MGM Research Note #2021-2

Maximum Size – Density relationships for western boreal and montane forests

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Introduction

The boundary line for tree density – size relationships provides a measure of stockability, which represents the maximum number of trees of a certain size that a site could support (DeBell *et* al. 1989). This measure is used to constrain densities in growth models such as the Mixedwood Growth Model (MGM) (Yang and Titus 2002). This research note summarizes methods and results from the fitting of a density-size relationships for use in MGM21.

Methods

Quantile regression was used to determine maximum density-size relationships using PSP data from 3652 permanent sample plots in Alberta, British Columbia, Yukon, Manitoba, Northwest Territories, Saskatchewan and Alaska (Figure 1). Data were filtered to remove all trees below 9.0 cm DBH. Since these PSP's had been remeasured multiple times, only the observation with the highest basal area, was selected for fitting.

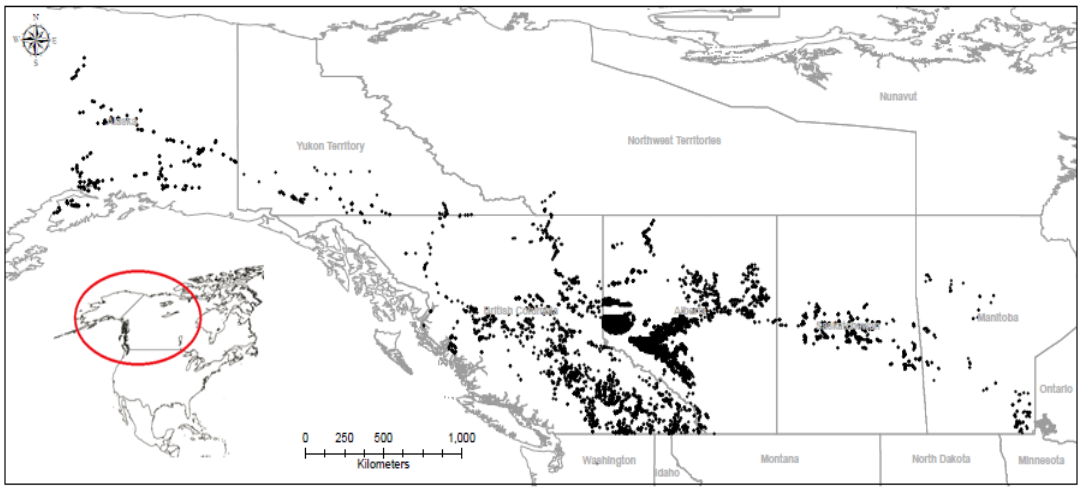

Figure 1. Locations of permanent sample plots (PSP's) used in model fitting (Each black dot represents the location of one Permanent Sample Plot).

Model fitting included testing for effects of tree size (QMD, quadratic mean diameter), stand composition (percent deciduous, percent spruce/fir, and percent pine), and climate variables (30 year (1981-2010) normals for MAT, MWMT, MCMT, MAP, MSP and CMI) and first order interactions. Aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.) and paper birch (*Betula papyrifera* Marsh.) were modeled as a deciduous species group, white spruce (*Picea glauca* (Moench) Voss), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), hybrid/interior spruce (*P.glauca* x *P. engelmannii*), black spruce (*Picea mariana* (Mill.) BSP.), balsam fir (*Abies balsamea* (L.) Mill.) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) were modeled as the spruce/fir group, and lodgepole pine (*Pinus contorta* Douglas ex Loudon) and jack pine (*Pinus banksiana* Lamb.) were modeled together as a pine group. Backward selection was used to obtain a final model where all variables were significant.

Table 1. Sample sizes and ranges for selected variables within the dataset used for analysis (N=3652).

Variable	Mean	Std Dev	Minimum	Maximum
year	1998	11.36	1963	2015
Latitude	55.218	2.899	49.008	67.323
Longitude	117.037	10.908	151.558	95.440
Elevation	806.6	372.7	24.0	2081.9
MAT	1.28	1.51	-6.10	4.20
MWMT	15.21	1.46	9.80	19.10
MCMT	-13.60	4.49	-26.20	-5.10
MAP	548.6	117.0	219.0	1070.0
MSP	366.4	80.4	141.0	603.0
DD5	1145.85	177.44	457.00	1718.00
FFP	99.04	11.40	48.00	135.00
CMI	14.46	12.97	-13.60	82.44
tph	1100.40	632.70	111.25	4108.91
G (m^2/ha)	35.51	9.20	20.01	67.29
QMD (cm)	22.48	6.39	10.84	52.89

MAT = mean annual temperature (° C); MWMT = mean warmest month temperature (° C); MCMT = mean coldest month temperature (° C); MAP = mean annual precipitation (mm); MSP = mean summer precipitation (mm); DD5 = growing degree-days above 5° C; CMI = Climate Moisture Index (Hogg et al. 2013; calculated from annual monthly climate data for the 1981-2020 normal period obtained from ClimateNAv5.60*); tph = trees per hectare; G = basal area (m^2ha^{-1}); QMD= quadratic mean diameter (cm). Climate variables are for the 1981-2020 normal period and were obtained from ClimateNAv5.60 (Wang et al. 2016).*

Results and Discussion

The final model:

$$\ln(TPH)=8.5870+0.9013*\ln(QMD)-0.4601*(((\ln(QMD))^2)$$
$$-0.008596*dec\_pct+0.001968*sf\_pct+0.002786*\ln(QMD)*dec\_pct$$
$$+0.01314*CMI-0.00013532*CMI^2-0.00006326*CMI*dec\_pct-0.00005859*CMI*sf\_pct$$

where: *QMD=quadratic mean diameter for the stand (cm); dec_pct=percent of stand basal area that is deciduous; sf_pct= percent of stand basal area that is spruce or fir; and, CMI=Climate Moisture Index.*

The resulting model indicates that maximum densities are higher for shade tolerant spruce and fir than for intolerant aspen or pine and that adding intolerant aspen or pine to a spruce stand leads to a decrease in maximum density while increasing CMI is associated with increasing maximum densities across all species and mixtures.

This maximum density – size function has been implemented in MGM 21.

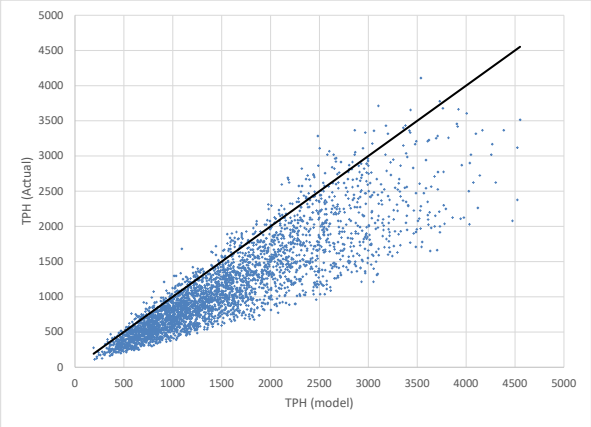

Figure 2. Plot of actual stand densities versus maximum stand density (TPHmax model) predicted by the final model (using the 90th quantile). The solid black line shows the 1:1 line.

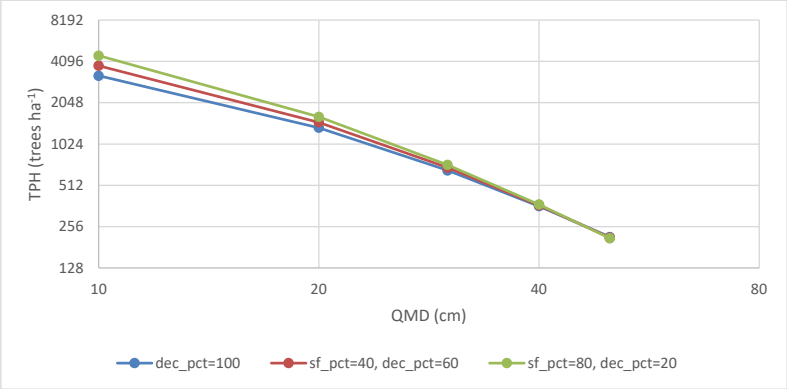

Figure 3. Effects of varying spruce and aspen composition on the position of the maximum density line at CMI=14.5.

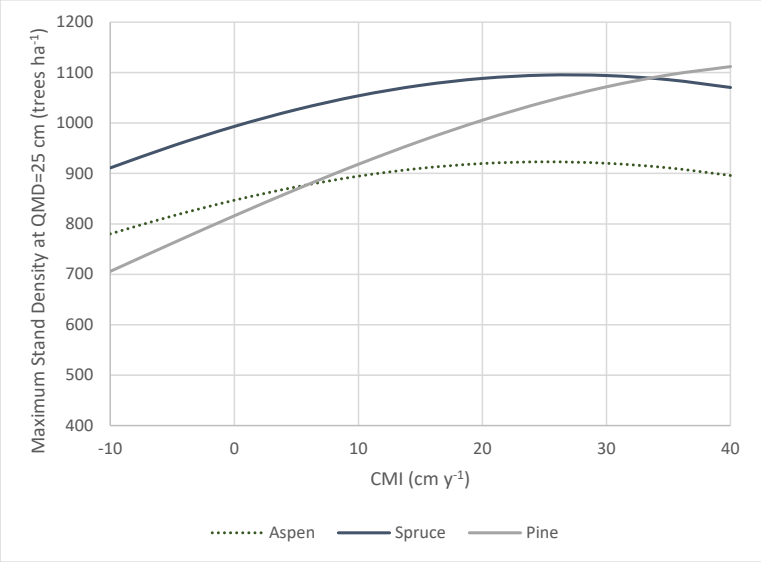

Figure 4. Effects of CMI on maximum density for pure aspen, spruce or pine stands at a QMD of 25 cm.

References

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