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Institut de recherche sur les feuillus nordiques Inc.
Northern Hardwoods Research Institute Inc.

How well can OSM (Open Stand Model) predict tree recruitment in the Acadian Forest Region of North America?

March 2019

Technical Note

Regeneration

Introduction

The processes underlying forest regeneration and the recruitment of new trees into new cohorts are highly variable and largely stochastic (Li et al., 2011, Vanclay 1992). Understanding the dynamics of forest regeneration and recruitment is pivotal to predict the growth and yield of commercial hardwood species and to improve management practices in the Acadian Forest Region of North America (Danyagri et al., 2017). In particular, there is a critical need to predict how commercial species will regenerate and be recruited into new cohorts under various environmental scenarios (Matías et al., 2011). The main objective of this project is to determine how well a tree list model can predict the recruitment of stems into new cohorts in unharvested stands for different species found in the Acadian Forest Region of North America. The recruitment of stems into new cohorts can be estimated by the ingrowth, which is defined as the number of trees in a sample plot that have grown into a required threshold size (e.g. diameter at breast height [hereafter "DBH"] treshold). We achieved the objective using a tree list model to predict the ingrowth in unharvested plots, and we then compared the predictions with observed values of ingrowth from field data.

Highlights

- **A key question for forest stakeholders in NB is how well OSM, a tree-list growth model calibrated for the Acadian Forest Region, can predict the recruitment of new stems with a DBH equal or above 5 cm over a 9-10 year period (hereafter "ingrowth"). We started answering this question in this study.**
- **We aimed at providing results for hardwood species, but statistical analyses for these species require further work to provide valid information that can be use by forest stakeholders in NB. We here present result for two softwood species, but further analytical work can allow determining how well OSM can predict ingrowth of hardwood species.**
- **For both balsam fir and black spruce, more observed ingrowth in permanent sample plots corresponds to more predicted ingrowth by OSM. Yet, OSM underestimates ingrowth, and this is more pronounced for balsam fir than for black spruce.**
- **For balsam fir, when 100 new stems were recruited only 1 new stem was predicted by OSM.**
- **For black spruce, when 100 new stems were recruited only 50 new stems was predicted by OSM.**
- **Further analytical work can allow us to determine how well OSM can predict ingrowth for other species, and compare how OSM performs for different species across a range of stand types (FUNA) and basal area classes.**

Reviewed: March 2019

Methodology

We used data collected in permanent sample plots (PSP) of 0.05 ha obtained from the JDIrving-AMA database (hereafter PSP-JDI-AMA). PSP-JDI-AMA are situated in the Black Brook Forest District, owned by J.D. Irving, Limited, in northern New Brunswick, Canada. Forests in this region are typically defined as a mixed-species stands (Salmon *et al.,* 2016). Species composition was consisted of 18 species with mainly; balsam fir (*Abies balsamea* (L.) Mill.), black spruce (*Picea mariana* (Mill.) B.S.P.)), red maple (*Acer rubrum* L.), eastern white cedar (*Thuja occidentalis* L.), red spruce (*Picea rubens* (Sarg.)) and sugar maple (Acer saccharum Marsh.) (Table 1). The following variables were obtained for each tree and/or plot: species, DBH (cm), height (m), height at the base of live crown (m), survey year, number of stems, and a biomass growth index (BGI) (FORUS Research, 2016; Hennigar *et al.,* 2016). The BGI is an index of productivity for the majority of the Acadian forest region that we used for the purpose of improving stand growth model forecasts. We used data from 97 unharvested PSP-JDI-AMA. These plots were surveyed initially in 2002 or 2003 and then in 2013.

To predict ingrowth (DBH≥5cm) over 9 to 10 years (2002 and 2003 to 2013), we used the Open Stand Model (OSM) (Hennigar, 2013). OSM is a tree-list growth model calibrated for the Acadian Forest Region (Lamb *et al.,* 2018). For each PSP and/or tree measured in these plots, we used the following variables as inputs into OSM: survey year, DBH, species, tree height, number of stems, plot ID, treeID, and the BGI. We obtained the predicted ingrowth per species by using the OSM output and summing the number of new stems with a DBH equal or above 5 cm in 2013 compared to 2002 or 2003 for each species. We obtained the observed ingrowth over the same 9 to 10 years (2002 and 2003 to 2013) by summing the number of new stems with a DBH equal or above 5 cm in 2013 compared to 2002 or 2003 in PSP-JDI-AMA for each species.

We analyzed results in two ways. First, we present the average and standard deviation of predicted and observed ingrowth by species, basal area class of PSP-JDI-AMA in 2002 or 2003, and species composition (characterized by the Forest Unit Name, hereafter "FUNA" type). Second, we used linear models (LMs) to determine the relationship between the observed and the predicted ingrowth for the different species. We used the predicted ingrowth as the response variable, and applied a log-transformation to insure that the conditions of homoscedasticity and normality of residuals were respected (Zuur *et al.,* 2009). For some species, the LMs did not respect the conditions of homoscedasticity and normality of residuals, and the distribution of data for other species did not allow conducting the LMs. We identified these species in the result sections; further analytical work could be done to extract information for these species if needed. We performed statistical analyses using the R 3.5.1 software (R Core Team 2018).

Results

1. Descriptive statistics

We report the average and standard deviation of predicted and observed ingrowth by species (Table 1), basal area class of the plots in 2002 or 2003 (Table 2), and species composition ("FUNA" type; Table 3). Given that we did not perform statistical analyses to estimate the difference between the predicted and observed ingrowth, we will not further interpret these tables.

Results

Table 1: Average and standard deviation of predicted and observed ingrowth per species (all plots combined).

Species	Average of predicted ingrowth (trees/ha/10 years)	Standard deviation of average of predicted ingrowth	Average of observed ingrowth (trees/ha/10 years)	Standard deviation of average of observed ingrowth
American Beech	0	0	5.3	21.5
American Elm	0	0	0	0
Balsam Fir	18.9	51.9	49.6	71.5
Balsam Poplar	0.3	3.1	0.2	2
Black Ash	1	8.6	0	0
Black Spruce	12.4	68.3	13.1	75.3
Eastern White Cedar	4.8	18	15.2	45.2
Pine Cherry	0.8	7.1	0.6	4.5
Red Maple	9.7	37.8	5.3	17.6
Red Spruce	4	17	12.7	44.3
Striped Maple	0	0	0.4	4
Sugar Maple	2.7	14.2	10.1	20.8
Tamarack	0.1	0.7	0.2	2
Trembling Aspen	6.1	21.2	1	5.3
White Birch	9.3	29.4	4.5	10.9
White Spruce	11.9	43	2.4	7.7
Willow NC	0.1	0.5	0.8	3.9
Yellow Birch	2.7	11.2	2.2	9
Total	**4.7**	**18.4**	**6.9**	**19.2**

Table 2: Average and standard deviation of predicted and observed ingrowth per basal area (BA) class in 2002 or 2003.

Initial BA_class	Average of predicted ingrowth (trees/ha/10 years)	Standard deviation of average of predicted ingrowth	Average of observed ingrowth (trees/ha/10 years)	Standard deviation of average of observed ingrowth	Number of plots
10_20	20.8	14	11.5	16	12
20_30	4.1	9.1	7.2	7.8	43
30_40	0.6	0.4	5.3	4.8	35
40_50	0.7	0.8	4.7	2.5	7
Total	**6.5**	**6.0**	**7.1**	**7.7**	**24.2**

Results

Table 3: Average and standard deviation of predicted and observed ingrowth per FUNA type.

FUNA type		Average of predicted ingrowth (trees/ha/10 year)	Standard deviation of average of predicted ingrowth	Average of observed ingrowth (trees/ha/10 year)	Standard deviation of average of observed ingrowth	Number of plots
	INSW	11.2	13.6	8.1	7.4	16
	TOHW	1.7	6.4	3.8	3.6	16
	SMTH	1.8	3.6	3.4	2.5	12
	RMMX	0.3	0.1	6.1	2.7	8
	BFMX	7.7	12.1	5.7	2.4	6
Softwood multiple FUNA types	BSPR BFSP SPRC WSPR RSPR RSBF BSBF BFIR SPBF	7.1	3.4	8.9	6.2	2.4
Mixedwood multiple FUNA types	INMX SPMX BIMX TOMX RSMX THMX	3.1	3.9	6.3	1.8	2.1
Hardwood multiple FUNA types	FPHW BETH	0.1	0	7.1	0.9	2
Total		**4.1**	**5.3**	**6.1**	**3.4**	**8**

2. Linear regressions

We here present result for two softwood species, because more effort is needed to better adjust the models for the following hardwood and softwood species (distribution of data did not allow conducting statistical models or residuals were not homogenous, in which case analyses cannot yet provide reliable results): red maple, American beech, white birch, sugar maple, Eastern white cedar, trembling aspen, red spruce, and yellow birch, American elm, black ash, balsam poplar, pine cherry, striped maple, tamarack, white spruce, and willow.

For balsam fir, predicted ingrowth increased with observed ingrowth (slope= 0.005, CI = [0.001, 0.009], adjusted-R^2 =0.06; Fig.1, Table 4). For black spruce, predicted ingrowth increased with observed ingrowth (slope= 0.6, CI = [0.5, 0.7], adjusted-R^2 =0.4; Fig.2, Table 4).

Results

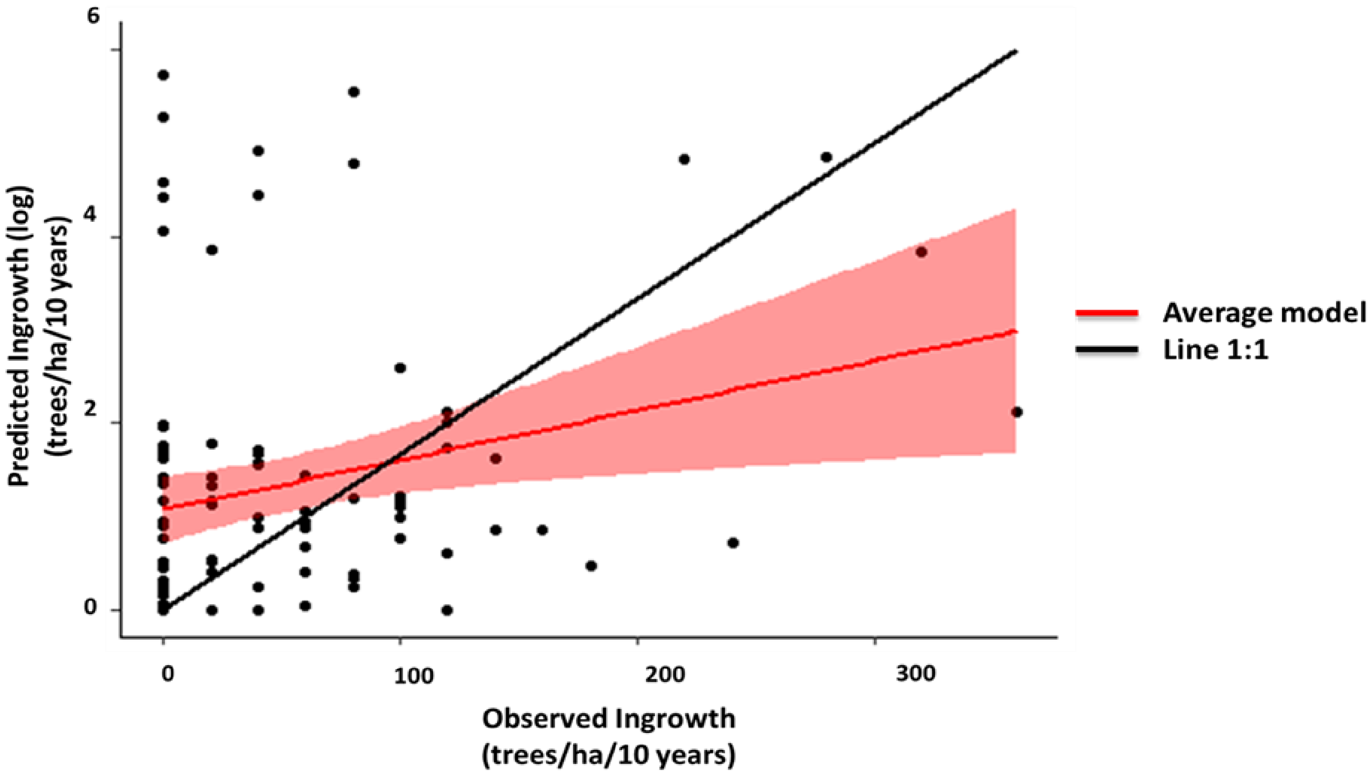

Figure 1: Increase in predicted ingrowth as a function of observed ingrowth (trees/ha/10 years) for balsam fir (n=97 plots).

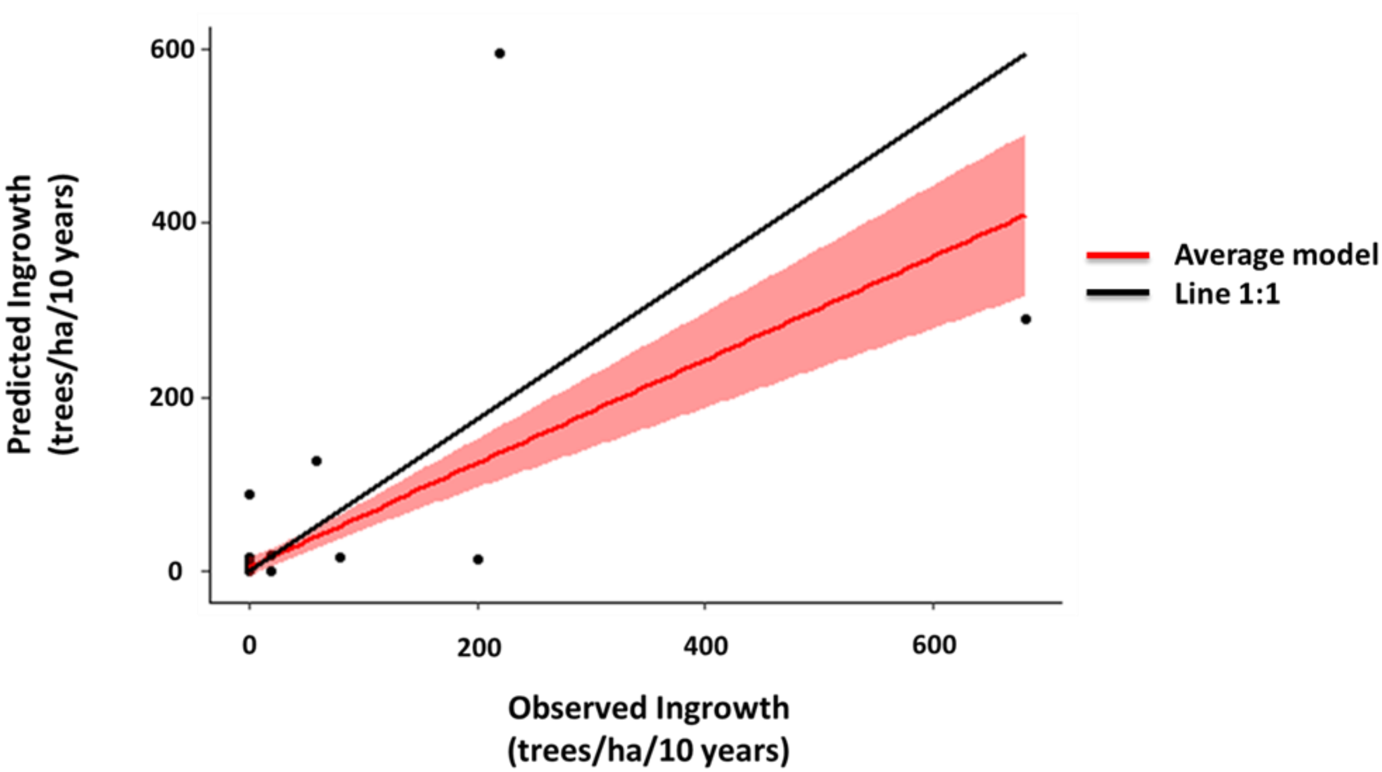

Figure 2: Increase in predicted ingrowth as a function of observed ingrowth (trees/ha/10 years) for black spruce (n=97 plots).

Results

Table 4: Results from the simple linear regression models fit of balsam fir (BF) and black spruce (BS) and their 95% confidence intervals (CI).

Variable	*Slope*	*Low CI*	*High CI*	*Adjusted-R^2*
Balsam fir Model:				0.06
- Intercept	1.07	0.71	1.42	
-Observed ingrowth	0.005	0.001	0.009	
Black Spruce Model:				0.4
- Intercept	4.6	-6.0	15.2	
-Observed ingrowth	0.6	0.5	0.7	

Discussion and conclusion

This study contributed to determine how well OSM can predict the recruitment of trees into a new cohort (DBH≥5 cm) over a 9-10 year period in unharvested plots. The descriptive comparison of average predicted and observed ingrowth value per species, basal area class, and FUNA type will contribute to provide information that can allow improving OSM. A statistical comparison of predicted and observed ingrowth value for these different categories would be highly recommended to identify the species, basal area class, and FUNA type for which model adjustment are needed.

The linear models allowed determining whether predicted and observed values were correlated, and whether the 95% confidence intervals of the slope between these two variables included 1. A slope of 1 corresponds to predicted values that are equal to observed values. The analyses for both balsam fir and black spruce showed that OSM underestimates ingrowth, and such underestimation was more pronounced for balsam fir than for black spruce.

To keep providing the required information to improve OSM, we suggest conducting the statistical comparison of predicted and observed values for the different species, basal area class, and FUNA type. Then, we suggest conducting optimization analyses that would aim at finding parameter values that would minimize the difference between predicted and observed values for these different variables.

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For more informations, contact:

Marie-Andrée Giroux
Assistant professor
Holder, K.-C.-Irving Research Chair in Environmental Sciences and Sustainable Development, Université de Moncton

506-858-4152
marie-andree.giroux@umoncton.ca

UNIVERSITÉ DE MONCTON
EDMUNDSTON MONCTON SHIPPAGAN

Chaire de recherche K.-C.-Irving en sciences de l'environnement et développement durable

Authors and affiliations:

Ines Khedhri[1,2], Chris Hennigar[3], Stéphanie Lebel-Landry[2], and Marie-Andrée Giroux[1]

[1] K.-C.-Irving Research Chair in Environmental Sciences and Sustainable Development, Université de Moncton, Canada

[2] Northern Hardwood Research Insitute Inc., Edmundston, Canada

[3] Department of Energy and Resource Development, New Brunswick, Canada