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Support vector machines and object-based classification for obtaining land-use/cover cartography from Hyperion hyperspectral imagery

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ABSTRACT

The Hyperion hyperspectral sensor has the highest spectral resolution, acquiring spectral information of Earth's surface objects in 242 spectral bands at a spatial resolution of 30 m. In this study, we evaluate the performance of the Hyperion sensor in conjunction with the two different classification algorithms for delineating land use/cover in a typical Mediterranean setting. The algorithms include pixel-based support vector machines (SVMs) and the object-based classification algorithm. Validation of the derived land-use/cover maps from the above two algorithms was performed through error matrix statistics using the validation points from the very high resolution QuickBird imagery. Results suggested both classifiers as highly useful in mapping land use/cover in the study region with the object-based approach slightly outperforming the SVMs classification by overall higher classification accuracy and Kappa statistics. Results from the statistical significance testing using McNemar's chi-square test confirmed the superiority of the object-oriented approach compared to SVM. The relative strengths and weaknesses of the two classification algorithms for land-use/cover mapping studies are highlighted. Overall, our results underline the potential of hyperspectral remote sensing data together with an object-based classification approach for mapping land use/cover in the Mediterranean regions.

1. Introduction

Deriving thematic maps, which describe the pattern and the spatial distribution of land cover, has traditionally been performed from remotely sensed data (Chintan et al., 2004). Image classification is the most commonly applied approach in deriving spatially distributed maps of land use and land cover (Borak and Strahler, 1999; Mathur and Foody, 2008). Many classification methods have been developed for classifying a remote sensing imagery; a comprehensive review of the same is given in Lu and Weng (2007). Supervised classification approaches are based on using training samples taken directly from the imagery to be classified and they attempt to group the spectrally similar pixels of a remote sensing imagery using various statistical approaches. Object-based classification is a different technique and is based on the classification of image objects which have resulted from previous segmentation applied to a remote sensing imagery. This method depends on knowledge-based membership functions that clearly define rules to classify a feature, essentially a group of pixels, rather than applying a single decision rule on a pixel by pixel basis (Wuest and Zhang, 2009). Blaschke (2010), in a recent all inclusive overview of the use of object-based classification, underlined its potential for thematic information extraction from remote sensing observations. Evaluation of these two different algorithms for mapping land use/cover in diverse landscapes has gained significance.

Recent advances in sensor technologies have led to the launch of hyperspectral remote sensing systems. Hyperspectral sensors are able to record reflected light from land surface objects in numerous narrow continuous spectral bands from the visible to the shortwave infrared parts of the electromagnetic spectrum, acquiring a vast amount of spectral information (Xu et al., 2008). This allows hyperspectral systems to provide an enhanced level of spectral information useful for a wide variety of applications (Galvao et al., 2005; Dalponte et al., 2009). The potential of hyperspectral images to improve discrimination among similar ground-cover classes in comparison to traditional multispectral images has also been highlighted by earlier researchers (Zhang and Ma, 2009). As a result of the merits offered, the use of hyperspectral imagery is becoming increasingly widespread in various applications including land classification and change detection (Li et al., 2010). Currently, hyperspectral remote sensing

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imagery is regarded as one of the of the more significant Earth observation data sources (Du et al., 2010).

The launch of the Hyperion spaceborne hyperspectral sensor in 2000 under NASA's New Millennium Program onboard the Earth Observer-1 (EO-1) satellite platform opened up an opportunity to close this gap, as it merges the spectral resolution of airborne hyperspectral instruments with the practicality of satellite remote sensing (USGS, 2006). Hyperion is the first spaceborne imaging spectrometer having the same orbital characteristics as the Landsat ETM+ multispectral sensor, only 1 min behind, acquiring spectral information in 242 spectral bands and at a spatial resolution of 30 m. The Hyperion sensor has two spectrometers, one in the visible and near-infrared (VNIR) (bands 8–57, region 427–925 nm) and one in the shortwave infrared (SWIR) region (bands 77–224, region 912–2395 nm). The swath width of Hyperion is 7.6 km across-track, and approximately 53.6 or 80.4 km along-track. A detailed description of Hyperion technical specifications can be found in Folkman et al. (2001) and Ungar et al. (2003). The availability of Hyperion hyperspectral imagery has opened up new opportunities to the remote sensing community to exploit such data in a wide range of applications, including those related to land-use/cover mapping. The potential of Hyperion imagery for land-use/cover mapping has been examined by many investigators (Goodenough et al., 2003; Walsh et al., 2008; Galvao et al., 2009; Pignatti et al., 2009; Pengra et al., 2007; Binal and Krishnayya, 2009).

Although the potential of Hyperion data is widely recognized, to our knowledge, very little attention has been paid in evaluating the different classification algorithms in mapping land use/cover using Hyperion data, in particular, Mediterranean environments. More specifically, comparison of different classification algorithms using Hyperion data for land-use/cover mapping would be of great interest for the Mediterranean conditions, due to the high relevance of desertification and land degradation phenomena frequently pronounced in such regions (Castillejo-Gonzalez et al., 2009). In such a context, in this study, we evaluate the performance of support vector machines (SVMs) and the object-based classification approaches for land-use/cover mapping in a typical Mediterranean setting using the Hyperion data.

2. Study site and datasets

The study area covers approximately 230 km^2, extending from 24° 04′ to 24° 12′ East, and from 35° 22′ to 35° 36′ North, and is located in the prefecture of Chania of the island of Crete, in Greece (Fig. 1, left image). The area is representative of typical Mediterranean conditions in terms of landscape structure and heterogeneity. The terrain of the area is variable, with the average altitude varying from 0 to 800 m above sea level, and a mainly south-facing aspect orientation. The area is characterized by hot and dry summers (April–September) and relatively mild and rainy winters. Geologically, the area is composed of limestone and dolomites and by shallow carcalic lithosols soils. There is a high degree of vegetation cover variation in the area which also changes as the elevation and topography changes. Land is principally occupied by agriculture, mainly vineyards, fruit trees, and olive groves, with significant areas of natural vegetation, mainly schleroplyllous vegetation and grasslands. Also, a large part of the study area is covered by sparse vegetation of low height, often alternating with bare rocks. Urban areas are often discontinuous and considerably less in proportion.

The Hyperion imagery over our test site was acquired on March 17, 2006 (Fig. 1, middle image). The imagery was received at from the United States Geological Survey (USGS) archive as a full long scene (185-km strip) and at level 1 (L1GST) processing. This processing level product is a geotiff image format, and is already radiometrically corrected, geometrically resampled, and registered to a geographic map projection with elevation correction applied (USGS, 2006). In addition, a very high spatial resolution (0.61×0.61 m) panchromatic satellite imagery from a QuickBird-2 sensor with an acquisition date of February 9, 2006 was obtained from Google Earth. Finally, the CORINE2000 Land Cover (CLC) map (JRC-EEA, 2005) with a spatial resolution of

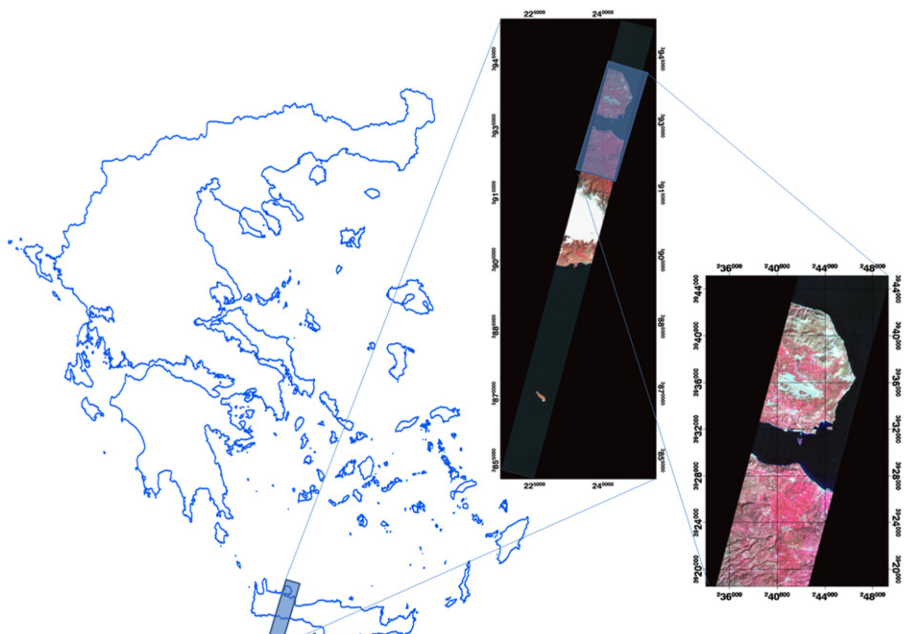

Fig. 1. Location of our study area (left), showing also the Hyperion acquired imagery (middle) and the Hyperion subset covering the studied area of Crete island (right) (Hyperion FCC composed of R, 42; B, 21; G, 11).