Silviculture and Growth and Yield Research in Québec’s Boreal Forest

Research Note
Tabled at the XII World Forestry Congress – Québec, Canada 2003,
by the Ministère des Ressources naturelles, de la Faune et des Parcs du Québec

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Direction de la recherche forestière (Forest Research Branch)
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by

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Abstract

Québec’s boreal forest is composed of four bioclimatic domains. The two most southerly, the balsam fir/white birch and black spruce/mosses, are the site of intensive forestry activities and the majority of research into silviculture and growth and yield in the boreal forest. Because Québec’s boreal forest ecosystems seem to be well adapted to recurring natural disturbances (fire, epidemics, windthrow), it appears logical to employ a forest management approach that mimics the effects of these disturbances. To achieve this, the usual silvicultural interventions support this principle by creating, at the stand level, disturbance conditions that are sometimes similar to nature. Current silvicultural knowledge of the boreal forest comes mainly from experiments carried out in even-aged forests. Therefore, few silvicultural tools exist that are adapted to uneven-aged stands, such as overmature black spruce cover types.

Silvicultural research at the Direction de la recherche forestière (Forest Research Branch) of the Ministère des Ressources naturelles, de la Faune et des Parcs du Québec (MRNFP) aims at filling these gaps and solving the practical problems being faced by forest managers. With this objective, the MRNFP is using networks of provincial sample plots to identify the forest types that react best to treatments, and to verify growth and yield hypotheses. This approach allows for the validation of strategic simulation models to predict the evolution in merchantable volume of vast forest complexes. The MRNFP is also relying on locally established experiments in order to adjust the criteria for applying treatments or to test new silvicultural systems. The latter approach is based on taking more varied and detailed measurements that make it possible to calibrate tactical simulation models. The development of these models, more flexible in their application and able to simulate a broad range of situations, is the current objective of a large MRNFP research program.

Keywords: Bioclimatic domains, natural disturbances, silvicultural treatments, stand yield, forest modelling

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4 On April 29, 2003, the Ministère des Ressources naturelles du Québec (MRN) became the Ministère des Ressources naturelles, de la Faune et des Parcs du Québec (MRNFP).
Portrait of Québec’s boreal forest

The boreal forest in Québec is part of a vast floristic complex that circles the Arctic pole and crosses the continents of North America, Europe and Asia (Figure 1). Vegetation in this circumpolar zone is distinguished from more southerly forests by its low number of tree species. These species belong mainly to the conifer class (Hare and Ritchie 1972; Hämet-Ahti 1981), in which dominance seems to be controlled by climate (Pastor and Mladenoff 1992; Sirois 1992).

In Québec, the boreal forest covers a wide band between 48° and 58° lat. N. (Figure 2). Its southern limit is bordered by forests composed of a mixture of softwoods and hardwoods, called mixedwoods, in which the typical stand is the balsam fir/yellow birch type. To the north, the boreal forest disappears where climatic conditions become so severe that tree species cannot reach a height greater than 5 m, which corresponds to the northern tree line (Payette 1983).

Because Québec’s boreal forest covers a vast area (1,090,700 km² or 71% of Québec) (Grondin 1996), the climate is not even. This range of climatic conditions is responsible for a wide diversity of stand types. Therefore the area can be broken down into four
bioclimatic domains (Grondin 1996; Saucier et al. 1998), which are spread out along an increasing temperature gradient on a north-south axis. From north to south, these four domains are forest tundra, black spruce/lichens, black spruce/mosses and balsam fir/white birch (Figure 2). The forest tundra is composed of discontinuous stands of black spruce, where the generally open structure seems related to regeneration problems following recurrent forest fires (Payette 1992). Further south, in the black spruce/lichens type, or taiga, the establishment of black spruce and jack pine regeneration is achieved more rapidly after fire, which results in the establishment of a more continuous forest, though composed of relatively open stands.

The two most southerly bioclimatic domains in the boreal forest, the black spruce/mosses and balsam fir/white birch types, have high socio-economic importance because they are intensively harvested for timber to supply sawmills and pulp and paper mills. Silviculture and boreal forest growth and yield research in Québec are therefore concentrated in these two domains, which cover 557,380 km², or 37% of Québec and 51% of Québec's boreal forest (Grondin 1996). In addition to the latitudinal temperature gradient, physiographic changes are the cause of a second gradient, precipitation, which has an influence especially on an east-west axis. This longitudinal precipitation gradient explains the presence of a continental climate in the western part of these two domains. This climate is characterized by moderate precipitation that favours the occurrence of forest fires, but limits balsam fir regeneration. To the east of these two domains, however, balsam fir benefits from a more maritime climate, characterized by more abundant precipitation and longer fire cycle. The low fire frequency favours the presence of overmature stands, which are susceptible to other types of natural disturbances, such as the spruce budworm and windthrow. The structure and composition of stands are affected by these disturbances, which contributes to diversifying the boreal forest and makes for more creative silviculture.

Silviculture in the boreal forest

Assuming that the boreal forest is well adapted to natural disturbances that have periodically affected it for millennia, it seems correct to base the management of forest stands on the effects of these disturbances, to preserve the integrity of the current ecosystems (Bergeron et al. 1999). We are attempting to support this principle at the stand scale by employing silvicultural interventions that could resemble natural disturbances. For example, harvesting with regeneration and soils protection (HRSP) in jack pine stands can give rise to conditions similar to those following a forest fire, since only a small amount of regeneration generally grows under this cover type. However, HRSP applied in balsam fir stands could simulate the effects of a severe spruce budworm epidemic more than those of a fire, because the HRSP maintains a good part of the advance regeneration, whereas fire can destroy both the regeneration and the organic matter accumulated on the soil.

Precommercial and commercial thinning also have points in common with natural disturbances. Indeed, a light or moderate spruce budworm epidemic generally kills only
the less vigorous trees in a stand (Pothier 1998). Consequently, mortality caused by this type of epidemic closely resembles the removal of trees in a low thinning, which leaves standing most of the dominant and codominant trees.

Furthermore, the usual silviculture practised in the boreal forest results from studies that were carried out in even-aged forests, and is therefore well adapted to large-scale disturbances. However, when the infrequent recurrence of fires observed in the eastern section of the boreal forest is paired with the longevity of black spruce, the result is uneven-aged stands composed of trees of all ages and sizes. A silvicultural system based on partial cutting, and that does not use HRSP as the final cut, seems more appropriate to manage this type of forest (Weetman and Algar 1976). Silvicultural research in this type of stand is in its initial stages. However, it is destined to expand considerably during the coming years.

Silvicultural research in the boreal forest

Silvicultural research at the Forest Research Directorate of the MRNFP is steadfastly directed toward the practical problems faced by forest managers. Also, the MRNFP has the duty to quantify the effects of the silvicultural treatments now used, which often leads to undertaking long-term research. The variety of silvicultural treatments applied and the regional features of application conditions results in the MRNFP’s silvicultural research differing according to the scale of established experiments. At the provincial scale, in order to cover all of the forest types where they are employed, permanent sample plot networks have been established for the principal silvicultural treatments. In the boreal forest, the treatments covered by these plot networks are HRSP and precommercial and commercial thinning. Plots are established operationally in treated stands and are always paired with control plots. The particular objective of these plot networks is to determine the forest types which are most apt to react positively to the treatment, and to verify current growth and yield hypotheses. They therefore should be useful in orienting how the principal silvicultural treatments are implemented, and to validate the strategic prediction models—the simulation models used to determine the evolution in merchantable volume of the large forest complexes.

However, the provincial plot network cannot be used to adjust the implementation criteria of the silvicultural treatments, or to test the relevance of new approaches. This is why the MRNFP is also establishing local-scale experiments within which it is possible to control implementation conditions and isolate any interesting elements. In these experiments, more silvicultural treatments can be examined than in the provincial plot networks and, for each of them, a wide range of implementation criteria can be tested and compared. Besides the HRSP, precommercial and commercial thinning, these experiments include treatments such as shelterwood methods, irregular shelterwood, strip clearcutting, group seed-tree cutting, forest drainage, scarification, etc. The objective of these experiments is to adjust silvicultural treatments implementation criteria to a given situation, or to determine the best treatment to use in certain stand types. Measurements in these experiments are often much more varied and detailed
than in the provincial network, which makes calibration of tactical simulation models possible—flexible models designed to meet specific needs. These models fill certain shortcomings of the strategic models by simulating treatments or implementation conditions for which long-term results have never been tested.

**Forest growth and yield models**

Forest growth and yield models generally aim at predicting the evolution of merchantable volume in managed stands. These models are the basis of allowable cut calculations which, for a given area, determine the volume of timber that can be removed annually on a perpetual basis. Besides merchantable volume per hectare, forest growth and yield models can supply information on the diameter distribution of trees, the evolution of a stand’s dominant height, the number of trees of merchantable size, the evolution of stand composition, etc. The variety and precision of the information coming from the model not only depend on the range and quality of the data that were used to calculate the mathematical relationships of the model, but also on the type of model.

For calculations related to boreal forest stands having an even-aged structure, the yield tables of Pothier and Savard (1998) are now used. They were produced using a stand-scale empirical model. The mathematical relationships of this model stem mainly from information extracted from temporary sample plots established since 1970 by the MRNFP. Among these plots, only those where the dominant species covered at least 75% of the merchantable basal area were used. Furthermore, the plots that meet these criteria were mainly established in natural untended stands. By referring to the definition of an empirical model, the model of Pothier and Savard (1998) can only be used for natural unmanaged stands, composed mainly of a single species and with a quite regular single-storied structure. The evaluation of the model’s performance proved very good when it was used for this stand type (Pothier and Savard 1998), which represents an appreciable portion of the boreal forest.

However, large forested areas are covered by stands that do not correspond to those types for which growth can be simulated by the Pothier and Savard (1998) model. This is the case for uneven-aged black spruce, where the evolution of merchantable volume can only be predicted with difficulty using the available model. This stand type covers vast areas, especially concentrated in northeastern Québec, where the low fire frequency has allowed these black spruce types to develop this kind of structure (De Grandpré et al. 2000). This is also the case with numerous softwood stands in the boreal forest, which have been the object of an increasing silvicultural effort for about 15 years. For these stands, it is particularly important to predict tree diameter growth, because it is one of the principal parameters required by sawmills. It must therefore be concluded that it is necessary to develop a tactical modelling approach that will be more flexible and that will be able to offset the implementation limits of empirical models.

This is why the MRNFP has set up a research program intended to develop more
flexible models. These models should be able to more efficiently simulate various situations. Part of the flexibility could come from carrying out growth calculation routines at the tree scale. The characterization of stands will therefore be done using a tree list. However, the volume of data needed for them to function should be limited to what is currently gathered in the temporary sample plots. The models' flexibility could also be provided by introducing functional elements to the simulation routines. However, to simulate a stand's merchantable yield, it will not be necessary to use a model where all the growth processes are functionally simulated. This means that the level of functional details must be such that the quantity of data required to use it remains practically unchanged. Since the situations for which the model must be used include growth conditions that are sometimes very different between trees in the same stand, a model that combines the characteristics of simplicity, efficiency and versatility could use a semi-functional approach (or hybrid) at the tree scale, which means pairing empirical and functional elements (Landsberg 2001).

Finally, it must be emphasized that if the development of hybrid models requires particular data, they will not be necessary for everyday applications. Indeed, the results of tactical hybrid models will be integrated into the strategic model so that users will not notice any changes, either at the stage of data entry, the mechanics of simulation or in the presentation of results. By broadening the range of simulation models to a complete range of situations present in the boreal forest, it will be possible to improve the forecasting precision for merchantable volume. Reliable tools will thus be available to support the demands of the forest industry, which wants to maintain employment in the regions, and those of the other forest stakeholders, who want present and future generations to fully benefit from all of our forest resources.

References


