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Evaluation of the composite burn index for assessing fire severity in Alaskan black spruce forests

Eric S. Kasischke[A,F], *Merritt R. Turetsky*[B,C], *Roger D. Ottmar*[D], *Nancy H. F. French*[E], *Elizabeth E. Hoy*[A] *and Evan S. Kane*[B]

[A]Department of Geography, University of Maryland, 2181 LeFrak Hall, College Park, MD 20742, USA.
[B]Departments of Plant Biology, and Fisheries & Wildlife, Michigan State University, East Lansing, MI 48824, USA.
[C]Present address: Department of Integrative Biology, University of Guelph, Guelph, ON, N1G 2W1, Canada.
[D]USDA Forest Service, Pacific Northwest Research Station, 400 N 34th St, Seattle, WA 98103, USA.
[E]Michigan Tech Research Institute, Michigan Technological University, 3600 Green Court, Suite 100, Ann Arbor, MI 48113-4001, USA.
[F]Corresponding author. Email: ekasisch@umd.edu

Abstract. We evaluated the utility of the composite burn index (CBI) for estimating fire severity in Alaskan black spruce forests by comparing data from 81 plots located in 2004 and 2005 fire events. We collected data to estimate the CBI and quantify crown damage, percent of trees standing after the fire, depth of the organic layer remaining after the fire, depth of burning in the surface organic layer (absolute and relative), and the substrate layer exposed by the fire. To estimate pre-fire organic layer depth, we collected data in 15 unburned stands to develop relationships between total organic layer depth and measures of the adventitious root depth above mineral soil and below the surface of the organic layer. We validated this algorithm using data collected in 17 burned stands where pre-fire organic layer depth had been measured. The average total CBI value in the black spruce stands was 2.46, with most of the variation a result of differences in the CBI observed for the substrate layer. While a quadratic equation using the substrate component of CBI was a relatively strong predictor of mineral soil exposure as a result of fire ($R^2 = 0.61$, $P < 0.0001$, $F = 60.3$), low correlations were found between the other measures of fire severity and the CBI ($R^2 = 0.00$–0.37). These results indicate that the CBI approach has limited potential for quantifying fire severity in these ecosystems, in particular organic layer consumption, which is an important factor to understand how ecosystems will respond to changing climate and fire regimes in northern regions.

Introduction

Fire is an important process in many ecosystems, particularly in boreal forests where burning represents a dominant form of disturbance (Wein and MacLean 1983; Goldammer and Furyaev 1996; Kasischke and Stocks 2000). Most area burned in the North American boreal forest is the result of natural processes, where lightning ignited fires accounted for 80 to 90% of the total area burned in the 1980s and 1990s (Stocks *et al*. 2002; Kasischke and Turetsky 2006). In response to recent climate change, average annual burned area across the North American boreal region doubled between the 1960s/70s and 1980s/90s. In addition, the amount of late season burning has substantially increased in western ecozones found in continental Canada and Alaska (Gillett *et al*. 2004; Kasischke and Turetsky 2006).

Recent changes in the North American fire regime have likely impacted several ecosystem processes. However, the exact nature of these effects depends on changes in fire frequency and fire type (e.g. ground, surface, or crown), which determines the intensity, rate of spread, and duration of burning. Together, these characteristics control the severity of the fire (e.g. the rate of tree mortality, the amount of aboveground biomass, dead woody debris and ground layer organic matter consumed during the fire, ash deposition, and changes to the soil hydrophobicity; Lentile *et al*. 2006). Quantifying fire severity is important to understand carbon and nutrient cycling and to predict how an ecosystem will change in response to a fire event (e.g. burn severity; Key and Benson 2006; Lentile *et al*. 2006).

A review of recent literature shows that while many studies have developed approaches to quantify fire and burn severity, most have focussed on measures that deal with a relatively narrow range of ecosystem types and fire-damage characteristics. Odion and Hanson (2006) used tree mortality to assess fire severity in conifer forests in the Sierra Nevada range of California. Keyser *et al*. (2006) measured crown and stem damage to assess factors that affect mortality in ponderosa pine stands. Knapp and Keeley (2006) evaluated how stand characteristics and site geomorphology influenced scorch height and percent of ground burned. Kemball *et al*. (2006), Jayen *et al*. (2006), and Greene *et al*. (2007) evaluated how exposure of mineral soil during fires affected seedling germination and survival in Canadian coniferous forests. Kasischke and Johnstone (2005) evaluated how depth of the remaining organic layer influenced post-fire

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