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What determines area burned? Relative importance of fuel management, ignition management and weather in five landscape-fire-succession models

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Abstract

Debates over the relative importance of fuel management, ignition management and year-to-year variation in weather in determining area burned by unplanned fires are controversial and lack consensus. We investigated the relative importance of these factors in a standardized simulation design involving five landscape fire models (CAFÉ, FIRESCAPE, LAMOS(HS), LANDSUM and SEM-LAND) from around the world. Importance was measured as the proportion of variation in total number of pixels burned that was explained by each factor and all interactions among them within each model. In all models, weather and ignition management were consistently more important in determining modelled area burned compared with fuel management approach and effort. A lower ignition management effort resulted in a greater area burned in all of the models, as did more severe weather years. When variation in total pixels burned was analysed separately for each of the different fuel management approaches, variation in fuel management effort was found to be important for the random fuel management approach in one model. By comparison, when the number

of edge pixels burned was analysed separately, effort in managing fuel at landscape edges was important in three of the five models. Our results suggest that inter-annual variation in weather and the extent of success in ignition management consistently prevail over the effects of fuel management in determining area burned in a range of modelled ecosystems for around the world. Greatest protection of assets adjacent to the edge of vegetated landscapes will likely arise if fuel management is co-located there. Further details can be found in Cary *et al.* (in press).

Introduction

There is a range of factors that result in variation in area burned by fires, including climate and weather (Keane et al. 2003; Flannigan et al. 2005; Cary et al. 2006) and fuel management and fire suppression (Finney 2001; Miyanishi and Johnson 2001; Minnich and Chou 1997) amongst others. Conducting meaningful field experiments to quantify the relative importance of these effects at appropriate spatial and temporal scales, and with sufficient replication, is problematic and resource intensive. As an alternative, simulation modelling provides an important tool for evaluating the effects of natural and anthropogenic factors on area burned (Cary and Bradstock 2003; Keane et al 2004).

The objective of this study is to determine the relative importance of fuel and ignition management, and weather, in determining area burned and number of edge pixels burned in five landscape fire models from around the world.

Models

The five landscape fire models included in this comparison represent considerable variation in fire modeling approach and construction (Keane et al. 2004). They simulate patterns of fire on large landscapes, over long time periods using daily weather data. Modelled fire events are combined, over time, into patterns of fire regime. The models are CAFÉ (Bradstock et al. 2006), FIRESCAPE (Cary 2002), LAMOS(HS) (Lavorel et al. 2000), LANDSUM (Keane et al. 2002), SEM-LAND (Li 2000).

Methods

Relative importance of fuel management, ignition management and weather was determined for each model using a standardized design involving variation in fuel management approach (random, edge, interior fuel buffer), fuel management effort (zero, low, moderate and high i.e. 30% of the landscape in a low fuel state), ignition management effort (zero, low, moderate and high i.e. 75 percent of ignitions suppressed), and natural variation in weather (ten different years representing variation found in the weather record). Simulations were run on flat landscapes that were 250,000 ha in size and comprised of an array of 1000 by 1000 square pixels, each 0.25 hectares.

A total of 2,400 year-long simulations, comprising of five replicates of each unique combination of fuel management approach and effort, ignition management effort and the ten different weather years, were conducted for each model. The relative importance of the management and weather factors for total pixels burned and number of edge pixels burned was determined separately by comparing the variance explained by each factor and their interactions in a fully factorial ANOVAs performed in the SAS statistical package. Factors and interactions that explained more than five percent of the total variation in pixels burned were considered important.

Results

Weather and ignition management effort were important in determining the total number of pixels burned in all models. Fuel management approach and effort were found to be unimportant (less than five percent of total variation explained by each). When variation in total pixels burned was analysed separately for each of the different fuel management approaches, sensitivity to fuel management effort was considered important for the random fuel management approach in one model.

Ignition management effort was important in determining the total number of edge pixels burned in three models while variation in weather was important in four.

Variation in number of edge pixels burned arising from fuel management approach was considered important in one of the five models. When variation in number of edge pixels burned was analysed separately for each of the different fuel management approaches, sensitivity to fuel management effort was considered important for the edge management approach in three of the models.

Discussion

It is well known that variation in weather is important in determining area burned in simulations models of fire (Cary et al. 2006) and in fire-prone ecosystems (Bessie and Johnson 1995; Hely et al. 2001). The results presented here demonstrate that variation in both weather and ignition management consistently prevail over fuel management effects, consistently for area burned, and in a majority of models for number of edge pixels burned.

Fuel amount and fuel treatments are important in determining area burned by unplanned fires (Fernandes and Bothelo 2003; King et al. 2006), and a decline in total area burned with increased, randomly-located fuel management effort was found for all models. Nevertheless, the maximum effort in fuel treatment (30 percent of landscape in low fuel state) resulted in an approximately commensurate reduction in area burned across all models on average.

Our results show area burned tended to decrease with increasing levels of ignition management effort for all models. The efficacy and success or otherwise of these management actions often depends on interacting variables including weather

conditions, fuel moisture and load, and vegetation type, as is the case with likelihood of initial attack success (Pyne et al. 1996; Cary 2005).

Our findings are applicable to areas of forest or shrubland vegetation near assets of high economic value including housing and plantations. Management of the wildland-urban interface (WUI) (Radeloff et al. 2005) is a major issue in wildland fire management (Moritz and Stephens 2008) because of the high value of assets and the vast length of the WUI around cities in locations such as south-eastern Australia (Bradstock et al. 2001), southern California and elsewhere in the United States (Hammer et al. 2007).

Finally, there is scope to extend the approach presented here to compare the importance of dynamics arising from vegetation succession and other landscape dynamics for spatial variation in fire regimes.

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