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Institut de recherche sur les feuillus nordiques Inc.
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An Ingrowth Model Developed for Partial Harvesting in Northern New Brunswick

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Technical Note

Silviculture

INTRODUCTION

Ingrowth (i.e., trees that have grown into a threshold diameter, usually merchantable diameter, over a certain period of time) is an important component of forest development. Ingrowth is useful for simulating short- and long-term stand changes. Modeling ingrowth is complicated by factors such as the heterogeneity of species composition and stand structure, as well as the variety of silvicultural activities employed in the past. Inventories taken at one instant in time provide information on current wood volumes. This binary event (i.e. ingrowth recruitment) presents challenges to forest managers when projecting stand growth and future stand structure. As a result, ingrowth sub-models are often the weakest component of forest growth and yield models. In this study, the objective was to develop an ingrowth model to predict annual ingrowth tree density using stand and site characteristics. This will enable forest managers to predict ingrowth under different stand types and stages of stand development.

HIGHLIGHTS

- **The number of ingrowth trees is influenced by an interaction between stand development stage (quadratic mean diameter) and stand type.**
- **Salvage harvesting associated with blowdown of overstory trees decreases the annual ingrowth recruitment.**

METHODOLOGY

A database (Table 1) from a natural disturbance emulation project from Northern New Brunswick (AMA) was used. The study began in 2002 and consisted of treatments inspired by spruce budworm-induced tree mortality and gap replacement. The database was complemented with plots from a group selection trial (G1-G2) and plots in reserves (Core). The plots were classified into hardwood or mixedwood stand types. Hardwood stand types were those with at

Table 1: Post-treatment stand attributes by treatment class.

Variable	Mean	Minimum	Maximum	Standard deviation
Class AMA				
QMD	23.39	15.13	35.92	5.17
N (trees/ha)	550.70	220	1000	193.96
BA (m^2/ha)	21.75	12.84	38.49	7.48
DWT (m)	7.46	00.00	20.95	5.74
Class G1-G2				
QMD	26.50	16.99	37.21	5.52
N (trees/ha)	284.30	80.00	600.00	148.32
BA (m^2/ha)	14.84	2.27	29.81	6.36
DWT (m)	15.01	2.785	35.02	8.74
Core reserve				
QMD	20.85	15.17	34.50	3.17
N (trees/ha)	940.10	400	1380.00	265.60
BA (m^2/ha)	31.20	14.14	48.05	7.99
DWT (m)	7.40	00.00	31.15	7.46

least 70% of their basal area in hardwood species. Mixedwood stand types contained 50— 69% of their basal area in hardwood tree species. All plots were measured before and immediately after treatments. The time interval between treatment and re-measurement ranged from 6—12 years. Therefore, the annual ingrowth trees was obtained by dividing the total ingrowth trees in each plot by the re-measurement length of time (years). The threshold diameter for ingrowth was set at 10 cm at breast height (1.3m above ground). Pre– and post-treatment stand attributes such as trees per hectare, basal area (m^2/ha), quadratic mean diameter (cm), and harvest intensity were obtained from the database. Other variables such as presence of blowdown, overstory tree mortality, site factors (depth to water table (m), soil texture) and harvesting system used during the treatments were derived from the database for model building. After testing several independent variables, the best model predicting the average annual recruitment of ingrowth (trees/ha) was:

$$AIG = QMD + ST + BD + DWT + DWT^2 + Soil\_Text + HS + QMD{*}ST \qquad Eq.1$$

Where:

AIG = Annual ingrowth density (trees/ha)

QMD = Quadratic mean diameter (cm)

ST = Stand type (hardwood or mixedwood)

BD = Blowdown (N or Y)

DWT = Depth-to-water table (m)

Soil_Text = Soil texture

HS = Harvesting system

*QMD*ST* = Interaction between *QMD* and *ST*

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.

A generalized mixed model (Eq. 1, with a random intercept allowed to vary among treatment class and location) was fitted using *lme4* package (Bates et al. 2015) in *R* (R Core Team 2018).

RESULTS

The final model shows a pseudo coefficient of determination (R^2_m) of 62% for the fixed component only and a pseudo R^2_c of 88% for both the fixed and the random components of the model (Table 2). In general, the model appears to be adequate. However, validation with independent dataset is required to test the model's reliability. As expected, the annual ingrowth density (stems/ha) decreased as the quadratic mean diameter of the stand increased. However, the pattern of decrease differed with the pre-treatment stand type (Fig. 1A). In general, the number of ingrowth trees was higher in mixedwood stands where the quadratic mean diameter of the stand was less than 21cm. Beyond this level, hardwood stands significantly generated more ingrowth trees than mixedwood stands. However, mixedwood stands recruited significantly more ingrowth trees overall than hardwood stands (Fig. 1B). The annual ingrowth density showed negative relationships with the presence of blowdown in the plot, wetter areas (low DWT), coarse-medium textured soils and plots that were harvested using full-tree harvesting system (Table 2). A positive relationship between annual ingrowth density and fine-textured soils and plots that were harvested using cut-to-length harvesting system was observed (Table 2).

Table 2: Parameter estimates, standard error (SE) and p-values for model (1). QMD = Quadratic mean diameter (cm), Stand_Type = Post-treatment stand type, Blowdown = whether blowdown occurred in the plot (Y or N), DWT = Depth-to-water table (m), Soil_Texture (F) = fine soil texture, Soil_Texture (M-C) = medium-coarse soil texture, Harvest_System (CLT) = Cut-to-length harvesting system used the treatment, Harvest_System (FT) = Full-tree harvesting system used during the treatment and QMD x Stand_Type= Interaction between QMD and Stand_Type. $R^2_{m=}$ variance explained by fixed factors only, $R^2_{c\,=}$ variance explained by both fixed and random factors.

Parameter	Estimate	SE	*P*-value	R^2_m	R^2_c
Intercept	2.1583	0.5897	0.0003	0.62	0.88
QMD	-0.0250	0.0039	< 0.001		
Stand Type (MW)	2.4944	0.2053	< 0.001		
Blowdown (Y)	-0.8043	0.0679	< 0.001		
DWT	-0.0880	0.0051	< 0.001		
DWT^2	0.0033	0.0002	< 0.001		
Soil_Texture (F)	1.1437	0.0722	< 0.001		
Soil_Texture (M-C)	-0.2926	0.0295	< 0.001		
Harvest_System (CTL)	0.8426	0.0828	< 0.001		
Harvest_System (FT)	-0.0699	0.0607	0.2498		
QMD x Stand Type	-0.1161	0.0064	< 0.001		

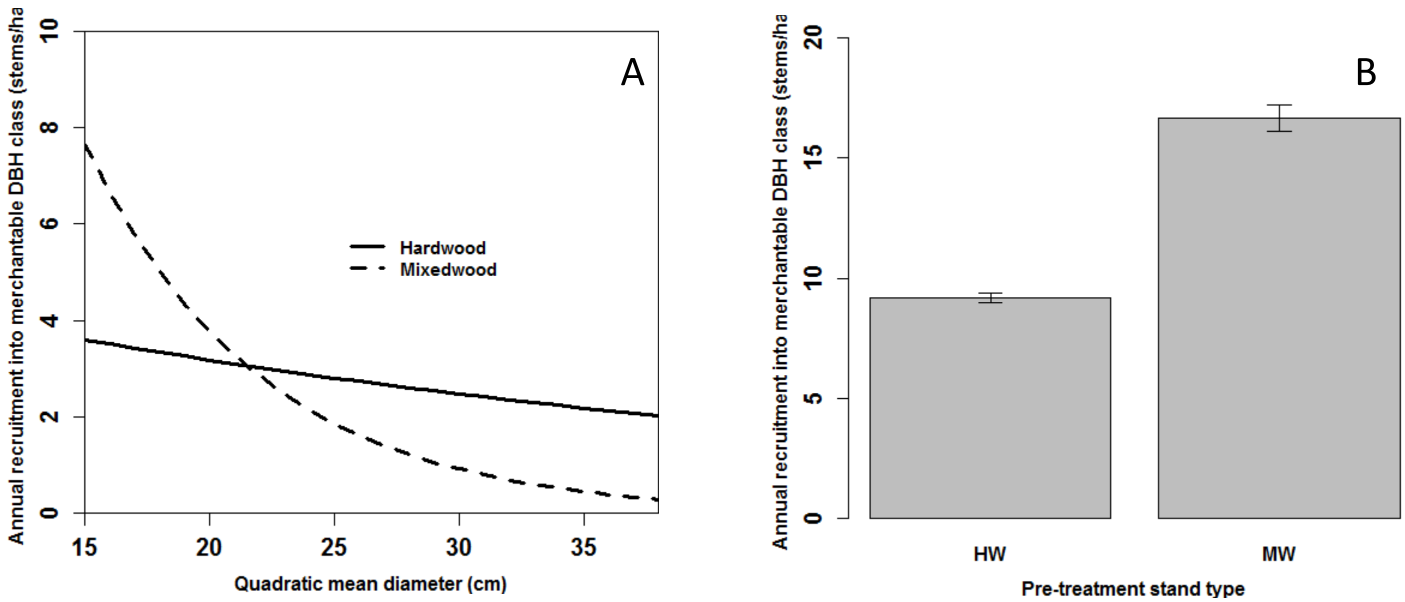

Figure 1: Expected average annual ingrowth recruitment (stems/ha) by quadratic mean diameter and pre-treatment stand type interaction (A), and pre-treatment stand type alone (B). HW = Hardwood, MW = Mixedwood.

CONCLUSION

This relatively logical annual ingrowth recruitment model for hardwood and mixedwood stands was developed using a database from previously treated plots. The negative parameter for quadratic mean diameter effect on annual ingrowth trees density implies that the ingrowth rate of trees generally decreases as the quadratic mean diameter increases. Greater quadratic mean diameter indicates mature stand or greater competition, so, they show less ingrowth recruitment than younger stands. Other ingrowth studies have found quadratic mean diameter to be a strong predictor (e.g. Adame et al. 2010). The intensity of basal area removal was initially assessed as a potential predictor variable considering that gaps created by overstory trees removal releases growing space for tree regeneration. However, percent basal area removed was negatively related to the number of ingrowth trees in this study. This might have been partly due to blowdown that occurred in greater levels (15%) in the treated areas and the subsequent salvage harvesting that followed. This caused significant damage to smaller trees and reduced their potential recruitment into the merchantable diameter class. While the model appears to be satisfactory, stochastics events such as windthrow that damaged the advance regeneration, and other factors not accounted for limited the overall adequate of the model.

REFERENCES

Li, R., Weiskittel and Kershaw, J.A. 2011. Modelling annualized occurrence, frequency, and composition of ingrowth using mixed-effects zero-inflated models and permanent plots in the Acadian Forest Region of North America. Can. J. For. Res. 41: 2077–2089 .

Bravo, F., Pando, V., Ordonez, C., and Lizarralde, I. 2008. Modelling ingrowth in the mediterranean pine fo rests: A case study from scots pine (Pinus sylvestris L.) and mediterranean maritime pine (Pinus pi naster Ait.) stands in Spain. Invest Agrar: Sist Recur For. 17(3), 250-260.

Adame, P., del Rio, M and Canellas, I. 2010. Ingrowth model for pyrenean oak stands in north-western Spain using continuous forest inventory data. Eur J Forest Res. 129: 669 — 678.

Bates, D., Maechler, M., Bolker, B. and Walker, S. 2015. Fitting linear mixed-effects models using lme4. J. Statistical Software 67(1), 1-48. doi:10.18637/jss.v067.i01.

Amos-Binks, L. 2005. Relating tree and stand level characteristics to blowdown following an emulated east ern spruce budworm, Choristoneura fumiferana, outbreak. BScF Thesis, Faculty of Forestry and Envi ronmental Management, University of New Brunswick, Fredericton, NB.

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