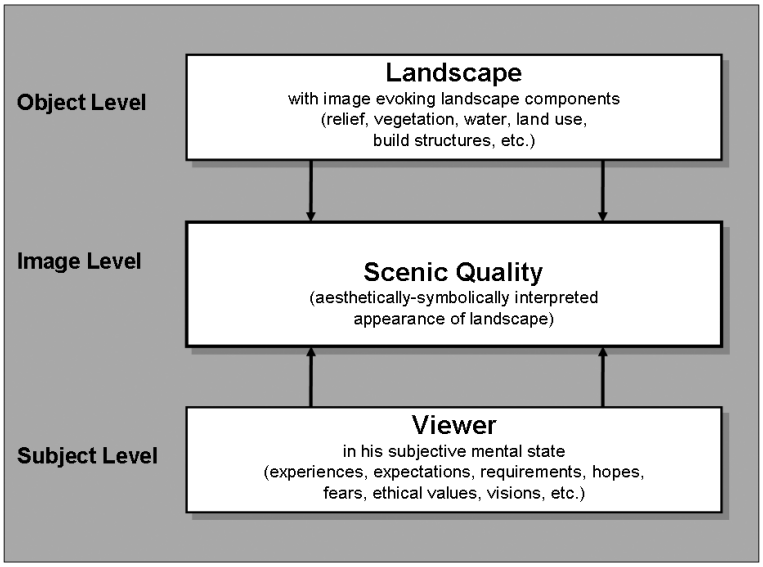

Fig. 1. Interdependence of landscape, viewer and scenic quality (Nohl 2001, Roth & Gruehn 2005)

While single ratings are extremely debatable, landscape preference ratings based on large random samples are more homogenous and scientifically well-grounded (Gruehn & Roth 2010).

The basic structure of our methodological approach is presented in figure 2. Following the psychological-phenomenological approach mentioned above, we assume that landscape as real or photographic representation evokes scenic quality "in the eye of the beholder". This reaction can be estimated by means of surveys, using different aesthetic criteria (variety, beauty, uniqueness etc.), not only for individuals, but also for a population. The image evoking landscape components are represented within the digital landscape data set and can be objectively measured within a GIS based on viewshed analysis (Roth & Gruehn 2005). Provided that statistic analysis reveals a significant and validated interrelationship between GIS-based landscape components and the participants' scenic quality ratings, the results subsequently can be used for an area-wide modelling of visual quality within the GIS aiming at generating visual quality maps.

For practical and economic reasons we replace ratings in real landscapes by ratings of photographs (of real landscapes). According to Roth and Gruehn (2005) and Roth (2006) this approach is justified by a strong correlation between people's ratings of real landscapes and their photograph-based ratings. For data acquisition we use traditional questionnaires as well as internet surveys according to Roth (2006). Table 1 reveals a high validity of internet ratings concerning different criteria (Roth 2011). This judgement is based on a strong correlation between the results of traditional ratings in questionnaires and internet surveys.

Statistical analyses comprise the application of parametric and non-parametric methods, especially ordinal regression analysis, in accordance with mathematical prerequisites (see Weinberg and Abramowitz 2008). The application of ordinal regression analysis is promising, because it is appropriate from a mathematical point of view, and it allows including non-linear relationships.

Table 1. Validity of Internet rating approach according to Roth (2011)

Scenic Landscape Quality Criteria	Validity (r)
variety	0.797
beauty	0.665
aesthetical	0.601
natural	0.683

Results

Figure 3 presents the results of an area-wide visual quality model of the German federal state of Saxony (18,000 square kilometers), based on an ordinal regression analysis (Gruehn, Roth & Kenneweg 2007), with large areas of lower variety in the north-western and north-eastern parts of Saxony and high values in the southern parts of this federal state. The (perceived) variety as dependent variable can be explained by the following factor or predictor variables:

• number of land-use types,
• relief conditions,
• proportion of water bodies,
• proportion of arable land,
• proportion of forests, and
• length of hedges.

The predictor variables were generated by landscape data (landscape metrics) derived from viewshed analysis based on ATKIS DLM25 as well as DGM25.

The model quality measured by Nagelkerke´s Pseudo R-squared is 0.65, which means that 65 % of the total variation of the dependent variable (perceived variety) can be explained by the predictor variables.

Figure 4 points out results of an area-wide visual beauty model of Mecklenburg-Western Pomerania (Germany), which has an area of about 23,000 square kilometres. This model again is based on an ordinal regression analysis (Roth & Gruehn 2011). Large parts of this federal state are characterised by high values of beauty. The (perceived) beauty as dependent variable can be explained by factor or predictor variables as follows:

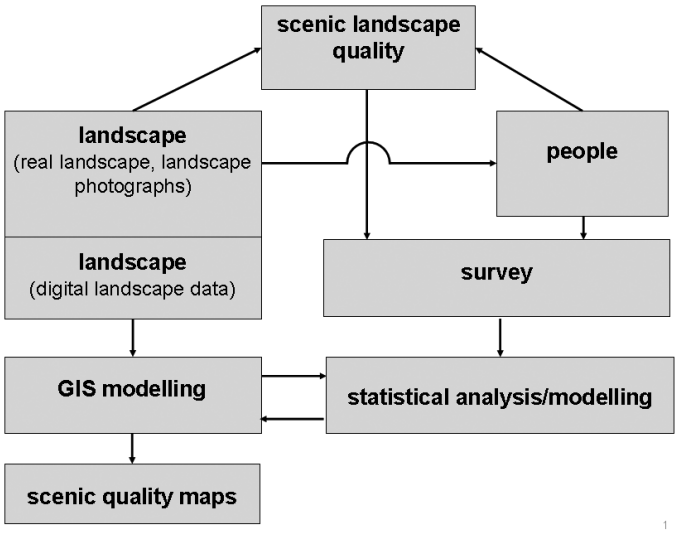

Fig. 2: Basic structure of the research methodology (Roth & Gruehn 2005)

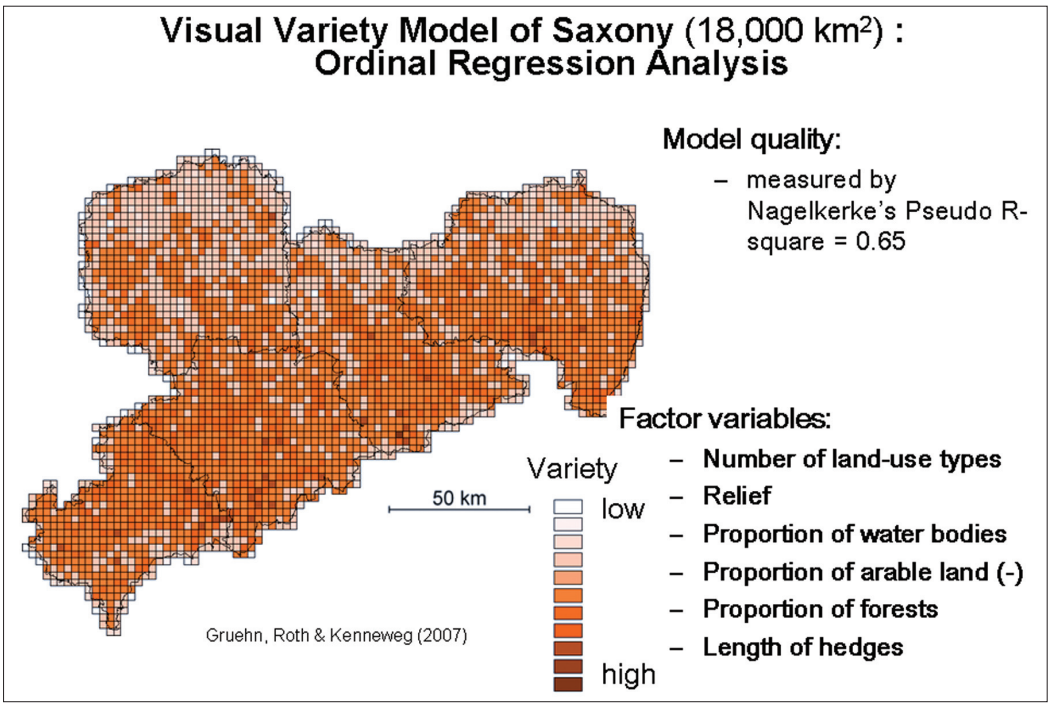

Fig. 3: Visual variety model of Saxony (Germany) based on an ordinal regression analysis (Gruehn, Roth & Kenneweg 2007)

• mean patch area,
• elevation above sea level,
• proportion of arable land,
• proportion of industrial zones, and
• proportion of sea area.

Again, predictor variables were generated by landscape data (landscape metrics) derived from viewshed analysis based on ATKIS DLM25 as well as DGM25.

The model quality measured by Nagelkerke´s Pseudo R-squared is 0.715, which means that nearly 72 % of the total variation of the dependent variable (perceived beauty) can be explained by the above mentioned predictor variables.

Besides, we developed separate models for a broad range of scenic landscape quality criteria, such as
• variety,
• beauty, and
• uniqueness/distinctiveness.

Table 2 summarises the model quality of different ordinal regression models developed for the federal states of Saxony and Mecklenburg-Western Pomerania. Nagelkerke's Pseudo R-squared was used as indicator for the model quality. For Saxony the model explains between 41 % and 65 % of the total variation of the perceived scenic landscape quality criteria. In case of Mecklenburg Western-Pomerania, model quality is better. Here, the explanatory power of the developed models is between 55 % to 72 %.

Another finding of our research is that there is no or at most a weak effect of demographic and other control variables on landscape perception. This includes the following variables:
• age, sex, education,
• local people vs. non-local people,
• andscape experts vs. laymen,
• behaviour and attitude concerning landscape/environmental issues,
• different seasonal aspects, and

• foliated vs. non-foliated vegetation.

Given that the developed models consider land-use types rather than vegetation types, we started to enlarge our data base by questionnaires about landscape photos, which reflect different hierarchically structured syntaxonomical units (figure 5). While the above mentioned ordinal regression models only consider "forest area" as land-use category, this approach enables to include differentiated information on vegetation classes, groups, alliances or associations with regard to spatial data resolution.

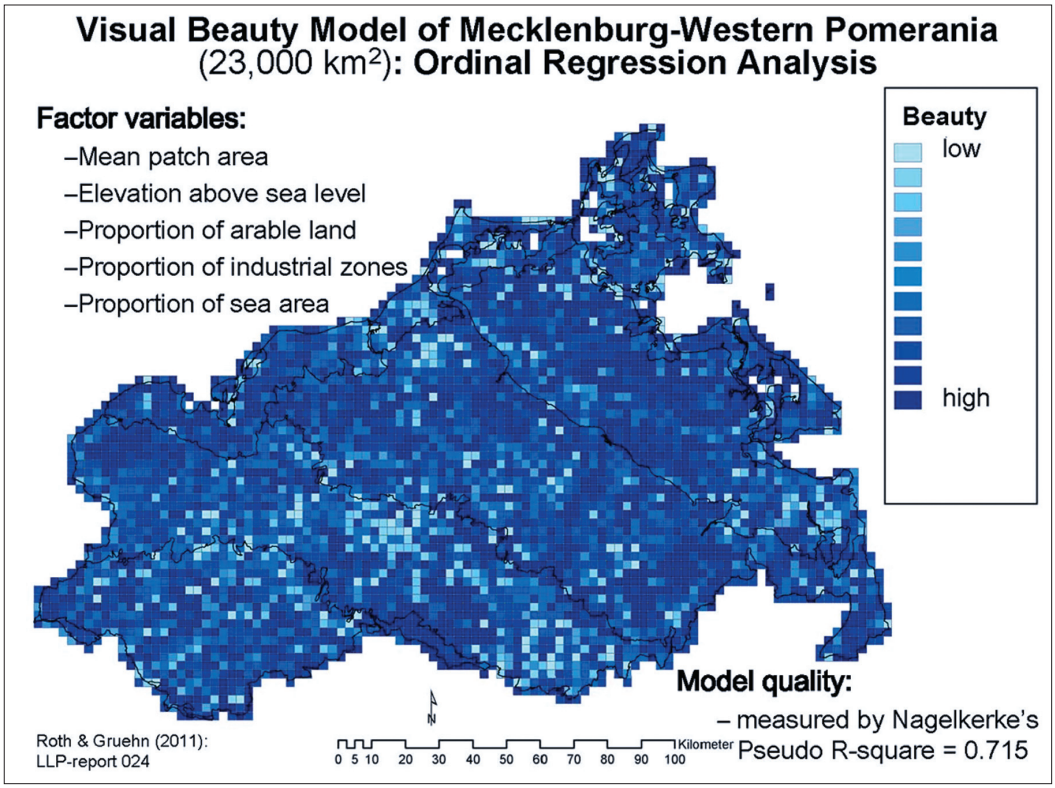

Fig. 4. Visual beauty model of Mecklenburg-Western Pomerania (Germany) based on an ordinal regression analysis (Roth & Gruehn 2011)

Table 2. Model quality (Nagelkerke's Pseudo R-squared) of different ordinal regression models (Gruehn, Roth & Kenneweg 2007; Roth & Gruehn 2011)

Federal State Scenic Landscape Quality Criteria	Saxony	Mecklenburg-West-ern Pomerania
Variety	0.65	0.624
Beauty	0.41	0.715
Uniqueness/ distinctiveness	0.48	0.547

Figure 6 points out landscape preferences of the interviewees (concerning "variety" and "beauty") with regard to different forest associations. There are considerable differences between varied forest types. Some associations, e.g. ash-elm alluvial forests (Fraxino-Ulmetum) or green spleenwort-fir forest (Asplenio-Piceetum), have been regarded as of both high variety, and high beauty. Other types, like Picea abies stocks can be characterised by low variety and low beauty. The fact that calcareous beech forests (Lathyro-Fagetum) have been regarded as beautiful habitats despite of their low (perceived) variety is remarkable. Contrary to this, larch forests (Larici molinietosum) have been assessed as less beautiful, despite of their higher variety, compared to calcareous

beech forests. The distinct forest associations explain 20 % of the total variation of the perceived variety, and 14 % of the perceived beauty.

The findings, presented in figure 6, reveal that specific changes of forest types, caused by global warming and/or by modification of land management methods will have a considerable effect on the perceived scenic landscape value. Thus, changes of the visual appearance of landscapes in general, and forest landscapes especially, will be of importance for the regional tourism sector, too.

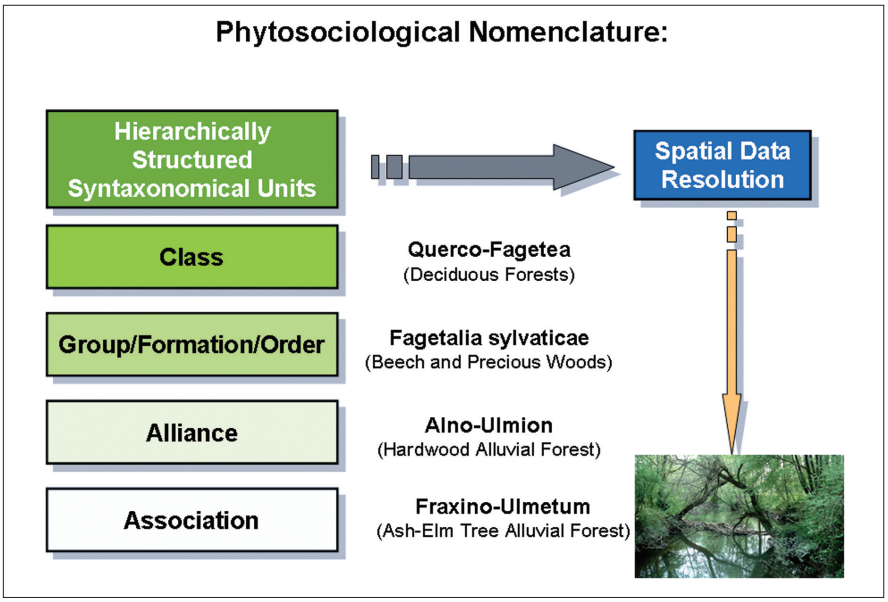

Fig. 5. Consideration of hierarchically structured syntaxonomical units

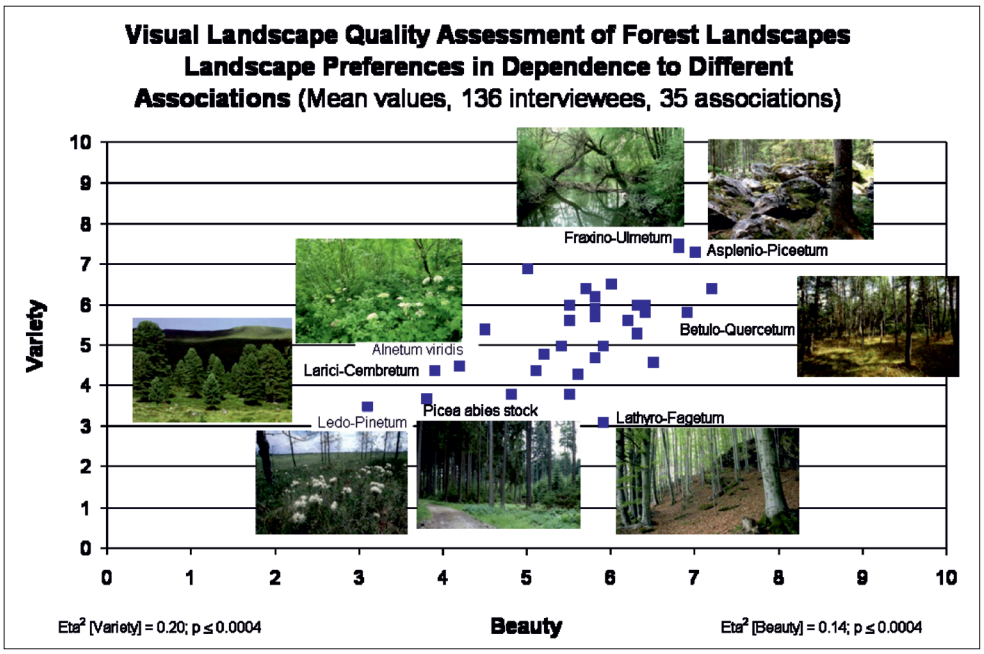

Fig. 6. Perceived visual variety and beauty of different forest associations

Conclusions

Empirical surveys help to better understand, to measure, and to model aesthetic landscape values. Ordinal regression analysis is an appropriate tool to connect individual (internet) ratings on visual landscape quality with landscape metrics. The model quality results are acceptable (including validity of photo and internet ratings). Landscape perception is more affected by features of real landscapes as well as spatial data resolution than by demographic or behavioural factors. Our further research activities will comprise

• a reflection on adequate validation techniques, including new approaches, such as the total skill score according to Frank et al. (2004),

• modelling on different scale levels,

• the consideration of noise, impacts of climate change, and different ethnic and cultural background of interviewees.

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