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Performance evaluation of multiple methods for landscape aesthetic suitability mapping: A comparative study between Multi-Criteria Evaluation, Logistic Regression and Multi-Layer Perceptron neural network

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A B S T R A C T

Landscape aesthetics, as a cultural ecosystem service should be included in land-use planning. Therefore, appropriate mapping algorithms that allow quick and accurate visualization of the scenic beauty in a spatially-explicit manner are of significant importance. The present study implements and compares three mapping approaches including Multi-Criteria Evaluation (MCE), Logistic Regression (LR) and Multi-layer Perceptron (MLP) neural network in a GIS environment for landscape aesthetic suitability mapping in the Ziarat watershed basin of northeastern Iran. Ground truth data were collected during several field observations and landscape photographs were taken in winter and autumn. Mapping algorithms were compared for their spatial accuracy using the Receiving Operator Characteristic (ROC) method and the comparison was made for automatic identification of scenic beauty on routes applying landscape metrics. According to the results, the ROC statistic scored at 0.94, 0.93 and 0.88 for MLP, LR and MCE methods, respectively. In addition, landscape metrics-derived results depicted the MLP method as more successful for automated delineation of a connected network of scenic routes. Finally, due to acceptable spatial accuracy, this study suggests expert-based mapping methods such as MCE and statistical algorithms such as LR can be used as ground truth layers for a sampling of presence/absence data. The map containing sampled points can be used as a training layer for iterative artificial intelligence-based methods such as MLP for quick and accurate suitability mapping of landscape aesthetics in neighboring watersheds. This application demonstrates how landscape aesthetics as one of cultural ecosystem services can be integrated into land-use planning practices.

1. Introduction

Scenic landscapes, as one of the cultural ecosystem services, are elements of the environment with capability for human enjoyment and in some cases, they are considered as worthy parameters of nature for conservation and management (Bishop and Hulse, 1994). However, cultural ecosystem services usually suffer from poor quantification and integration into management plans. The Millennium Ecosystem Assessment (Sarukhán and Whyte, 2005) defined cultural ecosystem services as “the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences”.

According to Naveh (1995), scenic landscapes are products of interactivity between human and nature systems where natural landscapes become inhabited, influenced or altered by mutual relationships between ecological and socioeconomic processes. Such interrelated feedback can lead to physical modifications of the environment that ultimately can be seen. Consequently, the physical properties of the landscape can be detected and analyzed by their visual characteristics (Ayad, 2005).

Along with the development of detailed and functional land-use planning paradigms, it was evident that the cultural ecosystem services required more work on finding relevant tools to measure, model and visualize scenic properties of the landscapes (Zhang et al., 2000; Ayad, 2005; Foltête and Litot, 2015). Franco et al. (2003) assessed the impacts of an agroforestry network on the perception of the landscape in terms of scenic beauty. They reported that there is a positive impact on the perceptive evaluation of the landscape and also a strong relationship between human scenic beauty perception and the landscape metrics. Ayad (2005) highlights that scenic quality increases as 1) topography

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variability and relative relief increases, (2) the occurrence of various water forms and water areas increases (3) patterns of ecological communities (e.g. forestlands and grasslands) become more diverse and mixed, (4) natural areas increase and human-constructed elements decrease and (5) land-use compatibility rises and land-use edge variety decreases. Vries et al. (2012) implemented a web-based platform for quantifying the impact of cultural elements on the scenic beauty of landscapes and some mitigation measures were proposed. They reported that various cultural parameters have different influences on landscape aesthetics among which wind turbines had the most effective minimizing impact. Frank et al. (2013) presented an objective and landscape metrics-based evaluation of scenic beauty. They concluded that landscape metrics have the potential for monitoring landscape aesthetics. Alivand et al. (2015) used VGI (Volunteered Geographic Information) data and viewshed analysis for automated computation of scenic routes in a trip planning system. Sakieh et al. (2016) measured the relationships between landscape aesthetic suitability and spatial patterns of urbanized lands to perform an integrated modeling framework for developing urban growth scenarios.

Considering these studies, successful land-use planning practices enriched with cultural ecosystem services require innovative, integrative and spatially-explicit tools for quantifying and mapping landscape aesthetics. This is because the scenic beauty is a holistic property of the landscape that is not analytically tractable from system components and their attributes alone. Therefore, such studies become highly data-demanding, methodologically complex and in some cases over-subjective. Thus, the suggestion of an algorithm for landscape aesthetic suitability mapping can facilitate inclusion of cultural ecosystem services into land-use planning studies.

There are various approaches to conducting a map overlay study including expert-based methods such as Multi-Criteria Evaluation (MCE), statistical approaches such Logistic Regression (LR) and Artificial Intelligence-based methods such as Multi-Layer Perceptron (MLP) Neural Network (Riveira and Maseda, 2006). These methods are currently being implemented for suitability mapping of utilities such as urbanization (Pijanowski et al., 2002; Hu and Lo, 2007; Pao, 2008; Mahiny and Clarke, 2012; Sakieh, 2013; Sakieh et al., 2015; Goodarzi et al., 2016), environmental conservation (Singh and Kushawaha, 2011; Mehri et al., 2014; Sakieh et al., 2015; Hasani et al., 2016) and agricultural activities (Mozumder and Tripathi, 2014; Sakieh et al., 2015; Baghri Bodaghabadi et al., 2015). But these methods are not often used for mapping cultural ecosystem services. Accordingly, a systematic comparison between these algorithms could provide valuable insights into their functionality for aesthetic suitability mapping and a basis for explicit, quick and accurate integration of such variables into land-use planning efforts. As a consequence, this study attempts to answer the following questions:

1) When mapping landscape aesthetic suitability, which one of the MCE, LR and MLP mapping algorithms yield results with higher spatial accuracy?
2) Which one of these methods automatically provides a more connected network of scenic routes in the natural landscape?

2. Materials and methods

2.1. Study area

The geographic location of the study area spans the Ziarat watershed basin of Golestan Province in northeastern Iran, with a total area of 9780 ha (Fig. 1). The average elevation and slope of the area is 1708 m and 41.5%, respectively (minimum = 550 m and maximum = 3806). The area is densely covered by Caspian Hyrcanian mixed forests. These forests possess significant biodiversity and are home to many endemic, native and migratory species of plants, birds and large mammals. This ecoregion is an important area for conservation not only because of its ecological merits but also because these ecosystems have a considerable aesthetic value. The area is visited by thousands of tourists and researchers each year for recreational and scientific purposes. Following the recent designation of Golestan as a new province in national administrative boundaries in Iran, the area became even more attractive for economic activity. In this regard, tourism agencies are now establishing more facilities to attract visitors. Therefore, evaluation of the area for its aesthetic and recreational potential is important for effective and functional management of the region.

2.2. Assessing landscape scenic beauty through field observations and workshop experiments

As the first step, several field observations were undertaken during the autumn and winter seasons of 2013, which are the most attractive periods of the year in the targeted area. This is because the area is visited by many local and international tourists during these seasons. Main walking tracks for field investigations included Ziarat waterfall, Chomazchal, Mazookesh, Talambar, Zebleh, Chekele Pirezan, Sefidcheshme and Khoshadare. These were chosen because they are the main walking tracks in the area. They are also distributed throughout the study area and cover acceptable variability for characteristics of the landscape structure and its elements (Fig. 2). Based on recommendations from experienced tour guides during field observations, several viewpoints along the track network were recorded (using a GPS device). Five hundred photographs were taken from the total number of walking tracks. Fifty of these were randomly selected and arranged to form the questionnaire. The selected set of photographs depicted various characteristics of landscape structure and its elements. In the next step, a workshop was arranged in which several participants from local communities, planners and environmental experts participated.

The participants were requested to rate all photos according to Likert scaling scheme (from 1, non-beautiful, to 5, very beautiful) in order to prioritize walking tracks following visitors' preferences. The rating scheme was supported by other researchers including Givon and Shaphira (1984), Crask and Fox (1987), Jaccard and Wan (1996) and Wu et al. (2006). To determine the most preferred photo, the following equation was used:

$$X = \sum [(W_i \times n_i) \times (W_R \times R)] \quad (1)$$

Where:

X is the scenic value of photo

W_i is the determined weight for the number of individuals, which is obtained from the following formula:

$$W_i = (\frac{n_i - n_{\min}}{N}) \quad (2)$$

where:

n_i is the number of observers who assigned i value to each photo

$n_{\min}$ is the minimum number of observers who assigned i value to each photo

N is total number of observers

R is the grade of each photo according to Likert scaling scheme

W_R is the determined weight for each grade

Accordingly, the final equation can be expressed as follows:

$$X = \sum [(\frac{n_i - n_{\min}}{N}) \times n_i) \times (W_R \times R)] \quad (3)$$

Finally, after specifying the scenic values of each photo as expressed above, the scenic value of each track was calculated through the following equation:

$$R_T = (\sum \frac{X_i}{N}) \quad (4)$$

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