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Impacts of climate change on forest fire risk in Paraná State-Brazil

Antonio Carlos Batista\textsuperscript{a}, Alexandre França Tetto\textsuperscript{a}, Flavio Deppe\textsuperscript{b}, Leocádio Grodzki\textsuperscript{c}

\textsuperscript{a} Federal University of Paraná, Av. Pref. Lothário Messner 900, Curitiba - Brazil, batistaufpr@ufpr.br, tetto@ufpr.br
\textsuperscript{b} SIMEPAR Institute, Centro Politécnico da UFPR - Curitiba – Brasil, deppe@simepar.br
\textsuperscript{c} IAPAR, Rua Máximo João Kopp, 274 - Santa Candida, Curitiba - Brasil, grodzki@hotmail.com

Abstract
Forest fires are a global phenomenon due to the interaction between climate, fuels and human activities. Fires are also a critical component in the dynamics of planet earth and atmosphere. Recent advances in remote sensing products gathered via sensors on board satellites, have demonstrated the possibility of fire identification and monitoring on a global scale. The weather and climate are the major factors directly affecting fire and are being modified due to climate change caused mainly by man. There is an expectation of most researchers that changes in climate over the next 100 years will cause a major impact on forest ecosystems. The aim of this study was to determine, by decade, forest fire risk zoning for the State of Paraná, Brazil, based upon the scenarios predicted by the Intergovernmental Panel on Climate Change (IPCC) in 2007. Vegetation maps, fuel moisture, Monte Alegre Formula (FMA) for forest fire risk, slope, population density and road network, were used. These information, after being classified according to the risk of fire hazard, were weighted in a mathematical model. The determined values were then used to compose the Forest Fires Zoning Risk (ZRIF) per decade for the State of Paraná. Results showed that for the best scenario, which considers an increase of 1.8 °C in the average temperature of the Earth by year 2100, there will be an increase in class extreme risk of forest fires, rising from 1.80% of the area of the State in 2020 to 8.49% in 2100. The same applies to the class of very high risk, which rises from 10.43% (2020) to 32.38% (2100). For the worst scenario, which considers an increase of 4.0 °C in the average temperature of the Earth by 2100, the class of extreme risk rises from 2.18% (2020) to 22.72% (2100). The higher risk class rises from 13.93% (2020) to 55.95% (2100). It was concluded that, if the IPCC predictions were confirmed, there will be an increase in the number of occurrences and area affected by forest fires in the State of Paraná, which will require integrated actions to prevent and suppress forest fires to minimize environmental, social and economic damages.

Keywords: forest fire risk, climate change, forest fire zoning risk, FMA fire risk

1. Introduction
The effects of fire on the forests affect not only vegetation but also soil, fauna and atmosphere characteristics, and can be highly destructive when it is a forest fire. A fire occurs in the simultaneous presence of oxygen, fuel and heat source (Marques \textit{et al.}, 2011). According to the terminology of wildfires proposed by the Food and Agriculture Organization (FAO), "fire hazard" is defined as the probability of starting a fire due to the presence and activity of active causal agents. Also, "fire hazard" is used to express the degree of involvement of fixed and variables factors that determine the ease of ignition, rate of spread, difficulty of control and impact of fires, usually expressed as an index (FAO, 2007).

The assessment of the risk of forest fires is a critical part in fire prevention, since for pre-suppression planning and fire-fighting tools are needed to monitor when and where a fire can occur or when its effects will be more negative (Chuvieco \textit{et al.}, 2010). Several factors may explain the ignition and spread of forest fires, such as: the characteristics of fuels, weather conditions, sources of ignition and topography. Fuel characteristics depend on the structure...