MGM Research Note #2020-2

Incorporating effects of spruce competition on growth of juvenile spruce.

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While juvenile white spruce height and diameter growth equations in MGM18 include effects of deciduous and pine competition, they do not consider effects of competition from taller spruce. This has led to MGM overestimating growth of juvenile (<4 cm dbh) white spruce which is most notable following partial cutting treatments such as understory protection (Grover et al. 2014).

This note presents the approach used to incorporate effects of spruce competition into the growth functions for juvenile spruce.

Table 3.10 from Krebs (2016, page 42) provides the parameter estimates for her equations. DBH of trees used in developing these models range from 1.2 cm to 12.2 cm.

Table 3.10 Estimates of parameters for fixed and random effects and their 95% confident intervals for equation $PAI_{ij} = a + b_1 * e^{(b_2 * CIcon_{ij} + b_3 * CIdecid_{ij})} * in.Ba_{ij}^{c} + \varepsilon_{ij}$ for the best BA and height model. Response variables are $PAI_{BA/Ht}$ in period 3.

	Parameters					Random effects
	a	b1	b2	b3	c	
PAI_{BA} Competition Index 2 *						
						c
Parameter estimate	0.08	0.33	-0.01	0.0003	0.75	0.05
(95% Confident interval)	(- 0.02 - 0.17)	(0.23 - 0.44)	(- 0.008 - - 0.005)	(- 0.001 - 0.002)	0.65-0.85	(0.03 - 0.11)
PAI_{Ht} Competition Index 1_{larger}						
						a
Parameter estimate	0.15	0.03	-9.36	1.55	0.49	0.04
(95% Confident interval)	(0.09 - 0.20)	(- 0.01 - 0.06)	(- 15.80 - - 2.92)	(- 3.62 - 6.73)	(0.16 - 0.83)	(0.02 - 0.09)

* size of main tree was set to 1.0 for calculation of competition index

Competition Index 1_{larger}=sum of basal area of larger DBH competitors
Competition Index 2= sum of dbh of competing conifers or deciduous within a 0.01 ha (5.64 m radius) or 0.005 ha plot divided by DBH of the subject tree.
Conifer competition is based on 5.64 m radius plots, and deciduous competition is based on 3.99 m radius plots.

The Krebs (2016) deciduous competition parameters have limited applicability since the data came from areas that had much of the aspen removed through understory protection harvesting, resulting in a narrow range in aspen competition levels. To provide consistent equations, BAL_{sw} (Competition Index 1 $_{larger}$) was used in developing the competition adjustment for basal area increment of juvenile spruce, as Krebs had done for height increment. BAL_{sw} is basal area larger of spruce and fir calculated in m^2/ha. In addition, competition index values are converted to per hectare values to reduce potential sources of confusion.

The equations presented below should only be applied to juvenile trees (<4 cm dbh), since functions for trees larger than 4 cm dbh already include effects of deciduous and conifer competition.

Height Increment of juvenile white spruce

Rather than replacing the current Height increment function used in the model with the Krebs 2016 equations, we develop and apply a reduction factor for spruce competition to be applied to the current (MGM18) HiSw function.

$$HiSw^* = HiSw \times \exp(-0.09366 * BAL_{sw})$$

Where:
HiSw*=adjusted HiSw (m/y)
HiSw=height increment calculated using the current (2018) MGM function
BAL_{sw}=basal area (m2/ha) of spruce and fir with larger dbh per hectare.

Krebs (2016) used basal area (cm^2) of spruce with larger dbh in a 5.64 m radius (0.01 ha) plot. To convert to m^2/ha, cm^2/plot values were divided by 99.9328. Krebs parameter b2 for height increment (b2=-9.36) was divided by 99.9328 to obtain a value of -0.09366 for b2.

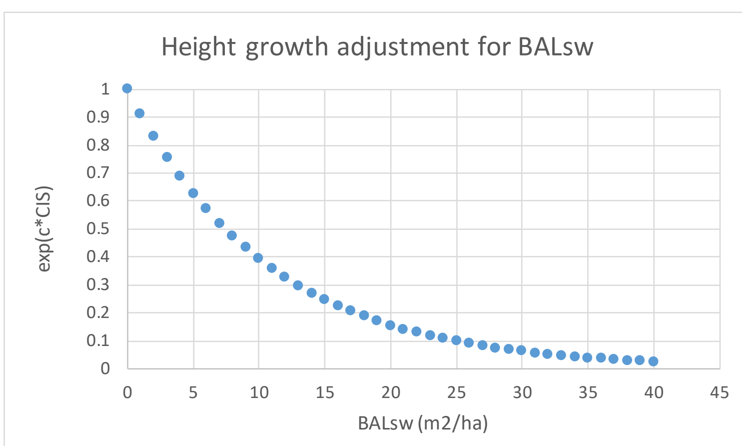

Figure 1. Illustration of effects of BAL_{sw} on adjustment factor for computing height increment "exp(-0.09366*BAL_{sw})". Note that BAL_{sw} = spruce/fir basal area larger in m^2/ha.

Basal area increment of juvenile white spruce

Data from Krebs (2016) were reanalyzed using non-linear regression to develop a model that uses BAL_{sw} and BAL_{dec} in place of CI2 to estimate annual basal area increment for each year between 2010-2014.

The resulting conifer competition adjustment was:

$BAI^{*}=BAI \times \exp(-0.0366*BAL_{sw})$

where:
BAI*=adjusted basal area increment
BAI = Basal area increment (cm^2/y) calculated using the existing (2018) MGM growth function for juvenile spruce.
c=-0.0366 (determined by fitting non-linear regression equation using annual breast height basal area increment for each year between 2010 and 2014).
BAL_{sw}= basal area (m2/ha) of spruce and fir with larger dbh per hectare.

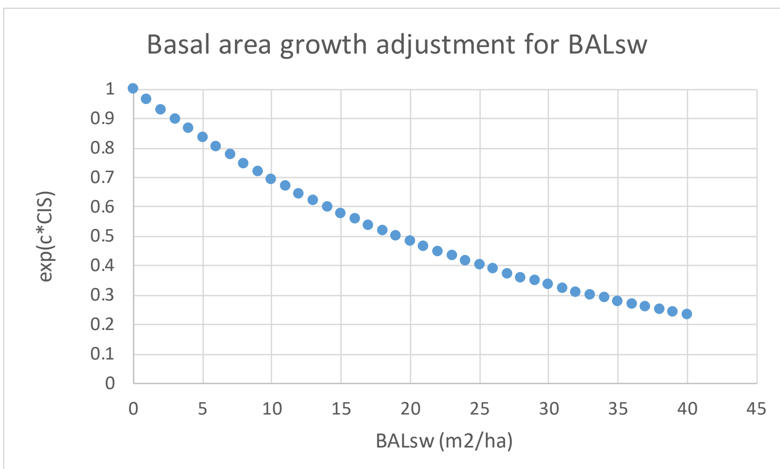

Figure 2. Illustration of effects of BAL_{sw} on the adjustment factor for computing basal area increment "exp(-0.0366 * BAL_{sw})" . Note that BALsw = spruce/fir basal area larger in m^2/ha.

To implement this adjustment in MGM:
1. BAI is calculated using the existing juvenile spruce growth function (MGM18 and MGM20):

$BAI=a*DBH*viewfactor^{b}$

where:
Viewfactor=arctan(1/sqrt(DecDenAbove/10000)(DEC10H)/(2π)
DecDenAbove= number of deciduous taller than the subject conifer
Dec10H = average height of the tallest 1% of all deciduous trees (m).
a=1.609776
b=0.208911

2. BAI is adjusted using the conifer competition adjustment for basal area increment at breast height - for trees taller than 1.3 m.

Incorporation of white spruce response equations into MGM:

The white spruce release response equations and parameters were coded into the juvenile height increment and diameter increment functions in MGM20. In addition, the "Options" event and options dialogue were updated to enable users to toggle (enable/disable) use of the white spruce release response.

Demonstration of Results

Addition of these white spruce release response functions to MGM20 reduces white spruce height increment and diameter increment based on spruce/fir competition from above. To demonstrate effects of white spruce release response on MGM predictions, a tree list from a 100 m^2 plot with nested sapling and regeneration subplots (tree layer plot=100 m^2, sapling plot = 40 m^2, and regeneration plot = 5 m^2) was used to initialize MGM at age 18. This plot contained only white spruce. The tree characteristics within the nested plot design are presented in Table 1. The height distribution (Figure 3) of this stand depicts a structure where an abundance of small white spruce exist below larger trees.

To demonstrate the effects of the release response functions on prediction, the tree list was projected to age 100 with and without the function enabled. In addition to the tree list the following settings were used: Central Mixedwood Natural Subregion, GYPSY site index curves, site index = 18m, CMI = -2.25, MAT = 0.2, maximum size density adjustment = off, no merchantability criteria.

Table 1. Summary of tree characteristics for the plot used to initialize MGM20 for this demonstration.

				DBH (cm)				Height(m)			
Plot	**Plot size (m^2)**	**n**	**Density (sph)**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**	**Min**	**Max**
Trees (≥5.1)	100	10	1000	7.12	1.47	5.70	10.60	8.18	2.15	5.60	13.30
Saplings (≥1.3m & <5.1m)	40	2	500	2.95	0.45	2.50	3.40	3.30	1.00	2.30	4.30
Regen (<1.3m)	5	12	24,000	-1.00	0.00	-1.00	-1.00	0.63	0.19	0.55	1.05

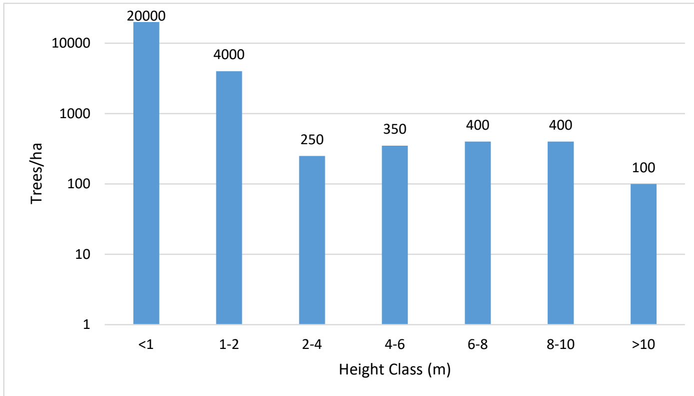

Figure 3. Height distribution in the 18 year old white spruce stand used to initialize MGM (Note that vertical axis is shown in log scale).

Results

Figures 4 through 9 contrast results from modeling spruce growth to age 100 with (With RR) and without (No RR) the competition adjustment factor applied to juvenile spruce. Since the release response functions do not affect trees above 4 cm in DBH, the top height curves for the two projections do not differ.

Average height initially does not include trees <1.3 m in height. As trees in the regeneration layer pass 1.3 m they cause the initial drop in average height shown between ages 18 and 30. Adding the conifer competition adjustment causes a reduction in average spruce height after age 20 (Figure 4).

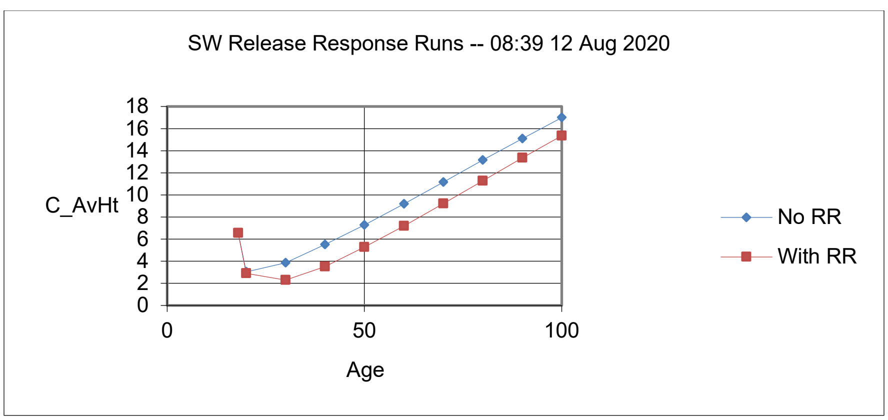

Figure 4. Effects of projections with (With RR) and without (No RR) the release response function on trends in average spruce height (C_AvHt, m).

Trees below 1.3 meters do not have a breast height diameter. As these trees pass the 1.3 meter threshold they begin to influence mean diameter, resulting in a decline in DBH between ages 18 and 20. The effect of the white spruce release response function on stand diameter is large at age 30 (Figure 5) but as trees become larger effects of this function diminish.

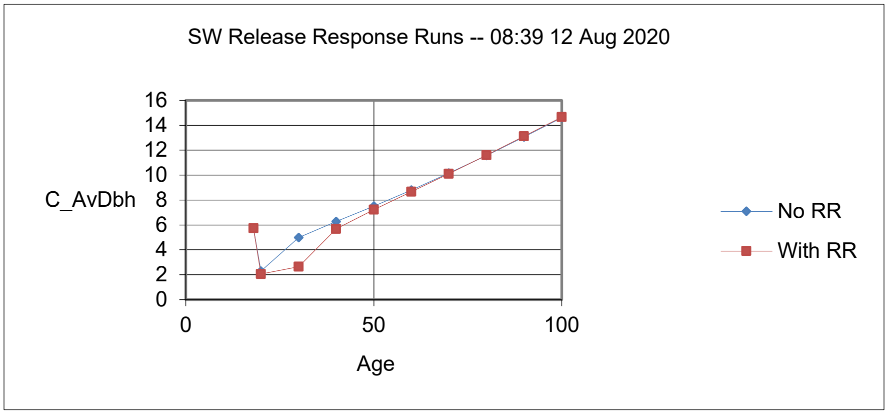

Figure 5. Effects of projections with (With RR) and without (No RR) the release response function on trends in average spruce DBH (C_AvDbh, cm).

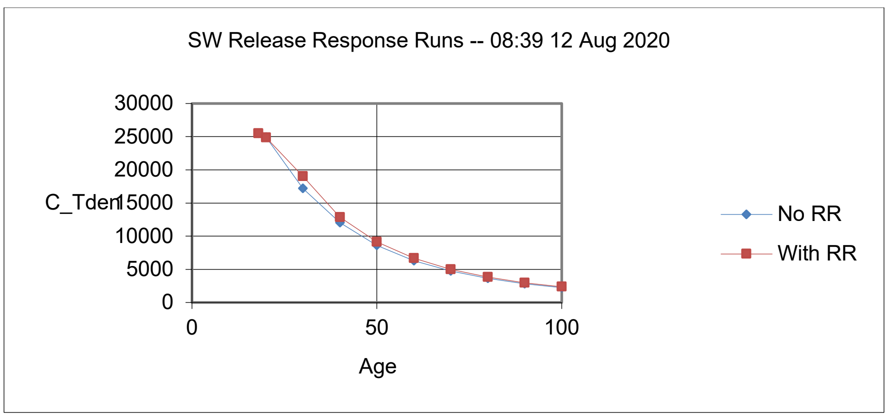

Figure 6. Effects of projections with (With RR) and without (No RR) the release response function on trends in spruce density (C_Tden, #/ha).

Addition of the release response function results in stands carrying slightly higher densities at ages 30 through 70 (Figure 6). While the effect is small, it is consistent with effects of reduced DBH leading to reduced competition and associated reductions in tree mortality. The trends for basal area per hectare (Figure 7) reflect effects of differences in stand density and DBH predictions resulting from addition of the release response function. Reduced diameter growth of small trees reduces basal area between ages 30 and 50.

Addition of the release response/competition function results in a small reduction in spruce volume from age 30 to age 90 (Figure 8) and an associated decrease in mean annual increment (Figure 9). Stand volumes and MAI converge at age 100.

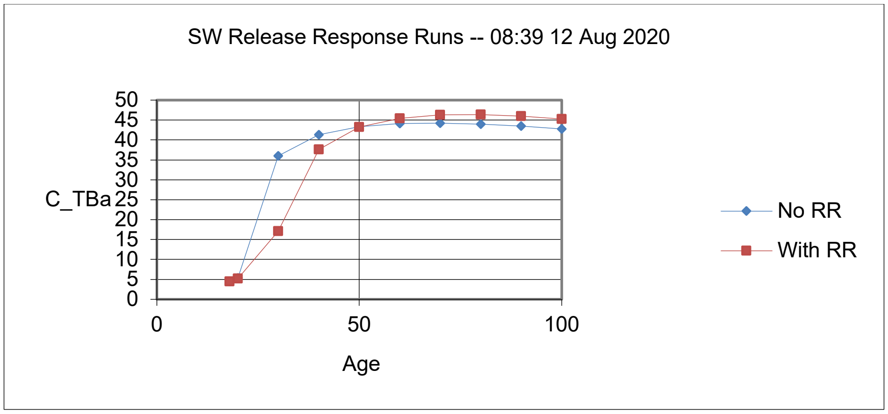

Figure 7. Effects of projections with (With RR) and without (No RR) the release response function on trends in stand basal area (C_TBa, m^2/ha).

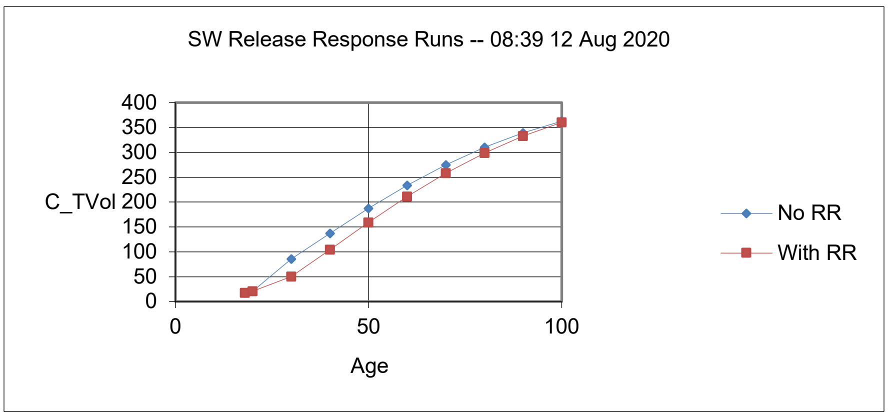

Figure 8. Effects of projections with (With RR) and without (No RR) the release response function on trends in stand volume (C_TVol, m^3/ha).

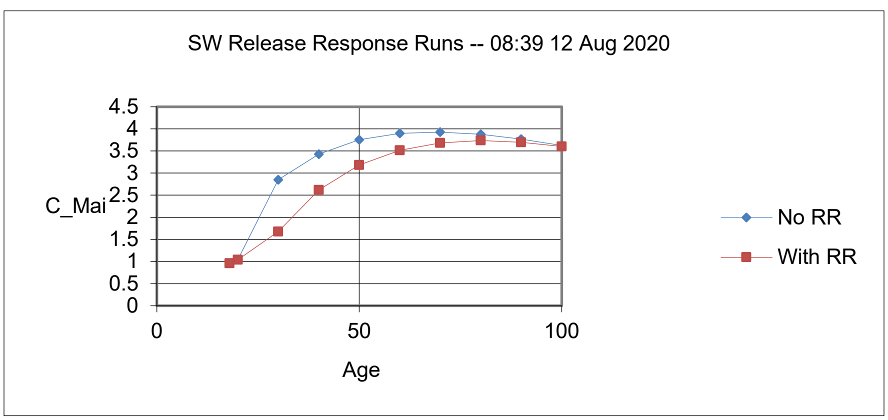

Figure 9. Effects of projections with and without the release response function on trends in stand MAI (C_Mai, m^3/ha/y).

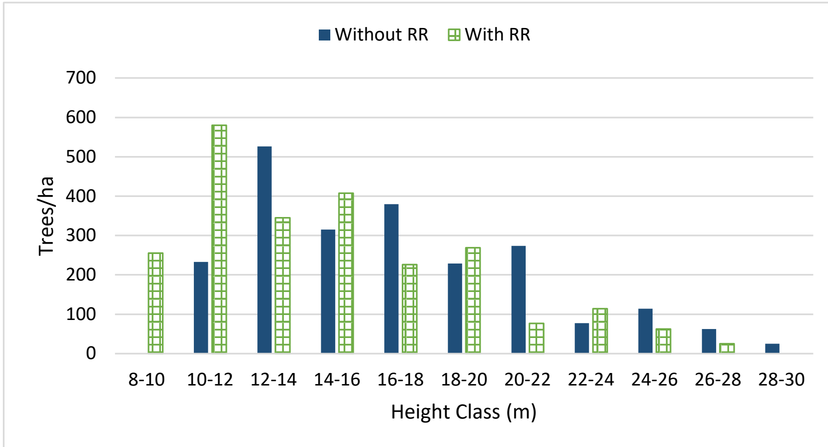

Figure 10. Effects of adding the release response function on predicted height distributions at age 100 for the simulated spruce stand.

Figure 10 illustrates effects of adding the release response function on the structure of the stand at age 100. Adding the release response function, which reduces growth of trees less than 4 cm DBH, results in a downward shift in the distribution of tree heights and more trees in size classes below 12 m height at age 100.

Results from this test indicate that addition of the release response functions leads to small reductions in height and diameter growth of juvenile white spruce and adjustments in MGM behavior. Results to date suggest that the resulting changes will improve MGM behavior and partially overcome problems with overestimates of spruce growth following understory protection harvesting (Grover et al. 2014).

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