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Original Articles

Inferring landscape change from differences in landscape character between the current and a reference situation

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ABSTRACT

The aim of this paper is to measure the difference in landscape visual character as an indicator of landscape change. We used seven map-based landscape character indicators calculated in two situations in a study area in the centre of the Iberian Peninsula. The first situation corresponds to the current landscape and the second to a reference landscape, assumed to be its historical condition. The results show that the difference in landscape character is mainly due to the loss of naturalness and the increase in landscape complexity brought about by agriculture and urban development. This work is replicable and transparent, and constitutes a methodological step for landscape indication, since it adds a reference value for analysing differences in landscape character and can be used to explain its change.

1. Introduction

Landscapes are resources for nature conservation and recreation, and for people's quality of life and place attachment (Kienast et al., 2015). The European Landscape Convention (ELC) understands landscape to be a territory "as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000). According to Antrop (2000), changes in landscape have increased in frequency and magnitude particularly since the second half of the 20th century. These changes are often irreversible and affect resources and heritage values, while creating new landscapes with new characteristics. Urbanisation, the effects of transportation networks and globalisation are the most important forces driving these changes and the emergence of new landscapes (Antrop, 2004). In this context, landscape planning, management and regulation are a challenge for researchers, planners, and policy makers.

It is necessary for natural resource management and spatial planning to monitor landscape changes over time (Kienast et al., 2015; Liu and Yang, 2015). Landscapes also have a heritage value, since they are an inherent part of the cultural and perceived environment and play a key role in people's place attachment (Van Eetvelde and Antrop, 2009). The characteristics of new landscapes brought about by anthropogenic activities such as transportation or urbanization are also considered in the European Landscape Convention ELC (Council of Europe, 2000; Van Eetvelde and Antrop, 2009). The Convention states that the landscape characteristics and the forces and pressures that transform them should be analysed by noting the changes in the landscape. There is a whole body of work on the assessment of landscape change detection, most of which focuses on land cover change. Changes in landscape structure patterns are assessed using GIS map-based landscape metrics (Amici et al., 2017; Paudel and Yuan, 2012), satellite images (Badjana et al., 2017; Wohlfart et al., 2017) or a combination of both (Fan and Ding, 2016; Liu and Yang, 2015; Martinez del Castillo et al., 2015; Sklenicka et al., 2014; Van Eetvelde and Antrop, 2009). Land cover information is obtained from image interpretation, while the use of remote sensing is enhanced by its integration with GIS techniques (Coppin et al., 2004). GIS techniques allow the inclusion of quantitative landscape ecology indices (Martinez del Castillo et al., 2015; Paudel and Yuan, 2012) and the analysis of the relationships between land-use transformations and topographic parameters (Amici et al., 2017).

The ELC also proposed the use of the term Landscape Character (Council of Europe, 2000). This is defined as "a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse" (Swanwick, 2002p. 8). Landscape character can be assessed using a set of indicators (Kienast et al., 2015; Ode et al., 2008). Ode et al. (2008) described a framework for assessing landscape visual character using theory-based visual indicators based on the work of Tveit et al. (2006), who carried out a review of the literature on landscape perception and identified nine key concepts to describe the visual character of the

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landscape: stewardship, coherence, disturbance, visual scale, historicity, imageability, naturalness, complexity, and ephemera. Their framework is a theory-based scheme with four levels of abstraction: the concepts, their visual dimensions, landscape attributes contributing to the concepts, and potential visual indicators for mapping and quantifying the concepts. Their approach considers visual quality to be the holistic experience of all these elements. It is consistent with the ELC and has been used as a theoretical framework in several researches (Fry et al., 2009; Martín et al., 2016; Ode et al., 2009, 2010; Sang and Tveit, 2013; among others).

A number of works study changes in the landscape in some of the elements that give it character. For example, Ode et al. (2009) proposed a set of indicators to assess changes in the landscape visual scale: proportion of open land, viewshed size, viewshed shape, depth of view and obstruction of view. Van Eetvelde and Antrop (2009) studied structural changes in land use, building and field patterns between two time periods. Sklenicka et al. (2014) evaluated the landscape structure quantifying various aspects of landscape heterogeneity, fragmentation and stability, during two years. Martín et al. (2016) proposed seven landscape character indicators to measure the main concepts proposed Tveit et al. (2006), and applied them to assess whether a road conveys the character of the landscape of which it forms part.

Landscape Character Assessment (LCA) requires a holistic approach that integrates both natural and cultural information (Warnock and Griffiths, 2015; Trop, 2017). However, it is less common to find works that assess changes in landscape character from a holistic point of view. Notable among these are the Swiss Landscape Monitoring Program (Kienast et al., 2015) and The Living Landscapes approach (Warnock and Griffiths, 2015). Kienast et al. (2015) proposes a set of indicators for the Swiss Landscape Monitoring program, divided into physical landscape properties and land-use indicators (general, recreational use, agriculture and forestry use), perception indicators (evolutionary determined landscape perception, culturally determined landscape perception), and indicators relating to legal aspects of landscape conservation. Warnock and Griffiths (2015) propose an approach to LCA that introduces a spatial framework based on homogeneous landscape units that reflect differences in the natural and cultural dimensions of landscapes at different scales. Atik et al. (2017) assume this approach and they combine map-based biophysical information with on-site visual landscape characteristics into the LCA process.

Landscape planning, management and regulation must be approached through evaluation and assessment (Dale and Kline, 2013; De Montis, 2014), and should combine the conservation and protection of ecosystems with maintaining the visual landscape quality affecting people's valuation of places (Dronova, 2017). According to Jessel (2006), visual landscape should be a part of ecological monitoring, as a reflection of ecosystems' informative function, their environmental structure, and their function in satisfying people's needs. LCA helps shed light on the relationship between human perception and the territory, which contributes to its suitability as a method for land-use planning, natural resource management, and identifying priorities for environmental restoration and enhancement (Bartlett et al., 2017). Environmental assessment indicators help document changes and understand the causes and effects of those changes. A key issue when selecting landscape –or any environmental- indicators is providing a reference value against which to compare, to define target values or to evaluate if changes have positive or negative impacts (Hersperger et al., 2017; OECDE, 2003). This research topic is still much-needed in the field of landscape studies (Hersperger et al., 2017). Reference conditions can be used to measure the effects of human activities (Karr and Chu, 1999). The indicator scores are compared to some expected or reference condition, i.e., a range of values rather than a single absolute value. According to Stoddard et al. (2006) the reference can be (i) a historical condition (the condition of streams at some point in their history, for example, before the start of any human disturbance; (ii) the best attainable condition (expected condition of least-disturbed sites if the best possible management practices were in use for some period of time); and (iii) the least disturbed condition (the best available conditions given today's state).

The aim of this paper is to measure the difference in landscape visual character as an indicator of landscape change. We compare the current landscape character with a reference situation, and consider changes in agricultural, urban and transportation land uses. This work provides a methodological step for landscape indication, since it adds a reference value to an existing LCA method to analyse the differences, and can be used to explain landscape change. The set of landscape character indicators based on GIS techniques proposed by Martín et al. (2016), which are sustained on the solid theoretical framework proposed by Tveit et al. (2006), are used in two scenarios (current landscape and reference landscape as a historical condition). The Madrid Region (Spain), a territory within the area of influence of a metropolis, serves as a case study.

2. Methodological approach

The proposed methodology describes two landscape states (scenarios) and the difference between them. The first state is the current landscape, which is characterised through a set of indicators proposed in previous research by Martín et al. (2016), and calculated with GIS. The indicators measure the concepts that define the landscape following the approach of Tveit et al. (2006) (Table 1). The second state is characterised with the same set of indicators, and corresponds to a reference landscape situation (a historical condition). The difference between the two scenarios is then measured as an indicator of landscape change. The analysis of the difference is used to explain the manmade changes in the landscape.

2.1. Approach to landscape character assessment

2.1.1. Observation points

The landscape character is assessed from a set of observation points arranged in a grid with a separation of less than the limit of visual perception, in order to cover the whole area without leaving any blind spots.

Once the observation points are defined, the viewsheds with a visual of 360° are calculated from each one. The limit up to which the viewsheds are calculated varies depending on the authors. In this work, this limit is considered to be where the background scene becomes separated from the foreground and mid views. Most individual elements in the background scene are barely distinguishable, the colours become paler, the lines subdued, and the contrasts in texture decrease. The limit used in this work is 5 km from the observer and was established by the USDA Forest Service (1974) to separate the background from the foreground and mid views. This 5 km value has also been used in previous research works on visual landscape (eg. Brabyn and Mark, 2011; Lange, 2001; Martín and Otero, 2012).

2.1.2. Indicators

Landscape character is assessed by the following variables measured with a set of GIS indicators: coherence, disturbance, historicity, visual scale, complexity, naturalness and ephemera. Table 1 explains the indicator selected to measure each concept (a more detailed description on the use of the indicators can be found in Martín et al. (2016), and the complete description of the landscape concepts is in Tveit et al. (2006)).

The mapping materials necessary to calculate the indicators are a Digital Elevation Model (DEM), and a land-use database.

The method involves assigning each observation point a value for each indicator to capture the character of the landscape (see Fig. 1):

- CCI_i, $PARA_i$, and S_i are calculated for the whole study area, following Eqs. (1)–(3) (for each pixel i, land-use patch i, and natural land-cover patch i, respectively). The average value under the