Exploring forest structural complexity by multi-scale segmentation of VHR imagery

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Abstract

Forests are complex ecological systems, characterised by multiple-scale structural and dynamical patterns which are not inferable from a system description that spans only a narrow window of resolution; this makes their investigation a difficult task using standard field sampling protocols.

We segment a QuickBird image covering a beech forest in an initial stage of old-growthness – showing, accordingly, a good degree of structural complexity – into three segmentation levels. We apply field-based diversity indices of tree size, spacing, species assemblage to quantify structural heterogeneity amongst forest regions delineated by segmentation. The aim of the study is to evaluate, on a statistical basis, the relationships between spectrally delineated image segments and observed spatial heterogeneity in forest structure, including gaps in the outer canopy. Results show that: some 45% of the segments generated at the coarser segmentation scale (level 1) are surrounded by structurally different neighbours; level 2 segments distinguish spatial heterogeneity in forest structure in about 63% of level 1 segments; level 3 image segments detect better canopy gaps, rather than differences in the spatial pattern of the investigated structural indices.

Results support also the idea of a mixture of macro and micro structural heterogeneity within the beech forest: large size populations of trees homogeneous for the examined structural indices at the coarser segmentation level, when analysed at a finer scale, are internally heterogeneous; and vice versa.

Findings from this study demonstrate that multiresolution segmentation is able to delineate scale-dependent patterns of forest structural heterogeneity, even in an initial stage of old-growth structural differentiation. This tool has therefore a potential to improve the sampling design of field surveys aimed at characterizing forest structural complexity across multiple spatio-temporal scales.

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1. Introduction

In the study of ecological systems spatial heterogeneity, multiple-scale analysis and hierarchy are becoming increasingly used concepts. The complex systems approach, notably, is emerging as a possible unifying theory for a comprehension of the structure and functioning of ecological systems across spatio-temporal scales (Proulx, 2007). A complex system can be generally described as a network of many components whose

aggregate behaviour is both due to, and gives rise to, multiple-scale structural and dynamical patterns which are not inferable from a system description that spans only a narrow window of resolution (Parrott, 2002). Stated another way, the complex systems approach asserts that ecological relationships between patterns and processes span multiple scales of organization; ecosystems show a modular and hierarchical topology in which higher-level structures emerge from lower-level interactions (Proulx & Parrott, 2008).

Spatial heterogeneity is regarded a key dimension of ecological complexity (Cadenasso et al., 2006): it can be defined as the uneven, non-random spatial distribution of ecological entities. Forest habitat heterogeneity is an example of this kind of

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