TESTING THE ROBUSTNESS OF THE PROTECTED AREA SYSTEM IN ONTARIO: THE TEMPORAL DIMENSION

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Abstract

Just as Ontario's system of protected areas has developed greatly over the past century, so has Ontario's approach to selecting and designing new candidate protected areas. Current approaches are based on principles of conservation ecology, with ecological representation being the primary criterion. Various forms of "gap analysis" have been used to identify ecosystems in need of representation. However, the selection and design of protected areas to fill the ecological gaps rarely has explicitly incorporated the element of ecosystem change through time. This project examines two contiguous ecodistricts (5E-9 and 5E-10) in south-central Ontario to determine whether their systems of protected areas are likely to contain ecosystems representative of these ecodistricts at various time steps into the future. We are applying a landscape modelling approach, incorporating existing knowledge of natural succession, fire regimes, other natural disturbances, and predicted land-uses (particularly forest harvesting) to develop scenarios though space and time, and then assessing the ecological representation of the resulting landscapes. This paper focuses on the conceptual approach, with hypothetical outcomes that may have implications for future site selection and design, if the goal is to have a robust protected area system that contains the full set of representative ecosystems in the long-term.

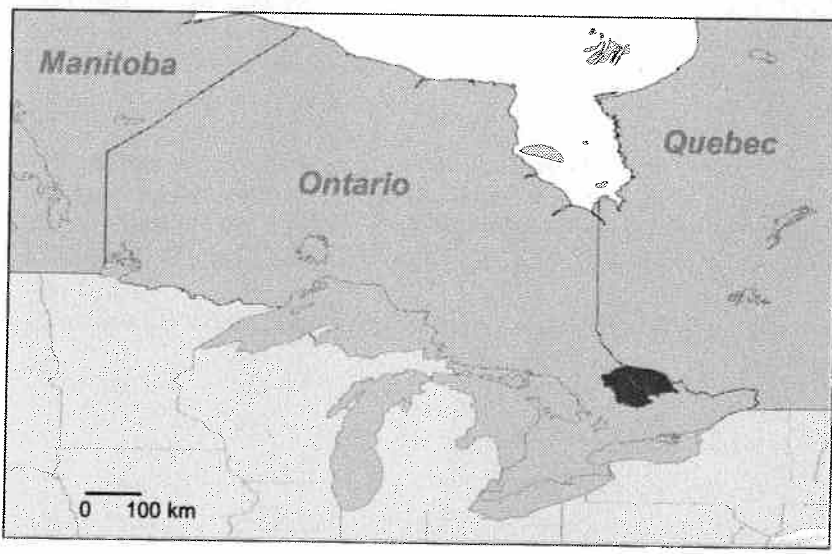
Introduction

The protected area system in Ontario has evolved and expanded since the creation of its first provincial park, Algonquin, in 1893. Likewise, the objectives of the system, and the approaches used to select sites for natural heritage protection, have changed through time. Previous approaches for selecting and designing protected areas for ecological representation purposes have focused on biological diversity at a point in time, with little explicit consideration of how such features might change through time. Clearly, the continual changes that ecosystems undergo from various disturbances and successional processes have important implications on the ability of the protected area system to represent these features through time. Ecosystem dynamics must be factored into the design of individual protected areas and the system as a whole, to account for such temporal changes.

Protected area ecologists have long recognized the need to accommodate the dynamic nature of ecosystems into protected area frameworks (e.g., Beechey, 1980). However, explicit methods for dealing with this dynamism, and the ability to test the assumption that it has been accounted for within a protected area or system of areas, generally have not been available. Landscape-scale modelling of ecosystem dynamics now offers a potentiá solution. Landscape modelling can generate future potential landscapes, based on variou possible but realistic probabilities and trajectories of change. These future potential land scapes can then be assessed with regard to how well their protected area systems repre sent the range of ecological diversity.

Currently, we are engaged in a research project with two purposes: 1) to investigat whether the current protected area system within two Ontario ecodistricts is likely to con tinue to provide ecological representation into the future; and, 2) to inform efforts t restore and maintain ecological integrity in protected areas through fire management This paper focuses on the first of these purposes. The study area consists of two adjacen ecodistricts, 5E-9 and 5E-10, situated in central Ontario on the southern portion of th Precambrian Shield. These ecodistricts contain Algonquin Provincial Park and severa smaller protected areas (Figures 1 and 2).

Figure 1. *Location of the study area (ecodistricts 5E-9 and 5E-10) in Ontario.*



The western ecodistrict (5E-9, named "Algonquin Park") is cloaked largely in upland forests, exhibits a rolling topography with rich layers of gravelly to loamy till, and has a moist, cool climate relative to the adjacent ecodistricts. Wind disturbance is believed to be the main natural perturbation in this tolerant hardwood-dominated ecodistrict. The eastern ecodistrict (5E-10, named "Brent") is warmer, drier, and lower in elevation. The topography is variable, with flat areas of sandy outwash plains and rugged areas of cliffs and incised river valleys. Pines and intolerant hardwoods are more prevalent than tolerant hardwoods, and depend to a greater degree on fire to maintain ecological integrity. A portion of this ecodistrict contains lands held by Canadian Forces Base Petawawa, the Petawawa National Forestry Institute and Atomic Energy of Canada Limited. These areas are excluded from the study due to a lack of available Forest Resources Inventory (FRI) data.

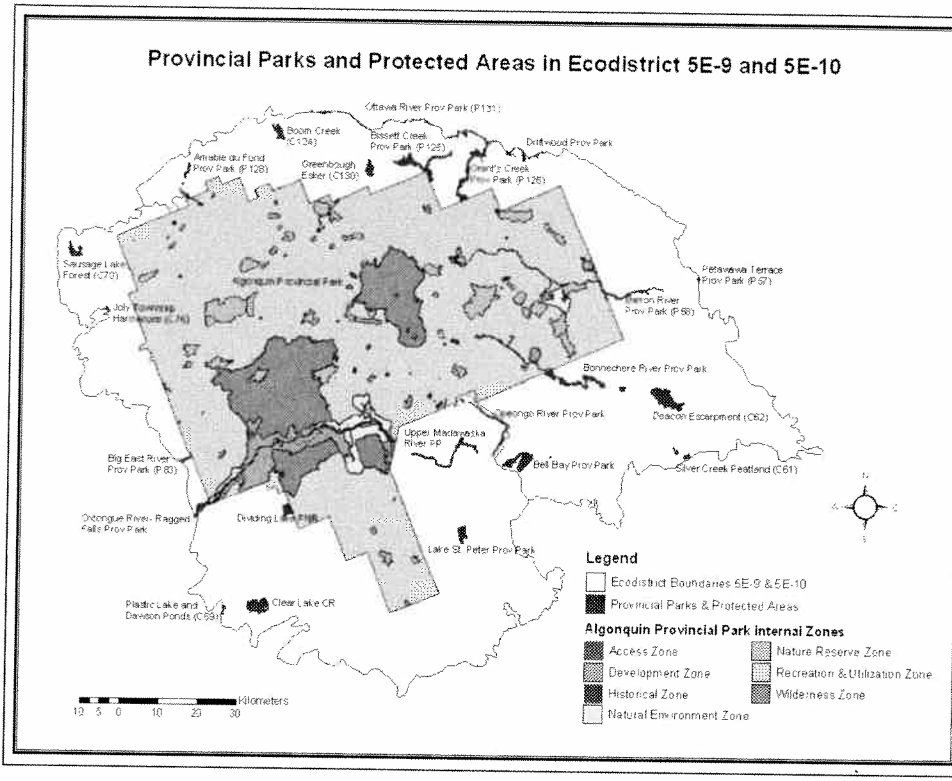
Different jurisdictions have used various forms of gap analysis to identify ecosystems that are not yet represented in protected area systems, in order to focus efforts on site selection to fill those gaps. In Ontario, landscape level gap analysis is conducted on the basis of ecodistricts. Each ecodistrict contains landform patterns and biological productivity traits that differentiate it from other ecodistricts (Crins, 2000). For life science features, landform/vegetation associations in each ecodistrict are assessed, and a set of natural heritage areas is selected that best meets the selection criteria (Crins and Kor, 2000). In the study area, there are just over 200 unique landform/vegetation combinations.

For the purposes of this study, we applied a relatively strict definition of protection. Within Algonquin Provincial Park, only those areas zoned as Nature Reserve, Wilderness, and Natural Environment are considered to be protected (for a brief review of the development of the Nature Reserve Zone system in Algonquin Provincial Park, see Crins, 1993). The portions of Algonquin zoned for commercial forestry and relatively heavy recreational use are excluded (Figure 2). Conservation reserves and provincial parks outside of Algonquin Provincial Park are considered protected, since industrial uses are excluded.

Understanding the role of fire requires describing the kind of fire history that characterized an area, and the ways in which fire influences its various ecosystems (Heinselman, 1981). Prior to European colonization, stand-replacing disturbances caused by fire, insects, and wind were the predominant natural disturbances in the study area. Fire suppression has reduced the extent of fire-dependent communities, including white pine (*Pinus strobus*)and red oak (*Quencus rubra*), and favoured their conversion to tolerant hardwoods. The study area is within the Great Lakes- St. Lawrence forest region, which is now fragmented by agricultural lands, roads, railroads, utility corridors, and urban areas. These human influences produce a lack of continuity of fuels for forest fires compared to presettlement times, creating firebreaks that are effective in stopping low intensity fires. This infrastructure, in combination with fire control, forest harvesting, and land clearing, has lengthened and modified fire cycles (Stechishen, 2002).

The *Algonquin Provincial Park Management Plan* (Ontario Parks, 1998) recognizes the need for fire management (natural or human caused fire) as a means of reaching resource management goals. In some provincial parks and conservation reserves, MNR's response to forest fires may range from full suppression near certain values to a more measured response including fire monitoring in certain areas such as wilderness zones and nature reserve zones. The latter approach may allow natural fires to burn as natural disturbances to maintain ecosystems and critical wildlife habitat, providing that they do not threaten public safety, park property and infrastructure. Providing such a range of responses usually requires the preparation of a fire management plan. Prescribed burning programs also may be an option for ecological stewardship or hazard reduction objectives (OMNR, 2003).

Figure 2. *Provincial parks and protected areas in ecodistrict 5E9 and 5E-10.*



The Modelling Approach

To generate various scenarios of ecosystem change, we are modelling this landscape through space and time using the LANDIS model (Mladenoff *et al.*, 1996; Mladenoff and He, 1999). Natural disturbance regimes (fire, wind) and current land uses (forest harvesting, protection) are being examined over a 500-year time horizon for the landscapes encompassed by ecodistricts 5E-9 and 5E-10. Existing knowledge of successional trajectories and fire regimes has been incorporated into the model to generate hypothetical but plausible future landscapes and disturbance scenarios. These results may assist in interpreting the effects of existing fire suppression policies and practices on vegetation patterns, and the ability of the current protected area system to represent ecosystems through time.

LANDIS is a spatially explicit model designed to simulate forest landscape change over large spatial and temporal extents. It simulates succession based on user-defined tree species life history attributes such as shade tolerance and seed dispersal, site conditions, and disturbance regimes. Natural disturbances such as fire, windthrow, and insect defoliation are modelled according to user-defined attributes including disturbance frequency, fuel accumulation, land type, and species age-class susceptibility to the disturbances. These disturbances are modelled as stochastic processes. Forest harvesting also can be represented. Detailed information on LANDIS can be found in several publications, including Mladenoff *et al.* (1996), He *et al.* (1996) and Gustafson *et al.* (2000).

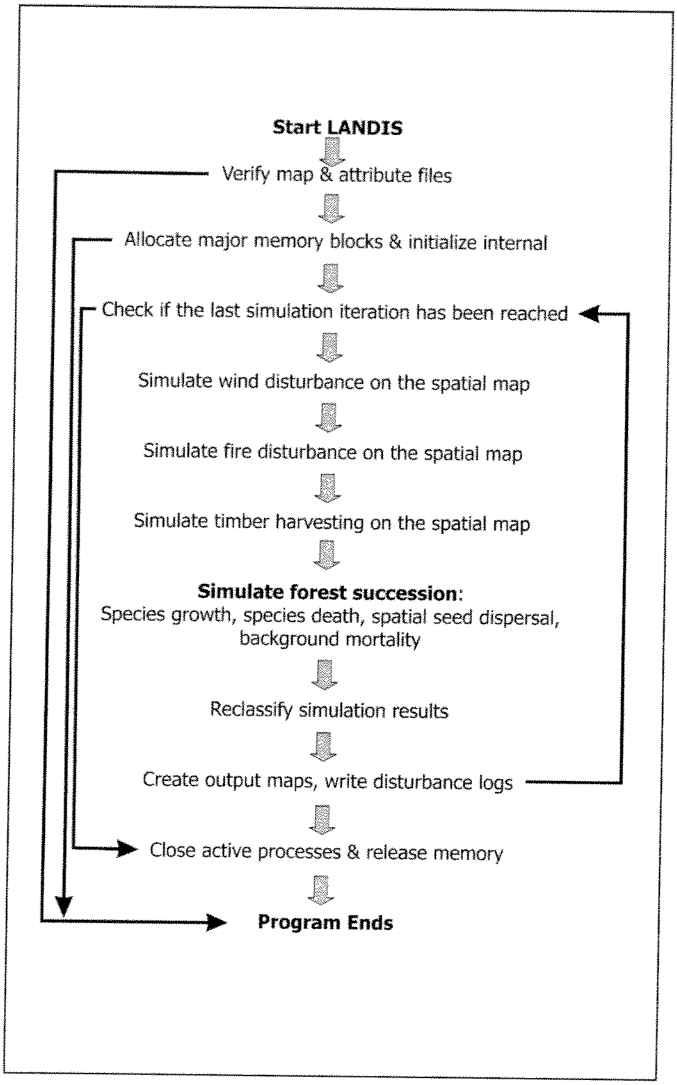
We chose LANDIS for several reasons. The model can simulate changes in the forest landscape over a large spatial area for many hundreds of years (of course, the user must recognize the fact that uncertainties magnify through time). It is relatively "open", and is capable of handling a wide variety of landscape types and sizes within reasonable processing times. LANDIS tracks the presence and absence of tree species in 10-year age cohorts for each cell. The model has some ecological "smarts". For example, fire is modelled as a "bottom-up" disturbance in which small, young trees are consumed before large, older trees. Since LANDIS simulates fire intensity as five classes, from low intensity ground fires to high intensity crown fires, low intensity fires may consume only trees that are young and/or with low tolerance to fire. At present, the model is limited to a maximum of 255 unique combinations each for species and land types. Therefore, in large spatial extents such as that used in the present study, groupings of species combinations or land type combinations is required.

Figure 3 illustrates the steps in a simulation session in LANDIS. At each step, the model verifies the information from the previous simulation, then runs disturbances and succession for the current time step. After re-classifying the resulting forest, the model creates maps to be used in the next iteration. The user can later retrieve and assess maps from any time step. Due to the size of the study area (ca. 1.7 million ha), it was most efficient to partition the modelling simulations between the two ecodistricts. To examine the differences between model outputs in the transition zone between the two ecodistricts, we applied a 10-kilometre buffer to the boundary between them. Two user-defined input files in a GIS format describe the current landscape conditions. One layer, which describes land types, is assumed to be static through time. The other layer, which describes tree species composition, is modelled as dynamic. We used Forest Resources Inventory (FRI) data, modified in different ways, as a basis for both the land type and species composition layers.

The land type input information requires both non-active and active land types to be classified. Active land types are forested polygons. The user defines species establishment, natural succession, and most disturbance information according to these land types. Non-active land types are not processed by LANDIS, but they are represented on output maps. Using FRI information, we generated non-active land types called "empty", "water", "wetland", "bog", "lowland" and "non-forest".

As a tool for ecosystem management, OMNR staff have grouped forested ecosites in central Ontario into relatively similar groupings based on site, vegetation and fire regime characteristics (Chambers *et al.*, 1997). To create the land type layer, we applied an algorithm to generate the likely forest ecosystem classification (FEC) ecosite associated with each forested polygon in the current FRI data. We chose to assign ecosites because they integrate vegetation communities and soil characteristics, and have been categorized with regard to their fire regimes. To account for fire history, we overlaid all fires greater than 200 ha in size that were recorded between the 1920s and 1990s. To allow us to represent different management regimes, we also overlaid the protected area boundaries.

Figure 3: A schematic of simulation steps to complete a LANDIS session.



To generate the species composition GIS file, we classified pixels using the first two dominant species in the FRI species string. Because the FRI information does not include age information for each tree species, we applied the FRI stand age to each tree species in the pixel. Another user-defined input file instructs the model on the ecological characteristics of tree species, including longevity, age of sexual maturity, seed dispersal distances, vegetative propagation, shade tolerance, and fire tolerance. We consulted the literature, and foresters and biologists familiar with the area, to define these parameters.

Each ecodistrict simulation took approximately 12 hours to run on a personal computer with succession and fire disturbance enabled over the 500-year horizon. Our intent in the future is to incorporate windthrow, forest harvesting, and perhaps other known disturbance regimes, into the simulations.

LANDIS is extent-sensitive and requires calibration. To verify its behaviour, we checked two main aspects. Species occurrence across the landscape over time should follow a predictable pattern. Sporadic behaviour of a species that cannot be related to known successional pathways or known responses to disturbance could indicate that the user should reexamine his/her assumptions. The disturbances that are created during a simulation also should be checked to determine if the simulations achieve realistic results relative to the disturbance input information. Calibration can be achieved by comparing values in the disturbance log files created by LANDIS with the theoretical mean disturbance size and mean fire return interval.

Preliminary Results

To date, simulations incorporating fire regimes and successional pathways have been conducted for the two study ecodistricts. An assessment of the effects of these simulations on the contents of the protected area system (effects on representation of ecosystems) has not yet been completed. However, the following preliminary results provide a sense of the trends that are emerging in terms of overall ecosystem change.

Under a scenario with no fire suppression in ecodistrict 5E-9, 480 individual fires ignited over the 500-year simulation, ranging from 1 ha (1 pixel) to 15,000 ha in size, with over 1,000,000 ha affected. In 500 years, 84% of the total forested area of 5E-9 (buffered) was influenced by fire. Approximately 25% of the burned area in this ecodistrict consisted of Sugar Maple-Hemlock-Yellow Birch ecosites, another 21% of the burned area was in Sugar Maple-Yellow Birch ecosites, 12% were Sugar Maple-Beech-Red Oak ecosites, and nearly 12% were Poplar-White Birch ecosites. These ecosites comprised nearly 72% of the total area burned in the 500-year simulation. Since fire is a stochastic event, total area burned per 10-year period ranged from 0% to 8.4% of the landscape. Approximately half of all fires had an intensity of 2 (surface fires), and 35% had an intensity of 4 (intermittent crown fires).

Under a similar scenario with no fire suppression in ecodistrict 5E-10,255 individual fires ignited over the 500 year-simulation, ranging from 1 ha (1 pixel) to 15,000 ha in size, with over 665,000 ha burned. In 500 years, approximately 68% of the total forested area of 5E-10 (buffered) was affected by fire. About 20% of the area burned in this ecodistrict were White Pine-Red Pine-White Spruce- White Birch- Trembling Aspen ecosites, another 18% were White Pine- Largetooth Aspen- Red Oak ecosites, 14% were Poplar-White Birch-White Spruce- Balsam Fir ecosites, and 9% were White Pine- Red Pine ecosites. Combined, these ecosites comprised just over 60% of the total area burned in the 500-year simulation. In this ecodistrict, the total area burned per 10-year interval ranged from 0% to 7.88% of the landscape. Approximately 43% of these fires had an intensity of 4 (intermittent crown fires), and 32% had an intensity of 5 (crown fires). The higher fire intensities likely are the result of more fire-dependent tree species such as pines there than in ecodistrict 5E-9.

Additional scenarios to be examined include partial fire suppression, full fire suppressioı predicted commercial forest harvesting operations based on recent forest managemeı plans, and natural disturbances caused by wind and insects. Under a partial suppressio scenario, all fires except for those within Algonquin Provincial Park's wilderness zone and nature reserve zones will be suppressed in the model.

Summary and Future Direction

This paper focuses on the conceptual approach, with hypothetical outcomes that may hav implications for future site selection and design, if the goal is to have a robust protecte area system that contains the full set of representative ecosystems in the long-term.

LANDIS has proven to be a powerful model with regard to its ability to simulate comple dynamics. In the present study, further analyses will be conducted to explore the sensitiv ity of the model outputs under different scenarios of ecosystem change, and to furthe investigate the influence of certain input parameters. These parameters include suck things as tree species establishment, maximum disturbance sizes, and fuel accumulatior for forest fires, and relationships among various types of disturbances.

Once satisfied that plausible future landscapes are being produced in accordance with various scenarios, we will focus on gap analyses of these future landscapes to investigate whether the current protected area system within two Ontario ecodistricts is likely to continue to provide ecological representation into the future. These results also will be used to inform efforts to restore and maintain ecological integrity in protected areas through fire management.

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