Compartmentalizing Fire in Large Parks and Protected Areas

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Abstract

The re-introduction of fire to parks and protected areas is essential for ensuring the ecological integrity of fire-initiated and fire-maintained ecosystems; however, there is also a need to ensure that competing consumptive and non-consumptive activities are protected. Miller and Landres (2004) forwarded a method to balance competing management objectives which was applied in two steps. First, a GIS application was developed to evaluate potential ecological benefits for tree species based on fire intensity. Second, Prometheus (Canadian Wildland Fire Growth Model) was used to develop priority zones around values based on fire behaviour in heterogeneous fuel. These were combined to create a fire ecological suitability map for Nagagamisis and Quetico Provincial Parks with "priority zones" around values. The implication of this research for park planners and managers is the ability to delineate areas where fire can perform its ecological role without exposing people, property and infrastructure to risk from fire.

Introduction

Fire planning and management, in large parks and protected areas, is a paradox: although it is an essential component for regulating forest succession and biodiversity (Van Wagner and Methven, 1980; OMNR, 2002a), it can also harm people, property and infrastructure (OMNR, 2003b). Planning for fire in parks and protected areas requires an understanding of ecology, vegetation response to fire, fire regime(s), and the values to be protected. It also requires an understanding of the established management objectives for the protected area. Managers must assess when and where fire is wanted or unwanted, while ensuring that a fire will not escape established boundaries and adversely affect neighbouring values. Moreover, fire behaviour changes with seasonal fluctuations in weather so allowing a more natural role of fire may become too hazardous and require suppression in some weather conditions. The objective of this study was to develop a decision support tool to facilitate planning for fire without overlooking the human and ecological values.

Importance of fire

Fire plays an important role in forest ecosystems by altering patch and edge dynamics, cycling soil nutrients, and ensuring different age classes and distribution of species (Heinselman, 1970); yet, decades of forest fire suppression is pushing fire dependent ecosystems to more fire-intolerant species (OMNR 2003a; OMNR 2004). Heinselman (1970) extolled the importance of fire for ecosystem renewal and maintenance in Minnesota, USA. In 1979, the Canadian Park Service also recognized the importance of fire and began to alter its policies to reflect the role of fire in the ecosystem (Van Wagner and Methven, 1980; Woodley, 1995; Canadian Park Service, 1989). Van Wagner and Methven (1980) documented the importance of allowing a more natural role for fire in large parks because most forest vegetation species in Canada were either fire-initiated or maintained by regular fire regimes. Altering these fire regimes, through years of fire suppression, could lead to changes in forest species composition, which may not reflect the vegetation management objectives of the park.

Fire's important ecological role conflicts with both consumptive and non-consumptive human activities and poses many challenges for planners and resource managers striving to achieve a balance. This conflict has led to an acknowledgement of the need to incorporate ecological, social and economic factors into the planning process (OMNR, 2003a; Woodley, 1995; Heinselman, 1970).

Fire management strategy for Ontario and Provincial Protected Areas

The fire management strategy for the province of Ontario focuses on the protection of: people; property and infrastructure; where possible, timber resources; and ecological values, such as species at risk (OMNR, 2004). The diversity of ecosystems and human activities in the province has led to the designation of six broad fire management zones that reflect social, ecological and economic land uses or processes. Designation of the "Parks Zone" encourages managers to allow fire to perform its ecological role, provided fire does not negatively impact other uses or values that the park is striving to protect (e.g., critical wildlife habitat). It also recognizes that fire, as an ecosystem process fundamental to restoring ecological integrity, is an under represented process in provincial parks and protected areas. There are three objectives set out in Ontario's fire management policy for facilitating the re-introduction of fire: 1) to encourage the inclusion of fire into the park planning and management process to achieve vegetation management objectives, such as ecosystem restoration; 2) to require consideration and documentation of fire's role in achieving management objectives; and 3) to establish clear goals for the use of, and response to, fire such that the people, property, infrastructure and ecological values at risk are not lost to fire (OMNR, 2004).

Methods

To balance the ecological need for fire on the landscape and protect people, property and infrastructure, a decision support tool was developed based on the conceptual methodology proposed by Miller and Landres (2004). As case studies, both Nagagamisis (North East Ontario) and Quetico (North West Ontario) Provincial Parks were selected because the parks:

- have forest vegetation species consisting of boreal species (fire-initiated or fire-maintained);
- are large in size (approximately 475,000+ hectares (ha) for Quetico and almost 70,000 ha for Nagagamisis);
- contain Aboriginal values, including archaeological sites (OMNR, 2002b);
- have adjacent cottage communities and timber resources;
- are mandated to have a fire management strategy integrated with neighbouring forest management units to ensure that landscape scale ecosystem objectives, such as the woodland caribou recovery plan, are not compromised by catastrophic fire.

The methodology behind the decision support tool consisted of two distinct components: 1) establishment of fire priority zones around values to protect; and 2) evaluation of the potential ecological effect of a forest fire using the 95th percentile fire weather as a worst case scenario.

Protecting Values

The development of fire-priority (buffer) zones around values is problematic in heterogeneous fuels because it is possible to create a buffer zone that is representative of potential fire behaviour. The spatial arrangement of fuel composition and continuity, topography, and the uncertainty associated with weather also make it difficult to calculate a suitable fire-priority zone around a value using conventional GIS. To overcome this limitation, Prometheus (Canadian Wildland Fire Growth Model) (Anon. 2005) was used to create the priority zones around values. The innovation here was instead of simulating fires approaching a value, the value itself was used as the ignition point and the wind direction was rotated through the cardinal direction for each simulation. Additionally, adjustments were made to the topographic data (aspect) to ensure the effect of topography was properly accounted for. The results of the simulations (fire perimeter polygons) were combined using the overlay capability of GIS to create the priority buffer zones for each value.

Species Response to Fire

Assessing the ecological response of vegetation to different intensities of forest fire was also problematic because there was a general lack of information as to how species respond to different intensities of forest fire. The Fire Effects Information System (FEIS) database (Ulev, 2005) provides some insight into species fire ecology but there is still a lack of detailed research into fire effects based on intensity. For this study the ecological impact was defined as the ability of a species to survive a given fire intensity or the ability of a species to regenerate following a fire. An index was developed to standardize the ecological response to fire based on the calculated head fire intensity for each fuel type and compared with the available literature on tolerable fire intensities for each species. The Normalized Difference Fire Intensity Index (NDFII) is given as follows:

Equation 1. Normalized Difference Fire Intensity Index (NDFII).

$$NDFII = \frac{Spp_{tol} - HFI}{Spp_{tol} + HFI}$$

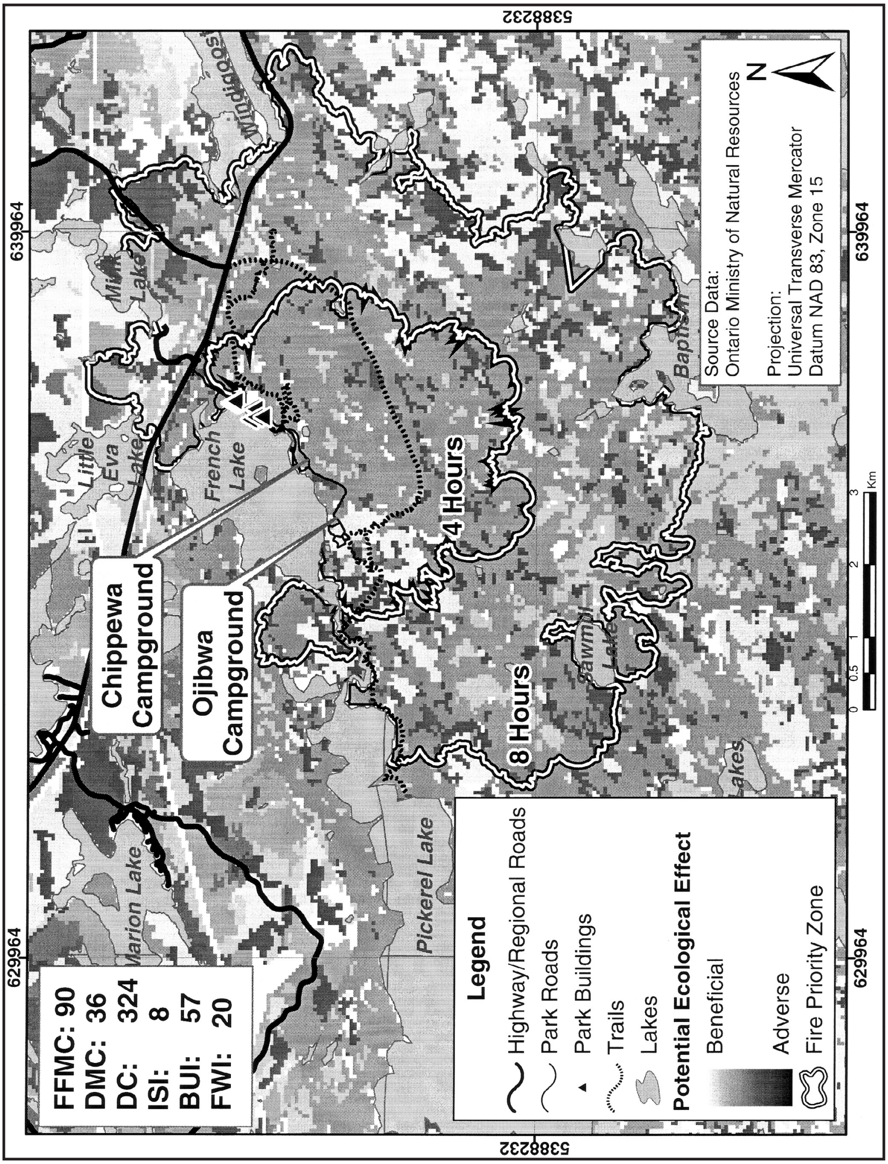
Where: Spp_{tol} is the species maximum tolerance for fire intensity in kW/m; and, *HFI* is the head fire intensity as calculated by the Fire Behaviour Prediction System (FBP) (Hirsch, 1996; Taylor *et al*., 1997; Stocks *et al*., 1989; Van Wagner, 1987).

The rationale for this equation was to reduce the range of fire intensities to a measure from -1 (adverse) to +1 (indifferent or possibly beneficial). The index does not provide a measure of how much a given species will be affected by fire. It should also be noted that this index could be applied to all flora, provided tolerance to head fire intensity is known, but this study was limited to tree species only. The establishment of species tolerance level was based on the literature (Ulev, 2005; Taylor *et al*. 2000; Chambers *et al*., 1997) and the FBP system (Hirsch, 1996; Taylor *et al*., 1997; Stocks *et al*., 1989; Canadian Forest Service, 1984). The species tolerance for fire (kW/m) was derived using the average fuel build-up conditions and the point (in the FBP tables for that fuel type) at which more than 50% of the crown of coniferous species would be burned (FBP system). A custom application was developed to calculate the NDFII using the same 95th percentile fire weather data to establish fire-priority zones, for selected areas in each park. The overlay capabilities of GIS were then employed to combine the ecological response and fire-priority zones to create a map for planners, park staff or fire personnel to use in dealing with present or future fire events.

Results

Figure 1 shows the results from Quetico Provincial Park and the Dawson Trail Campground (results from Nagagamisis were similar). The shape of the priority zones clearly reflects the potential fire behaviour and the effect that natural fire breaks, such as water, have on the delineation of fire priority zones. The values to protect in this example were the Chippewa and Ojibwa campgrounds. The two highlighted fire-priority zones reflect the amount of time a fire would take

Figure 1. Fire-priority zones and potential ecological effect of fire for Quetico Provincial Park, Ontario.



FFMC = fine fuel moisture code DC = drought code BUI = build up index
DMC = Drought moisture code ISI = Initial spread index FWI = fire weather index

to reach the campgrounds (4 and 8 hours respectively). The results also show the varied ecological response to a fire, given the 95^{th} percentile fire weather conditions, ranging from adverse (dark grey) to possibly beneficial (light grey). The areas in light grey that are outside the fire-priority zones could be considered potential candidate sites for prescribed burning to reduce fuel loads or meet vegetation management objectives.

Discussion

The compartmentalization of forest fire in large parks and protected areas can be realized using this decision support tool because areas of beneficial or indifferent effects can be clearly delineated from those areas where fire has either an adverse effect or should be excluded to protect values at risk. One clear advantage of this tool, and the resulting map, is its simplicity. It allows park planners, staff or fire personnel to make either operational or long-term decisions about where and when fire can be allowed to perform its ecological role without compromising the safety of people, property and infrastructure. The ability to delineate fire-priority zones around values is not restricted to structures – other values such as timber stands or endangered species habitat could also be used. The potential for defining areas where fire can be allowed will also ease the fears of local resource managers afraid of economic losses as a result of fire. This decision support tool would facilitate the use of fire in parks and protected areas.

Compartmentalizing fire management also allows us to ensure that a wide range of activities, such as fire response and fire use (e.g., prescribed burning), can be managed in large parks and protected areas. The seasonality of extreme fire behaviour can prevent well developed prescribed burning plans from implementation because ideal burning conditions are often never realized. This decision support tool allows park planners to assess potential risk and benefits based on daily, historical or forecasted weather data. In addition, the combination of a forest fire risk probability map would also help identify if areas are more susceptible to or at a high risk of burning (Doran, 2004). Knowing the relative risk for the surrounding area will help guide the implementation of prescribed burning plans to help meet vegetation management objectives, such as fuel hazard reduction, or ensuring ecological integrity.

This methodology provides park planners and land use managers with a simple decision support tool that has many advantages. The key benefits are the simplicity and ease of use: In the event of a fire, park staff can examine its location in relation to priority zones and make an informed decision as to a course of action. This tool does not require the collection or creation of any new spatial data sets because it exploits the existing forest resource inventory and provincial fuel and fire weather databases used for other OMNR applications. The use of existing data sources does not add to the cost of implementation because the data already exists. In addition, by using existing data the decision support tool can be applied to any area within the province – or country for that matter – where fuel, weather and forest resource data is available.

Future Research

The development of this decision support tool is a first step toward integrating ecological benefits with the risk of loss from forest fire, yet there are still many areas that must be examined to improve the robustness of this tool. A more realistic measure of ecological benefit/risk is needed for different species, including non-tree species. How species respond to different intensities of forest fire may not be easily standardized, therefore more research to examine or quantify the benefits based on head fire intensity is also needed. Furthermore, the inclusion of fire regimes will greatly improve the ability to compartmentalize fire because areas that are overdue for fire can help park planners prioritize fire treatment options and assess the risk to neighbouring activities. In addition to fire regimes, proximity to seed sources should be included in any assessment of potential benefits from fire. Other ecological effects such as the provision or restoration of habitat and the reduction of invasive species need to be incorporated into the decision support tool.

The technological component of this decision support tool will require further development of the user interface so that it is easily integrated with existing GIS software used by OMNR staff and so that parameters, such as species response to fire intensity, can be easily modified by the user. In addition, this tool should be integrated with the internet map server capabilities of GIS such that park personnel do not have to rely on GIS technology, nor GIS software licensing fees, to use the tool.

In conclusion, the development of this decision support tool will help park planners and local resource managers balance the fire management paradox such that the ecological integrity of fire-initiated or fire-maintained ecosystems can be ensured while also accounting for the protection of people, property and infrastructure. Compartmentalizing fire in large parks and protected areas will help balance the competing land uses within and around parks with the ecological goals and objectives established in the park planning process. Fire-initiated and fire-maintained species must be allowed to burn – with this tool, park planners and resource managers can easily determine when to allow fire and where it can perform its ecological role.

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