Geospatial Techniques for a Multi-Resolution Assessment of Post-Fire Boreal Vegetation Residual Patterns

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1. Introduction

Boreal wildfires, regardless of their size or intensity leave residuals of unburned vegetation on the landscapes that they affect. These residuals occur in forms varying from individual trees to large patches with differing degrees of vegetation density, edge, and internal characteristics (Bergeron et al. 2002). Although forest managers in Ontario attempt to emulate fire and residual patterns in forest harvest planning, there is still little consensus on how to define, describe, or measure the burned and residual spatial patterns within the scientific literature (Perera et al. 2004) or how to define 'natural' disturbance regime sizes or their spatial patterns (Hunter 1993).

This study provides an objective approach to examining fire patterns, and specifically their residuals in north-western Ontario, Canada, by scrutinizing post-fire IKONOS imagery for 21 natural (unsuppressed and lightning ignited) wildfires ranging from 50 ha to over 16,000 ha. Furthermore, our approach examines the influence of spatial resolution on the definition of residuals and the spatial relationships with surrounding and pre-fire land cover types. This investigation is the first of its kind in observing multiple fires to identify characteristics in fire event and residual stand boundary geometries. Our goal is to draw conclusions regarding boundary strength and vegetation residual likelihoods at multiple spatial resolutions given a suite of spatial land cover conditions. Our approach is completely independent of, and unbiased by existing fire boundary delineations for these fires, and builds a repeatable, robust technique for characterizing fires based on their geometry and compositional structures.

1.1 Study Area and Data

Our study area comprises 21 lightning-initiated wildfires in north-western Ontario, Canada (Figure 1) that were completely unsuppressed. Each fire is completely within the boreal forest region and was examined as a natural disturbance, external to any anthropogenic influences. For each fire event, we obtained post-fire IKONOS imagery (1 and 4 m spatial resolution panchromatic and multi-spectral respectively), year 2000 (pre-fire) classified Landsat TM imagery for prior land cover assessment, and Ontario Ministry of Natural Resources fire perimeter delineations (vector GIS layers).

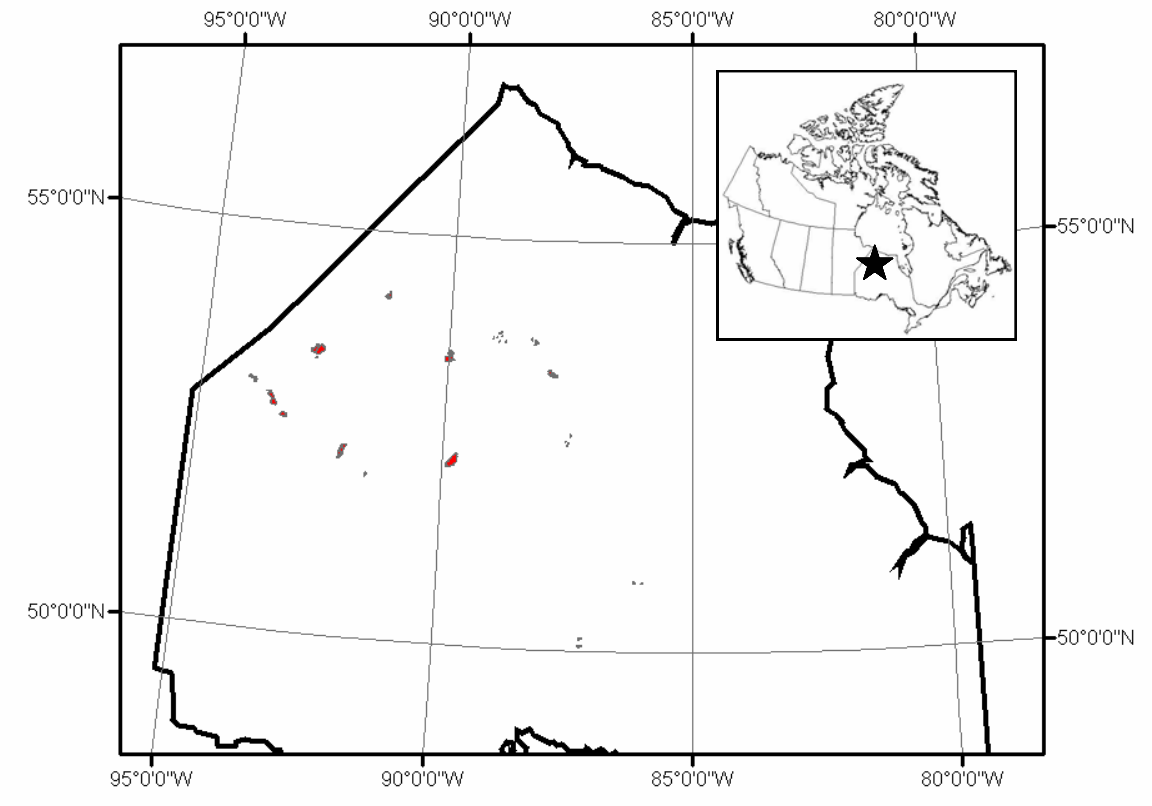

Figure 1. A map of the north-western Ontario, Canada, study area showing the general spatial distribution for the 34 wildfires examined in this study. The bold line represents the political boundary for the Province of Ontario. The black star on the inset map of Canada identifies the general location of this site.

2. Methods

The IKONOS imagery was classified by a third party specializing in Ontario land cover assessment (Spectranalysis Inc., 2005) to generate consistent forested land cover products for each independent fire event. Land cover characterizations included several burn severity, forest type, wetland class, shrub presence, and water categories. We considered these classes to be correct and conducted our analysis using this classification as base data.

The first stage was to identify the maximum extent (footprint) of each fire using a logical rule-base at spatial resolutions of 2, 4, 8, 16, 32, and 64 m, that did not necessarily include all pixels identified as being either partially or completely burned. The general approach to the footprint delineation was to automatically remove some of the noise or spuriously classified fire pixels along the edges of a fire or at great distances of the core fire area. This was achieved by combining all pixels identified as being either partially or completely burned, converting them to vector polygons, buffering them outwards by the original spatial resolution and then merging all newly constructed polygons. Subsequent internal buffering (i.e., shrinking) of the result by the original spatial resolution distance acted to return the fire perimeter to its original position; however, the new delineation now includes proximal burned patches (merged during the outward buffering). The result was converted to a binary raster layer and was considered the maximum footprint for the fire (at the specified spatial resolution).

The footprint mask was further sub-divided into two mutually exclusive parts, masking the burned and unburned (residual) pixels within the footprint. The residual patches were grouped based on an 8-cell neighbourhood contiguity rule and assigned a unique identifier to permit the counting of individual residual patches (Figure 2). This process was conducted at each of the 6 specified spatial resolutions above.

Pre-fire vegetation within the footprint, burned, and residual masks were computed for comparison. Similarly, residual patch and footprint geometries were computed to assess trends and linkages with land cover types, abundances, and their distributions. Although the literature is saturated with landscape pattern indices (Riitters et al. 1995) for measuring patch geometry and patterns, their uses and comparisons are riddled with problems (Remmel and Csillag 2003); thus, we selected only some of the more intuitive and tangible indices for our geometric descriptors as postulated by Remmel and Mitchell (2005).

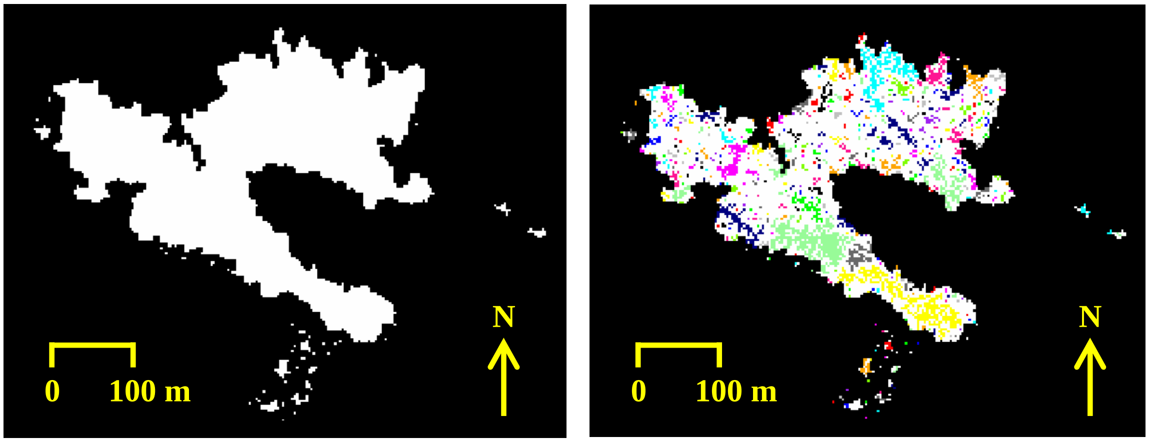

Figure 2. A fire footprint mask (left: white = fire) for one of the fires examined and the same fire with unique residual clusters uniquely coloured (right). The example shown is at 8 m spatial resolution.

To explore distance effects on residual edge strength, the Euclidean distance from each residual pixel to the closest burned pixel was computed and the distributions within each residual analyzed. Residual sites further from the interface between burned and unburned pixels are less likely to exhibit ‘edge’ characteristics and represent stronger belonging to the core of a residual patch; large and compact residuals would express more core pixels per unit area than highly irregular or elongated residual patches. Furthermore, the land cover classes forming the burned and residual interfaces were explored; expecting that water, non-vegetated, and wet classes would be most common in forming barriers to fire spread. These analyses were also conducted at each of the stated spatial resolutions to test for spatial aggregation effects.

3. Preliminary Results

Our initial investigations indicate that spatial resolution has a significant effect on the tabulation of residual patch occurrences and their area calculations. In each case, there appears to be a spatial resolution at which computed area is maximized (typically around 4 or 8 m spatial resolution), with significantly lower areas represented by very high or low spatial resolution mapping units. Analysis of the year 2000 land cover classification reveals that water classes and wetland pixels are relatively common in residual patches (considering the dominance of conifer forest pixels). This illustrates that fires favour burning non-wet land cover types and that wetlands and water bodies can act as firebreaks or barriers to fire spreading. Further investigations will explore more specific relationships among land cover classes acting as firebreaks and burned areas by assessing. Specifically we will assess the proportion of land cover types within 30 and 90 m buffer zones around lakes and compare results with a related in a different region of Ontario to test whether larger lakes behave as better firebreaks than smaller lakes, ponds, or wetlands. Initial results indicate that this hypothesis cannot be rejected. This project is the first of its kind; compiling fire pattern and land cover analyses for multiple natural fires of various sizes. Our goal is to summarize burned and unburned patches in terms of their area distributions in conjunction with geometric characteristics, and spatial/distance metrics to construct an improved knowledgebase for natural fire behaviour.

4. Acknowledgements

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