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ORIGINAL PAPER

Canopy fuel characteristics in relation to crown fire potential in pine stands: analysis, modelling and classification

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Abstract Crown fire occurrence and subsequent crown fire behaviour are strongly dependent on canopy fuel characteristics, especially canopy fuel load (CFL), canopy bulk density (CBD) and canopy base height (CBH). Therefore, quantification of such variables is required for the appropriate selection of silvicultural treatments aimed at reducing susceptibility to crown fire. Data from the IV Spanish National Forest Inventory and individual tree biomass dry weight equations were used to estimate the canopy fuel characteristics of four representative types of pine stands in north-western Spain. Probability of crown fire initiation and crown fire rate of spread were simulated by using the mean surface fuel load observed for each type of pine in this area and assuming different burning conditions. The results indicate that a 22.13 % of the sample plots analysed showed a rather high potential for active crown fire spread under moderate burning conditions, and this value increases to 69.27 % under extreme burning conditions. Equations relating the canopy fuel characteristics to common stand variables (stand density, basal area and dominant height) were fitted simultaneously for each pine, and weighting factors for heteroscedasticity were included. The models explained more than 93.90, 74.70 and 69.42 % of the observed variability in CFL, CBD and CBH, respectively. Basal area was the most important variable for estimating CFL and CBD while dominant height explained most of the observed variability in CBH. The use of the fitted equations together with existing dynamic growth models and fire management decision support systems will enable assessment of the crown fire potential associated with different silvicultural alternatives used in these types of pine stands.

Keywords Canopy fuel load · Canopy bulk density · Canopy base height · Crown fire simulations · CART · Allometric models

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Introduction

Most forest fires in Spain occur in the autonomous region of Galicia (NW Spain), and a larger area of forest land is burned in this region than in the rest of the country (SECF 2010). More than 319,000 hectares of forest land were burned in Galicia between 1999 and 2008 as the result of more than 85,000 wildfire events. In this period, 8.5 % of the tree-covered area in the region was burned, representing 29.9 % of the total tree-covered area burned in Spain. Wildfires, especially crown fires, have therefore become the most important ecological, economic and social forestry concern in Galicia. Approximately 36 % of the tree-covered area in Galicia comprises pure and even-aged pine stands, mainly *Pinus pinaster* Ait. (271,281 ha), *Pinus radiata* D. Don (96,177 ha) and *Pinus sylvestris* L. (32,737 ha), with more than 68 million cubic metres of standing timber (MARM 2011) providing 51 and 27 % of

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