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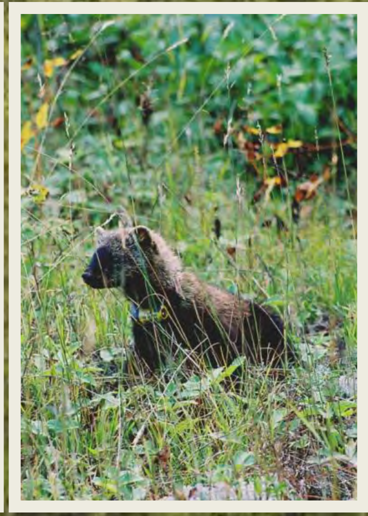
Science and Information in support of the Forest Management Guide for Boreal Landscapes

Science and Information

Simulations, Rationale and Inputs



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Electronic Document – Version 2019

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Various linked embedded objects are highlighted in blue with context specific descriptions and underlined text.

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Contents

Tables

Figures

Overview

This document describes the science, rationale and methods used in the simulation modeling that was considered in preparing the background for the Forest Management Guide for Boreal Landscapes.

The results of simulations can be found in the Landscape Guide Region-specific Science and Information Packages and Ontario's Landscape Tool. Caribou and moose results can be found in their respective specific packages.

1 Forest management guides for landscapes, adaptive management and science

The goal of the Forest Management Guide for Boreal Landscapes (hereafter referred to as "landscape guide") is to direct forest managers in how to meet the objective of conserving biodiversity in an effective and efficient manner, thereby, contributing to forest sustainability in an effective and efficient manner. The direction identifies and helps to set landscape level goals and desirable levels of forest composition (forest tree species groups and age classes) and structure (pattern) in forest management plans. Application of forest management guides recognize the importance of the natural variability of landscapes and provides a parsimonious set of standards and guidelines designed to assist planners in conserving these characteristics within desirable ranges into the future. The application of the landscape guide will result in strategic landscape maps that forecast the future characteristics of landscape mosaics in the context of the long-term management direction of forest management plans. Additional guides (e.g. stand-site, silviculture guides) provide complementary direction at finer scales.

The effectiveness of specific goals and targets in conserving biological diversity will be measured through an adaptive management process. The landscape guide is organized into three sections based on an adaptive management approach: planning, implementation, and monitoring and evaluating.

Our Sustainable Future (OMNR, 2005) speaks to uncertainty in resource management:

As our understanding of the way the natural world works and how our actions affect it is often incomplete, [we] *should exercise caution and special concern for natural values in the face of such uncertainty*.

The landscape guides deal with "caution and special concern" (See OMNR 2005) by applying aspects of adaptive management (Holling 1978, Walters 1986 and Baker 2000) and decision analysis approaches (Morgan and Henrion 1990). Adaptive management links science and policy to develop policy in a cycle that facilitates continuous improvement to practices using a four-phase adaptive management cycle (Figure 1).

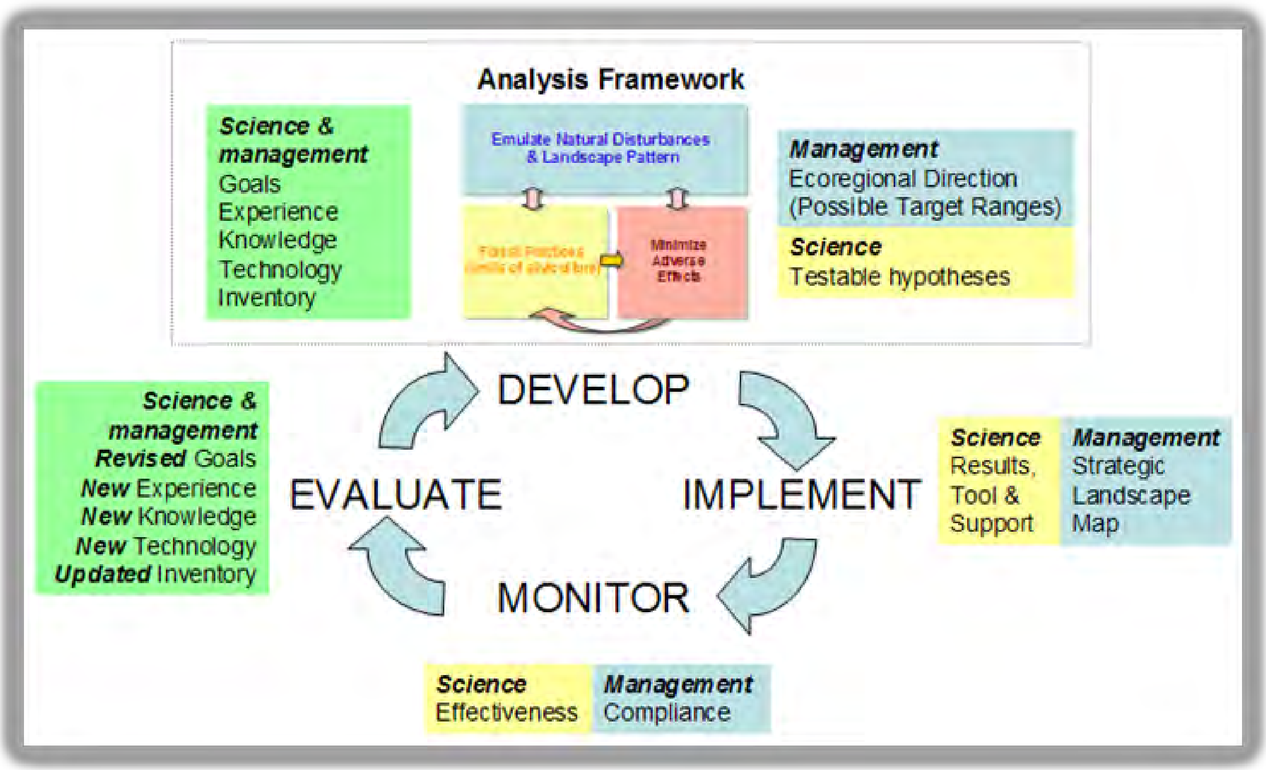

Figure 1 Analysis framework embedded in larger adaptive management cycle.

In the development phase, the guides were developed by linking science and policy based on organizational goals, existing knowledge, current technology, and existing inventories. This "analysis framework" allows for gaming of alternative scenarios of predicted management actions and evaluates the effects of these actions. These alternative scenarios to meet landscape guide goals were treated as hypotheses to be tested by; i) predicting outcomes of alternative guide standards and guidelines, ii) selecting and applying the one that is predicted to best meet goals, iii) monitoring its effectiveness in achieving the desired, predicted outcomes, and if necessary, iv) revising it considering experience.

An analysis framework was created to deal with the “inside loop” of making predictions, determining degrees of belief, and selecting a best action.

In doing so, we have variables that indicate the result of management actions (prescriptive indicators) and variables that indicate if these actions are meeting our goals (evaluative indicators) (see Rempel *et al*. 2004 for a discussion on prescriptive and evaluative indicators, and Kneeshaw *et al.* 2000 for related concepts). There are two outcomes of the development phase:

1. Predicted changes in the variables we directly control through manipulation of forest cover (e.g. edge, patch size, old growth).

2. Predicted changes in the variables not directly managed for but used to evaluate our goals (e.g. presence/absence of gold crowned kinglet).

The first outcome of the **development** phase is eco-regional direction to forest management planning teams in the form of ***desirable levels*** for the prescriptive indicators.

In the **implementation** phase, science and management continue through the adaptive management loop in a separate but parallel manner. On-the-ground actions are initiated through forest management plans in the creation of strategic landscape maps in which planning teams may adjust possible target ranges through the development of ***desired ranges*** that balance other management objectives. Scientific studies are initiated to assess the effectiveness of guide direction based on the predicted changes in landscapes established in the **development** phase.

In the **monitor** phase, management will simply ensure compliance of operational planning with the strategic landscape maps. Science will carry out monitoring activities that will contribute to the evaluation of the effectiveness of guide direction. In the **evaluation** phase, management and science rejoin to support the review of the landscape guide and bring new experience, knowledge, technology and updated inventory to the review process to assist in revising goals. This evaluation becomes the basis for future versions of the landscape guides. See the monitoring and evaluating section of the landscape guide for more details.

1.1 Analysis framework

In the development phase, existing knowledge, technology and inventories were combined to create an analysis framework that was used to predict outcomes of alternative guide scenarios. The landscape-level direction considered in guide development may have cumulative effects on landscapes over long time periods and wide spaces – effects that may not be detected until long after management prescriptions have been applied. Thus, analysis frameworks were constructed for ecoregions in the Boreal and Great Lakes - St. Lawrence (GLSL) forest regions, using “virtual reality” approaches. In each framework, three types of simulation exercises were used: simulation of landscape dynamics, using models of possible and historical landscapes to understand the range in variation; simulation of strategic forest management activities to predict future forest landscapes in response to management direction from possible standards and guidelines; and simulation of the effects of future forests on other values such as wildlife habitat, wood cost, and recreation.

These three components created a framework that *estimated* the range of variation of natural disturbances and landscape patterns, *simulated* the ability of forest management to emulate these within silviculture limitations and *evaluated* effects on plant life, animal life, water, soil, air and social and economic values, including recreational values and heritage values – hence linking back to Ontario’s Crown Forest Sustainability Act principles of sustainability (Figure 2).

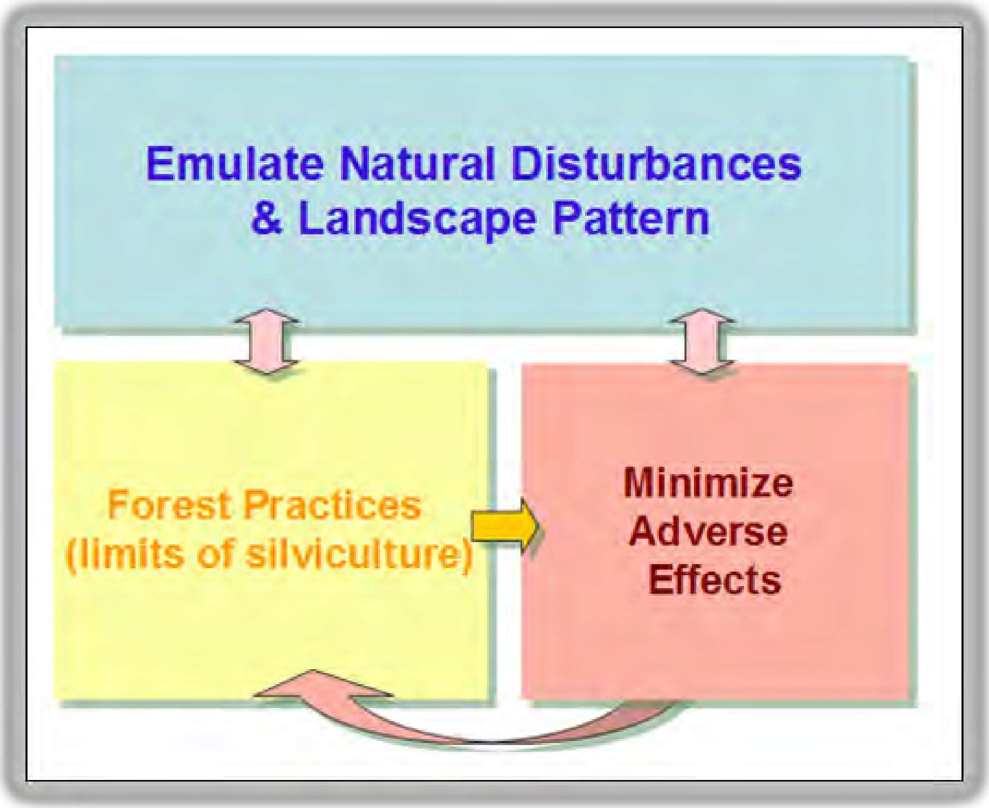

Figure 2 Three components of the analysis frameworks that simulated forest practices, natural disturbances and landscape patterns and effects on plant life, animal life, water, soil, air and social and economic values, including recreational values and heritage.

Simulating landscape dynamics provides natural landscape patterns as a null hypothesis for biodiversity conservation. Science teams estimated natural ranges of variability for landscape composition and pattern using landscape simulation models calibrated by science and expert opinion and historical information. It was assumed that these natural patterns support the conservation of biodiversity.

Strategic forest management simulations were used to assess alternative ways to meet goals and objectives. The development team and the science team assessed combinations of potential standards and guidelines as alternative ways to conserve biodiversity using management simulation models. This enabled parsimonious selection of the standards and guidelines required to direct the emulation of natural landscape patterns thereby achieving landscape-level biodiversity conservation.

Simulation of potential guide effects on other values provided a socio-economic impact analysis. The measured effects on industrial forest management included wood cost, harvest volume, transportation and road building. Non-timber values included habitat for featured wildlife species and recreational opportunities. Explicit acceptable levels of tolerance for effects of management simulations on social and economic values were not generated in the development of this guide. Relative impacts, however, were assessed by the development team through the comparison of possible management scenarios. The frameworks were adapted for use in developing eco-regional direction and continued use in effectiveness monitoring.

1.2 Conceptual analysis model

The conceptual analysis in each landscape guide region consisted of the following steps:

i) Estimating simulated ranges of natural variation (SRNV),

ii) Simulating forest management using various scenarios (guideline sensitivity analysis),

iii) Evaluating landscape biodiversity and

iv) Evaluating landscape non-biodiversity values.

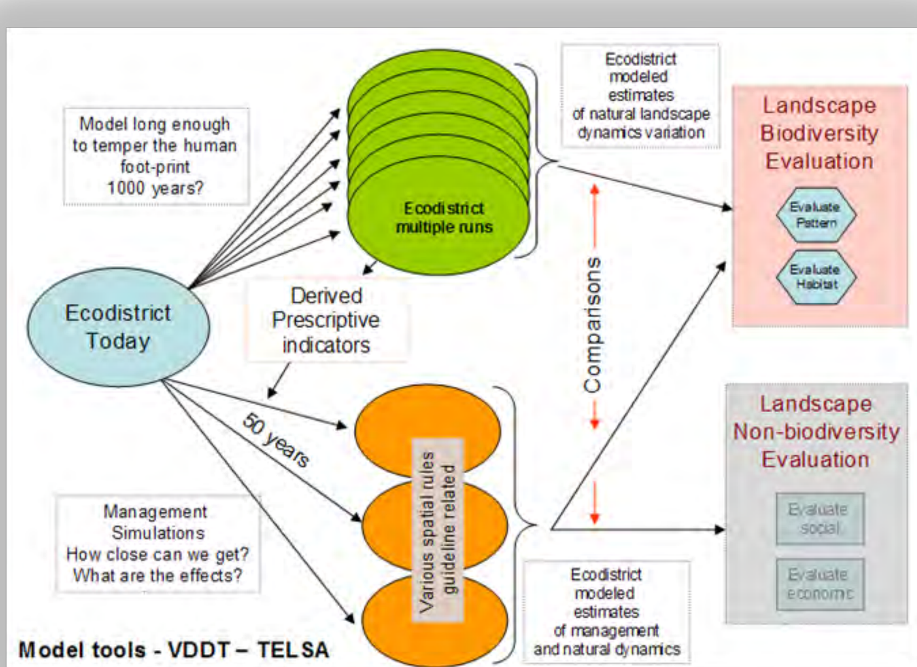

Figure 3 Example of conceptual model used for various analyses. Note: in the boreal forest region models were developed at the ecoregion level and were run for 100 years to remove the human foot-print effect.

1.3 *Science scope*

The initial request to the science teams was to provide answers to the following questions:

1) What arrangement and composition of forest patches provides the best compliance with natural landscape pattern signatures?

2) What arrangement and composition of forest patches and strategic forest management options provides the best compliance with landscape habitat signatures?

3) How well do landscapes generated by simulation exercises inspired by natural landscape pattern signatures comply with landscape-level and stand-level direction of the natural disturbance pattern emulation guide (NDPEG)?

This science and information package provide a record of the of the work carried out by the Boreal science team who developed the methods and models to address these questions.

1.3.1 Boreal Science Team Membership (alphabetical order)

- Jim Baker, Science Business Coordinator, Ontario Forest Research Institute, Sault Ste. Marie.
- Rob Bowen, Regional Planning Analyst, Regional Planning, Thunder Bay.
- Neil Dawson, Wildlife Assessment Leader, Science and Information, Thunder Bay.
- Shelagh Duckett, Northwest Region Silviculture Specialist, Thunder Bay.
- Phil Elkie, Forest Policy/Northwest Science and Information, Thunder Bay.
- Julie Elliott, Research Technician, Centre for Northern Forest Ecosystem Research, Thunder Bay.
- Dave Etheridge, Forest Landscape Specialist, Science and Information, South Porcupine.
- Michael Gluck, Ecology Forester, Forest Policy, Thunder Bay.
- Glen Hooper, Regional Planning Biologist, Thunder Bay.
- Janet Jackson, Landscape Research Analyst, Centre for Northern Forest Ecosystem Research, Thunder Bay.
- Gordon Kayahara, Forest Science Specialist, Science and Information, South Porcupine.
- Rob Kushneriuk, Forest Landscape Ecology Analyst, Centre for Northern Forest Ecosystem Research, Thunder Bay.
- Rob MacKereth, Research Scientist, Centre for Northern Forest Ecosystem Research, Thunder Bay.
- Greg Lucking, Regional Planning Biologist, South Porcupine.
- Tom Moore, Spatial Planning Systems Ltd., Deep River.
- Marc Oullette, Landscape Ecology Systems Analyst, Ontario Forest Research Institute, Sault Ste. Marie.
- Ajith Perera, Research Scientist, Ontario Forest Research Institute, Sault Ste. Marie.
- Bruce Ranta, Biologist, Forest Policy Section, Kenora Ontario.

- Rob Rempel, Research Scientist, Centre for Northern Forest Ecosystem Research, Thunder Bay.
- Kevin Ride, Regional Planning Analyst, Regional Planning Thunder Bay.
- Kim Taylor, Terrestrial Ecologist, Science and Information, South Porcupine.
- Heather Tumber, Spatial Planning Systems Ltd. Deep River.
- Peter Uhlig, Forest Ecologist, Ontario Forest Research Institute, Sault Ste. Marie.
- Stan Vasiliauskas, Project Forester, Science and Information, South Porcupine.
- Jonathan Wilkinson, Fire Management Planning Officer, Sault Ste. Marie.

2 Landscape simulations

2.1 Modeling currencies - forest units

For the purposes of the many analyses that support the development and implementation of the landscape guides, modeling surfaces were created by classifying forest resource inventories (FRI) into surfaces representing various biodiversity values (i.e., forest units, habitat, age, development stages, etc.). The starting point for each classification was forest unit based. These forest unit classifications are aggregations of common or associated forest cover types as described by various attributes in the FRI for Ontario. We developed forest units considering a balance between ecological function and management practices. The forest unit frameworks that were developed are enough detail to represent the level of information that science is able to provide including assumptions at an appropriate level in the tools and models used, and the level of information to be reported that serves as quantifiable targets and milestones.

From an analytical perspective, many different terms are used across the many models and tools used to define or describe the forest aggregation classes. Even within the tools used for analysis, the technical language for forest units is more commonly referred to as vegetative state classes or cover type codes. The terminology of forest units was chosen primarily because they are the currency used in forest management planning.

2.1.1 Boreal forest units

In both the northeast and northwest regions, we used the regionally approved (2004) **forest units (link)** as our modeling currency in the simulations. Since that time several changes/revisions have been made to query sets due to changes in FRI attributes etc. The integrity of the queries used in Ontario's Landscape Tool has been maintained to ensure that the simulated ranges of natural variation (SRNV) are valid estimates and targets to use in planning.

2.2 Boreal forest region landscape simulations

2.2.1 Overview

The Boreal Forest Landscape Dynamics Simulator (**BFOLDS (link)**), a grid-based, spatially explicit model that contains a simulation module for crown-fire regimes (FSM) and a vegetation transition module (VTM) was used to estimate ranges of natural variation in the boreal forest region. BFOLDS simulates the fire regime and fire induced forest cover dynamics at broad spatial and temporal scales (i.e. 10 million hectares over 300 years) but uses a relatively fine spatial scale - 1 ha spatial resolution for some processes.

BFOLDS is a modeling tool developed specifically for simulating stand initiating fire, succession and post fire transitions in the boreal forest region of Ontario. BFOLDS was developed by the Forest Landscape Ecology Program at the Ontario Forest Research Institute. The mechanics of BFOLDS are described in the linked references; here we describe the calibrations and inputs developed for the landscape guide project.

2.2.2 BFOLDS calibration and inputs by landscape guide region

2.2.2.1 Forest cover and forest age layers

BFOLDS uses forest units to model forest cover. The most recent planning inventories were used to create 100 metre forest unit-based raster grids. Landscape guide regions 3W, 4S3S and 4W used a condensed form of the northwest region standard forest units (i.e. soil depth modifiers were removed), whereas 3E used the northeast region standard forest units. Ages were calculated from year of origin based considering the year of inventory update. A **numeric code and forest unit relationship (link)** was created for both regions as part of the initial calibration.

2.2.2.2 Soils layers

2.2.2.2.1 Northwest region

BFOLDS uses soil moisture and nutrient information to control succession and fire behaviour (e.g. fuel loading). The input BFOLDS soil moisture and soil nutrient grids for the boreal west landscape guide regions were created using forest resource inventories (FRI). The moisture classes were dry, mesic and wet, and the nutrient classes were poor, mesotrophic, rich and organic. Ancillary, inventory-specific, photo-interpreted information was used to assign polygons. For example, where photo-interpreted lowland designations exist, polygons where classed as organic nutrient and wet moisture classes. Ecosites, when available, were used to assign polygons into nutrient classes. Figure 4 illustrates the classification of ecosites into moisture and nutrient classes. Where no ancillary or ecosite information was available, species composition and site class attributes were examined on a forest-by-forest basis and soil class assignment of polygons was done by experts. Areas without FRI data were assigned soil classes based on the Soil Landscapes of Canada mapping.

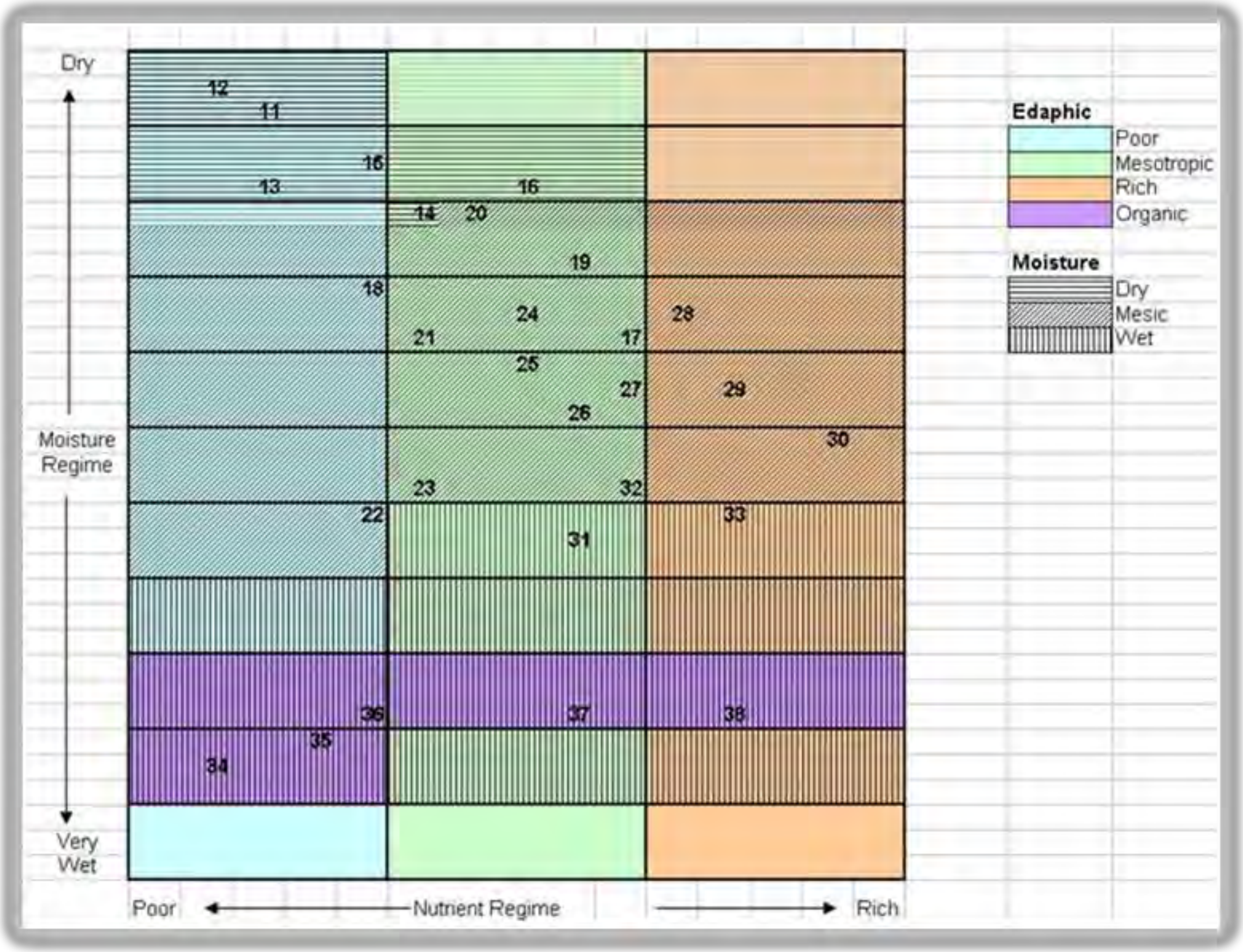

Figure 4 Nutrient and moisture class assignment based on NWR ecosite classification.

2.2.2.2.2 Northeast region

The input BFOLDS soil moisture and soil nutrient grid for 3E was created using forest resource inventories. In the initial attempt soil moisture and nutrient layers were based on the Northern Ontario Engineering Geology Terrain Study (NOEGTS) through a series of expert opinion queries. However, through model calibration runs it was felt that the soil moisture layer created from NOEGTS was too course and that a finer layer was need. At the time Northeast FRIs did not have ecosite or soil attribute information like their northwest counterparts. To obtain a somewhat consistent resolution of spatial input data the standard forest units were used to determine moisture classes (Table 1).

Table 1 Northeast forest unit – soil moisture classification.

Forest Unit	Soil Moisture
PJ1, PR1	Dry
PO1, BW1, MW1, MW2, MW3, PJ2, PRW, PW1, PJ2, SF1, SP1	Mesic
LC1, SB1	Wet

Soil nutrient assignments were developed using both **expert opinion rationale (link)** (Kim Taylor, Dave Etheridge, Rob Arnup) and **queries (link)** from the local NOEGTS layers.

2.2.2.3 Transitions

2.2.2.3.1 Transitions – Northwest region

We used, with some revisions, the succession rules and post fire transition rules outlined in the Northwest Region report "*Estimates of Eco-regional Forest Composition Derived Using Modelled Bounds of Natural Variation in Northwestern Ontario: NWSI Technical Report* TR-136*"* (link).

2.2.2.3.2 Transitions – Northeast region

We used the succession rules outlined in the Northeast Region publication "*Successional Pathways Proposed SFMM rules for Northeast Regional Standard Forest Units:* Version 2*"* (link) as default succession rules.

2.2.2.4 Fuel typing

BFOLDS uses fuel types as described in the Canadian Forest Fire Prediction System (Taylor *et al.* 1988). In both the northeast and northwest regions, we converted forest units to fuel classes/types using expert opinion.

2.2.2.4.1 Fuel types – Northwest region

Fuel type table (link) – Northwest region

2.2.2.4.2 Fuel types – Northeast region

We used SFMMTool to compute the average species composition for each northeast standard forest unit for both the claybelt and non-claybelt landscapes. We used this information in assigning fuel types to each standard forest unit.

Fuel type tables of classes used include: NE fuel types site age on the claybelt (link), site age non-claybelt (link), non-claybelt (link) and claybelt (link).

2.2.2.5 Ignition weighting

Fire ignitions were weighted to a density surface based on lightning-caused fires from 1963-2001.

2.2.2.6 Calibration with pre-industrial forest conditions

We calibrated BFOLDS to estimate a natural fire regime that was comparable to the amount of disturbance that occurred in the pre-industrial condition. Independent sources of pre-industrial condition (PIC) information were used to estimate fire cycles and in turn calibrate BFOLDS to simulate natural ranges of variability.

In 4S/3S, 4W and 3W the threshold at which the duff moisture code would allow a fire to burn in BFOLDS was varied to calibrate with the amount of disturbance found in the PIC. Additional comparisons to long term drought cycles supported either maintaining a default value of 20 or modifying this value as follows:

- 4S/3S: default value of 40 with a +/- 10% daily variance,
- 3W: default value of 20 (default) with a +/- 10% daily variance or
- 4W: mixed default values of 40 and 60 with a +/- 10% daily variance.

Fire cycles (link) generated from BFOLDS runs were compared to pre-industrial fire cycle estimates which assisted in calibrating BFOLDS.

2.2.3 Number of replications/simulations

Initially, in both the Northeast and Northwest regions, we ran multiple BFOLDS simulations over several hundred years with various inputs while observing the behaviour of burn amount and composition variance across the entire simulation period. We did this as a test to measure current landscape state with anthropogenic influence and to provide a sensitivity assessment of when landscape dynamics began stabilizing providing an estimate of natural. We found that it took approximately 75-100 simulation years before the variance became stable. Consequently, we decided to use simulation results beginning at 100 years.

In both the northwest and northeast regions, we used various fire intensities in BFOLDS to generate results for a range of conditions. In the northwest region we used 75 simulation replications from three fire intensities 250 kw/m^2, 300 kw/m^2 and 350 kw/m^2. In the northeast region we used 90 simulation replications also from three fire intensities 250 kw/m^2, 300 kw/m^2 and 350 kw/m^2 with transitional biases set to be either more deciduous and coniferous dominant.

2.2.3.1 BFOLDS – input Files

2.2.3.1.1 Ecoregion 3E

Canopy age, fire fuel, post fire transitions, succession (link)

Fire intensities: 250, 300, 350

2.2.3.1.2 Ecoregion 3S and 4S

Canopy age, fire fuel, post fire transitions, succession (link)

Fire intensities: 250, 300, 350 (link)

2.2.3.1.3 Ecoregion 3W

Canopy age, fire fuel, post fire transitions, succession (link)

Fire intensities: 250, 300, 350 (link)

Refer to BFOLDS user's manual for directions on how to use and interpret input files.

3 Historic pre-settlement surveys: composition and burn estimates

3.1 Overview

There are different techniques and data sources to estimate the natural range of variation in Ontario’s forested landscape. Historic survey notes that include records of forest attributes can provide information on the forest condition prior to industrial forest management. The Forest Stewardship Council’s National Boreal Standard – Canada Working Group requires that pre-industrial forest and disturbance regime be characterized and lists “early surveyor’s notebooks and maps” as verification tools. We use historic survey notes to validate, provide reference and in some cases (e.g. 4W – red/white pine) provide estimates of the natural conditions.

3.1.1 Northwest region

In the Northwest region 4,600 square kilometers of forest cover captured from original survey (link) notes from the pre-industrialized forests of northwest Ontario (*circa*. 1880 – 1930) were compared to current forest cover. The results indicated that the pre-industrialized forests were:

- i) richer in conifer,
- ii) contained more pure stands,
- iii) had larger disturbance areas,
- iv) had similar amounts of young disturbed forest and
- v) were less fragmented.

In two ecoregions, 4W and 4S, the amount of red and white pine on the landscape as a dominant stand type (e.g. greater than 40% of stand composition) was greater at the turn of the twentieth century than present day. These results were considered when calibrating BFOLDS and for comparing and setting targets of the relative amounts of red and white pine.

3.1.2 Northeast and Southern regions

In the Northeast region, Ontario land surveys (OLS) were conducted prior to non-native settlement. These surveys recorded forest stand and site information as well as spatially referenced points and lines. The instruction provided to Land Surveyors was consistent which resulted in similar survey and record information methodologies, thus providing a powerful data set to describe the pre-settlement forest condition in Ontario.

The methods were as follows:

i) Used the initial land survey record of each township boundary within Ecoregion 3E, 4E and 5E and compared this data to current Forest Resources Inventory (FRI) forest stand data for the same township boundaries.

ii) Standardizing tree species names in the OLS data set based on historic common names described in the literature.

iii) An analysis to determine if sampling along township boundaries was sufficient to enable us to describe the composition of the whole forest.

iv) A comparison of the percentage length of township line first listed tree species (Working Group or WG) occupied along each historic survey to the current Forest Resource Inventory (FRI) description of the same township line. We used 546, 274, and 218 township boundaries in Ecoregion 3E, 4E and 5E respectively for this analysis.

v) To determine changes in tree species within stands the species recorded in the OLS dataset were weighted based on the order they were listed by the Land Surveyor or the FRI. First listed species were given a weight of 3, second listed species a weight of 2 and third and subsequent species a 1. A similar analysis was also done assuming the listed tree species were not ranked.

vi) Patch size of burns were determined assuming fires were circular and calculating the probability of a transect crossing the circle being chosen by the Land Surveyor. The diameter of the fire was then determined by multiplying the length of actual survey transect by the ratio of the most probable survey transect to the diameter of a circle. Fires within 500 m of each other were merged.

vii) To calculate the fire disturbance cycle, the physical evidence of a fire was assumed to be visible for a period of 15 years.

Comparisons of the historic surveys and FRI data in the northeast indicated the following:

i) Conifer WG's, other than the jack pine in 5E, have become less common in all three ecoregions studied. An increase in the jack pine WG was observed in 5E.

ii) Poplar and maple WG's have become more common in all three ecoregions. Birch WG (primarily white birch) increased in 3E and 4E. An increase in white birch was observed in 5E, however the small sample size prevented further analyses to determine if the increase was statistically significant.

iii) Red and white pine WG's have been reduced significantly in all three ecoregions studied. These species have also become less dominant within stands and are also found in fewer stands today than in pre-settlement times in 3E, 4E and 5E.

iv) Changes in individual species dominance and prevalence within stands in 3E were as follows:

   a. White birch, poplar, and maple are more dominant in stands today than in pre-settlement times.
   b. White birch, spruce and maple are found in more stands today than in pre-settlement times in 3E.
   c. In ecoregion 3E spruce has become more dominant, however there are fewer stands with spruce as the first listed species. Therefore, the portion of

the forest in 3E occupied by the spruce WG has decreased since pre-settlement times.

d. Tamarack and cedar have become less dominant within stands and are also found in fewer stands today than in pre-settlement times.
e. Jack pine has become less dominant within stands and is also found in fewer stands today than in pre-settlement times in 3E.

v) Changes in individual species dominance and prevalence within stands in 4E were as follows:

a. White birch, poplar, and maple are more dominant in stands today than in pre-settlement times.
b. Spruce is found in more stands today than in pre-settlement times.
c. Tamarack and cedar have become less dominant within stands and found in fewer stands today than in pre-settlement times.
d. Balsam fir has become less dominant within stands and also found in fewer stands today than in pre-settlement.

vi) Changes in individual species dominance and prevalence within stands in 5E were as follows:

a. Birch (primarily white birch), poplar, oak, ash, spruce and maple are more dominant in stands and found in more stands today than in pre-settlement times.
b. Hemlock, cedar, larch and balsam fir have become less dominant within stands and found in fewer stands today than in pre-settlement times

vii) The evidence of forest fires of various sizes; some over 10,000 ha were recorded in ecoregions 3E and 5E.

3.1.2.1 Ecoregion results

Ontario land surveys were conducted in ecoregions 3E (link), 4E (link) and 5E (link) (maps). Fire size (link) and area burned were estimated for each of the ecoregions. Working group changes (historic versus current) were estimated for each ecoregion 3E (link), 4E (link) and 5E (link).

3.1.2.2 Forest management unit results by dominant species composition

At the forest management unit level, the dominant species compositions were compared, historic versus current for each of the following management units (link): Algoma Wawa, Algonquin, Bancroft Minden, Big Pic, White River, Black River French Severn, Gordon Cosens, Hearst, Iroquois Falls, Kenogami, Nipigon, Magpie, Mazinaw Lanark, Moose River Cochrane, Nagami, Nighthawk, Nipissing, Northshore, Ottawa Valley, Pineland, Romeo Malette, Shining Tree, Smooth Rock Falls, Spanish, Sudbury, Superior Martel, Temagami and Timiskaming.

Note: These comparisons are by dominant species which is often different than working group (first listed species).

4 Landscape Classes

4.1 Landscape class definitions

The forest mosaic across a landscape provides habitat for many wildlife species, each with its own preferences for combinations of vegetation types, development stages, arrangement and configuration. It would be difficult to assess landscapes for each species within the context of a forest management plan. To reduce the complexity of this problem and as a coarse filter approach, the landscape development team and science teams developed landscape classes according to our collective understanding of how forests function as habitat. We developed landscape class classification schemes of between 5-10 classes for easy visual and analytical interpretation. These landscape classes represent the fundamental coarse filter assessment units.

Landscape classes were developed based on clustering analyses of preferred and used habitat types depicted in OMNR's habitat matrices (e.g., Holloway *et al*. 2004). The habitat matrices summarize habitat affinities of selected vertebrate species based on forest type and development stage. The matrices contain up to 150 habitat classes and the objective of the clustering analysis was to find smaller subsets that generally reflect how vertebrates use habitat. Cluster analysis, also called segmentation analysis or taxonomy analysis, seeks to identify homogeneous subgroups. More specifically, cluster analysis seeks to identify a set of groups which both minimize within-group variation and maximize between-group variation.

We used SPSS hierarchical cluster analysis (average linkage technique) to group forest type by development stage combinations for each region based on the similarities in suitability ratings. Our goal was to identify between five and ten classes in each region. We felt five to ten classes would be appropriate for analysis and interpretation within the context of coarse filter application of the landscape guide. We also felt that between five and ten classes provided in-class flexibility for forest unit desired level and target achievement while providing a level of resolution while still maintaining the coarse-filter landscape guide direction for each region.

4.2 Landscape class results

Based on the clustering analysis landscape classes were developed for the northeast (Table 2) and northwest (Table 3) regions. Relationships between species from the habitat matrices and landscape classes (link) were generated for each region.

Table 2 Northeast region landscape classes.

Landscape Class *	**Northeast Region 3E** **Landscape Guide Forest Unit**	**Development stages**
1 - Presapling	All	Pre-sapling
2 – Sapling	All	Sapling
3 - Immature Conifer	PRW, SP1, LC1, PJ2, SB1 and SF1	Immature
4 - Immature and Older pine	PR1, PJ1	Immature, Mature and Old
5 - Mature & Older Upland Conifer	PJ2, SP1, SF1 and PRW	Mature and Old
6 – Immature and older hardwood and Immature mixedwood	PO1, BW1, MW1, MW2 and MW3	Immature, mature and old (MW1, MW2 and MW3 immature only)
7 - Mature and Older Mixedwood	MW1, MW2 and MW3	Mature and Old
8 – Mature & Older Lowland Conifer	SB1 and LC1	Mature and Old

*Although the clustering analysis did not discriminate between upland (PJ2, SP1 & SF1) and lowland conifer (SB1 & LC1) we felt that functionally two different landscape classes were needed. These additional landscape classes make up a significant amount of mature and old development stages on the landscape.

Table 3 Northwest region landscape classes.

Landscape Class	**Northwest Region 3W, 4S, 4W, 3S** **Landscape Guide Forest Unit**	**Development stages**
1 - Presapling & Sapling	All	Pre-sapling, Sapling
2 - Immature Conifer	BfDom, ConMx, PjDom, PjMx1, PrwMx, SbDom and SbMx1	Immature
3 - Immature Hardwood	BwDom, HrdMw, HrDom, OthHd, PoDom,	Immature
4 – Mature and Late BF	BfDom	Mature and Old
5 – Mature and Late Lowland Conifer	OcLow, SbLow	Mature and Old
6 – Mature and Late Hardwood & Mixed	BwDom, HrdMw, HrDom, PoDom	Mature and Old
7 – Mature and Late Upland Conifer & Mixed	ConMx, PjDom, PjMx1, PrwMx, SbDom and SbMx1	Mature and Old

5 Simulated ranges of natural variation – SRNV

5.1 Area based SRNV

We used the simulation models to estimate the "natural" range of conditions (i.e., composition and pattern) in a landscape without anthropogenic influences. The BFOLDS model simulations included crown fire disturbances, succession and post fire transitions. BFOLDS has stochastic components where the model samples from input distributions when simulating natural landscape dynamics resulting in a different result each time a simulation is run.

Multiple simulations provide a range of landscape conditions. Area results for indicators (e.g. amount of conifer, amount of habitat etc.) are represented using box and whisker diagrams. These box and whisker diagrams include the maximum, minimum, 25th percentile, 75th percentile and median for a given indicator. Collectively these make up the simulated range of natural variation (SRNV) (Figure 5).

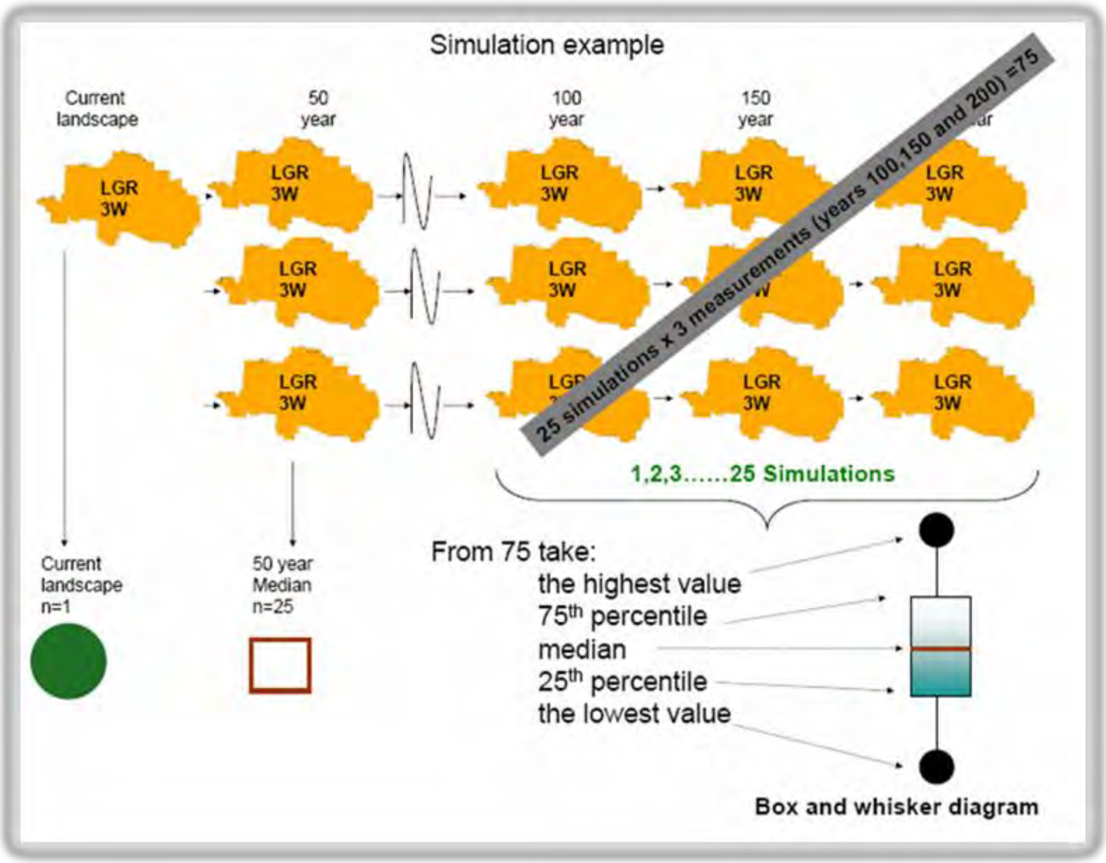

Figure 5 Example showing stylized ecoregion simulations and resulting box and whisker diagram. The box and whisker diagram is the estimated SRNV for area-based indicators based on multiple simulations.

5.2 Patch based spatial indicator SRNV

In many cases, the area based SRNV is a satisfactory measure and provides a valid estimate of the natural landscape. However, for species such as forest-dwelling woodland caribou that need habitat to be arranged in large areas and high concentrations, the relative arrangement of the habitat is important. Depending on the indicator of interest, we use patch size and/or landscape texture as spatial indicators.

We use the Landscape Scripting Language (LSL) to assess the spatial arrangement of indicators of patch and texture based SRNV. LSL partitions the landscapes into hexagons and uses the frequency distribution of hexagon occupancy relative to the indicator being measured. For instance, forest under 36 years in age is classified as young forest according to the landscape guide indicators. LSL classifies the forest into stands less than 36 years old, then drapes a hexagon fabric onto the classified surface and estimates the amount of young forest within each hexagon. We used seven hectares as our base hexagon size in most analyses. The proportion of young forest is estimated based on the forested area within each hexagon. Hexagons with 50% or less forest are not used. A hexagon is classed as young if it occupied with 50% or more forest and of that – 50% or more is less than 36 years. Adjacent hexagons classed as young become part of the same patch.

LSL produces both a map and a histogram of the result. The histogram is a frequency distribution representing the proportion of patches (relative to the total number of patches) in various size classes (Figure 6).

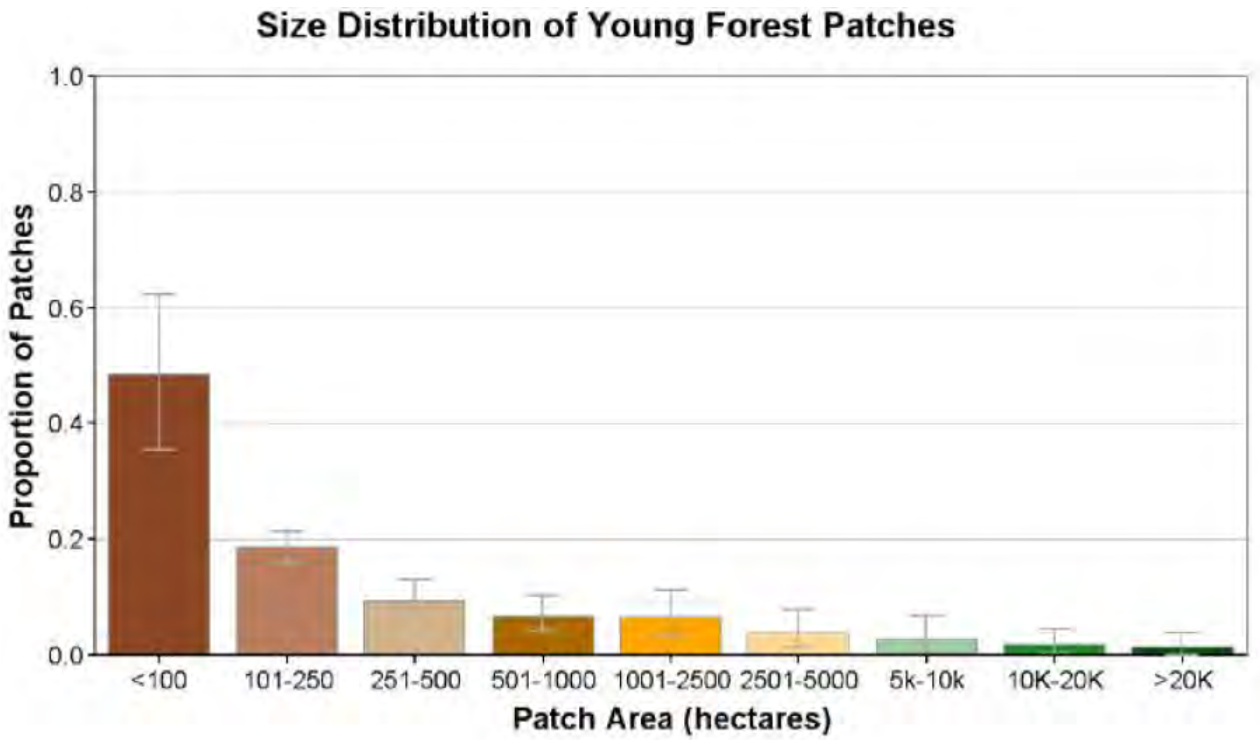

Figure 6 Landscape scripting language (LSL) frequency distribution histogram of young forest (<36 years) in various size classes. The top of each bin represents the mean from the collective BFOLDS simulations and the error bars represent the minimum and maximum measurements.

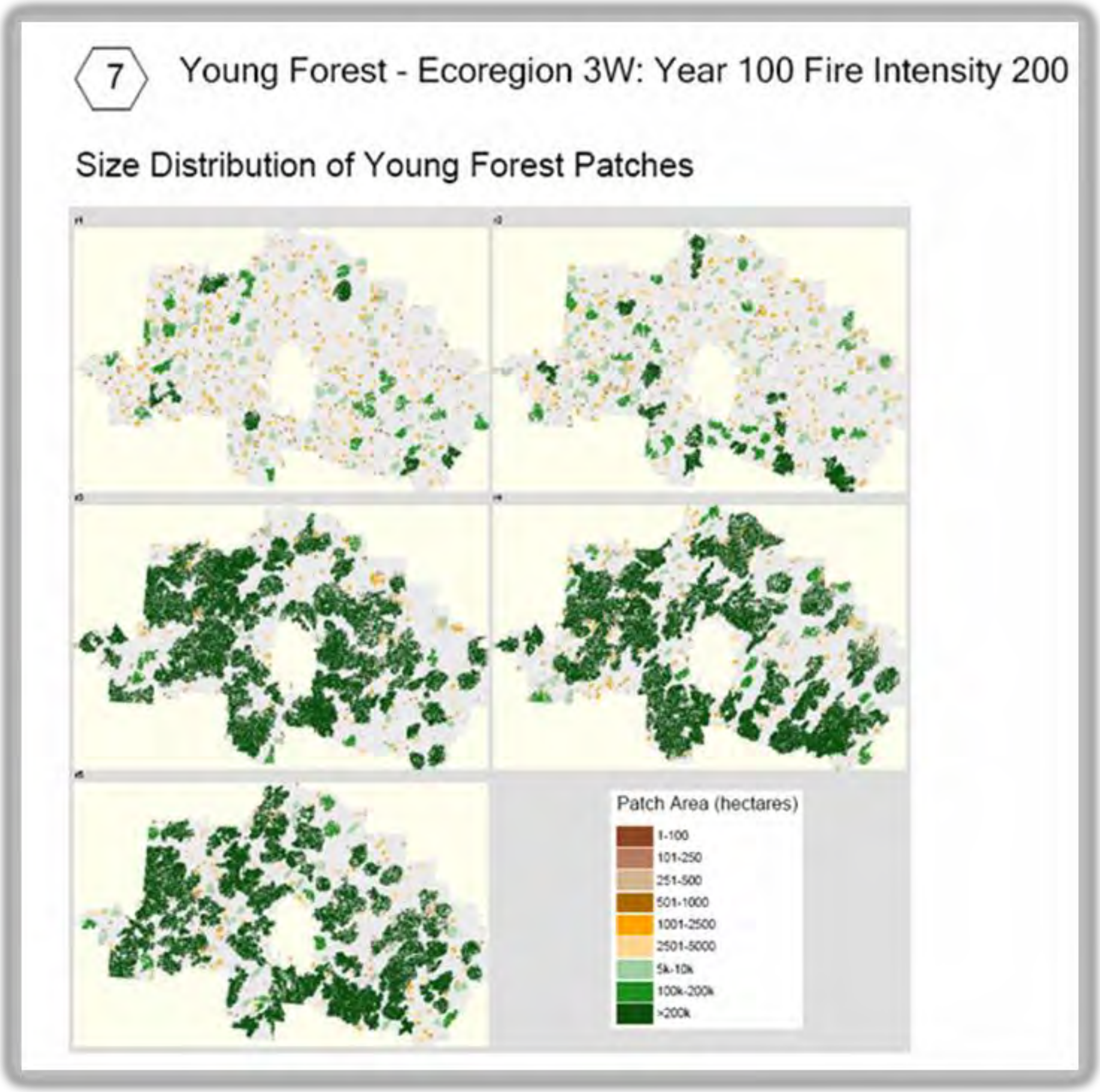

Figure 7 Landscape Scripting Language (LSL) example of five maps showing the patch size distribution from BFOLDs simulations.

5.3 Texture based spatial indicator SRNV

For some indicators, characterizing the landscape using traditional measures such as patch size and frequency is not valid. For instance, using the patch size frequency technique for the mature and old forest on landscapes that are several hundred thousand hectares in size, reporting a mean or median patch size for several thousand patches is difficult to interpret and consequently use for management targets. The mature and old forest is often distributed across the landscape with areas made up of high concentrations and other areas with relatively low concentrations.

Using an LSL texture analysis is a more meaningful- less ambiguous method because it reduces the problems associated with the traditional patch measurement methods. For instance, at the 500-hectare level, LSL creates a 500-ha hexagon fabric which it overlays on a landscape classified into mature and old forest at the FRI polygon level. Within each hexagon, the amount of mature and old forest is estimated, and the relative proportion is estimated based on the amount of forest in the hexagon. Hexagons with less than 50% forest are not used. LSL then creates a frequency distribution (Figure 8) and map (Figure 9).

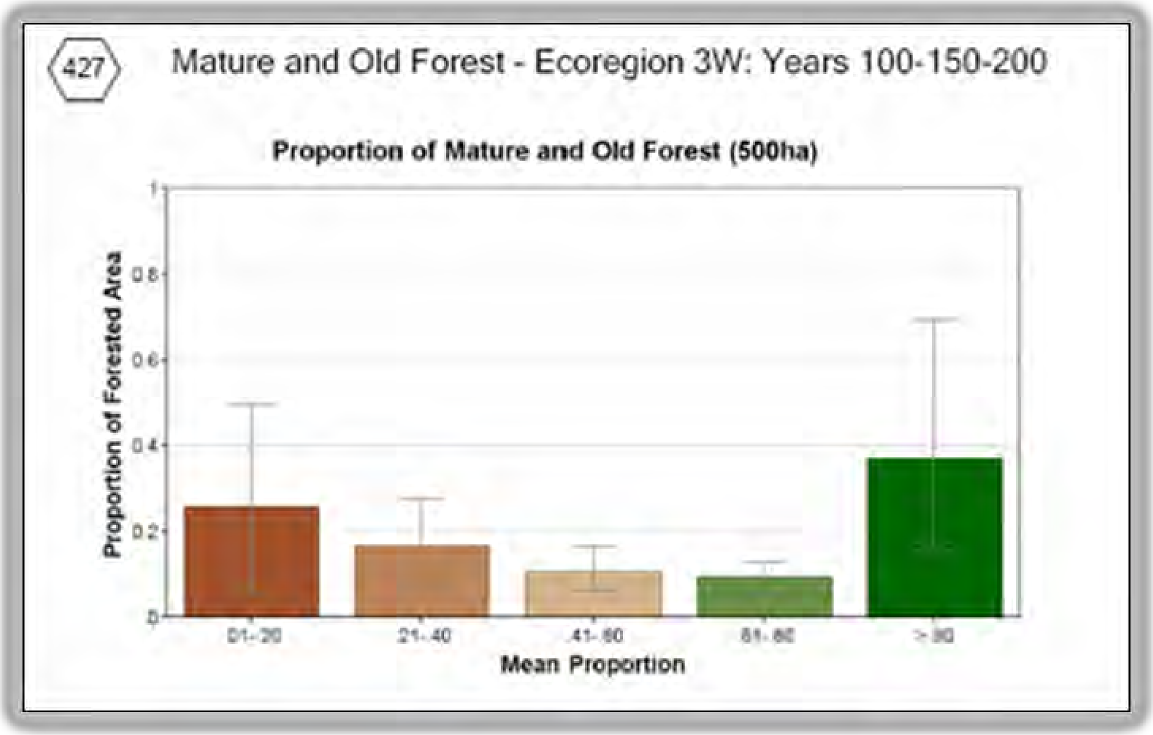

Figure 8 Frequency distribution histogram representing the relative distribution of 427-hectare hexagons with 0-20, 21-40, 41-60, 61-80 and 81-100 % of forested area in the mature and old class. Error bars represent the range from multiple simulation runs.

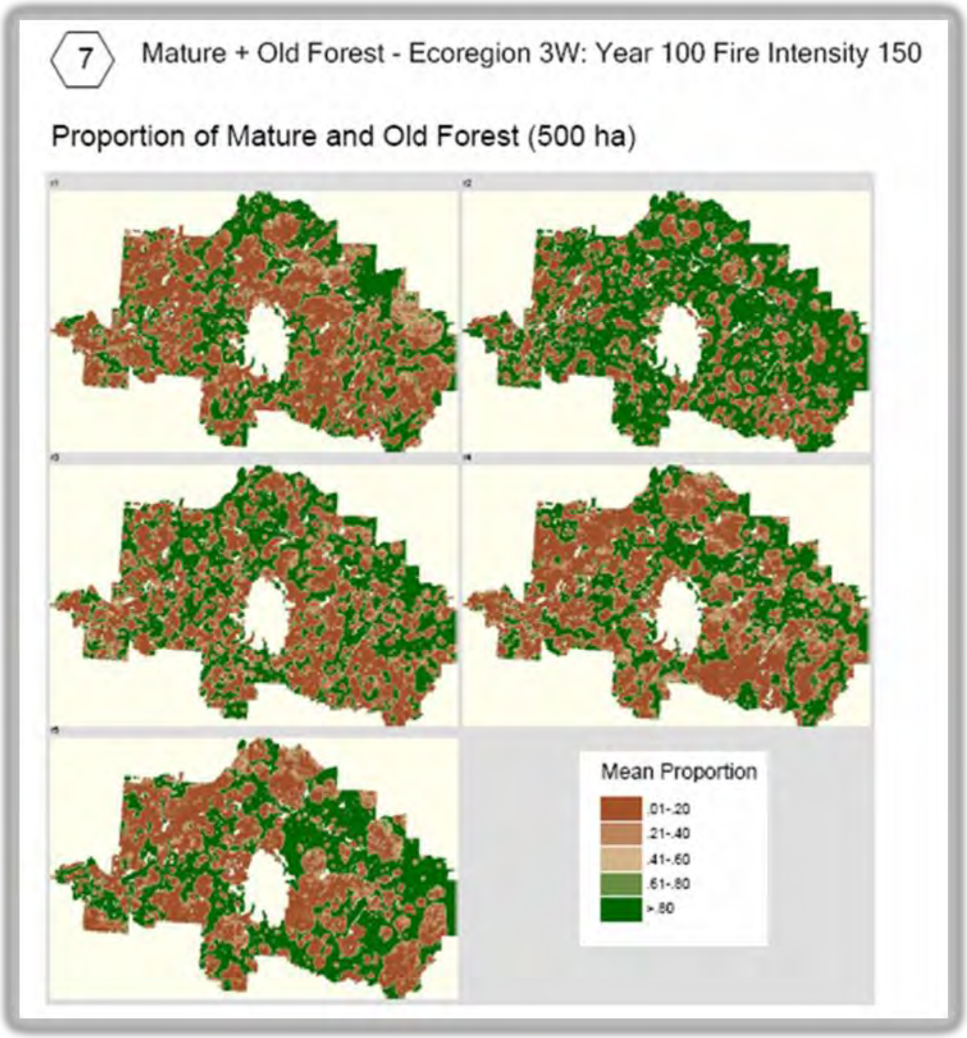

Figure 9 Landscape Scripting Language (LSL) example of five maps showing the texture of mature and old forest from BFOLDS simulations.

6 Prescriptive indicators

Ontario's forest landscape is designed through application of the coarse filter by addressing three key prescriptive indicators: pattern, composition and structure. Prescriptive indicators were defined by the landscape guide development team. Refer to the landscape guides for a listing and description of each prescriptive indicator. Ontario's Landscape Tool contains techniques for estimating each of these indicators.

7 Evaluative indicators

Evaluative indicators are generally habitats for various wildlife species and are used in the landscape guides as indicators that are subject to the evaluation of the effectiveness of the guides through monitoring.

The boreal science team developed a list of species that could be used for evaluating the effectiveness of the landscape guide within an adaptive management framework. This list is intended to be inclusive and is expected to change over time. We developed a model for each animal based on peer-reviewed literature and/or on-going research.

7.1 General boreal evaluative indicator models

Each of the following generalized models was developed using ecosystem comparisons from boreal classifications and is available in Ontario's Landscape Tool. The following is a list of evaluative indicators used in the boreal forest region – for descriptions of models open the evaluative model descriptions (link) portfolio.

i) Lynx (*Lynx canadensis*) boreal west,

ii) Lynx (*Lynx canadensis*) boreal east,

iii) Northern Flying Squirrel (*Glaucomys sabrinus*),

iv) Snowshoe Hare (*Lepus americanus*) boreal west,

v) Snowshoe Hare (*Lepus americanus*) boreal east,

vi) American marten,

vii) Boreal songbirds,

viii) Moose (refer to Moose Science Package),

ix) Woodland caribou (refer to Caribou Science Package).

7.1.1 Northwest region marten models

In response to the release of the *Forest Management* Guidelines *for the Provision of Marten Habitat* the Northwest Region created models (Ontario Marten Analyst (link) and Marten 1 and 2 models) specific to the definitions of habitat in the guides. The most current marten 2 (link) models were converted to forest unit models used in the landscape guide analysis and are available in Ontario's Landscape Tool.

7.1.2 Northeast region marten models

Like the northwest marten models, the NE marten models (link), based on recent studies (2008) were converted to forest unit models.

7.1.3 Boreal song bird models

Boreal song bird models were developed and current and SRNV of probability of occupancies were estimated and are included in Ontario's Landscape Tool. The models were developed by Rob Rempel of the Centre of Northern Forest Ecosystem Research: Forest policy scenario analysis – Evaluating the effectiveness of coarse-filter policy options on conserving songbird communities (Rempel *et al.* 2007 (link)).

7.2 Evaluative indicators – forest dwelling woodland caribou

A separate science and information package was developed for caribou. Refer to Science and Information Package – "Caribou" for a complete description of Caribou models and simulation results for each region.

7.3 Boreal bioclimatic moose models

A separate science and information package was developed for moose.
Refer to Science and Information Package "Moose" for model descriptions and simulation results at the forest management and wildlife management unit levels.

8 Literature

8.1 Main body - literature cited

Note – refer to the various embedded objects for specific component literature citations.

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8.2 List of BFOLDs reports and publications (uncited)

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