International Journal of Applied Earth Observation and Geoinformation 50 (2016) 95–105

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Using remote sensing products to classify landscape. A multi-spatial resolution approach

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ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form 11 March 2016
Accepted 18 March 2016
Available online 25 March 2016

Keywords:
CORINE
Land cover
NDVI
NOAA
Uncertainty

ABSTRACT

The European Landscape Convention encourages the inventory and characterization of landscapes for environmental management and planning actions. Among the range of data sources available for landscape classification, remote sensing has substantial applicability, although difficulties might arise when available data are not at the spatial resolution of operational interest. We evaluated the applicability of two remote sensing products informing on land cover (the categorical CORINE map at 30 m resolution and the continuous NDVI spectral index at 1 km resolution) in landscape classification across a range of spatial resolutions (30 m, 90 m, 180 m, 1 km), using the Cantabrian Mountains (NW Spain) as study case. Separate landscape classifications (using topography, urban influence and land cover as inputs) were accomplished, one per each land cover dataset and spatial resolution. Classification accuracy was estimated through confusion matrixes and uncertainty in terms of both membership probability and confusion indices. Regarding landscape classifications based on CORINE, both typology and number of landscape classes varied across spatial resolutions. Classification accuracy increased from 30 m (the original resolution of CORINE) to 90m, decreasing towards coarser resolutions. Uncertainty followed the opposite pattern. In the case of landscape classifications based on NDVI, the identified landscape patterns were geographically structured and showed little sensitivity to changes across spatial resolutions. Only the change from 1 km (the original resolution of NDVI) to 180 m improved classification accuracy. The value of confusion indices increased with resolution. We highlight the need for greater effort in selecting data sources at the suitable spatial resolution, matching regional peculiarities and minimizing error and uncertainty.

1. Introduction

Different policies have been developed in Europe aiming to regulate landscape conservation, such as the Pan-European Biological and Landscape Diversity Strategy (Council of Europe, 1996), the Action Plan for European Landscapes (ECNC, 1997) and the European Landscape Convention (Council of Europe, 2000). Specifically, the European Landscape Convention encourages Contracting Parties to identify and classify their landscapes for protection, management and planning. In this way, a wide range of initiatives has been implemented at continental, national and regional scales in Europe, attempting to accomplish this recommendation. Examples are the European Landscape Map (LANMAP2) (Mücher et al., 2010), the Spanish Landscape Atlas (Mata Olmo and Sanz Herráiz, 2003) and the German Typology of Landscapes (Gharadjedaghi et al., 2004). However, despite efforts, the European Landscape Character Initiative (ELCAI) (Wascher, 2005) highlighted discrepancies in these landscape classifications in terms of methodology, data sources, spatial resolution and nomenclature (Mücher et al., 2010), which make them incompatible and largely incomparable (Van Eetvelde and Antrop, 2008). Thus, the development of consistent methodologies for landscape classification, able to identify with realism, basic spatial units for use in environmental applications at a large scale, is necessary to fulfil policy and operational requirements (Blasi et al., 2000).

Numerical landscape classifications allocate patches of territory with similar characteristics (e.g., geology, topography, hydrology, land cover, socio-economy) into homogeneous landscape units. Among all landscape components, land cover is probably the most relevant, as it represents the interface between natural conditions and human influences, both across space and time. There is a wide range of data sources that can be used to describe land cover in

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http://dx.doi.org/10.1016/j.jag.2016.03.010
0303-2434/

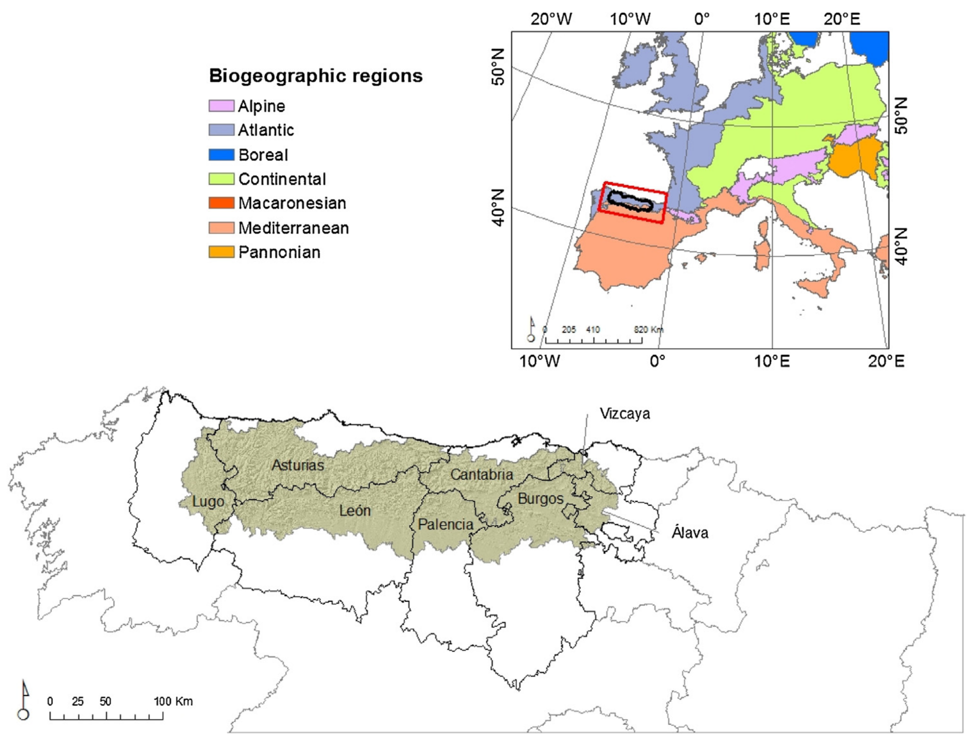

Fig. 1. Study area: The Cantabrian Mountains (NW Spain). Information on biogeographic regions was obtained from the Spanish Ministry of Agriculture Food and Environment (http://www.magrama.gob.es/).

environmental applications (Tomaselli et al., 2013), mainly consisting of categorical land cover maps derived from remote sensing data, as the International Geosphere-Biosphere Programme (Belward, 1996), the FAO land cover classification system (Di Gregorio and Jansen, 1998, 2004) or the CORINE Land Cover Programme (Bossard et al., 2000). Currently, most of these data can be found freely available, which can be useful for landscape managers, mainly when founding is limited (Nagendra et al., 2013). However, the matching between the spatial resolution of these products, with that at which landscape is intended to be characterized it is not always achievable (Garrigues et al., 2006; Shao and Wu, 2008). A lack of appropriate information can result in a gap between both, desired and hard-headed spatial resolution at which patterns and process can be represented (McCabe and Wood, 2006), generating spatial discrepancies between reality and analysis resolution.

Within the European context, CORINE is probably the data source most used to generate integrative landscape classifications in combination with other thematic data (Mücher et al., 2003, 2006, 2010; Van Eetvelde and Antrop, 2008; Cullotta and Barbera, 2011). However, despite its wide application, CORINE is a classification product derived from Landsat TM imagery that shows important problems of uncertainty (Regan et al., 2002), which can be propagated in subsequent analyses (Shao and Wu, 2008). Therefore, it should be carefully evaluated prior use to guaranty its applicability in management (Foody and Atkinson, 2002; Rae et al., 2007; Kennedy et al., 2009; Hou et al., 2013). This issue become especially relevant in mountain systems, where topographic and microclimatic patterns (Oke and Thompson, 2015) make ecological conditions to change substantially over relatively short distances, providing a wide range of environments and hence, a great diversity of habitats and species (Becker and Bugmann, 2001). Because of this environmental heterogeneity, classifying land cover in mountain areas is especially challenging due to the existence of mixed pixels that can mislead the final classifications (Álvarez-Martínez et al., 2010). Considering these constraints inherent to categorical maps, a good alternative could be the use of continuous variables as the spectral indices derived from remote sensing imagery (Suárez-Seoane et al., 2002; Morán-Ordóñez et al., 2012; Álvarez-Martínez et al., 2015; Roces-Díaz et al., 2015). The spectral index most commonly used in environmental research is the Normalized Vegetation Index (NDVI) (Rouse et al., 1973; Tucker, 1979). This index has been related to functional attributes of ecosystems like aboveground net primary production (Paruelo et al., 2001), vegetation functional characteristics such as phenology or primary productivity (Gamon et al., 2013) and vegetation structure such as aboveground biomass (Zhu and Liu, 2015). Many authors have applied this index to produce categorical land cover maps which are then used in subsequent analysis (Muniaty and Ratshibvumo, 2010; Tchuenté et al., 2011; Pervez et al., 2014). Nevertheless, we found no studies using this product as a direct input in integrative landscape classifications. The reason could be that NDVI provides an indication of the “greenness” of vegetation but does not inform directly on land cover, which may hamper the interpretation of final maps (Wang and Tenhunen, 2004).

This study aims to explore the applicability of two of the most readily available open remote sensing products accounting for land cover (the CORINE land cover classification from Landsat at 30 m resolution and the spectral index NDVI from NOAA-AVHRR at a 1 km) for integrative landscape classification across spatial resolutions. In particular, we explore: (i) how classification typology and landscape pattern change across spatial resolution; (ii) how the error and uncertainty associated with data source, spatial resolution and landscape classification process could influence results in a complex mountain system.

2. Material and methods

2.1. Study area

The study area lies in the Cantabrian Mountains (northwest Spain) located at the transition between Eurosiberian and Mediterranean biogeographical regions (Rivas-Martínez, 1987) (Fig. 1). This