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Growth Response of Sugar Maple and Yellow Birch to Partial Harvesting

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Technical Note

Silviculture

Introduction

The Acadian forests, located between the temperate deciduous forest and the boreal forest, possess the elements of both, deciduous as well as boreal forests. Although the small-gap producing events are the usual natural disturbance events occurred in this forest ecosystems, the shade tolerant hardwood forests were intensively harvested by a combination of high-grade logging and large-scale clear cutting in the past. Currently, tolerant hardwood stands are partially harvested using different silvicultural techniques, e.g.: patch cut, single tree or group selection cutting etc. Disturbance history and unique geographic location of hardwood forests in New Brunswick causes an uncertainty on using growth models developed elsewhere for predicting growth response of hardwood trees to partial harvesting. Thus, as an aim to assess growth response to partial harvesting, an individual tree growth model for sugar maple and yellow birch is presented.

Highlights

- ***A cutting cycle of approximately 20 years is suitable for uneven-aged hardwood silviculture in New Brunswick.***
- ***Trees of DBH > 45cm should be harvested, since they don't grow well in the future and start to lose vigour and value.***
- ***Avoid yellow birch that was long-suppressed as saplings for crop trees.***
- ***When on poor site quality, choose yellow birch over sugar maple for crop trees.***

Methodology

The study was conducted with a total sample of 334 trees (sugar maple and yellow birch) growing in 116 plots, all located in 46 different stands in the northern hardwood forests of the Acadian region, northeast of Edmundston, New-Brunswick. The sampled trees were cored at breast height, cross-dated, and their basal area growth response after harvesting was measured. For each sampled tree, cross-dated increment cores were used to reconstruct tree diameter at the time of harvest and to quantify their period of juvenile suppression (defined as years taken to reach 10 cm diameter at breast height). Stand characteristics were observed during a field survey in 2012. Stand basal area at the time of harvest was reconstructed using the

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2012 stand basal area, time since harvest and net basal area growth rate observed by Forget et al. (2007) for tolerant hardwood stands. Previous harvesting records were obtained from Acadian Timber Corp. and all other physiographic information was extracted from digital elevation model obtained from the Department of Natural Resources (DNR) of New Brunswick. An index of site quality (biomass growth index) for each plot was obtained from Acadian site model (Henningar et al. 2015).

Results

Individual tree basal area growth model — a mixed model:

$$Ln(BAI)_{ij} = (\beta_0 + b_i) + \beta_1 \cdot (TSH) + \beta_2 \cdot (TSH)^2 + \beta_3 \cdot (TBA_0) + \beta_4 \cdot (TBA_0)^2 + \beta_5 \cdot (SBA_0) + \beta_6 \cdot \left(\frac{DBH}{QMD}\right) + \beta_7 \cdot (BSGI) + \beta_8 (PJS) + \varepsilon_{ij}$$

Where:

b_i = Random effect parameter

ε_{ij} = Error component

β_n = Parameter estimate

BAI = Basal area increment of tree *i* in year *j* (cm^2/year)

TSH = Time since harvest (years)

TBA_0 = Tree basal area at the time of harvest

DBH = Diameter at breast height

QMD = Quadratic mean diameter in 2012 (cm)

BSGI = Biomass growth index (ton/ha/year)

PJS = Period of juvenile suppression (years)

SBA_0 = Residual stand basal area at the time of harvest (m^2/ha)

Table 1: Parameter estimates on individual tree basal area growth model.

	Sugar maple			Yellow birch		
Co-efficient	Estimate	Standard erro	P-value	Estimate	Standard error	P-value
β_0	0.0472718	0.3973879	0.91	1.4998761	0,21225852	<0.01
β_1	0.0364768	0.0086407	<0.01	0.0532311	0,00891207	<0.01
β_2	-0.0007346	0.0003144	<0.05	-0.0013657	0,00034221	<0.01
β_3	0.0008716	0.0004277	<0.05	0.0011643	0,00043555	<0.01
β_4	-0.0000005	0.0000003	<0.05	-0.0000006	0,00000025	<0.05
β_5	-0.0136680	0.0056632	<0.05	-0.0108941	0,00522831	<0.05
β_6	0.5512291	0.1862947	<0.01	0.6559374	0.16204160	<0.01
β_7	0.7285754	0.1899215	<0.01			NS
β_8			NS	-0.0096310	0.00300115	<0.01

The final model was validated using DNR New Brunswick permanent sample plot data. Basal area growth response to partial harvesting (after 3-6 years) of 58 sugar maple and 98 yellow birch trees was used for model validation. A moderate correlation was found between predicted and validation basal area growth response for sugar maple (r=0.48) and yellow birch (r=0.38).

The different statistics associated with the parameter estimates indicated that the coefficients for the final model for sugar maple and yellow birch were highly significant, except the $ß_8$ coefficients for sugar maple and $ß_7$ for yellow birch (Table 1). Non-significant (NS) $ß_8$ indicated that tree basal area increment of sugar maple was not influenced by the period of juvenile suppression. Similarly, non-significant $ß_7$ indicated that site quality, defined as biomass growth index (ton/ha/year), was not important for basal area increment of yellow birch trees (Figure 3D).

Both sugar maple and yellow birch responded positively to partial harvesting by increasing individual tree basal area at a higher rate with time since harvest (Figure 2 and 3A). However, this increasing rate was higher for yellow birch than sugar maple. β_1 and β_2 coefficients indicate that the increasing rate of basal area increment was found to be maintained until 18 and 25 years after partial harvesting for yellow birch and sugar maple respectively (Figure 2 and 3A).

Tree size at the time of harvest (basal area at breast height) was found to have significant effect on basal area increment for both species (Table 2). Basal area increment increased for trees smaller than 35 cm DBH (≈1000 cm^2

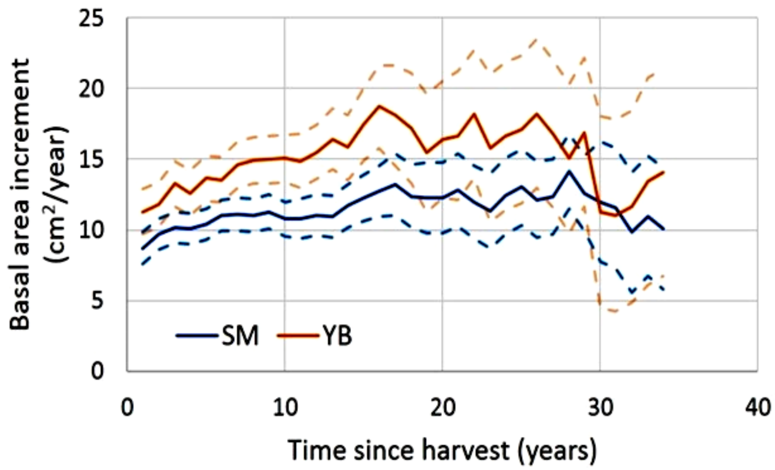

Figure 2: Observed basal area growth response to partial harvesting. The solid lines indicate average growth response and the dashed lines indicate the 95% confidence intervals.

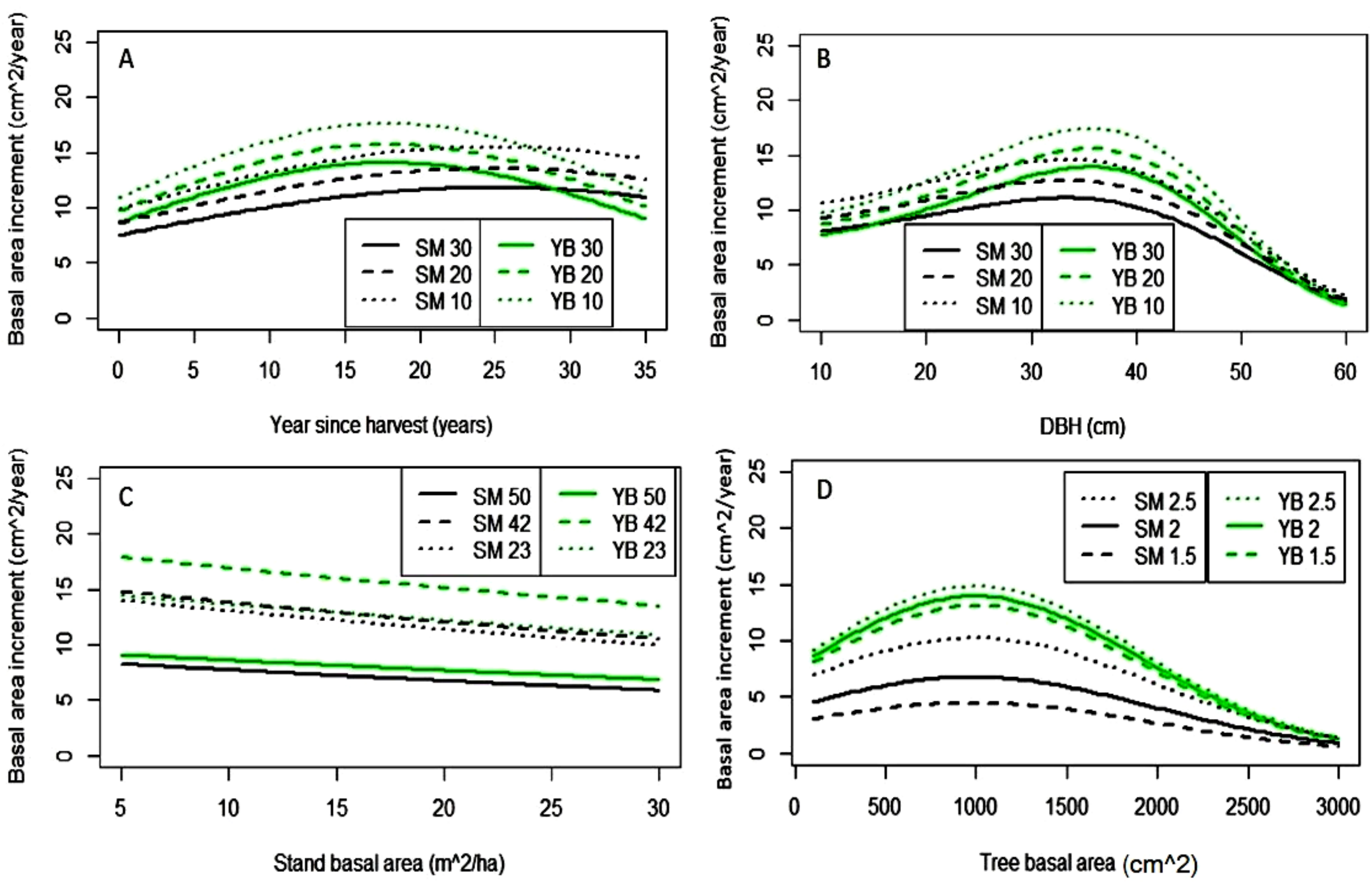

Figure 3: Relationship between model prediction and independent variables. (A) Annual increment of individual tree basal area with years since harvest at different residual basal area (30, 20 and 10 m2/ha) (B) Annual increment of individual tree basal area with tree size at different residual basal area (30, 20 and 10 m2/ha), (C) Annual increment of individual tree basal area of different sized trees (DBH: 23, 42 and 50 cm) with residual basal area, and (D) Annual increment of individual tree basal area of different sized trees (basal area at breast height) at different levels of site productivity (BSGI: 2.5, 2 and 1.5). Mean value was used to control the effect of other explanatory variables.

tree basal area at breast height), reached plateau, and declined for larger trees (Figure 3B). For both species, basal area increment was found higher for trees that were growing in lower residual stand basal area (Figure 3C). The ratio of tree diameter to quadratic mean diameter of the stand is considered as a distance-independent index of trees' competitive position.

It was evident that the $ß_6$ coefficients for both species were positive, indicating a tree of better social position (facing lower competition) would have higher basal area increment than that of a tree of poor social position (suppressed tree). Although, type of partial harvest, number of previous treatments, and softwood/hardwood proportions were expected to have effects on basal area increment; these variables were not found to be statistically significant.

Conclusion

Partial harvesting promotes growth of sugar maple and yellow birch trees in a residual stand as resource availability increases due to the reduction in competition. The results of this study indicate that the increasing growth trend is maintained for 18 to 25 years. In average residual basal area stands of 15 to 17 m^2/ha, canopy gaps created by partial harvesting would close in 20 years by sub-canopy trees. This will exert intense competition among trees and eventually tree growth response would decline. Therefore, it is suggested to maintain a 20-years cutting cycle for higher basal area growth of individual trees in the residual stand. Partial harvesting should focus on creating canopy gaps for sub-canopy trees smaller than 35 cm DBH as they respond to canopy opening more vigorously. As trees are suppressed longer (during their juvenile phase), they are more likely to receive stem damage. These trees will need to be removed when implementing partial harvesting as they not only have poor growth response but also possess poor quality stems, lowering their value over a long period of time.

Site productivity is one of the important factors that influence growth response of sugar maple. However, it is difficult to make any conclusion about actual site-specific limiting factor that influence sugar maple growth as biomass growth index was used in the model as an index of site productivity. Based on published literature, it can be assumed that sugar maple has poor growth in drier and acidic soils, therefore, yellow birch trees need to be promoted in such areas.

Result of this study also indicates that the growth response of sugar maple trees to partial harvest remains independent of period of juvenile suppression. Unlike sugar maple, the growth response of yellow birch trees to partial harvest is negatively influenced by period of juvenile suppression. This must be due to sugar maple's higher level of tolerance to shade and damages. It is usual that yellow birch trees with various degree of juvenile suppression are present in uneven-aged stands. Therefore, diameter or basal area growth models of such trees need to consider the period of juvenile suppression (history) for intermediate shade tolerant species like yellow birch.

References

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