CANADA'S FOREST RESOURCE INVENTORIES: COMPILING A TOOL FOR BOREAL ECOSYSTEMS ANALYSIS AND MODELLING

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A BACKGROUND DOCUMENT

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Steve Cumming
Canada Research Chair in Boreal Ecosystems Modelling
Département des sciences du bois et de la forêt
Université Laval

Fiona Schmiegelow
Department of Renewable Resources
University of Alberta

Erin Bayne
Department of Biological Sciences
University of Alberta

Samantha Song
Canadian Wildlife Service
Environment Canada

In association with

Executive Summary

This project addresses certain data needs in modelling wildlife habitat relations for boreal conservation and forest management. Our specific concern is the provision of appropriate landcover data for various national modelling initiatives. Modelling efforts to date have used either remote-sensed data, which was available for the entire boreal region, or forest resource inventory (FRI) data, which has greater spatial and thematic resolution but was limited to regional scale studies (e.g., an individual tenure area or province). Over the past decades, a number of studies have demonstrated the value of FRI data in modeling wildfire, forest bird habitat and abundance, stand dynamics, and landscape pattern metrics, all at large spatial extents. Collectively, these studies acquired a large sample of the available FRI in Canada, and it became clear that a cooperative venture to assemble a comprehensive, integrated coverage of Canada's FRI would be feasible. This cooperation has resulted in the assembly of a virtually complete set of extant digital FRIs from all Canadian jurisdictions, providing extensive coverage of the boreal region. Models based on this digital forest inventory database have spatial and thematic resolution commensurate with forest management planning and are thus of great utility for multiple objectives, including the evaluation of management scenarios at large spatial and temporal scales. This national product should have broad applicability and relevance to forest managers, researchers in government and academia, and members of stakeholder organizations.

Introduction

The boreal and taiga regions cover significant areas of most provinces and territories in Canada, totalling more than 290 million hectares (Figure 1). These forests, dominated by both coniferous (black and white spruce, jack and lodgepole pine, balsam fir, larch) and deciduous (paper birch, trembling aspen, and balsam poplar) tree species, are characterized by extensive wetland systems and support large populations of songbirds and waterfowl as well as mammals such as beaver, wolverines, wolves, moose, and caribou.

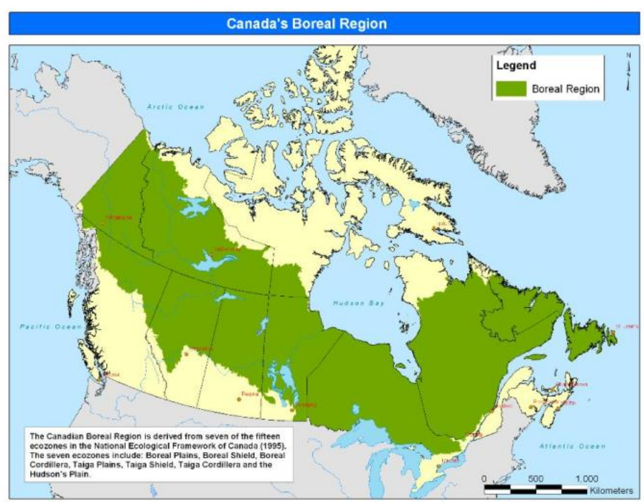

Figure 1. The Canadian boreal region as delineated by the Canadian BEACONs project and as used by the Boreal Avian Modelling project.

Pressures on these regions from economic development (forest management, oil and gas production, mining, agriculture) and climate change are increasing rapidly at both regional and national extents. Concerns about declines in forest biodiversity underscore the need to effectively manage the boreal and taiga for multiple objectives, including wilderness protection, biological conservation, and sustainable development. Regulators, managers, planners, and scientists are increasingly reliant on statistical models to evaluate the consequences of forest management activities and conservation plans over large spatial and temporal scales. To develop such models, we require information about habitat characteristics over large extents and with thematic precision and spatial resolution sufficient to support management decisions.

The work described here was designed to support a number of initiatives by government, ENGOs, and university-based researchers to develop predictive wildlife habitat models for all boreal regions of Canada. The Boreal Avian Modelling (BAM) project, as an example, is an initiative to develop comprehensive statistical models for boreal songbirds, for which extensive quantitative information has been lacking. Great efforts have been directed at collecting and synthesizing data from across Canada to model avian habitat associations in terms of climate and land cover. The purpose of the models is to predict bird abundances and distributions as well as reveal spatial and temporal patters in populations. Similar national initiatives are underway for waterfowl (joint venture between Ducks Unlimited Canada and Cumming's lab at Laval) and woodland caribou (Environment Canada, led by Schmiegelow). A related effort is the Canadian BEACONs project, which is developing methods for comprehensive conservation planning in boreal Canada in which predictive species models will play an important role.

Biophysical Data Assembly

The development of predictive habitat models requires appropriate spatial covariates at national extents. Such covariates measure details of climate, hydrology, and forest type and structure across the boreal region. The specific need for detailed forest cover information is the motive for the work we have undertaken here. Our collaborating research groups have assembled an extensive library of spatial biophysical data including national cartographic data (e.g., streams, rivers and lakes, land use), spatially interpolated climate data, comprehensive fire history and fire regime data, and remotely-sensed measures of productivity and land or vegetation cover classes. These have provided the spatial covariates for the various national habitat modelling initiatives.

Until now, these initiatives have relied on landcover data derived from space-based sensors, such as LANDSAT and MODIS. These data have the advantage of availability over the entire boreal region. However, these remote-sensed data may be inadequate for classifying forest cover or vegetation in terms of both spatial resolution and thematic precision. For example, many species of forest birds are sensitive to variation in forest age, canopy height, and tree species composition, yet these basic vegetation attributes are generally not available from existing satellite-based products. Furthermore, because the satellite-based data lack the detail needed to project stand growth, succession, and regeneration through time, models derived from them cannot be used to link forest management actions to biotic indicators at the scale of forest tenure areas. Importantly, forest tenure holders now routinely link predictive species models to their spatial forest management planning tools. However, these tools use Forest Resource Inventory (FRI) data, not remote-sensed landcover classes. At present, substituting satellite data into the planning process is not possible because of the inability to link the classes to harvest sequencing, growth and yield, or regeneration models.

Digital Forest Inventories

Digital Forest Resource Inventories (FRIs) are the primary tool of commercial forest management planning in Canada. They consist of stand maps interpreted from aerial photography at scales ranging from 1:10,000 to 1:40,000, which are typically conducted on a 10- to 20-year cycle. The stand maps estimate the location, extent, condition, composition, and structure of the forest resource. They are at least partially validated through field sampling. Each jurisdiction has developed its own procedures and standards for forest inventories. Depending on the province, inventories may be continual (where a percentage of the province is mapped and inventoried each year) or discontinuous (where a complete inventory is conducted in a short interval once per cycle). Inventories are periodically updated for major changes such as burned area, harvesting, insect and disease damage, silviculture activities, and forest growth.[1]

The photography and mapping inventory standards vary over time within jurisdictions, generally tending to increasing spatial resolution and thematic detail. In the 1970s and earlier, FRIs were essentially map-based products with associated data tables. Beginning in the 1980s, they have increasingly been produced as purely digital products using geographic information systems (GIS) and automated mapping technologies. Modern digital inventories exist in some form for much of the Canadian boreal, especially the actual or potentially commercial forests. These inventories provide detailed information on the canopy height and species composition of forested areas as well as some characteristics of wetlands. Moreover, they provide this information at a spatial resolution on the order of 2 ha, comparable to the resolution of remote-sensed data (typically 30 m, 250 m, or 1 km), and thus can provide much of the hitherto missing thematic and spatial detail.

FRI data have been widely used to model forest songbird habitat in many parts of Canada[2,3,4], and regionally for waterfowl in Québec[5] and for caribou habitat in boreal Saskatchewan[6]. They have also been used in combination with climate and weather data to model the frequency, size, and effect of wildfires.[7,8,9] In the past, such applications of FRIs have been limited to regional studies using data from one jurisdiction (e.g., as provided by cooperating provincial governments or forest products firms). However, there is clearly great potential for applications of FRI data to descriptive analyses, statistical modeling, and spatial simulation over large extents, such as entire ecozones, Bird Conservation Regions, or conceivably the entire Canadian boreal region. This potential inspired a collaborative effort between the Canadian BEACONs project, two research groups in the Sustainable Forest Management Network, the Boreal Avian Modelling Project, and Cumming's lab at Laval, who together have assembled a comprehensive coverage of all extant Canadian FRI data. This data is now being assembled into a usable form.

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[1] Leckie DG, Gillis MD. 1995. Forest inventory in Canada with emphasis on map production. *The Forestry Chronicle* 71(1): 74-88.

[2] Vernier PR, Schmiegelow FKA, Hannon A, Cumming SG. 2008. Generalizability of songbird habitat models in boreal mixedwood forests of Alberta. *Ecol Modell* 211: 191-201.

[3] Drapeau P, Leduc A, Giroux JF, Savard J-PL, Bergeron Y, Vickery WL. 2000. Landscape-scale disturbances and changes in bird communities of boreal mixed-wood forests. *Ecol Monogr* 70:423-444.

[4] Rempel RS, Baker J, Elkie PC, Gluck MJ, Jackson J, Kushneriuk RS, Moore T, Perera AH. 2007. Forest policy scenario analysis: sensitivity of songbird community to changes in forest cover amount and configuration. *ACE-ECO* 2(1): 5. [online] URL: http://www.ace-eco.org/vol2/iss1/art5/

[5] Lemelin L-V, Darveau M, Imbeau L, Bordage D. 2010. Wetland use and selection by breeding waterbirds in the boreal forest of Quebec, Canada. *Wetlands* (in press).

[6] Rettie WJ, Sheard JW, Messier F. 1997. Identification and description of forested vegetation communities available to woodland caribou: relating wildlife habitat to forest cover data. *For Ecol Manag* 93: 245-260.

[7] Cumming SG. 2001. A parametric model of the fire size distribution. *Can J For Res* 31(8): 1297-1303.

[8] Cumming SG. 2001. Forest type and wildfire in the Alberta boreal mixedwood: what do fires burn? *Ecol Appl* 11(1): 97-110.

[9] Krawchuk MA, Cumming SG, Flannigan MD, Wein RW. 2006. Biotic and abiotic regulation of lightning fire initiation in the mixedwood boreal forest. *Ecology* 87(2): 458-468.

Common Attribute Schema

A major challenge in assembling a national coverage of FRI data is reconciling the many differences in variable formats, attributes, and standards among disparate inventories. Standardization is necessary so that models can be developed using data from multiple jurisdictions or inventory versions. The Canadian Forest Service's CanFI product provides an example of how multiple inventories from across Canada can be integrated into a standardized schema.[1,10] CanFI is an aggregation of provincial and territorial FRI data into 100 km^2 reporting units. The constituent inventories were standardized so that consistent summaries could be provided at the level of reporting units; for example, one can query the areas of coniferous or deciduous-dominated forest in each unit. CanFI is stored in a relational database and GIS. The CanFI product was first developed in 1981, with periodic updates to 2001. CanFI has since been superseded by the new National Forest Inventory,[11] a sample-plot based product developed to "assess and monitor the extent, state, and sustainable development of Canada's forests…" It uses a combination of ground and photo-plots to measure forest composition and condition according to standardized mensuration protocols. However, neither CanFI nor NFI meet the needs of this project. In the case of CanFI, the underlying digital data are not available, so the product cannot be used (and was not designed for) high-resolution modeling. NFI, as noted, is a plot-based product that was never intended to produce comprehensive spatial products such as required by our applications. Notably, both CanFI and NFI were designed as inventories of Canada's forests, and are not intended as complete spatial assemblages of high resolution FRI data.

At a BAM team meeting in November 2007, we began to develop a Common Attribute Schema (CAS) to consistently represent the attributes (e.g., canopy species, height, age, and density) commonly recorded in Canadian FRIs. The complete development of a formal specification of the CAS was contracted to Timberline Natural Resource Group Ltd., a corporation with almost 40 years of experience in forest inventory production and management. The first draft of the CAS was completed in April 2009 and is now under review. The specifications focused on the most common attributes that are consistently recorded in forest inventories across Canada and which are relevant to habitat modeling. These attributes included crown closure, species composition, height, mean canopy or stand origin age, stand structure (e.g., as multiple vertical layers), moisture regime, site class or site index, non-forested cover types, non-vegetated cover types, and disturbance history. Two additional attributes of ecological interest, ecosite and wetlands, were included as they were considered important for the target habitat models, especially for waterfowl and woodland caribou. These two attributes are not present explicitly in all Canadian forest inventories, but can be acquired from other sources or approximated from other inventory attributes. For example, thanks to the efforts of the lead contractor, Mr. John Cosco, the CAS wetland classes are consistent with emerging national wetland mapping standards.[12,13]

Each jurisdiction has developed its own protocols and standards for conducting forest inventories. In some jurisdictions, several different standards are currently in use. Accordingly, we conducted an extensive review of previous and current inventory standards to tabulate the attributes and attribute codes for all existing inventories. In many cases,

[10] http://cfs.nrcan.gc.ca/subsite/canfi/home
[11] https://nfi.nfis.org/index.php
[12] National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series No. 24.
[13] Halsey L, Vitt D. 1997. Alberta Wetland Inventory Standards. Version 1.0. June.

attributes are coded as interval data with upper and lower bounds (e.g., height or age classes). However, the number and range of classes varies widely among FRIs. For example, crown closure is captured in four cover classes (A, B, C and D) in the Alberta Vegetation Inventory but as values ranging from 1 to 100 to the nearest 1 percent in the British Columbia Vegetation Resource Inventory. To preserve the precision of the information from the original inventories, the CAS captures crown closure as an interval providing two values, the lower bound and upper bound. Therefore, an Alberta "B"-value would be represented in CAS by the interval bounded by 31% (lower) and 50% (upper) while a British Columbia crown closure value of 36 would be represented in CAS as a value of 36% (value of both lower and upper bounds). This method retains all the original information, and is a unique feature of the CAS. All such attributes are coded as interval data, preserving the measurement precision of each contributing inventory. The CAS standard is similar to that developed for CanFI; a full description of the CAS standard will be published in due course.

Each inventory database is unique and therefore procedures to convert the data to the CAS had to be defined. This included the creation of detailed tables to summarize each inventory standard by province or territory and production of conversion rule sets to identify how the attribute codes from each recognized standard would translate into CAS attribute codes. To implement the translation for a particular source data set, the translation rules are encoded in computer scripts written in Perl.

Some other novel features of the CAS include i) storage of photo year, where available, so inventory attributes can be assessed relative to the time of the particular ecological survey; and ii) a comprehensive list of all tree species in Canadian forest inventories, which facilitates the use of standardized classification schemes for ecological modelling.

Source FRI assembly is complete. CAS tables have been developed for all inventory standards, excepting two data sets from Parks Canada that are in progress. The state of the project as of October 2009 is summarized in Figure 2. The final resultant will be stored in the open source spatial database engine PostGIS, which will retain the underlying spatial structure of all the original mapped data. Completion is scheduled for April 2010.

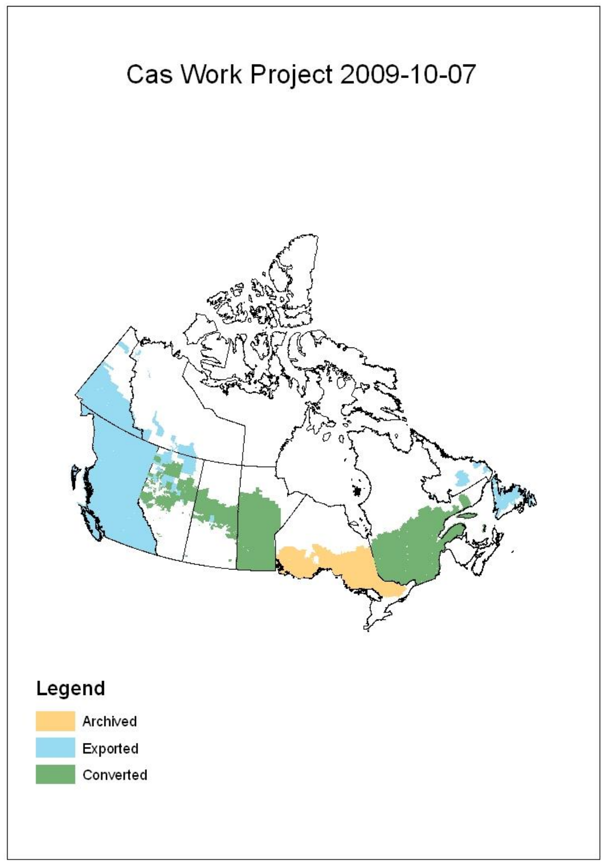

Figure 2. Status of the CAS project, Oct. 2009. Archived data have been acquired and processed so far as to delineate extents and verify contents. Exported data sets have been converted into an intermediate form necessary for the final conversion stage, after which the standardized data may be uploaded into PostGIS or a similar geodatabase.

Applications

The landcover data resulting from this effort are much more detailed than those previously available for the entirety of Canada's managed forest lands. We expect they will have many applications to wildlife habitat modelling, especially in relation for forest management and conservation planning. It will be possible to develop models sensitive to land management practices over a broader area and range of contrasting treatments than has ever before been achieved. Because models based on the digital forest inventory database have spatial and thematic resolution commensurate with forest management planning, they are of great utility for assisting in environmental impact assessments, developing objectives and priorities for conservation planning, identifying and assessing priority habitats, and evaluating management scenarios at large spatial and temporal scales. We also anticipate applications to many yet unforeseen ecological modelling problems.

Our hope is that this national product will have broad applicability and relevance to forest managers, researchers in government and academia, and members of stakeholder organizations. At present, however, the scope of application is limited by the various data sharing agreements that bind the project team. We hope in the future that new agreements can be developed with all the agencies, governments, and firms who own the data to permit its broader application. This would allow the potential of this enormous data resource to be more fully realized.

Acknowledgments

The biophysical datasets are the core of this initiative and the development of the database is founded upon the cooperation and contribution of researchers based in academic and other research institutions, governments, non-government organizations, and the private sector. We thank all the many contributors and collaborators who have made this initiative possible. This work was conducted with support from Alberta Pacific Forest Industries Inc., the Sustainable Forest Management Network, contribution agreements from Environment Canada and Ducks Unlimited Canada, the Canada Foundation for Innovation, the GEOIDE network, and the Canada Research Chairs program.

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