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SUPPORT OF MULTISPECTRAL VERY HIGH RESOLUTION REMOTELY SENSED IMAGERY FOR OLD-GROWTH BEECH FOREST DETECTION

In the Mediterranean basin human activity has modified landscapes for millennia, nevertheless there are few remote forest areas relatively untouched long enough from direct anthropogenic disturbance to develop old-growth attributes. The aim of this note is to assess the potential of QuickBird (QB) satellite multispectral imagery for detecting old-growth forest stands, considering as case study a Mediterranean beech forest in central Italy. The segmentation-based analysis of QB image proved to be a promising tool to detect scale-dependent pattern of forest structural heterogeneity. Values of remotely sensed attributes are compared in old-growth and not-old-growth stands: the statistical analysis showed that old-growthness is associated to the variability of multispectral reflectance from the image objects (polygons). Green band variability, notably, expressed by Ratio_band_2 has proven to be helpful for predicting old-growthness.

Key words: multiresolution segmentation; very high resolution satellite imagery; QuickBird; forest stand structural attributes; Italy.
Parole chiave: segmentazione multirisoluzione; immagini satellitari ad alta risoluzione geometrica; QuickBird; attributi strutturali di soprassuoli forestali; Italia.

1. Introduction

Old-growth forests became a relevant research topic over the past two decades. They play an important global role in biodiversity conservation (Lindenmayer and Franklin, 2002), in terrestrial carbon storage and eventually sequestration (Carey *et al.*, 2001; Luyssaert *et al.,* 2008) as well as in catchment hydrology (Vertessy *et al.,*1996; Wirth *et al.,* 2009). However there is still large knowledge gap about Mediterranean old-growth forests (Nilsson *et al.*, 2002). In Italy, like in other countries of the Mediterranean basin with old civilization, human activity has modified landscapes for

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millennia making old-growth forests very rare. Nevertheless there are few remote areas where it is still possible to find patches of relatively well-preserved forests. These forests mostly consist of small tracts that, usually due to poor soil productivity or inaccessibility, has remained untouched long enough from direct anthropogenic disturbance to develop old-growth attributes (ROZAS, 2006).

Multi-scale object-based image classification techniques are adapted to provide useful information about spatial heterogeneity in the structure of forest ecosystems (DE KOK *et al.*, 1999; BURNETT e BLASCHKE, 2003; LAMONACA and CORONA, 2007). Multiresolution segmentation (BAATZ and SCHÄPE, 2000), in particular, is able to fully explore the information content of high resolution images (CHIRICI *et al.*, 2003; LAMONACA, 2006). The segmentation procedure helps to detect through changes in image heterogeneity corresponding objects in the field which are relevant to a specific application: e.g. recent studies focus on image segmentation and multi-scale object representation for stand delineation or estimation of forest composition (LECKIE *et al.,* 2003; CHUBEY *et al.*, 2006; RADOUX and DEFOURNY, 2007; LAMONACA *et al.*, 2008).

We analyse the potential of multispectral remotely sensed data for detecting rare old-growth forest tracts under Mediterranean environments. Specific goal of this note is, notably, to assess the potential of QuickBird (QB) satellite multispectral imagery for delineating image objects that are meaningful as concerns attributes of old-growthness.

2. STUDY AREA

The selected study area is a beech forest (*Fagus sylvatica* L.) in the north-eastern part of the National Park of Cilento and Vallo di Diano (PNCVD) (latitude 40°26'; latitude 15°22'; Figure 1). An area of 30 ha was investigated, located around two permanent large sample plots belonging to the forest monitoring network established by the PNCVD (MARCHETTI *et al.,* 2010). The climate is Mediterranean with hot and dry summer and cool and wet winters. The forest is dominated by beech with the presence of oak (*Quercus cerris* L.), maple (*Acer lobelii* Ten., *Acer obtusatum* Willd.), elder (*Sambucus nigra* L.) and yew (*Taxus baccata* L.).

3. MATERIAL AND METHODS

A QB multispectral image (spatial resolution of 2.4 m) covering the study area was acquired under clear sky condition on July 2006. The image was ortho-corrected by a Rational Polynomial Function rectification process.

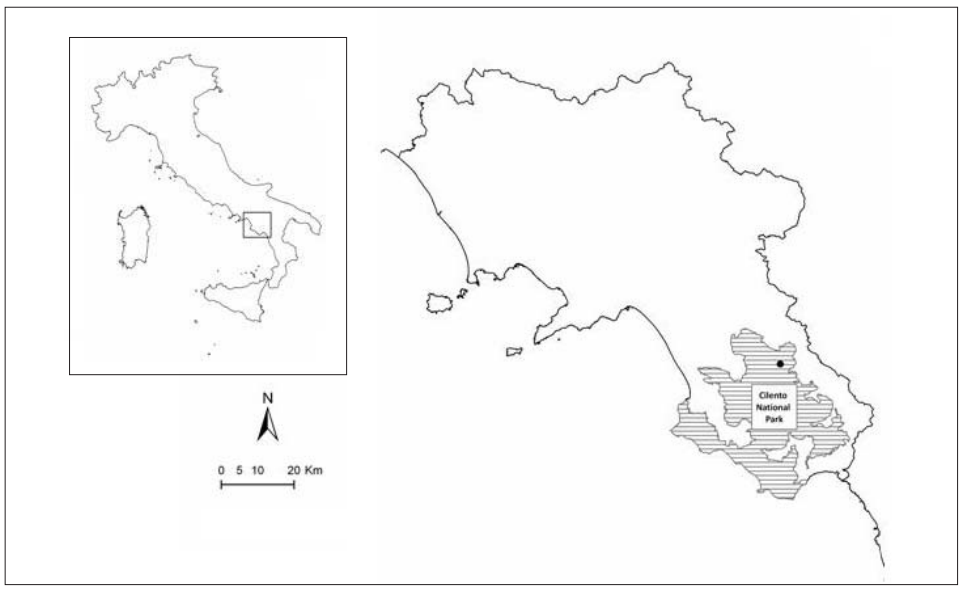

Figure 1 – Location of the study area.

A portion of the QB image corresponding to the study area was segmented to produce two segmentation levels using Definiens Developer 7 software (Definiens) (Figure 2). For the first-level of segmentation the following segmentation parameters were used: scale parameter = 50; geometric heterogeneity = 0.6; compactness = 0.9. For the second-level of segmentation the parameters were: scale parameter = 25; geometric heterogeneity = 0.6; compactness = 0.9. The setting of such parameters was guided by the size of meaningful ecological objects that can be extracted from the scene, according to previous findings (LAMONACA *et al.,* 2008).

The polygons derived from the second level of segmentation were localized in the field with the support of a GPS instrument (Trimble) and classified as old-growth or not-old-growth stands, based on stand structural parameters. Old-growth stands were considered as characterized by: basal area > 29 m^2ha^{-1} (KEDDY and DRUMMOND, 1996), number of large trees (dbh > 40 cm) > 10 ha^{-1}, multi-layered canopy (OLIVER and LARSON, 1996). Adjacent old-growth polygons were merged to derive a map of the distribution of old-growth stands with a minimum size of 1 ha, as suggested by RUBIN *et al.* (2006) for temperate forests.

Two sample areas of 2.5 ha each were established under the same site conditions, one in the old-growth forest tract and the other in the not-old-growth forest tract, with centres coinciding with two close permanent sample plots surveyed by MARCHETTI *et al.* (2010). The two sample areas were

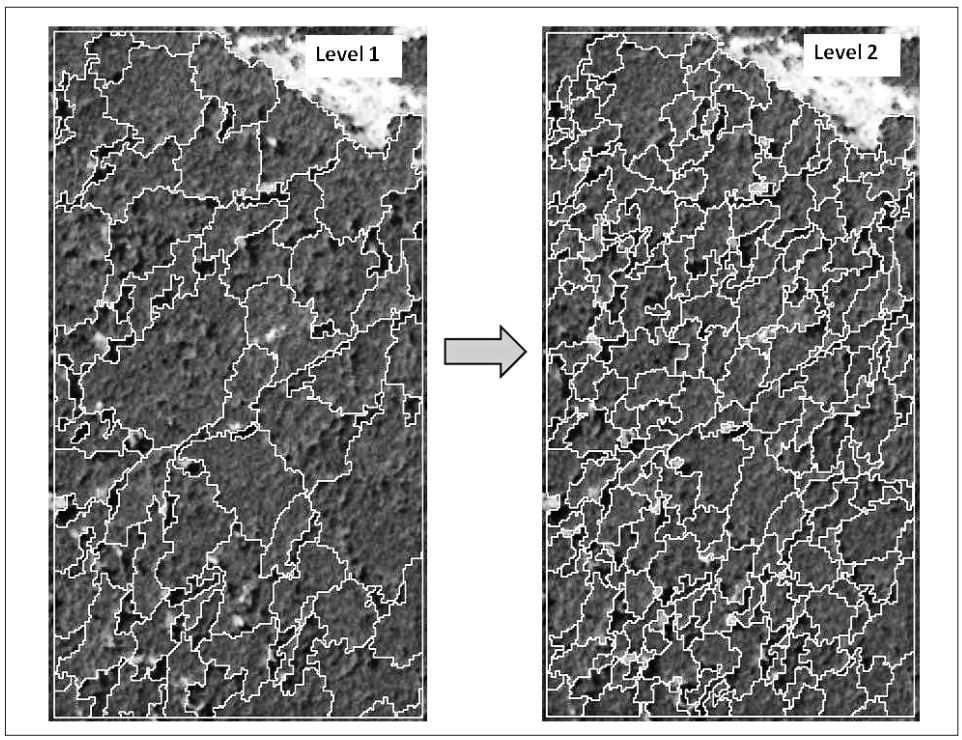

Figure 2 – Multi-scale segmentation of the multispectral Quick Bird image of the study area.

characterized by means of several remotely sensed attributes extracted for each image polygons: (i) geometric attributes (Asymmetry, Border Index, Compactness, Density, Length/Width, Roundness: for definitions see BAATZ *et al.,* 2004); (ii) spectral attributes (Brightness, Max Difference, Ratio: for definitions see BAATZ *et al.,* 2004); (iii) the minimum, maximum, average, median, coefficient of variation and range of digital number of each of the four QB bands; (iv) the minimum, maximum, average, median, coefficient of variation of three vegetation indices (Normalized Difference Vegetation Index, ROUSE *et al.,* 1974; Soil-Adjusted Vegetation Index, HUETE *et al.,* 1985; Chlorophyll Vegetation Index, VINCINI *et al.,* 2007). The differences among the two samples were assessed by one-way analysis of variance, with a p-value of 0.05 chosen as critical for statistical significance.

4. RESULTS

The multiresolution segmentation algorithm minimizes the multi-spectral heterogeneity within QB image objects: it allows to create an

hierarchy of image polygons that are increasingly homogeneous in terms of geometric and spectral properties across a range of (coarse to fine) spatial scales.

An important issue for getting qualitatively convincing segmentation results is the selection of scale parameters appropriate to the research question being addressed. In the examined case study, field measurements indicated that the first level of segmentation produced image polygons that are too large compared to the field-observed patchiness in old-growthness. Instead, second level image polygons are associated to more structurally homogeneous forest stands, with an average size that makes the field classification operatively feasible. Hence, these second-level polygons were used to detect old-growthness. In the two sample areas old-growth stands were included within 11 second-level polygons having an average area of 0.23 ha (std. dev. = 0.15 ha); not-old-growth stands were included within 19 second-level polygons having an average area of 0.13 ha (std. dev. = 0.07 ha), respectively.

The two sample areas showed significant differences concerning six attributes associated with the multispectral reflectance of the stands (Table 1). Brightness was lower for the old-growth polygons, while the opposite holds for MaxDifference. From a general point of view, old-growth stands proved to be characterized by higher variability of multispectral reflectance. Distinctively, old-growth polygons were characterized significantly higher Ratio parameters in all the bands.

A logistic model was developed to test the predictive potential of the considered image for predicting old-growthness in the considered beech forest. The significance of the effect of each remotely sensed attribute was assessed by the likelihood ratio test based on the chi-square statistics, as the difference in -2 log-likelihoods (-2LL) between the final model and a reduced

Table 1 – Mean values of remotely sensed attributes significantly different between old-growth and not-old-growth stands ($p < 0.05$).

Remotely sensed attribute	*Old-growth*	*Not-old-growth*
Brightness	324.7	362.8
Max Difference	2.270	1.900
Ratio_band_1	0.105	0.092
Ratio_band_2	0.137	0.119
Ratio_band_3	0.066	0.057
Ratio_band_4	0.521	0.436

model formed by omitting an effect from the final model; the null hypothesis was that all parameters of that effect were 0 (for details, see HOSMER and LEMESHOW, 2000). The adopted likelihood-ratio test allows to control the independence of the variables included in the logistic regression and provides better test for an effect than those based on the Wald statistics (HAUCK and DONNER, 1977). The regression fitted significantly for Ratio_band_2 parameter, with a Cox&Snell R^2 value of 0.75. Probability of old-growthness increases as the Ratio_band_2 increases.

5. CONCLUSIONS

The aim of this note has been to show techniques for supporting old-growthness detection by remotely sensed imagery. The segmentation-based analysis of QB image has been confirmed as a promising tool to predict scale-dependent pattern of forest structural heterogeneity (LAMONACA *et al.,* 2008). It allows to dissect in a semi-automatic way a given forest area into nested polygons characterized by expected decreasing levels of structural heterogeneity. The multiresolution segmentation may improve the spatial design of a monitoring protocol to assess forest old-growthness: the image polygons can be used as strata to optimize the field sampling design.

The statistical analysis showed that old-growthness is related to the variability of multispectral reflectance, as also noticed by MANES *et al.* (2010). Green band variability as expressed by Ratio_band_2 has proven distinctively helpful for predicting old-growthness. Based on these findings and exploiting similar image processing techniques, we expect to increase the portability of relationships between old-growthness and the remotely sensed attributes here considered for other sites.

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RIASSUNTO

Supporto di immagini multispettrali ad alta risoluzione per la individuazione di boschi vetusti di faggio

Nel bacino del Mediterraneo il paesaggio è stato modificato per millenni dall'attività dell'uomo; tuttavia esistono alcune aree forestali, relativamente isolate, escluse dall'attività antropica diretta per un tempo sufficientemente lungo da permettere lo sviluppo di caratteristiche proprie della fase di vetustà. Scopo di questa nota è valutare le potenzialità di immagini satellitari multispettrali Quick Bird nell'individuazione di soprassuoli vetusti, con riferimento a un caso di studio in boschi di faggio del centro Italia. L'analisi di immagini QB si è rivelata un valido strumento per definire modelli scala-dipendenti di eterogeneità strutturale della foresta. I valori di attributi telerilevati sono stati confrontati in soprassuoli vetusti e non-vetusti. L'analisi statistica ha mostrato che la condizione di vetustà sembra essere legata alla variabilità della riflettanza multispettrale dei poligoni dell'immagine. La variabilità nella banda del verde, espressa dall'attributo Ratio_band_2, si è dimostrata particolarmente utile per identificare condizioni di vetustà del bosco.

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