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A multi-scale approach for modeling fire occurrence probability using satellite data and classification trees: A case study in a mountainous Mediterranean region

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Abstract

Fires constitute one major ecological disturbance which influences the natural cycle of vegetation succession and the structure and function of ecosystems. There is no single natural scale at which ecological phenomena are completely understood and thus the capacity to handle scale is beneficial to methodological frameworks for analyzing and monitoring ecosystems. Although satellite imagery has been widely applied for the assessment of fire related topics, there are few studies that consider fire at several spatial scales simultaneously. This research explores the relationships between fire occurrence and several families of environmental factors at different spatial observation scales by means of classification and regression tree models. Predictors accounting for vegetation status (estimated by spectral indices derived from Landsat imagery), fire history, topography, accessibility and vegetation types were included in the models of fire occurrence probability. We defined four scales of analysis by identifying four meaningful thresholds related to fire sizes in the study site. Sampling methodology was based on random points and the power-law distribution describing the local fire regime. The observation scale drastically affected tree size, and therefore the achieved level of detail, and the most explanatory variables in the trees. As a general trend, trees considering all the variables showed a spectral index ruling the most explicative split. According to the comparison of the four pre-determined analysis scales, we propose the existence of three eventual organization levels: landscape patch or ecosystem level, local level and the basic level, the most heterogeneous and complex scale. Rules with three levels of complexity and applicability for management were defined in the tree models: (i) the repeated critical thresholds (predictor values across which fire characteristics change rapidly), (ii) the meaningful final probability classes and (iii) the trees themselves.

Keywords: Fire risk; Ecological hierarchy theory; Static models; Power-law distribution; Fire history; Observation levels

1. Introduction

The five Mediterranean-climate regions of the world occupy less than 5% of the Earth's surface, yet sustain about 20% of the world total vascular plant species (Cowling et al., 1996) and are considered to be biodiversity "hot-spots". In the Mediterranean Basin, natural and human-caused fires have driven landscape change for thousands of years (Trabaud et al., 1993), constituting one major ecological disturbance which influences the natural cycle of vegetation and the structure and function of ecosystems (Koutsias & Karteris, 2000).

Although fire alters ecosystem and biogeochemical processes at multiple scales (Rollings et al., 2004), most empirical research on the ecological effects of fire has been conducted at the stand level, and then conclusions are often extrapolated to broader scales (McKenzie et al., 2000). However, this kind of generalization is rarely ideal because natural systems show characteristic variability on a range of spatial and temporal scales (Levin, 1992). Indeed, landscape pattern and biodiversity arise through positive feedbacks on short time scales and local spatial scales and are stabilized by negative feedbacks on longer time scales and broader spatial scales (Levin, 2000). Therefore,

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