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Generation of high-resolution fuel model maps from discrete airborne laser scanner and Landsat-8 OLI: A low-cost and highly updated methodology for large areas

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ABSTRACT

Wildfire risk is increasing in the context of global change, and the need for accurate fuel model maps in broader areas is becoming urgent to manage large wildfires. Among remote sensing technologies, Airborne Laser Scanner (ALS) is extremely useful for fuel mapping as it provides 3D information on vegetation distribution. A cost-effective methodology to obtain high-resolution fuel model maps in large forest areas from ALS data (1 pulse/m^2) and Landsat-8 OLI images is presented. A two-phase approach was used to generate the fuel model maps: i) ad-hoc vegetation classification derived from ALS and Landsat-8 OLI, and ii) fuel model assignment based on fuel complex structure from a limited number of ALS-derived metrics: fractional canopy cover, fuel height, and canopy relief ratio. Fuel model maps for the Canary Islands (Spain) were generated for two fuel classification systems, standard Northern Forest Fire Laboratory (NFFL) and specific Canarian fuel models (CIFM), at 25 m resolution (3678 km^2) according to decision rules based on ALS-derived metrics developed for each vegetation type. Fieldwork was used to validate the fuel model maps, obtaining an overall accuracy of 82% (kappa = 0.777) and 70% (kappa = 0.679) for the standard NFFL and CIFM fuel models respectively. Discrimination between fuel models associated to forests with and without understory was satisfactory, showing higher errors due to species composition classification rather than to ALS-derived fuel structure. Errors due to underestimation of ALS-derived fuel cover and height were more evident in mixed grassland and shrubland fuels. Results demonstrated the potential of combining imagery and ALS for fuel model mapping at a large scale from existing data sources, even with low laser pulse density and temporarily mismatched data sets. The proposed methodology may be applied for fuel mapping in other large areas provided that ALS information is available and that fuel model definition has explicit structure characteristics allowing decision rules based on ALS data. Once algorithms are defined for fuel model assignment, the low number of ALS-derived metrics and the semi-automated processing ensures that fuel model maps can be easily updated as new data sources become available providing managers with useful spatial information in large areas.

1. Introduction

Wildfire risk and occurrence is increasing in many forest areas due to the context of global climate change, which poses a major concern because of the environmental, societal and economic consequences (Moreira et al., 2011; Moritz et al., 2012; San-Miguel-Ayanz et al., 2013). In addition to climate, other factors such as ignition agents, length of the fire season, vegetation characteristics and human activities, such as fire management policies and landscape fragmentation, may greatly influence the fire regime in the next century (Flannigan et al., 2000). As in other parts of the world, the Canary Islands had a significant increase in the number and extent of forest fires during the last decade, showing the highest increasing tendency in wildfire occurrence in Spain (MAGRAMA, 2012). The situation is expected to worsen due to the predicted extreme fire weather increase according to future climate change scenarios, as longer fire intervals in conjunction with land abandonment and fuel accumulation would make these areas more vulnerable to catastrophic wildfires (Moritz et al., 2012; San-Miguel-Ayanz et al., 2013).

Fuel characterization is key to wildfire prevention as forest fuel is one of the primary factors affecting wildfire risk and behaviour. In the context of wildfires, vegetation is grouped into different large classes generally called "fuel types". These classes vary according to different classification schemes, which intend to summarize the main physical characteristics (live and dead biomass, particle size, etc.) related to

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