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The application of large scale survey data to the diagnosis of post-harvest regeneration.

Final report from the project entitled:

Developing early indicators of productivity in managed forests through a retrospective analysis of the effect of silvicultural practices since 1970 in the southwestern boreal forest of Quebec.

by

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Brief description of the original project

In the original proposal for this project we emphasized the importance of improveing our understanding of the effects of past and current silvicultural practices on forest dynamics,and the importance of including such impacts in growth and yield predictions. A better understanding of post-harvest stand dynamics would be most useful in a context in which yield estimates arebased on the post-harvest growth rates of forest stands, rather than on growth rates that follow natural disturbance. The need for such measurementsbecomes reinforced when we consider that past and current yield allocation in eastern Canadian boreal forests results from the expectation that managed stands will grow and develop in the same way as natural forest stands.

The **general working hypothesis** of this project is that future stand condition and development can be predicted by current regeneration characteristics and that losses or gains in wood production can be related to silvicultural practices. More specifically, this project aims to: i) evaluate the usefulness of broad scale forest inventory data to provide accurate information on current site and stand conditions, past silvicultural treatments, and stand composition to establish relationships among these variables; ii) identify *the best and the worst* silvicultural treatments used in relationship to specific site conditions and pre–harvest stand composition; iii) identify mechanisms of competition that lead to regeneration failure; iv) recognise and predict cases of regeneration failure in the absence of competition.

By the end of this project we anticipate being able to provide: i) a summary of the current state of regenerating stands at the landscape level, ii) a contribution to the development of a Manual for monitoring regenerating stands which will assist the forester in the prediction of forest development and the need to intervene using appropriate silvicultural treatments; and iii) a better knowledge of the problems occurring in the development of regeneration. A better understanding of the real effects of post-cutting treatments and site preparation could lead to a readjustment of silvicultural prescriptions concerning time and method of intervention to be used.

Achievements

Since the original proposal was written, the project has been restructured around two major axes given by: i) the analysis of composition following harvesting, and ii) the analysis of growth and development. The following sections describe how these two milestones have allowed us to achieve most of our objectives.

1) Composition following harvesting

Changes in stand composition following harvesting were assessed by the comparison of pre- and post-harvesting stand composition. The original stand composition before harvesting was given by forest inventory maps dating from 1972 and 1984 forest inventory programs. The post-harvesting composition was obtained by regeneration survey provided by Norbord Industrie. A total of 4800 regenerating stands were surveyed. These were distributed among four sectors in Abitibi region. Of this total nearly 15% were discarded because their original species composition was unknown. Sample unit measurements followed a standard inventory protocol developed by Quebec Natural Resources Ministry for regeneration stands. Recognition of stand type was allowed by using an idendification key applied on stocking scores obtained for each commercial tree species recorded in a 10 microquadrats transect. Site conditions (slope, aspect, soil texture, hydric regime, stoniness) were also evaluated in the field and compared to information available from ecoforest maps (initiate in 1994) produced by the MNRQ. Finally, ancillary information (date and season of the harvesting, history of site preparation, precut stand composition) are available in each forest companies GIS's by overlaying the geographic location of sample points and ecoforest maps.

Results showed that 18% of regenerating stands were subject to regeneration failure. For the purposes of this study, regeneration failure meantthat coniferous stocking (all species combined) was less than 60 percent, and poplar stocking was less than 40 percent. In other words, to be recognized as a failure, at least 6 out of ten microquadrats would not include any commercial species.

Another way by which standcomposition changes following harvesting si for deciduous regeneration to replace a stand originally stocked with conifers. This transformation is naturally observed in mixedwood boreal forest in which young seral stages are usually composed of hardwood species whereas old seral stages are more dominated by coniferous species. What could appear less natural in a managed forest mosaic is the rate with which this process occurs because of the higher rate of harvesting compared to that of natural disturbance.

In the data set, a stand type was considered to have been converted when its definition changed from coniferous or mixed-coniferous to mixed-deciduous or deciduous (as defined by coniferous stocking). In the data set, this kind of change occurred in 8% of all cases, meaning that only 8% of harvest stands having maintained their commercial stocking see their coniferous stocking falling below a minimal threshold. In fact, this evaluation is very conservative since it lies only on the maintaining of coniferous stocking. A more realistic assessment given by the poplar stocking shows that near 14% of stands became stocked by poplar after cutting. Finally, another form of composition change occurs when balsam fir dominated stands regenerate fromthose that were dominated by black spruce before harvesting. This kind of change may occur more frequently when careful logging is applied in black spruce standsthat have balsam fir regeneration. In the data set, nearly 15% of black spruce stands regenerated to balsam fir dominated stands following harvesting.

Now, if we try to identify forest conditions that were more sensitive to regeneration failure, results of contingency tables analyses have shown that pre-harvest composition of stands is the most predisposing factor. With an incidence of 27% and 28%, balsam fir stand and mixedwood stands were clearly more sensitive to regeneration failure then black spruce stands, in which 13% had regeneration failure. Harvesting system was also important. Compared to careful logging (16 % failure), clear cutting produced 21% failure, for example. Finally, mesic clay appeared to be the site type most sensitive to regeneration failure, with 28% of stands in this category showing inadequate stocking. Mesic coarse textural deposit had a 22% failure rate, and tills and sub-hydric clays(the most common substrate types in the region), had16 and 18% failure rates, respectively.

Pre-harvest stand composition was a predisposing factor to post-harvest domination by poplar. With an incidence of 16%, mixedwood stands had the greatest sensitivity to increased poplar stocking following harvesting. This compares to 9% observed for balsam fir stands and 6% observes for black spruce stands. Harvesting system was also important. As expected, careful logging (4 %) appears to limit poplar reinvasion more efficiently than clearcutting (11 %). Finally, when we compare site types, mesic clay (12%) appears more sensitive than any other site types.

Contrary to our expectation, careful logging does not appears to be more favourable to balsam fir invasion when compare to clear cutting. Both harvesting methods gave a similar incidence of 20 %. However, clay deposit appears the most sensitive site type to an increase of balsam fir following harvesting. With an incidence of 24% and 18%, subhydric clay and mesic clay exceeded the mean value of 11% observed among other site types.

In brief, even though careful logging involves certain negative impacts on regeneration success, it constitutes an improvement relative to clearcutting. Mixedwood and balsam fir stands appear to be more vulnerable to regeneration failure or to conversion to a deciduous species composition when compared to black spruce stands. Finally, among all site type, mesic clay posed the greater challenge to forest managers. Although it offers the best growth conditions, mesic clay was also the substrate most sensitive to regeneration failure or a decrease in coniferous stocking.

2) Patterns of growth development following harvesting

Growth performance has been generally characterized through the assessment of a site index value. By positioning regenerating stands on a site index curve (at the point corresponding to the current age of the stand), we can control for the age of development in the comparison of different dominant stems heights. Although methods for constructing site-index curves are becoming more diversified and complex, site-index equations continue to reflect the basic relationship between stem height and stem age (Huang and Titus 1992). Huang and Titus (1994) have outlined several reasons to discard stem or stand age from height prediction models; among them, that stem age is considered and time-consuming to determine with certainty. Since relatively small errors in the estimation of stem age can lead to large errors in the estimation of SI (Nigh 2001), different age-independent indices have been proposed to estimate site productivity (Wykoff 1990; Nigh 1996; Huang 1994). The determination of age for young stands following HARP (harvesting with advance regeneration protection) or careful logging poses further problems. For advance regeneration, the age of the young stems cannot be used to position the stand along a reference site-index curve without producing an over estimation of stand age, and hence, an under estimation of SI. Measuring stem age at breast height (1.3 m) is often proposed as a means of discarding suppressed-growth years. However, this practice does not ensure that suppressed-growth is not included in the measurement, since stems originating from advance regeneration may exceed breast height at the time the forest cover is removed. Also, a stand cannot be considered to have an age equivalent to the time since harvest, since advance regeneration confers some gains in terms of stand development. Faced with this problem, foresters have attempted to use dominant height, not age, to position young stands on the site's pre-harvest SI curve. This method requires the assumption that a site's SI has not changed following harvesting and that regeneration delays and persistent suppression of advance regeneration will not occur, assumptions that cannot be retained for all coniferous stands (Groot and Hökkä 2000).

In general, SI curves are mostly used to predict stand development over time in the process of allowable cut assessments. Other age-independent indices allow the estimation of site productivity (Huang 1994). Their use in yield forecasting models is, however, limited because age cannot be used to drive the model over time. An age independent method that allows the positioning of sites on SI curves and the tracking of dominant height over time would facilitate sampling and avoid the potential bias introduced by the estimation of stem age.

The Quebec Ministry of Natural Resources has recently proposed a table in which site index approximation is provide as a function of stem age, total height and recent height growth (MRNQ 2001). The method used to generate this abacus is similar to the growth intercept method (Wakeley 1954; Day et al. 1960; Nigh 1996), with the important distinction that stem growth is measured down from the upper-most whorl of the dominant branch, over a given number of growth years (δAGE). Although stem age can be used to find the SI values, this is not a requirement and SI values can be found with only total height (H_t) and recent height growth (δH). Though not previously formally demonstrated, the equations that underlie this method are derived from standard SI-equations (where height is predicted as a function of age) and lie on the isomorphic properties of standard SI-curves. In fact, following these properties, each SI-curve shows a specific recent height growth (δH) for a given total height (H_t) and thus, permits the positioning of a dominant stem on an SI-diagram without knowledge of stem age (fig. 1). Another interesting property of this approach is that, once a stem has been positioned on an SI-diagram, the age can be evaluated with the equations derived from the standard SI-curve. This age will be identical to the true age of the stem if the growth of the tree has exactly followed the SI curve. The only prerequisite of this approach is that free-to-grow dominant stems are selected, i.e., stems for which the recent height growth performance was only or mostly limited by permanent site conditions.

For each sampled transect, from 3 to 5 dominant stems were selected to represent the growth performance that can be expected from dominant tree species occurring in regenerating stand. For each target tree, total height and length of the last 5 years of growth was measured for coniferous species by using distance between last 5 whorls. SI-values were assessed for each subject tree by adjusting Chapman-Richard equations with non-linear regression analysis. Site indexvalue of a regenerating stand corresponds to the maximum SI-value of target trees sampled for this stand.

When compared for black spruce sites from the same region (LaSarre), and growing under similar site condition (subhydric clay), SI-values show large variations (fig. 2). At first glance, these variations appears to be related to silvicutural treatments but

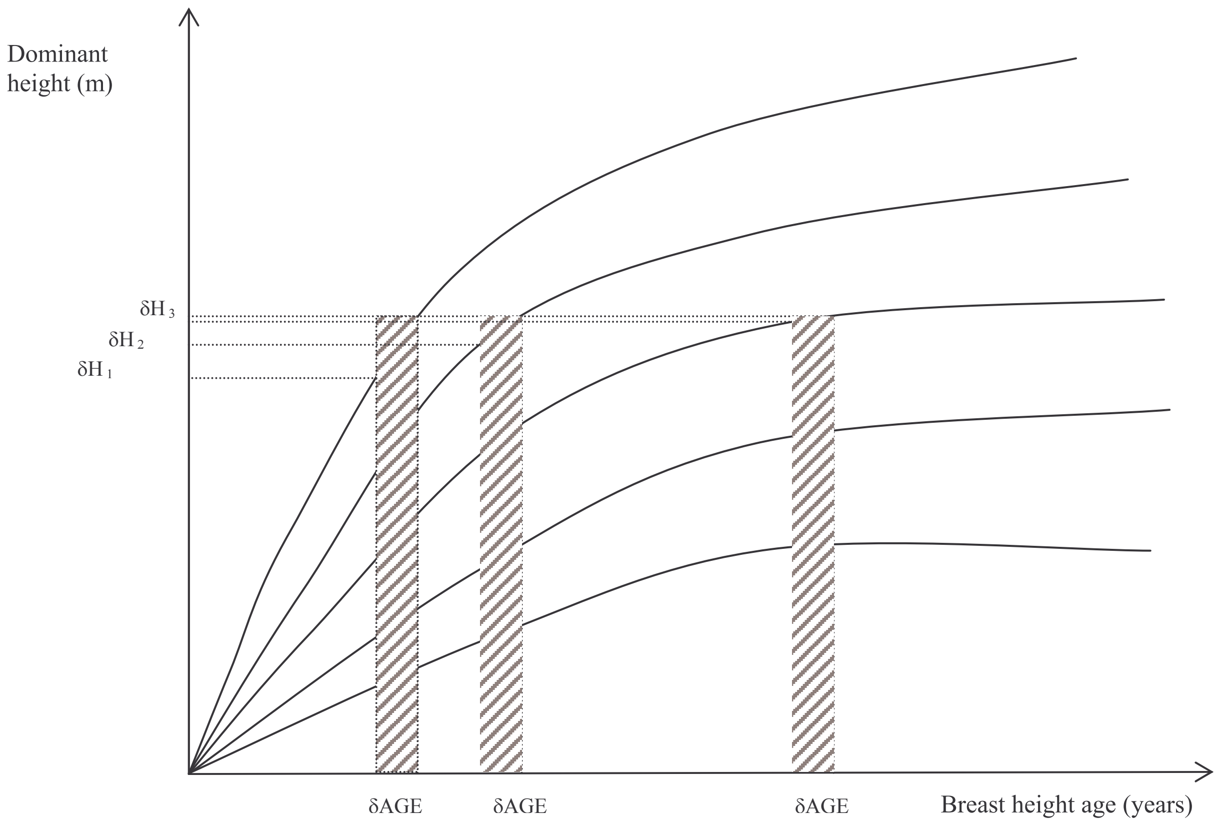

Figure 1. Standard site-index curve showing that for a given total height we have specific recent height growth (δH) corresponding to each site-index curve.

more detailed analyses have revealed that size of selected trees was more influential. Many of the dominant trees selected to characterize site productivity were less than 1.3 m of height. When we compare SI-values calculated for these small stems with those obtained from taller stems, we observe a significant difference that was not attributable to regional growth condition or site conditions (fig. 3). This suggests that some bias persist in the evaluation of SI-values when we use small stems. This bias might come from the fact that growth patterns of small stems are more susceptible to competition fromthe surrounding vegetation, and that, following careful logging, saplings can take until 12 years to adapt their physiology (e.g. root systems, ratio diameter/height) to the new stand conditions (Groot and Hökkä 2000). In all cases, SI-values evaluations appear more consistent when we exclude stems smaller than 1.3m of height (fig. 3).

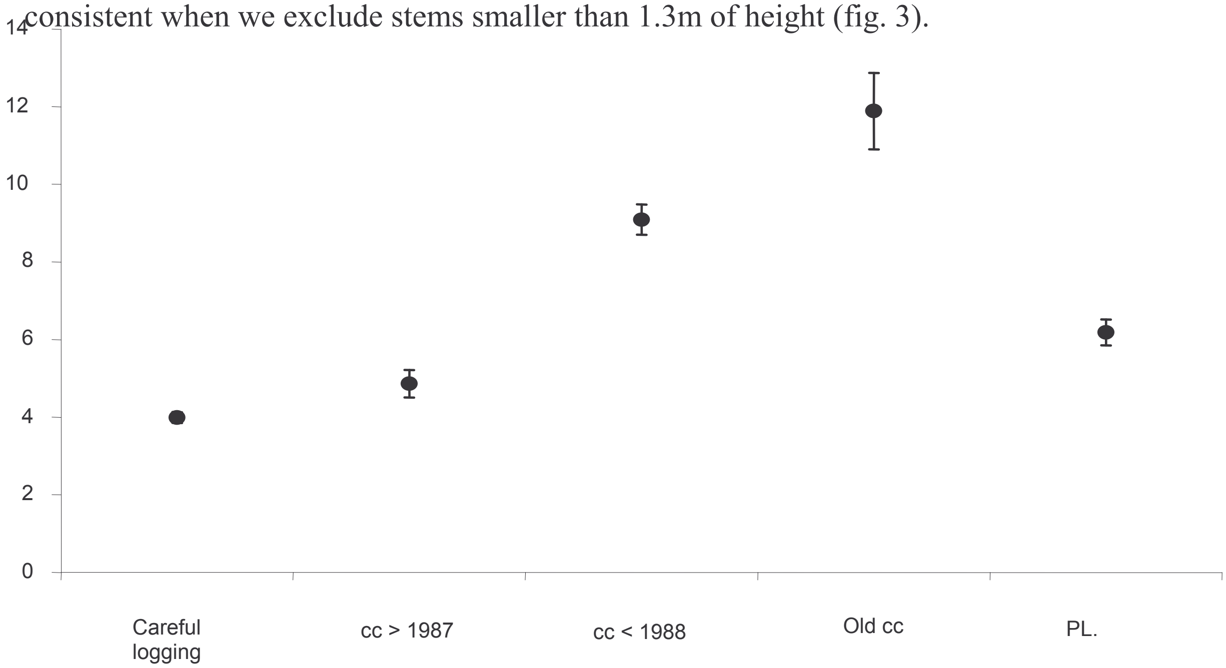

Figure 2. Site index values comparing various sylvicultural treatments for black spruce stand growing on subhydric clay in the sector of LaSarre. Cc: clear cutting; PL.: plantation; Old cc: old clearcutting dating from before 1976.

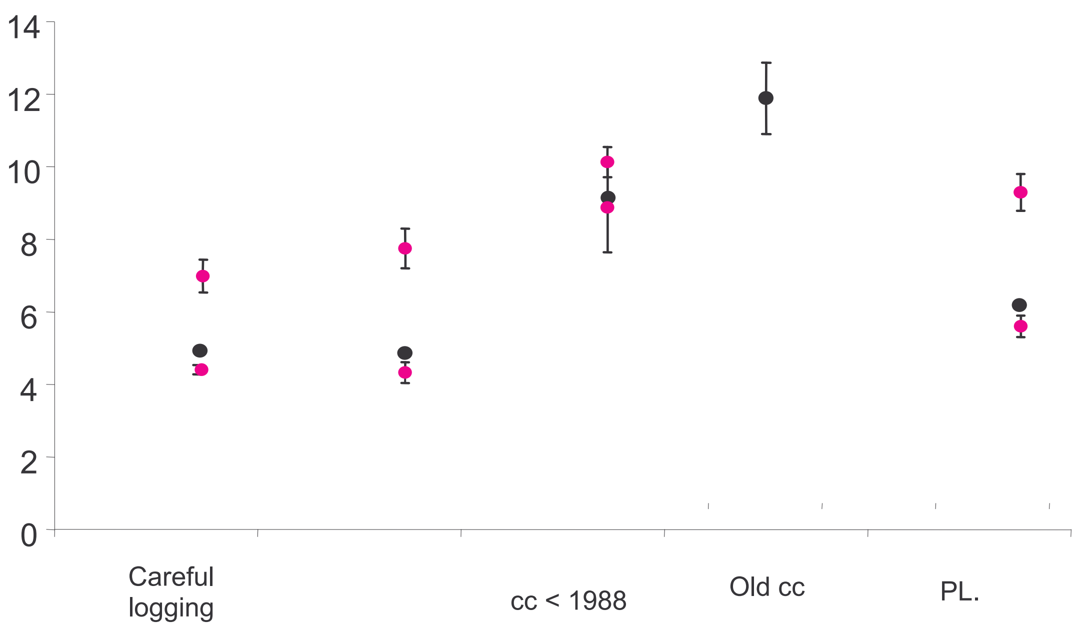

Figure 3. Differences between SI-values obtained from small black spruce stems of less than 1.3 m height (lower dots) and tall black spruce stems (upper dots) growing on subhydric clay in the sector of LaSarre. Cc: clear cutting; PL.: plantation; Old cc: old clearcutting dating from before 1976.

How this research has and could contributed to improve our management practices

Until now, partners have shown more interest in the integration of forest ecological maps produced by Ministry of Natural Resources in their planning processes. As a large part of this study is devoted to the characterisation of site type sensitivity to establishment problems or growth performances, we have received many questions on the different avenues allowing a better use of forest ecological maps. A major limitation of these maps seems to come from their inability to distinguish between mesic and subhydric clay. When we compare mapped site conditions with field characterisation, we found that 40% deposits that were classified as subhydric clay on maps were recognized as mesic clay on the field. This distinction is important since mesic clay is clearly more sensitive to establishment problems following harvesting. Greater accuracy in site type classification on maps, and more reliance on confirmation of substrate types in the field would be desirable.

The use of small stems (less than 1.3 m of height) in the evaluation of site index values, or the time needed to attain a merchantable yield is questionable because their inclusion results in biased SI assessments. On the other hand, the use of recent height growth increments measured on taller stems (more than 1.3 m) has an advantage over the more usual approach requiring an accurate age determination. However, we need to improve our understanding of proximal factors that influence growth release in regenerating black spruce stands. We also have few tools to assess the duration of growth stagnation in young black spruce stands, specially on sites susceptible to paludification. Faced with these questions, comparative studies between black spruce and balsam fir could be profitable, but areyet to be undertaken.

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