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Carbon emissions and vertical pattern of canopy fuel consumption in three *Pinus pinaster* Ait. active crown fires in Galicia (NW Spain)

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ABSTRACT

Accurate estimation of the canopy fuel load that is consumed during crown fires is critical for improving our knowledge of crown fire behaviour and for quantifying emissions of carbon and other gases during this type of fire. However, there is a lack of information about the actual fuel loads consumed during combustion of the forest stand canopy. Three active crown fires in *Pinus pinaster* stands were selected for quantification of pre- and post-fire vertical fuel load distribution in the canopy, and for the first time an assessment was made of the fuel consumed by size classes and categories (needles, twigs < 6 mm and fine branches 6–25 mm). Relative canopy load consumption was between 56% and 66%. The results revealed that all foliage and most of the dead twigs and fine branches were consumed by fire, and that pre-fire basal area was a good predictor of the total fuel load consumed. Carbon emissions from the canopy during active crown fires was between 3.0 MgC ha^{-1} and 5.0 MgC ha^{-1}. These results may be useful for both crown fire physical modelling and for assessing regional sources and sinks of CO_2. Moreover the information will help in the development of fuel treatments to reduce active crown fire hazard.

1. Introduction

Crown fire poses a special challenge in wildfire suppression tasks. This type of fire is often intense, fast spreading; the risk to firefighters, local inhabitants and property is high, and serious ecological impacts may occur (Scott and Reinhardt, 2001). Active crown fire involves combustion of both, the surface fuel bed and the canopy fuel stratum (Van Wagner, 1977). Consequently, one of the main issues involved in predicting crown fire behaviour is the lack of detailed information about the actual amount of fuels consumed in the canopy during passage of the crown fire front.

Accurate estimation of the canopy fuel load that is consumed in wildfires is critical not only for a better understanding of the crown fire phenomena but also for (i) estimating fire severity, which is a first step in evaluating the ecological impact; (ii) quantifying emissions of carbon dioxide and other gases during active crown fires and (iii) estimating wildfire fireline intensity.

From the point of view of fire severity, crown scorch (among other severity descriptors related to vegetation) can provide information about the potential effects of fire on processes such as soil erosion, tree growth, vegetation regeneration and nutrition cycling (Jain and Graham, 2007; Keeley, 2009).

From the point of view of emissions, wildfire is associated with one of the highest potential risks of loss of stored terrestrial C (e.g. van der Werf et al., 2006; Wiedinmyer and Neff, 2007) and other nutrients (e.g. Johnson et al., 2007; Alves et al., 2011). Fire accounts for the input of 2–4 PgC to the atmosphere each year (van der Werf et al., 2006). This loss pathway is difficult to quantify because of the high degree of spatial and temporal variation in fire emissions (Wiedinmyer and Neff, 2007). However, fire emissions are a critical component of the carbon cycle and must be considered when evaluating regional sources and sinks of CO_2 (Wiedinmyer and Hurteau, 2010; Kasischke and Hoy, 2012). Most studies on C emissions due to wildfires are based on the "fire emissions model" originally defined by Seiler and Crutzen (1980) and used for studies at local, regional and global scales (e.g. Huang et al., 2009; van der Werf et al., 2010; Wiedinmyer and Hurteau, 2010; French et al., 2011; Sun et al., 2011). The general equation for computing total carbon emissions (C_t) is:

$$C_t = ABf_c\beta$$

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