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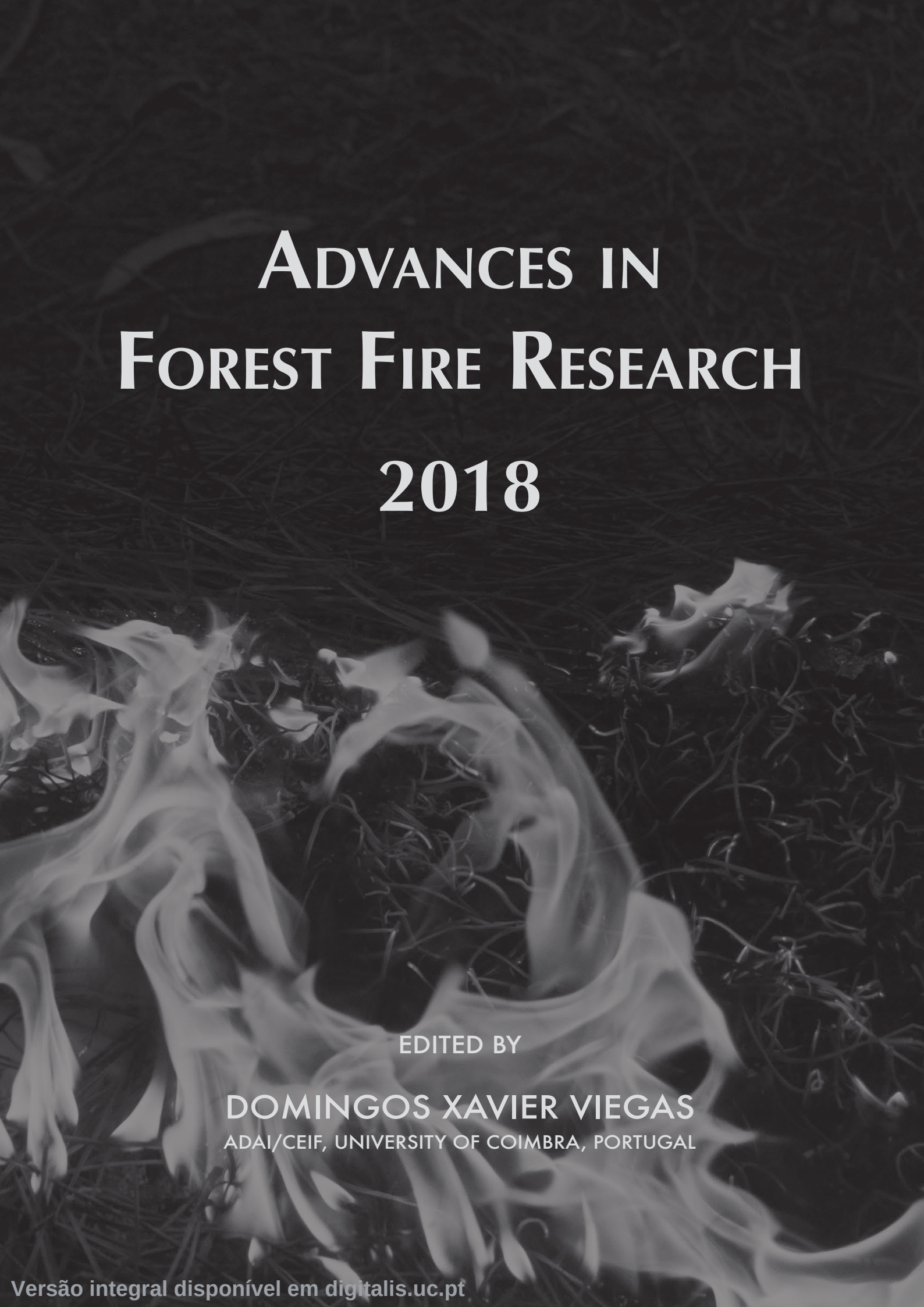

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Multi-scale modeling of the thermal degradation of woods

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Abstract

The modeling of the mass loss rate of vegetation is a key feature in models of forest fire as it allows quantifying the source term of combustible gases that supply the flames. In this work, we investigated the thermal degradation of two woods (oak and eucalyptus) using a multi-scale approach. At matter scale, experiments were carried out with a thermogravimetric analyser (TGA) under oxidizing atmosphere at several heating rates. We focussed on temperatures ranging from 150°C to 650°C in order to avoid the effect of the desication of free water and to consider only the thermal degradation of dry wood. Three kinetic mechanisms of degradation, each one consisting of four steps were developed by using the thermogravimetric results. The first one is based on an approach by constituents, the second one follows a lumped approach and the third one takes into account the formation of "active wood" which corresponds to a reduction in degree of polymerization. The kinetic parameters were calculated for each mechanism by using a genetic algorithms method. The lumped approach proved to be the mechanism that best represents the thermal decomposition of both woods. It was then tested at the material scale in the case of thermally thin wood plates heated with two radiant heat fluxes of 20 and 25 kW/m². These experiments were carried out with a cone calorimeter. The radiant heat flux was imposed at the top of the fuel sample. The mass loss rate was recorded as well as the temperature at the back surface of the wood, which was assumed equal to the temperature of the whole plate. For a radiant heat flux of 20 kW/m², the lumped approach predicted a mass loss close to the experimental results for temperatures lower than 400°C. Above this threshold, the prediction underestimated the mass loss. Then, for a radiant heat flux of 25 kW/m², the lumped approach did not allow predicting correctly the thermal degradation of the plate. For such radiant heat fluxes, the temperature gradient within the plate has to be taken into account to test the kinetic mechanisms of degradation at material scale.

Keywords: Fuel degradation, multi-scale, fire model input

1. Introduction

A reliable modeling of the mass loss rate of vegetation is a key feature in detailed models of forest fires (Mell *et al*. 2009). The gas quantity released by the vegetal fuel corresponds to this mass loss and it supplies the flame spread during the fire. An accurate modeling of the mass loss is thus a crucial point to obtain accurate propagation models of forest fires. In detailed models of forest fire, more or less complex kinetic mechanisms are implemented to describe the thermal degradation of plant fuels. The kinetic parameters associated with these mechanisms are generally calculated from thermogravimetric experiments at different heating rates (Leroy *et al*. 2006, Di Blasi 2008, Poletto *et al*. 2012), which are much lower than those encountered in actual fires. At this scale, the experimental conditions are well-controlled but they are not representative of those encountered in actual fires. The test of these mechanisms at a larger scale with higher heating rates and where heat and mass transfers occur is essential before using them in physics-based codes of forest fires. Cone calorimeter experiments are interesting tests to assess the ability of these thermal mechanisms to model the mass loss of materials. The cone calorimeter allows reaching realistic heating rates thanks to important radiant heat fluxes and tests are performed at material scale. With this device, the thermal transfers within the material influence the degradation for thermally thick samples. For such case, the problem