CSIRO PUBLISHING

International Journal of Wildland Fire **2008**, *17*, 500–514 www.publish.csiro.au/journals/ijwf

Evaluating the potential of Landsat TM/ETM+ imagery for assessing fire severity in Alaskan black spruce forests

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Abstract. Satellite remotely sensed data of fire disturbance offers important information; however, current methods to study fire severity may need modifications for boreal regions. We assessed the potential of the differenced Normalized Burn Ratio (dNBR) and other spectroscopic indices and image transforms derived from Landsat TM/ETM+ data for mapping fire severity in Alaskan black spruce forests (*Picea mariana*) using ground measures of severity from 55 plots located in two fire events. The analysis yielded low correlations between the satellite and field measures of severity, with the highest correlation ($R^2_{adjusted} = 0.52$, $P < 0.0001$) between the dNBR and the composite burn index being lower than those found in similar studies in forests in the conterminous USA. Correlations improved using a ratio of two Landsat shortwave infrared bands (Band 7/Band 5). Overall, the satellite fire severity indices and transformations were more highly correlated with measures of canopy-layer fire severity than ground-layer fire severity. High levels of fire severity present in the fire events, deep organic soils, varied topography of the boreal region, and variations in solar elevation angle may account for the low correlations, and illustrate the challenges faced in developing approaches to map fire and burn severity in high northern latitude regions.

Additional keywords: composite burn index, *Picea mariana*, spectroscopic index.

Introduction

Forest fires are a major contributing factor to the world's carbon cycle. These fires release emissions into the atmosphere through the burning of the surface and canopy fuel matrix. Boreal forest regions can be considered both a source and sink for carbon because of their potential for forest fires and in providing avenues for reforestation. Increasing summer temperatures and changing atmospheric circulation patterns are influencing the fire regime in the boreal region (Gillett *et al*. 2004; Kasischke and Turetsky 2006; Skinner *et al*. 2006), although the overall effects of these changes on the landscape are still under study (Chapin *et al*. 2005). Remote sensing research has provided new approaches and methods to monitor landscape change as a result of fire.

Over the past decade, much research has focussed on using satellite remote sensing data to improve estimates of carbon emissions from fires in temperate and boreal forests. Satellite data products that provide information on the timing of fires and burned area are now routinely used to estimate emissions from fires in high northern latitude forests (Kasischke *et al*. 1995, 2005; Kajii *et al*. 2002; Soja *et al*. 2004; van der Werf *et al*. 2006; de Groot *et al*. 2007). While variations in biomass consumption have been shown to be a key uncertainty in estimating emissions (French *et al*. 2004), only a few studies carried out on individual fire events have used satellite remote sensing to map variations in severity (which is then used to estimate biomass consumption) (Michalek *et al*. 2000; Isaev *et al*. 2002; Campbell *et al*. 2007).

In terms of improving the accuracy of emissions from boreal regions, the deep organic soils found in the forests underlain by permafrost and the peatlands common to this region present particular challenges. Black spruce (*Picea mariana*) forests represent some 50% of the forest cover in Alaska and Canada (Kasischke and Johnstone 2005) and make up 60% of the area burned in Alaska and across Canada (Amiro *et al*. 2001). Fires in the deep surface organic layers of this forest type can release from 10 and up to 70 t C ha^{-1}; thus, variations in depth of burning represent a major source of uncertainty in estimating emissions from boreal fires (French *et al*. 2004; Kasischke *et al*. 2005).

The terms fire severity and burn severity are often used interchangeably in the fire science and remote sensing literature. We chose to interpret the terms fire severity and burn severity using the fire disturbance continuum described by Jain (2004) and discussed in detail by Lentile *et al*. (2006). Fire severity is considered to be the direct effects of the combustion process such as tree mortality and the losses of biomass in the forms of vegetation and soil organic material. Burn severity is a term used to describe the response of the environment to fire and is indicated

