CHARACTERIZING BURN SEVERITY FROM REMOTE SENSING: RESULTS FROM 4 FIRES IN THE BOREAL[1]

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INTRODUCTION

Burn severity measures the degree of environmental change to an ecosystem due to fire (Epting et al. 2005). Understanding the effects of burn severity on post-fire vegetation succession will improve modeling of long-term successional dynamics (Arseneault 2001). Increasing knowledge of burn severity on a finer spatial scale may also help define its influence on forest fuel consumption and carbon released by fire (Michalek et al. 2000; Isaev et al. 2002).

Various studies have attempted to associate some measure of burn severity in the field with a remote sensing image, often through the use of a vegetation index (Michalek et al. 2000; Epting et al. 2005). Relationships between a field-based index called the Composite Burn Index (CBI), and numerous vegetation indices have been generated from single-date or pre-and post-burn images. Among the most frequently used index for burn severity has been the ratio of Landsat Thematic Mapper bands 4 and 7, described as the Normalized Burn Ratio (NBR) (van Wagtendonk et al. 2003; Lutes et al. 2006). Most of these studies have occurred in temperate and Alaskan landscapes, with little attention to evaluating the use of NBR or the difference in pre- and post-fire NBR (dNBR) for modeling burn severity in the Canadian boreal forest. The objective of this study was to determine the relationship between dNBR and CBI as an indicator of burn severity across four fires occurring in three different boreal forest regions, including north-central Saskatchewan, Northwest Territories (NWT) and central Yukon.

METHODS

Image Processing and Field Data Collection

A pre-fire and post-fire Landsat-5 or Landsat-7 image was acquired for each fire. Image selection was conducted to minimize temporal/phenological differences between image pairs. All images were corrected to radiance and to top-of-atmosphere reflectance values. All images were orthorectified to achieve a RMSE of less than 0.5 pixels (15m). For each dataset, the need for radiometric normalization was statistically tested by comparing a set of pseudo-invariant dark and bright targets from the pre- and post-fire images, and where necessary pre-fire values were regressed against and then normalized to post-fire values (Epting et al. 2005; Lutes et al. 2006). The NBR was computed for each image from which the change in NBR due to fire was derived (dNBR).

[1] Presented at the 3rd International Fire Ecology & Management Congress, November 13-17, 2006, San Diego, CA.

Randomly selected CBI plots were located throughout each fire and a CBI score was calculated, following the procedures outlined by Lutes et al. (2006). Forest fire fuel types were also recorded at each plot, according to the Canadian Forest Fire Behavior Prediction System fuel type classification (Forestry Canada Fire Danger Group 1992), and were used to investigate the influence of fuel types on dNBR values.

Data Analysis

The two Saskatchewan fire events were relatively small and their ecological and statistical similarity justified pooling data from the two fires (dNBR $p = 0.22$) into one database. The CBI-dNBR relationship was not linear, resulting in models based on the parameters of a saturated growth model form. The derived models for all three datasets were validated with leave-one-out cross-validation, based on a random selection of 100 trials with replacement. One-way Analysis of Variance tests were conducted on each dataset to determine if significant differences in dNBR existed among forest fuel types within each of the burns.

RESULTS AND DISCUSSION

A model form of CBI = dNBR/(a*dNBR+b) resulted in coefficient of determination (R^2) values of 0.80 to 0.82, with root mean square error values for CBI of 0.22 for Saskatchewan, 0.17 for NWT and 0.28 for Yukon. Further analysis of individual field assessments revealed that fire damage in many of the low-scoring CBI sites was mainly limited to the understory and forest floor, and therefore would have relatively minimal effect on measured spectral response acquired from a satellite-borne sensor. This observation explains why, in part, when CBI values increase from 0.5 to 1.5, dNBR values increase very little, but as CBI values continue to increase from 1.5 to 3, dNBR values increase at a higher rate (i.e., this trend is consistent with the non-linear relationship). There was more variation in the fit statistics for the Yukon fire compared to Saskatchewan and NWT fires, based on results from 100 trials of cross-validation for each dataset. These results need to be considered when specifying ranges of CBI or dNBR values for classifying burn severity into categories such as low, moderate and high. Values of dNBR varied by fuel type for two of the three fire data sets in Saskatchewan ($p = 0.03$) and NWT ($p = 0.001$). Significantly higher dNBR values were often associated with the boreal spruce (C2) fuel type. This result was likely explained by the larger amount of understory and ladder fuels that often occur at these sites.

SUMMARY AND CONCLUSIONS

A non-linear relationship for burn severity between CBI and dNBR was developed and validated across boreal fires from Saskatchewan, NWT and Yukon. This result contrasts those published elsewhere since a linear model form is often used to describe the relationship between these two variables. Fuel type was observed to have a significant influence on dNBR values, which justifies further investigation in models of burn severity that incorporate fuel type information. Research efforts are underway to a) analyze the nature of changes in burn severity models using immediate post-fire imagery versus one-year post-fire imagery, b) assess values for classifying burn severity in the boreal, and c) explore the possible utility of dNBR in explaining differences in fuel consumption.

ACKNOWLEDGMENTS

This study was undertaken as a component of the Canadian Wildland Fire Information System (http://cwfis.cfs.nrcan.gc.ca/en/index_e.php) being developed by Natural Resources Canada in collaboration with the Canadian Space Agency.

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