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Using texture analysis to improve per-pixel classification of very high resolution images for mapping plastic greenhouses

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Abstract

The area occupied by plastic-covered greenhouses has undergone rapid growth in recent years, currently exceeding 500,000 ha worldwide. Due to the vast amount of input (water, fertilisers, fuel, etc.) required, and output of different agricultural wastes (vegetable, plastic, chemical, etc.), the environmental impact of this type of production system can be serious if not accompanied by sound and sustainable territorial planning. For this, the new generation of satellites which provide very high resolution imagery, such as QuickBird and IKONOS can be useful. In this study, one QuickBird and one IKONOS satellite image have been used to cover the same area under similar circumstances. The aim of this work was an exhaustive comparison of QuickBird vs. IKONOS images in land-cover detection. In terms of plastic greenhouse mapping, comparative tests were designed and implemented, each with separate objectives. Firstly, the Maximum Likelihood Classification (MLC) was applied using five different approaches combining R, G, B, NIR, and panchromatic bands. The combinations of the bands used, significantly influenced some of the indexes used to classify quality in this work. Furthermore, the quality classification of the QuickBird image was higher in all cases than that of the IKONOS image. Secondly, texture features derived from the panchromatic images at different window sizes and with different grey levels were added as a fifth band to the R, G, B, NIR images to carry out the MLC. The inclusion of texture information in the classification did not improve the classification quality. For classifications with texture information, the best accuracies were found in both images for mean and angular second moment texture parameters. The optimum window size in these texture parameters was 3×3 for IK images, while for QB images it depended on the quality index studied, but the optimum window size was around 15×15. With regard to the grey level, the optimum was 128. Thus, the optimum texture parameter depended on the main objective of the image classification. If the main classification goal is to minimize the number of pixels wrongly classified, the mean texture parameter should be used, whereas if the main classification goal is to minimize the unclassified pixels the angular second moment texture parameter should be used. On the whole, both QuickBird and IKONOS images offered promising results in classifying plastic greenhouses.

Keywords: QuickBird; IKONOS; Texture; Land use

1. Introduction

Plastic-covered greenhouses have undergone rapid expansion in recent years, covering over 500,000 ha worldwide. The largest concentrations are in Asia (China with 20,000 ha, Korea with 27,000 ha, and Japan with 70,000 ha), followed by the Mediterranean basin (currently with over 130,000 ha). In the Americas, this trend has also been followed. Due to the high cost effectiveness of this production system, greenhouse agriculture

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strongly influences the economy of the area where it is implemented, in some cases representing practically the only source of income. This is the case at the Almería coast, in south-eastern Spain, with an annual production of approximately 3×10^9 kg of produce at an approximate value of 1900×10^9 Euros. As a consequence of the rapid expansion of the greenhouse surface area, with almost no planning in some of these areas, a number of environmental problems have arisen and are becoming more serious as this surface area keeps growing: the generation and accumulation of vegetable and plastic waste, over-exploitation of water resources in the area, encroachment on protected natural areas, the absence of a road network to cover the needs of existing transport, etc. These factors render the production system unsustainable and endanger the local economy (Parra, 2004). In order to alleviate these problems and to find solutions for the future, different organisations are seeking to establish methods to calculate as accurately as possible the surface area occupied by greenhouses.

In Spain, Sanjuán (2004) carried out a study using Thematic Mapper images from the Landsat 5 and 7 satellites in order to estimate the greenhouse surface area in south-eastern Spain. The problems of the imagery from these satellites to detect greenhouses are similar to those that appear when working in urban areas: few greenhouse pixels are thematically pure, and land use must be inferred from image characteristics or through the incorporation of ancillary information (Guindon et al., 2004). Consequently, aerial orthophotographs are used when working in areas with this type of land use. The arrival of new satellites that provide Very High Resolution (VHR) imagery, such as IKONOS (IK) and QuickBird (QB), has opened new ways of tackling this problem, as they can detect small objects. Although the use of imagery from IK or QB is widespread in urban areas, this is not the case in greenhouse areas. Besides the study by Sanjuán (2004) mentioned above, Agüera et al. (2006) also used a QB image to examine the evolution of the surface area occupied by greenhouses in a zone of south-eastern Spain. These VHR images had already been used for detecting buildings (Fraser et al., 2002; Weber and Ranchin, 2003; Mesev, 2005), roads (Yan and Zhao, 2003; Jin and Davis, 2005), vegetation (Nichol and Lee, 2005), and even buildings damaged by various disasters (Al-Khudhairy et al., 2005). For greenhouse detection by satellite imagery, a series of considerations must be taken into account due to the construction material used and its handling: the spectral signature of plastic changes drastically depending on the vision angle, chemical composition and even age of the plastic.

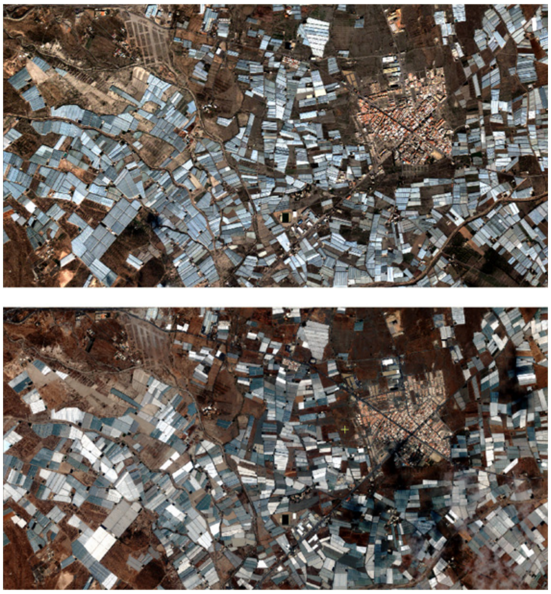

Fig. 1. Study site images from QuickBird (above) and IKONOS (below).

Moreover, in some areas at certain times of the year the plastic sheets are painted white to avoid excessive light and heat inside the greenhouse. At other times of the year, the plastic is not painted, and this changes its response to the band of the infrared spectrum. Also, different types of plastic are used in the same greenhouse, due to partial replacements, (repair of tears), and even materials other than plastic (i.e. the mesh covering the opening for roof ventilation) are used. All these factors trigger widely different spectral responses from one greenhouse to another, even within the same greenhouse, making it difficult to propose a specific image-classification technique for detection. Fig. 1 presents images from QB and IK for the study site, showing the heterogeneity of plastic spectral signature.

Most of the imagery classification methods are based on the statistical analysis of each separate pixel. These methods have shown good performance when used for images with a relatively large pixel size (Wang et al., 2004). In VHR imagery, with smaller pixel size, the detectable spectral variability may increase within a particular class, making the classification process even harder (Cushnie, 1987; Shaban and Dikshit, 2001), especially in the case of anthropogenic structures (Kiema, 2002). To avoid this problem as much as possible, different techniques have been developed that take into account both the spectral information and the information supplied by the texture of the image. These techniques have been used mainly in urban