Institut de recherche sur les feuillus nordiques Inc.
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Technical Note

Silviculture

Individual-tree Diameter Growth Model for Important Hardwoods in New Brunswick

Introduction

Growth and yield models help forest management decision making. Despite of their usefulness, a limited number of growth and yield simulators (e.g.: OSM, FVS-NE, SAMARE) are available that can be possibly used for New Brunswick hardwood forests. On the other hand, these simulators have not been tested adequately at the local level (at the scale of management unit). In this context, calibration of the component models (sub-models) of the growth simulators with local observations minimizes prediction bias and helps to provide biologically meaningful long-term growth projection. Diameter growth model is one of the key component models of these growth simulators. Diameter growth prediction is still challenging as it is affected by several factors related to tree growth conditions. Studies listed five major factors: (1) tree size, (2) tree health, (3) competition (4) site, and (5) genetics.

Among them, silviculture treatments influence level of competition, and alter species composition and stem quality proportion (tree health status) in a plot. Since better quality trees (with good health) are more efficient on utilizing growth resources, using stand quality information along with tree size, site factors and competition as predictor may help better predict diameter growth rate of the trees.

HIGHLIGHTS

- A relative individual tree diameter growth model specific to the hardwood trees in New Brunswick has been developed.

- Knowing whether the tree is in a recently treated partial cut block helps improve the individual-tree diameter growth predictions.

- Further work is required to get species specific models for OHW (e.g. RM, WA, WB).

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When stand health information is not available, information on whether the stand was treated or not may also be useful as treated plots may have larger proportion of good quality healthy trees that are more efficient on utilizing growth resources at the given stand and site conditions. Hence, this study compares the effects of tree and stand attributes along with site factors on diameter growth rate of important tolerant hardwood species in New Brunswick whether they received partial harvesting or not.

METHODOLOGY

The NB-Coop PSP database for treated-control paired plots was obtained from the New Brunswick Department of Energy and Resource Development, and used for this analysis. The database consists of long-term periodic forest inventory data. Hardwood dominated treated (Partial cut only)-control paired plots were used for the analysis.

The plot-level site quality information was obtained from Hennigar et al (2016). After testing several model forms, an equation recommended by Weiskittel et al. (2016) found to be suitable for modeling diameter growth of hardwoods in New Brunswick.

$$DBHI = e^{(b_0 + b_1 \times treatment + b_2 \times Ln(DBH) + b_3 \times DBH + b_4 \times BAL + b_5 \times Ln(BGI))} \qquad (1)$$

Where:
b_x = parameters estimates (see Table 2),
$DBHI$ = average annual diameter growth (cm/year),
treatment = a binary variable, place "1" for partial cut or "0" for control,
DBH = tree diameter at breast height,
BAL = basal area in larger trees (m^2/ha), and,
BGI = site quality index defined as biomass growth index (kg/ha/year) obtained from Hennigar et al. (2016).

A non-linear mixed model (Eq. 1, with a random intercept allowed to vary among blocks) was fitted separately for each species using *nlme* package (Pinheiro and Bates 2000) in R (R Development Core Team 2017). Heteroscedasticity was modeled using a power variance function described by Pinheiro and Bates (2000) and the first-order autoregressive moving average (ARMA(1, 1)) error covariance structure was used to fit Eq. (1) for all species.

RESULTS

Average stand structure between control and recently treated partial cut plots was not significantly different. However, significantly larger average annual diameter increment was observed for recently treated partial cut plots than the control (Table 1). Species-specific equations were developed and resulted in RMSE between 0.16 and 0.19 cm/yr (Table 2). As expected, diameter growth increased with DBH for small trees and decreased with DBH for larger trees (Figure 1&2).

Table 1: Average stand attributes of treated and control plots.

Attributes	Treatment		Control	
	MEAN	SE	MEAN	SE
DBHI (cm/year)	0.2968	0.0044	0.2072	0.0033
TPH (#/ha)	794	85	778	45
QMD (cm)	23.72	0.86	22.34	0.47
BA (m²/ha)	27.81	0.79	26.74	0.69
BAL (m²/ha)	22.84	0.74	20.66	0.58
BGI (kg/ha/year)	3702	50.73	3576	38.44

Table 2: Parameter estimates (b_0 to b_5) for model (1). MB=mean bias and RMSE=root mean square error. MB and RMSE were computed using the fixed effects only. SM=sugar maple, YB=Yellow birch, BE=American beech and OHW=other hardwood species. R^{2*} =Fixed effects only, R^{2**} =Fixed and random effects.

Species	n	b_0	b_1	b_2	b_3	b_4	b_5	MB (cm)	RMSE (cm)	R^{2*}	R^{2**}
SM	2662	-14.0910	0.3012	1.0396	-0.0504	-0.0193	1.3342	-0.0107	0.1619	0.11	0.27
YB	610	-14.2740	0.2441	0.4966	-0.0326	-0.0185	1.5375	-0.0132	0.1923	0.13	0.30
BE	487	-23.2380	0.6310	0.4157	-0.0738	-0.0383	2.7349	-0.006	0.1808	0.24	0.36
OHW	987	-1.8388	0.1706	0.5732	-0.0354	-0.0331	NS	-0.0132	0.1660	0.07	0.41

Trees in recently treated partial cut plots had significantly larger diameter growth than the trees in control plots (Table 2, b_1 & Figure 2). Negative b_4 (p < 0.01) indicates that diameter growth decreased with increasing level of competition (*BAL* = basal area in larger trees) whereas positive b_5 (p < 0.01) indicates that diameter growth increased with increasing site quality index (*BGI*) except for OHW (Table 2). For a given set of covariates, BE showed the greatest diameter growth at smaller tree sizes (DBH < 15cm), while YB showed the greatest diameter growth for larger tree sizes (DBH > 15cm; Fig. 2). The smaller MB indicates that the model is relatively unbiased (Table 2). However, the large difference between pseudo r-squared computed with fixed effects only and fixed as well as random effects indicate that fixed effect component of the model was inadequate (Table 2).
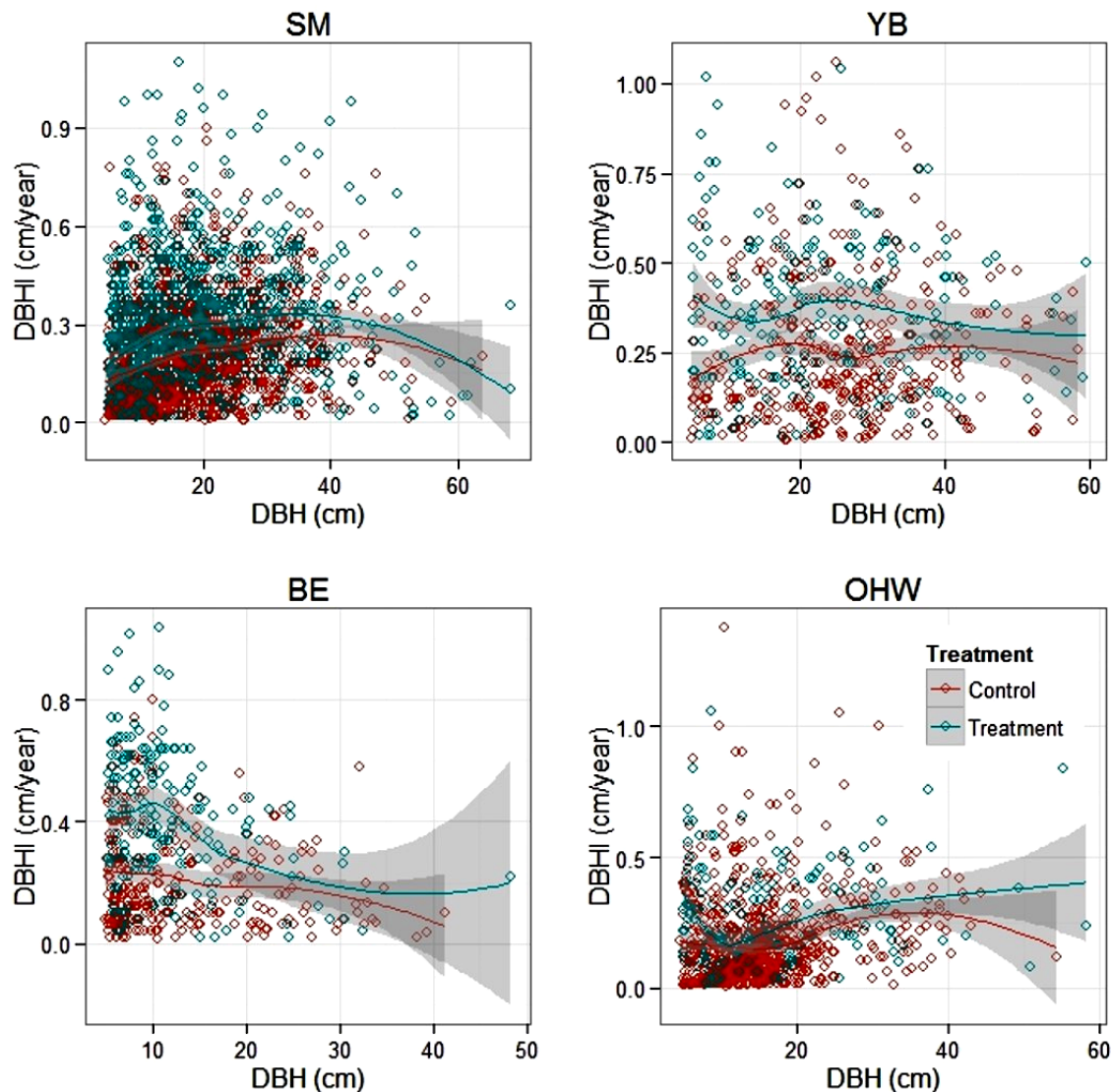
Figure 1: Observed average annual diameter growth (cm/year) of different sized trees growing in control and in plots that were subject to partial cut (treatment). SM = Sugar maple, YB = Yellow birch, BE = American beech, and OHW = Other hardwood species. The curve represents the lowest fit and the gray zone represents 95% confidence interval of the respective curves.

DISCUSSION AND CONCLUSION

A relatively robust and logical individual tree diameter growth model specific to hardwood trees in New Brunswick has been developed using permanent sample plot data. The proposed model is relatively unbiased compared to Fortin et al. (2008) and Weiskittel et al. (2016). Predicted diameter growth rates for SM and YB are similar to Baral et al. (2016) who observed a diameter growth of a 30 cm DBH SM tree = 0.28cm/year and YB tree = 0.36cm/year that were grown in a forest stand which was subjected to partial harvesting 15 years ago with $10m^2$/ha residual basal area. This study confirmed that trees in treated plots have significantly higher diameter growth. This must be due to the larger proportion of good quality (vigorous) trees in treated stands which are more efficient on utilizing growth resources (See Fortin et al. 2008). When tree health information is missing, knowing whether the tree is in a recently treated partial cut block along with other stand information would be useful for better predicting the individual-tree diameter growth.

Figure 2: Prediction of annual diameter growth across diameter at breast height using equation (1) for different species growing in the plots subject to partial cut and control. *BAL* and *BGI* were fixed at 20 m^2/ha and 3650 kg/ha/year, respectively.

Solid line = control;

Dotted line = treatment.
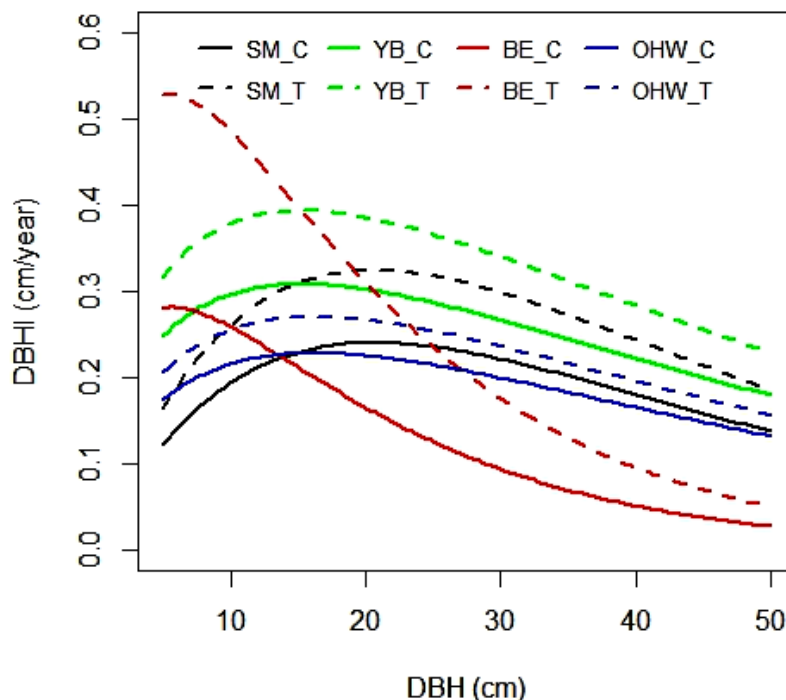
The model for OHW category performed poorly as a single model was fitted using the existing data for all minor species (red maple, aspen, white birch and other hardwoods) that did not have enough observations across their full range. Therefore, it is recommended to develop species-specific equations for those OHW species (e.g.: red maple, white ash, white birch, trembling aspen etc.). The inadequate fixed effect component of the proposed model could be improved in the future with the inclusion of spatially explicit competition index, species specific site-quality index, tree vigour and stand health information as covariates in the model.

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