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Timber supply analyses under conventional and ecosystem-based management scenarios in an eastern boreal forest

Highlights

- Conventional management (CM) and ecosystem based management (EBM) are two forest management practices used in Canada. The main difference is that under CM scenarios clear cutting is the predominant practice, whereas under EBM scenarios both clear cutting and partial cutting are practiced.
- Timber supply analysis (TSA) was used to compare timber supply obtained from CM and EBM taking into account First Nations' concerns and spatial criteria.
- Optimization of timber supply had a positive effect on harvest levels in both management scenarios. However, these effects were higher in the EBM scenario.
- Consideration of First Nations' concerns and spatial criteria in the TSA had a negative effect on timber supply.
- Availability of diverse silvicultural options makes EBM more robust in responding to the harvest spatialization criterion.

What is ecosystem-based management and why is it useful?

Forests are shaped by natural disturbances such as fire, insect outbreaks and diseases. Boreal forests are particularly adapted to such disturbances. Inspired by such forest dynamics, ecosystem-based management (EBM) offers an opportunity to maintain managed forests as close as possible to the structure and composition of natural forests. EBM is a tool that uses silvicultural scenarios and management strategies at the landscape level; its objective is to apply harvesting practices that mimic natural disturbances in their frequency, severity and distribution.

Forest managers in Quebec are currently considering EBM as a key forest management strategy as recommended by the Coulombe Commission (2004), and are interested in improving the practices of forest management inspired by natural disturbances. For these reasons, more research is needed to measure EBM's feasibility and acceptability by answering questions such as:

- How efficient is EBM in achieving forest management objectives?
- What are the effects of accounting for First Nation's concerns and other spatial criteria within EBM?

Application of ecosystem-based management in the field

The Forest Management Unit (FMU) 085-51 in northwestern Quebec was selected as a case study to apply EBM (Figure 1). This FMU is located within the spruce-moss bioclimatic sub-domain and covers an area

of 1.08 million hectares. This area was selected for two reasons: first, Tembec, the company responsible for the management of this FMU, is currently incorporating EBM as their main forest management strategy; second, Tembec had already initiated an EBM provincial pilot project in part of the FMU.

In order to maintain the structure of the managed forest as close as possible to that observed under natural conditions, a cohort-based EBM template suggested by Bergeron *et al.* (2003) was considered for this study. Under this template, 62% of the study area is managed as even-aged forests by clear cutting (cohort 1); 21% is managed as uneven-aged forest by partial cutting (cohort 2); and 17% is managed for irregular structure by selection cutting (cohort 3). We define clear-cutting as the harvesting of all merchantable trees in a stand with or without protecting the advanced regeneration. Partial-cutting corresponds to the harvesting of a certain proportion of merchantable trees in a stand. Selection-cutting (individual tree selection), also a type of partial cutting, emulates the natural mortality of individual trees in a stand. This model is based on successional pathways that reflect the natural forest dynamics of the boreal forests in north-western Quebec. Three main succession pathways for jack pine, trembling aspen and black spruce have been identified by Bergeron *et al.* (2003) in the FMU under study. The proportion of area under different cohorts and the transformations from one cohort type to another is a function of time since the last fire (Figure 2).

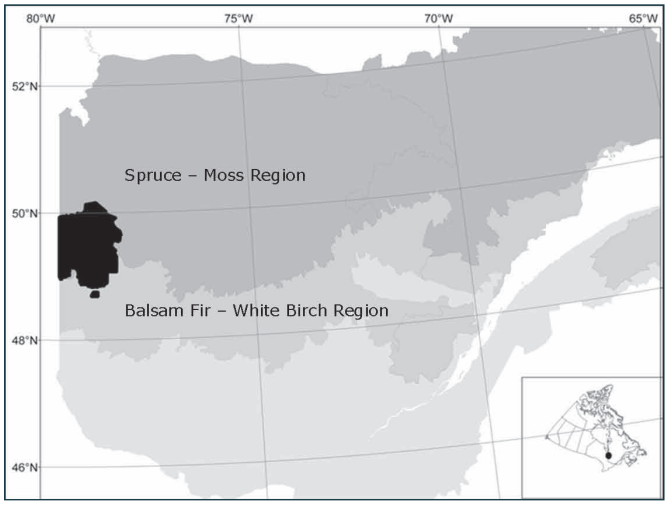

Figure 1. Study area (FMU 085-51) in black shade.

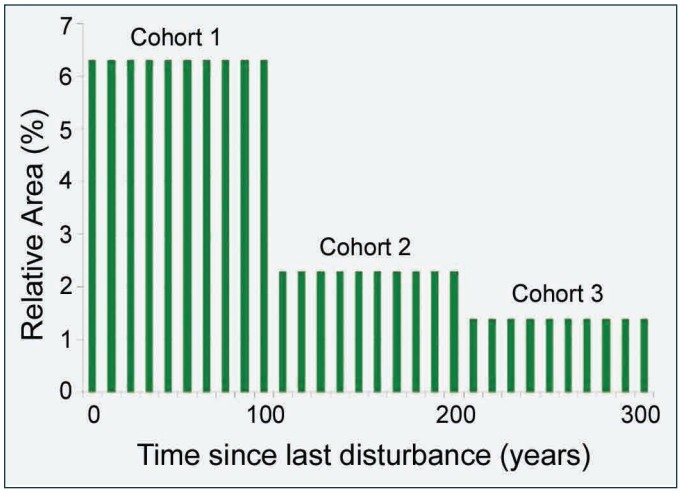

Figure 2. Ecosystem-based Management Template suggested by Bergeron *et al.* (2003).

Conventional and ecosystem-based management scenarios

Harvest levels implemented in Quebec are typically determined by the concept of sustained yield. Under this concept, the *periodic harvest level* is defined by the lowest volume available for harvest during the simulation horizon. Under the CM scenario, careful logging around advanced growth (CLAAG) is the only silvicultural option available for timber harvesting. Areas that undergo CLAAG and plantation during the planning period are fixed. A key consequence of this scenario is the distribution of large forest areas under the same age classes.

A key objective of EBM is to diversify the age class distribution over the landscape. To maintain and increase such diversification, the FMU was regrouped into various management strata and each stratum was assigned a cohort type based on the horizontal and vertical structure and species composition of the stands. We integrated the silvicultural scenarios proposed by Nguyen (2002) in our timber supply analyses (Figure 3), which include:

- CLAAG in black spruce stands to initiate regeneration of black spruce;
- Clear-cut, scarification and plantation in old black spruce forest (cohort 3) and clear-cut followed by plantation in jack pine forest to initiate jack pine regeneration;

- Clear-cut and scarification in old black spruce forest (cohort 3) and clear-cut in trembling aspen forest to initiate the regeneration of trembling aspen; and
- Partial cut of different intensity to transform a cohort type to another.

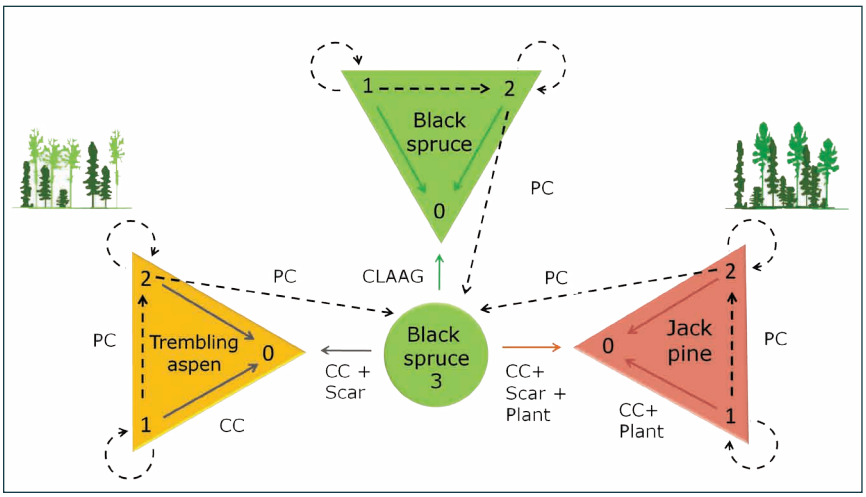

Figure 3. Successional pathways and elements of ecosystem-based management; cohort types (0 = regenerating stand, 1, 2, 3) and silvicultural treatments. CLAAG = Careful logging around advanced growth; PC = Partial-cut; CC = Clear-cut; CC + Plant = CC followed by plantation; CC + Scarif = CC followed by scarification; CC + Scarif + Plant = CC followed by scarification and plantation. (From Nguyen 2002).

We proposed clear cutting in 62% of the land base to recruit even-aged stands (cohort 1); partial cutting in 21% of the land base to develop an uneven-aged structure (cohort 2); and selection cutting to reflect gap dynamics in 17% of the land base (cohort 3). Existing growth and yield information obtained from the Chief Forester's Office was used in both scenarios.

Zones related to the capacity for the Pikogan Anicinapek First Nations community to pursue cultural activities in the area were excluded during timber supply analyses. Information about zones of potential aboriginal interest in FMU 085-51 were identified in a companion study (Germain and Asselin 2010). Their results showed that forest patches located near forest roads (less than 100 m) and water courses/bodies (less than 60 m) were preferred by the Pikogan Anicinapek people. Sensitivity analyses were carried out by excluding only the selected zones from the productive area.

Concerns over forest dwelling caribou habitat were addressed by introducing a spatial criterion during the calculation, assuming that partial-cutting is not detrimental to the caribou. In order to mimic the spatial distribution of fires over the landscape, harvest areas with clear cutting were concentrated into harvest agglomerations. These agglomerations correspond to homogenous spatial units in terms of age and height class and species composition. Sizes of these units varied between 30 and 150 km^2. An agglomeration was available for clear-cutting if 30% or more of its productive area was older than the minimum harvest age (between 70 and 100 years, depending on the management stratum). An area was defined as productive when harvestable volume per hectare exceeded 60 m^3 during the simulation period (150 years). We performed sensitivity analyses by requiring 30%, 50% or 70% of the productive area older than minimum harvest age for an agglomeration to be available for clear-cutting. Harvesting with partial cutting was not spatially constrained, since partial cutting emulates stand succession caused by gap dynamics (i.e. partial mortality due to tree longevity, mild defoliations or wind throws).

In both scenarios, CM and EBM, First Nations concerns and spatial criteria were considered and their cumulative effects on timber supply were quantified. The FMU timber supply determined by the Chief Forester's office (CFO) for the period of 2008-2012 was considered as the reference scenario to quantify the impact of First Nations concerns and spatial criteria on timber supply. Table 1 summarizes the results of different simulations.

Which scenario is more robust?

There were positive effects of harvest level optimization in both CM and EBM scenarios (CM-II and EBM-I, Table 1). However, positive changes in harvest level were much higher in the EBM scenario (19%). This increase is explained by the importance of jack pine plantations, because plantations are

more productive than naturally regenerated black spruce stands. Limiting plantation area brought down the timber supply by a third (EBM-IIc, Table 1). Both scenarios responded in a similar way to the First Nations criteria because both scenarios similarly excluded productive area from the land base.

As the spatial criteria tightened by requiring more productive area in an agglomeration to be available for clear-cutting, the conventional scenario could not meet the required level of timber supply, whereas the EBM scenario could. The conventional scenario did not have any harvests when harvest eligibility criteria for an agglomeration were set to 70% of the area older than the minimum harvest age (CM-VI, Table 1). This is explained by the availability of diverse silvicultural options in EBM. CLAAG is the only silvicultural treatment for timber harvest available under the CM scenario. As the admissibility criteria for CLAAG tightens, there is no other option for timber harvesting in this scenario. But in the EBM scenario, timber supply is compensated by utilizing different types of partial cutting, since spatial criteria are imposed only on clear-cutting. With the availability of diverse silvicultural options, EBM is more robust, or less sensitive, in responding to the spatial requirements of harvesting.

We also evaluated the scenarios in their abilities to maintain the specified proportion of area under different cohorts during the first simulation period (150 years). The model could not find a solution while considering 62%, 21% and 17% of area under cohort 1, 2 and 3 respectively, while considering First Nations concerns and spatial criteria. But it was possible to achieve at least half of this target as early as the first simulation period (EBM-IIb, EBM-III to EBM-VII, Table 1). In light of the Forest Stewardship Council's certification criterion of maintaining at least 50% of preindustrial old forests, our model seems to serve this purpose.

Scenario	Criteria	% Change in harvest level
CM-I	Calculated in Sylva II by Chief Forester's Office	Reference scenario
CM-II	= CM-I + Optimization in Woodstock	+7
CM-III [1]	= CM-II + Buffer strips of 100 m extending both side from the centre line of the road and 60 m from the water bodies excluded	-12
CM-IV	= CM-II + An agglomeration is admissible for clear-cut when more than 30% of its productive area is older than the minimum harvest age	-4
CM-V	= CM-II + An agglomeration is admissible for clear-cut when more than 50% of its productive area is older than the minimum harvest age	-16
CM-VI	= CM-II + An agglomeration is admissible for clear-cut when more than 70% of its productive area is older than the minimum harvest age	-99
CM-VII	= CM-III + CM-IV	-15
EBM-I	Optimization in Woodstock	+19
EBM-IIa [2]	= EBM-I + Plantation area less than 7500 ha by period + *Proportion of area under different cohorts as recommended by Nguyen (2002)*	+8
EBM-IIb	= EBM-I + Plantation area less than 7500 ha by period + *Half the target of distribution of area under different cohort proposed by Nguyen (2002)*	+12
EBM-IIc	=EBM – I + No plantation	-18
EBM-III	= EBM-IIb + Buffer strips of 100 m extending both side from the centre line of the road and 60 m from the water bodies excluded	-10
EBM-IV	= EBM-IIb +An agglomeration is admissible for clear-cut when more than 30% of its productive area is older than the minimum harvest age	-1
EBM-V	= EBM-IIb +An agglomeration is admissible for clear-cut when more than 50% of its productive area is older than the minimum harvest age	-7
EBM-VI	= EBM-IIb +An agglomeration is admissible for clear-cut when more than 70% of its productive area is older than the minimum harvest age	-45
EBM-VII	= EBM-III + EBM-IV	-11

Table 1. Results of simulations on timber supply under conventional and EBM scenarios.
[1] Dimensions of buffers recommended by Germain and Asselin (2010). [2] Periodic area actually planted by Tembec.

Conclusions

Under similar management criteria, EBM had higher levels of harvest than conventional scenarios due to the availability of diverse silvicultural options. Silvicultural options such as plantation and partial cutting are key factors in maintaining timber supply under EBM.

As expected, implementing First Nations concerns and spatial criteria within timber supply analyses had negative effects on the allowable harvest level. Responses to the First Nations criterion are similar in both management scenarios because both excluded productive area from the calculation to accommodate these factors. However, harvest responses to the spatial criterion were different in the two scenarios. The conventional scenario provided only one silvicultural option, i.e. CLAAG. Putting restrictions on the CLAAG option has a direct impact on allowable harvest. But in EBM, the partial cutting option is available. Although restrictions on clear-cutting reduced the harvest level, reductions in volume during critical periods were compensated by partial cutting in the EBM scenario. Therefore, the availability of diverse silvicultural options made EBM more robust in responding to the spatial requirements of timber harvesting.

Management Implications

- A variety of silvicultural options should be considered to diversify the structure and the composition of forests. Such diversification is considered to have positive repercussions for biodiversity and harvest level.
- Partial cutting should be incorporated into management planning as a potential harvest option. Such an option helps to maintain timber supply when clear-cutting is restricted by a harvest spatialization criterion.
- In the present case, jack pine plantations played an important role when optimizing the timber supply level.

Further reading

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