Forest and Tundra Fires in the Hudson Bay Lowlands of Manitoba

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Abstract

Forest and tundra fires occur frequently over large areas within the Hudson Bay Lowlands and are predicted to increase in frequency and extent in response to climate change. This study provides a detailed measure of fire extent and frequency within the region for the period 1994-2001.

Introduction

Fire is an important process in sub-arctic ecosystems and will continue to influence the structure and dynamics of the peatland dominated systems that comprise the Hudson Bay Lowlands (Brook 2001, Monson 2003, Brook 2005). As a result of climate change, it is predicted that by 2050 there will be a 50% increase in forest fire activity in northern Canada and that the fire season will be longer, with increased ignitions (both lighting and human caused) and an overall larger area burned. However, the frequency and extent of fires within the Hudson Bay Lowlands of Manitoba are not well understood. Accurate and up-to-date detailed mapping of annual burn coverage will provide important insights into trends in fires and an understanding of the relative frequency of burns within different habitat types.

This project was initiated to develop a consistent, repeatable methodology for mapping fires within the Wapusk regional ecosystem with sufficient detail to quantify annual burned area and support other ecological research and monitoring projects requiring burn data.

Study Area

The study area is 42,000 km^2 and includes Wapusk National Park (11,475 km^2), the Churchill Wildlife Management Area (CWMA) (7,295 km^2), and the surrounding ecosystem delineated as the area of interest for the Wapusk Ecological Integrity Statement (Figure 1). The area falls within the Hudson Bay Lowlands, the largest peatland in North America (Brook 2001). The vegetation forms a broad transition zone between the boreal forest to the south and the arctic tundra further north. This transition zone includes a dramatic change in both vegetation (Ritchie 1956, Scoggan 1959, Brook 2001) and wildlife (Jehl & Smith 1970, Wrigley 1974).

Plant communities of the study area include uplands and extensive fen and bog complexes of highly variable tree cover intermixed with vast numbers of ponds and lakes (Ritchie 1956, Sims *et al.* 1982, Pala & Weischet 1982, Brook *et al.* 2001b). The major tree species are black spruce (*Picea mariana)*, white spruce (*Picea glauca)* and tamarack (*Larix laricina)* (Brook 2001). Grazing by large herbivores, including geese and caribou, has significantly altered plant community structure in some areas (Campbell 1995, Ganter *et al.* 1996). Lightning induced fires are a frequent and recurring process on the landscape (Monson 2003). Higher tree cover and drier conditions result in much more extensive burns in the southwest portion of the study area (Brook 2001). Human disturbance has occurred only in localized areas. The dynamic nature of the region, through the combined and often synergistic effects of climate, isostatic uplift, snow cover, drainage, grazing and fire create a complex mosaic of vegetation both spatially and temporally.

Ritchie (1962) initiated mapping of the plant communities at a regional scale at 1: 1,000,000 scale, using black and white air photo interpretation. Clark (1996) used LANDSAT TM satellite imagery to map the region at 1: 1,000,000 scale. Brook (2001) completed the first fine scale regional mapping of the vegetation communities in the region and the resulting classification was 97% accurate overall.

Methods

The fire mapping protocol uses the methodology developed by Brook & Kenkel (2002). Recent burns in WNP are more spectrally unique from other vegetation types than regenerating burns (Brook & Kenkel 2002), so burns were mapped using Landsat TM imagery obtained as close to the actual fire date as possible. Dates for fires were estimated using field data collected throughout the region from 1998 to 2005, existing Landsat imagery (TM scenes 31/19 and 31/20, obtained August 18, 2001 and July 27, 1996) in conjunction with AVHRR fire monitoring data produced by the Canadian Wildland Fire Information System (Li *et al.* 1997, Kaufman *et al.* 1998, Li *et al.* 2000, Abuelgasim & Fraser 2002). Following Brook & Kenkel (2002) and Brook *et al.* (2001a&b), bitmap masks were generated over all burns identified in each satellite image for a single year (e.g. a classification was run for all burns in 1998 and another run for 1999).

During the classification process, stratification of the study area was also performed in order to limit class distribution with pre-defined boundaries (Hutchinson 1982, Mason *et al.* 1988, Joria & Jorgenson 1996). This procedure allows ancillary data to be used to define spatial limits for certain classes that would otherwise be problematic (Kenk *et al.* 1988, White *et al.* 1995). In each step, only the classes that are likely to occur under each mask are allocated in each unsupervised classification. This allows the number of misclassifications between classes to be reduced if they occur under different masks (Boresjö 1999).

The area under the fire mask for each image was classified using an unsupervised 28-class initial arbitrary cluster allocation (Isodata) classification (IMAGEWORKS, PCI Geomatics 1998). It is an iterative technique that initially seeds a specified number of cluster centroids. The euclidean distance between each pixel and each cluster centroid is calculated and the pixel assigned to a class. After each pixel is evaluated, a new series of clusters is created and continues to process until there is little change in class assignment between iterations or the maximum number of iterations is reached. The resulting classes were then sorted into a 2-class "burned" and "unburned" classification using the spectral and ancillary data. Vector boundaries and raster burn coverages were produced for each burn, along with attribute data, including burn area, % area burned, perimeter length, and where possible information on date and cause of ignition.

Results

The frequency and extent of fires within the study area are highly variable throughout the study area, with larger burns more common farther away from Hudson Bay and fewer and smaller burns close to the coastline (Figure 1). Burns also vary dramatically among years (Figure 2). During the eight years of the study (1994-2001) there were no fires in the study area in 2001 (Table 1). Numerous very large fires occurred in 1999 that consumed more than 90,000 hectares and comprised 48% of the area burned during the study. Lichen spruce bog is the most commonly burned habitat type, though other vegetation types will also burn (Figure 3).

Conclusions

Landsat satellite imagery provides sufficient spatial coverage and spatial resolution (30m x 30m) to effectively map burns within the study area at a scale which is useful for a wide range of applications including monitoring annual burn extent and studies of vegetation dynamics and wildlife habitat selection, as long as sufficient ancillary data are available to accurately date each burn. These ancillary data are particularly important in the many situations where fires from different years overlap. The Canadian hotspot and polygon data are the most accurate information on fire extent and timing for the study area for 1994 to present. Other information such as the Canada ignition points and Manitoba Conservation fire polygon datasets are useful for identifying some large fires but do not identify most of the burns occurring in the study area.

The number of fires in the study area and their size and shape are highly variable. Most of the fires within

Wapusk National Park occur in the southwest corner of the park where the proportion of lichen spruce bog is considerably higher. These generalizations are based on a limited time period (1994 to 2001) and so should be interpreted with caution since a comprehensive understanding of fire cycles requires data spanning decades and centuries.

Delineation of individual burns in the study area and identifying the proportion of burned vegetation within each burn is complicated by the highly variable intensity and spatial distribution of the burns. Many of the individual pixels within each burn were composed of a mix of burned and unburned vegetation. In many cases, fire kills trees and shrubs by burning the roots but does not burn the vegetation, leaving areas of dead unburnt standing trees. Further research to evaluate the mixed pixel effects is necessary.

Findings from this study are generally consistent with other estimates of burn frequency in the Canadian sub-arctic which reflect considerable variability. Horn (1981) measured a 2.7% burn area over a 4-year period in Nunavut from 1977-1980. Miller (1976) calculated an annual burn rate of 0.17% during a 12-year period from 1955-1967 in northern Manitoba and Nunavut. Scotter (1964) estimated 0.87% land area burned annually during the period 1940-1955 in north central Saskatchewan. The variability is largely related to natural variations in topography, weather, vegetation and fuel conditions, as well as landscape pattern and vegetation cover.

Fire is initiated by stochastic lightning strikes and its movement is determined by complex topographical, wetness, fuel, and climate variables and remains relatively unpredictable (Payette *et al.* 1989, Timoney & Wein 1991). However, wet fen types have a very low probability of igniting and sustaining a fire compared with drier bog types.

Connectivity of the drier sites is an important factor in determining fire spread. Areas further inland with a greater abundance of bog vegetation are more likely to facilitate the movement of fire across the landscape.

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Table 1. Summary of annual burn coverage within the study area.

Fire Year	Count Fires	Total Area Burned (ha)	% Study Area Burned	Min Fire (ha)	Max Fire (ha)	Mean Fire (ha)	Mean Perimeter (km)
1994	8	29301	0.70%	158	19553	3662	358
1995	3	1408	0.03%	91	968	469	18
1996	5	46610	1.11%	351	42663	9322	77
1997	2	776	0.02%	373	403	388	15
1998	5	12085	0.29%	179	5189	2417	40
1999	22	90353	2.15%	159	26557	5042	51
2000	6	8501	0.20%	360	4157	1416	28
2001	0	0	0.00%	0	0	0	0

Table 2. Vegetation classes in the regional vegetation map and their relative proportions within the study area (after Brook 2005).

	Class	% Study Area	Area (km^2)
I.	Sphagnum Larch Fen	0.5	109.6
II.	Sedge Rich Fen	3.1	718.4
III.	Willow Birch Shrub Fen	3.7	844.5
IV.	Sedge Larch Fen	4.7	1081.1
V.	Sphagnum Spruce Bog	9.0	2069.9
VI.	Graminoid Willow Salt Marsh	0.2	34.4
VII.	Lichen Spruce Bog	19.9	4561.1
VIII.	Sedge Bulrush Poor Fen	15.3	3515.7
IX.	Lichen Melt Pond Bog	13.9	3196.4
X.	Lichen Peat Plateau Bog	7.5	1715.4
XI.	*Dryas* Heath	0.6	126.8
XII.	Regenerating Burn	9.3	2123.1
XIII.	Recent Burn	2.2	509.6
XIV.	Unvegetated Ridge	0.0	11.2
XV.	Unvegetated Shoreline	1.8	423.9
XVI.	Water	8.3	1892.1

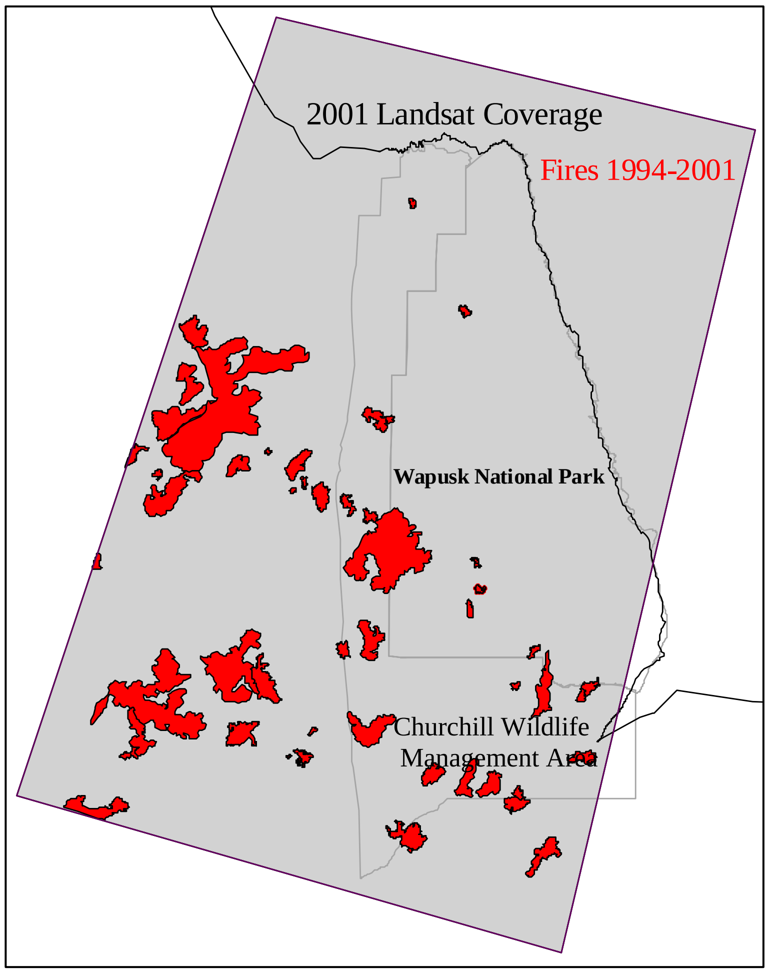

Figure 1. Burn boundaries within the study area (1994-2001) mapped using Landsat satellite imagery obtained in 1996 and 2001.

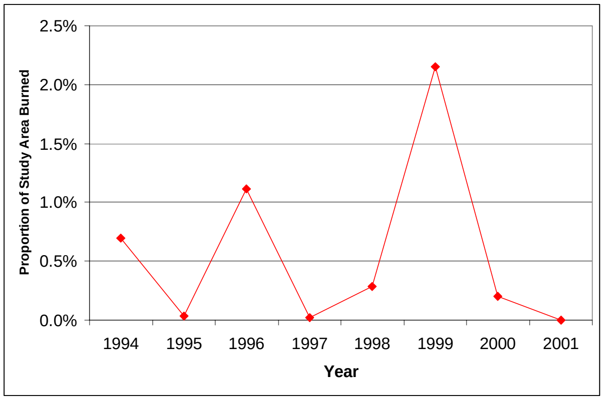

Figure 2. Percentage of study area burned annually within the study area (1994-2001) mapped using Landsat satellite imagery obtained 1996 and 2001.

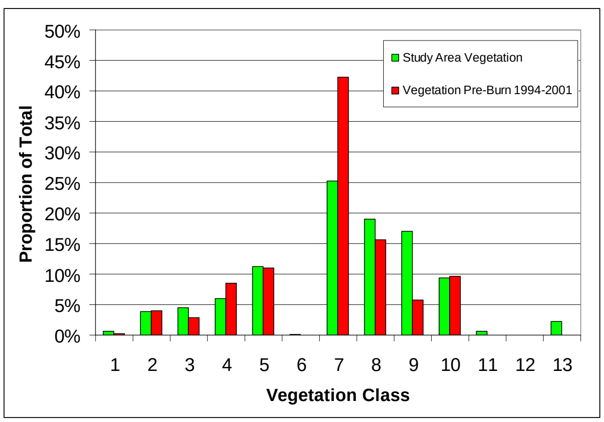

Figure 3. Vegetation composition within the entire study area in 1996 and within areas prior to being burned (1994 and 2001). Vegetation classes are listed in table 2.

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