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Sensitivity of landscape pattern metrics to classification approaches

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ABSTRACT

Computing of landscape pattern metrics from spectrally classified digital images is becoming increasingly common. Recently, object-orientated image classification is being seen as an alternative and is tending to replace pixel-based approaches. However, object-based methods are likely to influence and produce biases in the results of these spatial analyses. In this study, the sensitivity of 85 landscape metrics to different classification methods and parameters are analyzed. A Landsat image of a complex mountainous forest region of Mexico was classified using pixel-based and object-based approaches. Nine object-based classified images were obtained using a region-growing algorithm based upon different segmentation parameters. Pixel-based classified images were smoothed using different methods (majority filtering, sieving and clumping). Accuracy assessment was carried such that classified images with similar accuracy were compared. Landscape metrics were then derived from the different classified images and compared through a coefficient of variation computing. Almost all the metrics showed variability due to classification and post-processing methods, particularly core area metrics and some proximity and contagion/interspersion indices. Caution must be observed when comparing values of metrics derived from images with slight differences in their characteristics or in the way they have been processed as, for example, in landscape monitoring studies based upon multidate imagery.

1. Introduction

Numerous studies have shown that the spatial patterns of landscape may have significant influences on ecological processes, such as population dynamics, biogeochemical cycling, and biodiversity. Therefore, identifying and characterizing spatial patterns of landscape are often necessary in landscape ecological studies. Over the last decades, such studies have benefited from a proliferation of metrics for characterising landscapes (Frohn, 1998; Gustafson, 1998; McGarigal and Cushman, 2002; Vogt et al., 2007).

The digital nature of land cover information from satellite imagery enables a potentially large number of landscape metrics to be derived (Haines-Young and Chopping, 1996). The large area coverage and repeat viewing of remotely sensed data provides information over a considerable range of spatial and temporal resolution for mapping land cover. Typically, remote sensing images are classified using statistical (maximum likelihood) algorithms that utilise the spectral values of individual pixels. These methods do not make use of spatial information in the image: each pixel is classified independently taking into account only its spectral response and ignoring the response of the neighbouring pixels. As a consequence, the resulting thematic maps usually suffer from a 'salt-and-pepper' effect which is the presence of isolated pixels that belong to a different class than their neighbouring pixels. Due to the limitations of pixel-based methods, alternative approaches, such as contextual and object-oriented classification, which use neighbouring pixel information, are arising. The development of these methods stems primarily from the desire to use the important semantic information necessary to interpret an image, which is not presented in single pixels but rather in meaningful objects and their mutual relations. In object-oriented classification, homogeneous image objects are first extracted and subsequently classified. The mapping results thus represent real-world objects and lack the salt-and-pepper appearance of pixel-based classified images. An overview of these approaches can be found in Walter (2004). Object-oriented approaches are increasingly used by the remote sensing community, because generally they lead to more accurate maps.

The characteristics of the remotely sensed images and the methodologies applied for their processing and classification may strongly influence the spatial characteristics of the land cover data from which spatial metrics are calculated. For instance, many researchers have investigated the influence of spatial resolution (also referred to as grain in the literature) on landscape metrics. These authors found that the effects depend upon the metrics under consideration, and that there exists a spatial resolution beyond which the resolution effects are no longer obvious (Turner et al., 1989; Benson and MacKenzie, 1995; Riitters et al., 1995; Qi

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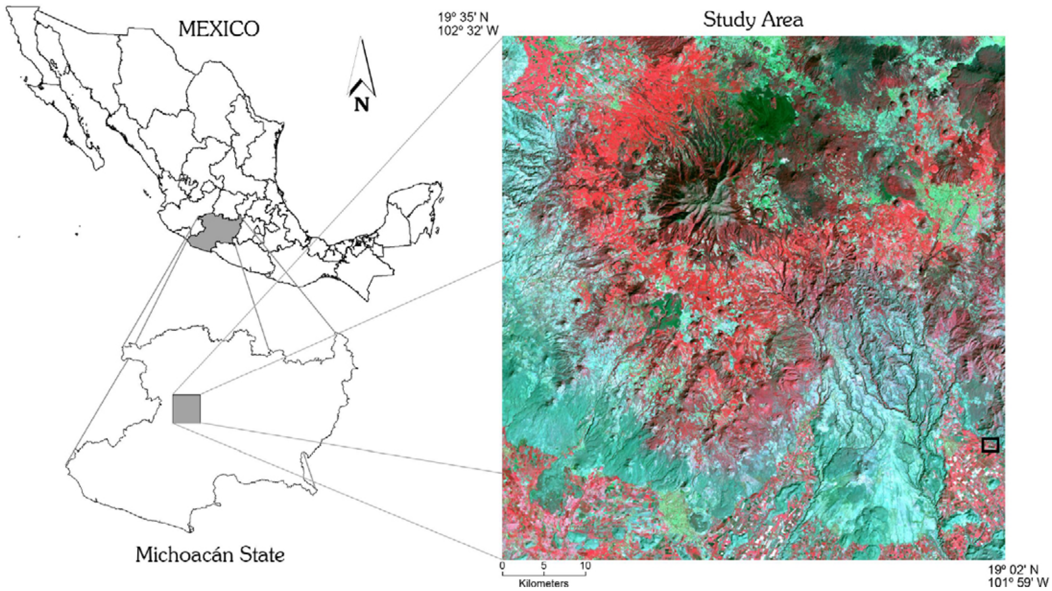

Fig. 1. Location of the study area. Left side of the figure are two sketch maps indicating Mexico and Michoacan state where the study area is located; right side is the false colour composite of Landsat image.

and Wu, 1996). Attention has also been devoted to the effect of the extent of the spatial area over which pattern metrics are estimated. Saura (2002) analyzed the effects of the minimum mapping unit on several commonly used landscape metrics and found that a larger minimum mapping unit implies the underestimation of landscape diversity and fragmentation. Kearns et al. (2005) analyzed the redundancy of metrics and the sensitivity to changes in extent. Brown et al. (2000) tested the effects of the amount of forest cover, the phenology, the atmospheric variability and the post-classification processing on the consistency of four metrics. They found that some metrics (average patch size and number of patches) were more sensitive than others (proportion of cover and edge density). Baldwin et al. (2004) examined the sensitivity of landscape metrics to spatial extent, spatial resolution and thematic resolution.

Recently, new processing approaches are being developed to classify remotely sensed data, such as artificial neural networks, object-oriented classification, fuzzy classification, and others. Pixel-based and object-based oriented approaches produce classified images with different spatial patterns. However, there is no study aimed at assessing the effects of these classification approaches in landscape pattern evaluation. This paper aims at assessing the effects of the classification method (pixel-based *versus* object-based) and of the parameters used to carry out object-oriented classifications on landscape metrics. A superficial analysis suggests that pixel-based classifications lead to more fragmented classified images, and that indices which are sensitive to the presence of small patches are more sensitive to the image processing approach.

2. Study area and data

The study area is located in the State of Michoacán, central west Mexico, within longitude 102°00′W and 102°32′W, and latitude 19°02′N and 19°36′N, and covers an area of approximately 58 km × 60 km (Fig. 1). It is a mountainous region, with elevation ranging from 220 m to 3830 m. The area is a complex mosaic of several land cover types including temperate pine and oak forest, dry tropical forest, orchard (mainly avocado plantations), bare soil (lava flow), crops and pasture lands (including secondary dry tropical forest used as pasture). This spatially complex area was chosen to highlight the differences between the image processing approaches.

3. Material

The available data comprise a Landsat ETM+ image obtained on 16/Feb/2003; ortho-corrected air photographs and a land cover map from the National Forest Inventory 2000. A geometric correction of the image was previously carried out using 86 ground control points extracted from the ortho-corrected photographs with a RMS error below one pixel (16.5 m).

Image segmentation was performed using the image processing package SPRING (Câmara et al., 1996), which is a non-commercial programme ranked second in segmentation quality among seven algorithms tested by Meinel and Neubert (2004). The landscape metrics were generated using the FRAGSTATS program version 3.3 (McGarigal and Cushman, 2002; McGarigal et al., 2002).

4. Methods

The research had several major components: (i) land use/cover classification; (ii) accuracy assessment of classified images; (iii) computation of landscape metrics; (iv) sensitivity measurement; and (v) interpretation and analysis. This section provides the technical details for the first four procedures (Fig. 2).

4.1. Image classifications

Training areas for eight land cover categories (irrigated agriculture, rainfed agriculture, grasslands, orchards, dry tropical forest, temperature forest, human settlement and, bare land) were defined using a colour composite of the Landsat image, the air photographs and field data. Classifications were carried out using the standard pixel-based maximum likelihood method and an object-oriented classification, based upon two steps. First a segmentation was carried out. This consisted of grouping neighbouring pixels with a similar spectral response into the same object. The segmentation was based upon a region-growing algorithm: segments are formed starting from suitable initial pixels (seeds) by iteratively augmenting them with neighbouring pixels that satisfy a chosen homogeneity criteria. In the second