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Research article

Spatial modelling of landscape aesthetic potential in urban-rural fringes

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ABSTRACT

The aesthetic potential of landscape has to be modelled to provide tools for land-use planning. This involves identifying landscape attributes and revealing individuals' landscape preferences. Landscape aesthetic judgments of individuals ($n = 1420$) were studied by means of a photo-based survey. A set of landscape visibility metrics was created to measure landscape composition and configuration in each photograph using spatial data. These metrics were used as explanatory variables in multiple linear regressions to explain aesthetic judgments. We demonstrate that landscape aesthetic judgments may be synthesized in three consensus groups. The statistical results obtained show that landscape visibility metrics have good explanatory power. Ultimately, we propose a spatial modelling of landscape aesthetic potential based on these results combined with systematic computation of visibility metrics.

1. Introduction

Landscape quality, defined as 'the relative aesthetic excellence of a landscape' (Daniel, 2001), has recently become an important dimension of public policies. The European Landscape Convention sets out recommendations for landscape quality issues and encourages public authorities to consider the aspirations of inhabitants regarding the landscape features of their environment (Concil of Europe, 2000). Landscape aesthetics is indeed recognized as a cultural ecosystem service that influences human well-being (de Groot et al., 2010; Millenium Ecosystem Assessment, 2003). Several scientific studies have shown for example that landscape is a significant component of residential satisfaction for inhabitants in urban and suburban areas (Hur et al., 2010; Kweon et al., 2010). But defining landscape quality involves assessing landscape preferences. Such preferences result from the interaction between landscape attributes and the characteristics of the observers.

Scientific research into landscape preferences has long focused on consensus among individuals about landscape quality (Van den Berg et al., 1998). Hagerhall (2001) has shown that such consensus is more important for pleasing landscapes than for ones that are judged less aesthetic. The similarities or consensus as to landscape preferences are part of evolutionary theories (Appleton, 1975; Kaplan and Kaplan, 1989; Wilson, 1984). These theories hold that landscape aesthetic preferences are formed by the common evolutionary history of humans who react positively to landscape features that supposedly ensure their survival and improve their well-being. Among these theories, the *biophilia* hypothesis (Fromm, 1964; Kellert and Wilson, 1993; Wilson, 1984) shows the influence of exposure to natural environments on psychological well-being. At the same time, studies about restorative environments demonstrate that individuals' health is directly linked to environmental characteristics. In this context, two fields of study have emerged (Van den Berg et al., 2014), focusing on the influences of the natural environment (1) on affective states (*Stress Recovery Theory*) (Ulrich, 1979) and (2) on the restoration of attention (*Attention Restoration Theory*) (Kaplan and Kaplan, 1989). Cognitive aspects of the environmental configuration have also been widely explored through *prospect-refuge theory* (Appleton, 1975) and information processing theory (Kaplan and Kaplan, 1989). In the first case, Appleton (1975) states that the development of humanity has led people to prefer places where they can have a wide view (*prospect*), while remaining concealed (*refuge*). In the second case (Kaplan and Kaplan, 1989), show that the combination of four informational factors

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(complexity, consistency, clarity and mystery) through a landscape preference matrix is likely to influence individual preferences. Starting from the premise that landscape quality is the same for all individuals, expert-based approaches to landscape assessment have largely dominated environmental management practices. They assume that the value to be ascribed to a landscape may depend directly on its visual attributes. Experts can therefore supposedly assess the quality of a landscape objectively (Karjalainen and Tyrva, 2002; Vouligny et al., 2009).

Unlike evolutionary theories, cultural theories (Carlson, 2001; Tuan, 1974) suggest that landscape preferences are constantly changing, shaped by individuals' personal and cultural experiences (Lindemann-Matthies et al., 2010). These perceptive approaches are based on a cognitive judgment of landscape characteristics (Daniel and Vining, 1983) and focus on landscape 'through the eye of the beholder'. Lothian (1999) asserts that 'the paradox is that in common usage, the landscape is taken to be beautiful but in actuality this beauty is literally a fragment of the imagination, a product of the viewer's own cultural, social and psychological constitution'. In this context, several studies demonstrate that landscape preferences may vary with individuals' socioeconomic, demographic or cultural characteristics (Stamps, 1999; van Zanten et al., 2014). Differences have been noted depending on age (Howley et al., 2012; Sevenant and Antrop, 2010; Van den Berg and Koole, 2006), sex and place of residence (Kalivoda et al., 2014), income (Campbell, 2007) and degree of knowledge or expertise about landscape (Rogge et al., 2007; Stumse, 1996; Tveit, 2009).

This opposition between (1) evolutionary approaches based on expert assessments and (2) cultural approaches based on perceptive evaluations still prevails. It relates directly to the objectivist (physical) and subjectivist (psychological) paradigm presented by Lothian (1999). However, other studies (Bourassa, 1991; Fry et al., 2009; Norton et al., 1998; Tress et al., 2001) have shown that evolutionary and cultural determinants jointly influence individuals' landscape preferences.

The approach focusing on consensus among individuals from an evolutionary perspective seems reductive to a fault and may omit some of the variability among individuals' judgments. Conversely, the exploration of individual preferences restricts the potential spatial modelling for designing decision support tools for land-use planning. However, the consideration of the landscape aesthetic preferences is an important issue for spatial planning. Landscape is a component of the living environment of people, and land use planning can lead to change this landscape. Although public policies clearly call for maintaining the visual quality of the landscape, this quality is never really defined.

In this paper, we therefore seek to propose a way to define this landscape quality through the eyes of the observers, with the aim to guide land use policies. Although landscape aesthetic preferences are the outcome of a complex process of perception, we assume that (1) there are similarities between aesthetic judgments of certain groups of individuals, and (2) these aesthetic judgments can be explained by some combination of landscape visibility metrics. The objective of this study is thus to model landscape aesthetic potential by arranging individual landscape preferences into a limited number of aesthetic judgment groups.

For this purpose, we develop a five-step modelling approach: (1) construction of a perception survey based on a corpus of landscape photographs, (2) computation of landscape visibility metrics from spatial data, (3) definition of homogeneous groups of landscape aesthetic judgments, (4) analysis of statistical relationships between aesthetic judgments and landscape metrics, and (5) spatialization of landscape aesthetic potential and identification of areas of consensus and disagreement.

This study is conducted in urban-rural fringes. These areas where town meets countryside (Scott et al., 2013) are particularly affected by agricultural changes, including intensification and scale enlargement, or conversely agricultural abandonment (van Zanten et al., 2014), and by urban sprawl that has been occurring in all European cities since the 1960s (European Environment Agency, 2006). Such development is characterized by the rapid extension of commercial areas and the construction of uniform and monotonous residential areas (Friedberger, 2000). This is mainly due to the desire of households to move into the peaceful environment of a semi-rural area while being able to enjoy the benefits offered by an urban area nearby (Daniels, 1998; Sullivan and Lovell, 2006). Although continuous physical transformations of these areas could affect the living environment of their inhabitants, urban-rural fringes have been neglected by land-use planning for decades (Gallent et al., 2004).

2. Methodological background

2.1. Landscape photo-based survey

Within the framework of the evolutionary and cultural approaches, landscape photographs are commonly used. They are considered an interesting medium for evaluating landscape preferences (Arriaza et al., 2005; Natori and Chenoweth, 2008; Wherrett, 2000). Although they cannot replace *in situ* observations, they do provide a holistic representation of landscape using visual stimuli that can approximate an actual experience of landscape (Barroso et al., 2012). These stimuli allow the mind to associate the visual information of landscape with other sensory knowledge and activate an intuitive recognition of its aesthetic quality (Bell, 2001). Two main groups of methods exist in photo-based landscape preference assessment. The methods by attitude scale, or "Scenic Beauty Estimation Method" (e.g. Daniel and Boster, 1976) involve evaluating each photo independently by assigning it a score, usually on a 5-point Likert scale (e.g. Cañas et al., 2009; Dramstad et al., 2006; Ives and Kendal, 2013). The ranking methods or "Law of Comparative Judgment" (e.g. Buhyoff and Leuschner, 1978) consist in ranking a set of photos according to the quality of the landscape represented, either in order of preference (e.g. Arriaza et al., 2004) or by pairwise comparisons (e.g. Tahvanainen et al., 2001). These judgments are then compared and contrasted with indicators relating to the landscapes represented in order to gain insight into individuals' landscape preferences.

2.2. Landscape visibility analysis

The construction of landscape indicators is an essential step in landscape preference assessment. Such indicators serve as a measuring basis by converting the visual perception of the physical landscape into quantifiable criteria (Sang et al., 2008). These indicators can be obtained by *in situ* observations (Arriaza et al., 2004; Otero Pastor et al., 2007) or by GIS modelling (Cavailhès et al., 2009; Sang et al., 2008; Schirpke et al., 2013). The first approach provides a wealth of information but is restricted to a limited area. The second approach, based on digital spatial data, allows the landscape analysis to be extended to the entire study area (Schirpke et al., 2013; Youssoufi and Foltête, 2013).

Landscape visibility analyses can be used to study individuals' landscape preferences (de la Fuente de Val et al., 2006; Lee et al., 2008). They can be split into two main methods. The sight-line method (Fisher, 1996; Joly et al., 2009) entails characterizing the visible landscape by counting the pixels seen from a virtual viewpoint. The solid angles method (Domingo-Santos et al., 2011; Germino et al., 2001) involves using trigonometric calculations to quantify the surface areas of the observer's retina occupied by