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A comparison of *in situ* and GIS landscape metrics for residential satisfaction modeling

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ABSTRACT

Residential satisfaction with landscape has to be modeled in order to include landscape in regional planning decisions. The landscape attributes of a location may be evaluated by means of field audits (*in situ* approach) or they may be based on variables derived from digital data (GIS approach). In order to compare these two ways of investigating residential satisfaction, a set of *in situ* metrics and a set of GIS visibility metrics were collated from residential locations in a suburban setting. These metrics were used as explanatory variables in multivariate statistical models designed to account for levels of satisfaction defined from a residential satisfaction survey. The results obtained show that *in situ* metrics and GIS visibility metrics have the same overall explanatory power. They also emphasize that both sets of metrics are complementary in providing relevant information about the elements that influence residential satisfaction. Ultimately, comparative examination of residuals of the models provides pointers for further improving residential satisfaction modeling.

1. Introduction

Residential satisfaction is an important subject of research in varied domains such as environmental psychology (Amerigo, 1997; Hur, Nasar, & Chun, 2010), sociology (Kahana, Lovegreen, Kahana, & Kahana, 2003), and urban planning (Ellis, Lee, & Kweon, 2006; Kweon, Ellis, Leiva, & Rogers, 2010). Residential satisfaction may be thought of as the match between an individual's ideal residential environment and certain attributes of her actual environment, including its psychological, social, and spatial components. For Amerigo (1997) residential satisfaction arises from the evaluation of objective attributes of the residential environment through the filter of personal characteristics related to the individual's expectations, experiences, aspirations, or values. Each individual expresses a degree of residential satisfaction that is peculiar to her and that arises from the confrontation between a cognitive process and objective, physical, or social attributes of her environment (Weidemann & Anderson, 1985, pp. 153–182). However, some similarities exist in landscape preferences, explained by evolutionary theories such as *biophilia* (Wilson, 1984), *restorative environments* (Ulrich, 1979), *prospect-refuge theory* (Appleton, 1975) or by the *landscape preference matrix* proposed by Kaplan and Kaplan (1989). These theories hold that landscape 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.

Of the various components of an individual's residential satisfaction, satisfaction with the landscape around her residence has been much studied (Hur & Morrow-Jones, 2008; Kweon et al., 2010; Lee, Ellis, Kweon, & Hong, 2008). Much work has been done on identifying the landscape criteria to which individuals are sensitive to varying degrees (Cavailhès et al., 2009; Cheshire & Sheppard, 1995; Cho, Kim, Roberts, & Jung, 2009; Kong, Yin, & Nakagoshi, 2007; Lee et al., 2008; Tyrväinen & Väänänen, 1998). Generally research can be split into two main bodies depending on the objective pursued. The first body of work endeavors to better understand individuals' landscape preferences by referring to the monetary value individuals are ready to attribute to landscape (Cavailhès et al., 2009; Cho, Poudyal, & Roberts, 2008; Gao & Asami, 2007; Jim & Chen, 2006; Tyrväinen, 1997) or by focusing on the various cognitive processes at work in the human–environment relationship (Kaplan, Kaplan, & Brown, 1989; Sevenant & Antrop, 2009; Zube, Sell, & Taylor, 1982). The second body of studies

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addresses more operational issues by looking to include landscape in decisions about regional planning (Domingo-Santos, de Villarán, Rapp-Arrarás, & de Provens, 2011; Kaplan & Austin, 2004), environmental management (Bell, 2001) or urban planning (Lee et al., 2008). This involves evaluating landscape quality.

There are two main approaches to evaluating landscape quality (Daniel, 2001; Vouligny, Domon, & Ruiz, 2009). The first 'perceptive' approach is based on individual preferences and looks at landscape through the eye of the beholder (Lothian, 1999). The aim is usually to ask an individual what he thinks of a given landscape or a specific landscape criterion. These methods borrowed from the cognitive sciences can be used to explore the affective relationship between the individual and the landscape rather precisely by concentrating on the subject's different mental and psychological processes (Daniel & Vining, 1983, pp. 39–84; Zube et al., 1982). However, they are limited by the necessarily subjective character of the evaluation of the landscape by individuals and so cannot be readily applied in a context of regional planning decision-making.

The second approach brings together what are called expert methods (Daniel, 2001). They start from the postulate that a landscape can be evaluated objectively and that its intrinsic quality depends on various visual attributes. By this approach, landscape exhibits inherent qualities that can be evaluated as neutrally as possible, although a strict objectivity may be not totally reached. The approach generally entails making a descriptive inventory of the various components of the landscape and capturing them in the form of variables describing the landscape content, shapes, colors, diversity, texture, harmony, and coherence (Vouligny et al., 2009). This landscape description may be based on (1) a field approach whereby an expert attempts to describe the landscape as seen *in situ*, using a grid to evaluate the landscape (Arriaza, Cañas-Ortega, Cañas-Madueño, & Ruiz-Aviles, 2004; Otero Pastor, Casermeiro Martínez, Ezquerra Canalejoa, & Esparcia Mariño, 2007; Vouligny et al., 2009); (2) a cartographic or GIS approach using digital modeling whereby landscape information is based on spatial data describing altitude and land use (Bastian, McLeod, Germino, Reiners, & Blasko, 2002; Bishop, 2003; Cavailhès et al., 2009; Domingo-Santos et al., 2011; Horst, 2006). The *in situ* approach provides a wealth of information but that is limited to the survey sites; by contrast, digital modeling can be used to evaluate the landscape systematically and continuously in space, the quality of the evaluation being closely tied to the precision of the initial data. Otero Pastor et al. (2007) compare a cartographic and an *in situ* assessment method. They show that there are no significant differences between the two and that a cartographic method with accurate information can be used in landscape assessment to make savings compared with field observation.

Within the approaches based on spatial data, GIS visibility analyses are particularly relevant for landscape assessment (de la Fuente de Val, Atauri, & de Lucio, 2006; Sang, Ode & Miller, 2008). Two main bodies of GIS computation methods exist for modeling the visible landscape: the sight-line method (Fisher, 1996; Joly, Brossard, Cavailhès, Hilal, Tourneux, Tritz, Wavresky, 2009) involves characterizing the visible landscape from a count of pixels seen from virtual viewpoints whereas the solid angles method (Domingo-Santos et al., 2011) uses trigonometric calculations to define the visual exposure of visible landscape elements (Llobera, 2003). The latter method measures the visual salience of landscape characters on the retina of a potential observer.

There are currently no studies comparing approaches based on *in situ* metrics and GIS visibility metrics to explain residential satisfaction related to landscape. The purpose of this paper is to compare the capacity of each group of landscape metrics to explain residential satisfaction of individuals by: (1) a GIS-based approach that involves generating spatial visibility metrics; (2) an *in situ* approach based on collecting landscape information by means of a field audit. Our main hypothesis is that the field audit is expected to explain more about individuals' landscape satisfaction because its descriptors are qualitatively richer. If this hypothesis is confirmed, it shall call into question the value of GIS visibility metrics based on land cover data. Conversely, if GIS visibility metrics explain more about individuals' landscape satisfaction, they could be substituted with interest for *in situ* observations. If both approaches have similar explanatory powers, then we would need to examine whether the methods complement or duplicate one another. This study has been conducted in a suburban area near Besançon (eastern France). The choice of study area means we can reexamine the results of a residential survey reported in Youssoufi and Foltête (2013).

2. Material and methods

2.1. Study area

Besançon is a medium-sized city of about 120 000 inhabitants around which a suburban ring has developed since the 1970s and now counts some 60 000 inhabitants. The study area chosen lies to the north-west of Besançon (Fig. 1). It is made up of a group of 11 administrative districts (*communes*) where substantial suburbanization has occurred. The relief is characterized by low limestone hills separated by marl depressions. Land cover is mostly woodland (40%), farmland (34%), and villages (14.5%) with varying degrees of detached suburban housing.

2.2. Measuring the degree of landscape satisfaction

The degree of landscape satisfaction was evaluated by a survey in June 2009 and presented in Youssoufi and Foltête (2013). Here we set out the most important points of the survey. A sample of 1057 people was stratified by population of the administrative districts. Each respondent answered a series of questions about their residential environment and was GIS-referenced based on the postal address. Four main themes were covered by the survey: (1) evaluation of the surrounding landscape, (2) access to various urban amenities, (3) perception of the residential built environment in terms of aesthetics and density, and (4) evaluation of the individual and public transport conditions. Individuals were invited to respond to a series of assertions by saying whether they agreed with them.

A multiple correspondence analysis (MCA) was performed (Tenenhaus & Young, 1985) to synthesize the responses in the form of factorial axes (see Appendix A and B for details). The interpretation made it possible to identify the first factor (the only one considered in the present article) as the landscape satisfaction gradient. As in Youssoufi and Foltête (2013), the coordinate of individuals on this axis is the target variable of the analysis. The second factor concerns the level of satisfaction for accessibility to urban amenities.

In the present study, the constraints of the field survey for producing *in situ* metrics (see Section 2.4.) mean that work has to be done on a subsample of individuals. A random draw of 60 individuals (5.7%) was made from the initial sample of 1057, maintaining the spatial stratification by administrative district. Fig. 2 shows the level of satisfaction and dissatisfaction for these 60 individuals.

2.3. Field audit and in situ metrics

The field audit consisted in examining the landscape on the ground by a descriptive inventory of landscape scenes (Arthur,