ORGANON Calibration for Western Hemlock Project

May 12, 2000

Height Growth Equation

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Introduction

The ORGANON model (Hann, et al., 1992) uses an equation to describe the height growth of each tree. Currently, the SMC variant of ORGANON uses the following equation (Marshall, 1998):

$$\Delta Height = \Delta Height_{pot}\,\beta_7\left[F_0 + (F_1 - F_0)e^{\left(-\beta_4(1-CR)^{\beta_5}\right)e^{\beta_6 CCH^{0.5}}}\right]$$
$$F_0 = \beta_0 e^{\beta_1 CCH} \qquad (1)$$
$$F_1 = e^{\beta_2 CCH^{\beta_3}}$$

where: ΔHeight = height growth, $\Delta height_{pot}$ = potential height growth (defined by the site curve for the stand), CR = crown ratio, CCH = crown cover at tip of the tree.

The purpose of this paper is to document the estimation of the coefficients for equation 1, to western hemlock data.

Willamette Dataset

The Willamette dataset was collected from temporary plots using a protocol developed by Hann (1992). Complete, compatible tree measurements were taken on all sample observations. Once points were established and measured, a systematic sub-sample of trees were identified, felled, and 5-year height growth measurements recorded. A summary of the dataset appears in the table below:

n = 145	**Mean**	**Minimum**	**Maximum**
ΔHeight	7.0	1.1	19.4
$\Delta Height_{pot}$	9.1	4.4	16.8
DBH	12.5	3.0	33.2
HEIGHT	81.1	33.1	131.6
CR	0.52	0.09	1.00
CCH	26.4	0.0	182.6
SITE (western hemlock)	112.3	97.9	137.3

Champion Dataset

The Champion dataset was constructed from remeasured untreated permanent plots where trees had initial crown ratio measurements. Again, no attempt was made at this time to impute crown ratio data for the remaining observations. Only those plots that had complete height measurements were used. A summary of the complete dataset appears in the table below:

n = 118	Mean	Minimum	Maximum
ΔHeight	8.7	0.0	26.7
$\Delta Height_{pot}$	10.4	5.8	15.1
DBH	12.3	6.5	26.2
HEIGHT	91.2	57.0	135.0
CR	0.34	0.10	0.80
CCH	7.4	0.0	66.3
SITE (western hemlock)	124.6	101.0	141.7

SMC Dataset

The Stand Management Cooperative (SMC) dataset was collected from Type I permanent plots using a protocol developed by the SMC (Rinehart, 1986). Although all trees on the permanent plots were tagged and measured for DBH, not all trees were measured for crown ratio and total height. The dataset used here contains only those trees with a full complement of tree measurements. All plots are controls, with no known density control or fertilization treatments. A summary of the dataset appears in the table below:

n = 850	Mean	Minimum	Maximum
ΔHeight	13.3	0.3	20.3
$\Delta Height_{pot}$	14.4	7.2	15.2
DBH	3.2	0.1	14.1
HEIGHT	24.3	5.2	116.5
CR	0.72	0.13	0.99
CCH	22.7	0.0	307.6
SITE (western hemlock)	120.2	91.9	123.6

Caution should be applied to inferences made with the SMC dataset. These data are from small trees, and a narrow distribution of site quality (SITE sd = 3.4 feet). The growth relationships defined by these trees may not apply other tree sizes and site qualities. Because of the relative size of this dataset, it may have a significant effect on the parameter estimates obtained through regression.

Analysis

Equation 1 was fit to the combined dataset (n = 1113). The resultant regression was significant and as were all parameter estimates. However, there were several parameter estimates that were not biologically reasonable or would cause poor behavior in ORGANON. The parameters of concern were:

$\beta_2 = 0.0082$
$\beta_7 = 0.9337$

β_2 has a positive value. This results in large crown ratio trees to have increasing height growth with increasing CCH (i.e., higher height growth with greater suppression). The β_7 estimate is below 1.0. The equation therefore never predicts a tree's height growth to meet or exceed site potential height growth. In ORGANON, this results in stands falling progressively away from their measured site index.

Using these observations as criteria for an acceptable model, Equation 1 parameters were successively deleted or fixed until a fit was obtained that had statistical significance and reasonable biological behavior. The following final estimates were obtained:

	Parameter Estimate	se
β_0	1.0	0.0
β_1	-0.0384415	0.01135210
β_2	-0.0144139	0.00322015
β_3	0.5	0.0
β_4	1.0440900	0.21299500
β_5	2.0	0.0
β_6	0.0	0.0
β_7	1.03	0.0

The residual standard error was 3.2054 feet and $r^2 = 0.4652$. Appendix A graphs the residuals against all the independent variables. Appendix B illustrates the performance of the equation over the range of independent variables.

Discussion

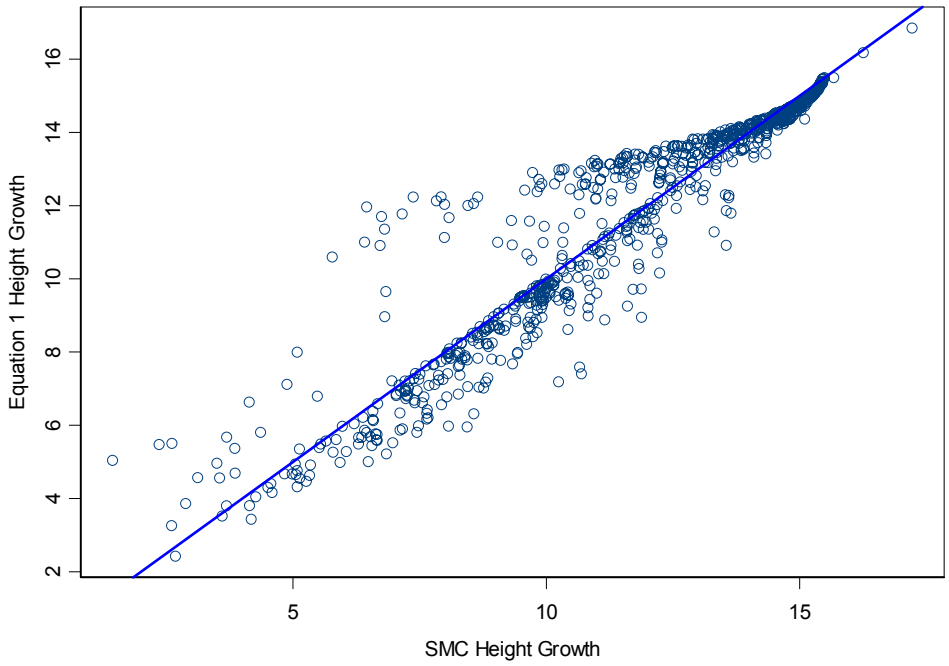
The final equation displays an over-prediction bias in trees with large crown ratios. This is likely the consequence of setting the β_7 parameter to 1.03. When this parameter was estimated, it always had a value under 1.0. As noted earlier, a value below 1.0 will result in biologically unmeaningful behavior.

A test of data source effects indicated that the datasets were statistically different from each other. However, the last graph in Appendix A displays the residuals separated by data source. There does not appear to be any trends of great concern. Because of the weakness of the Willamette and Champion datasets individually, there is not an option to fit Equation 1 to these datasets separately.

The final parameter estimates define a biologically reasonable height growth prediction function for ORGANON. The equation is compatible with two additional datasets (in addition to the original SMC data) that extend the range of tree sizes and stand conditions.

Figure 1 below, compares the new equation's predictions to those of the SMC-variant's equation. The new equation generally predicts slower height growth than the SMC equation except for the faster grow trees where the opposite is true. These trees are from the SMC dataset (small, fast growing).

Figure 1. Equation 1 height growth predictions compared with SMC-variant height growth predictions.



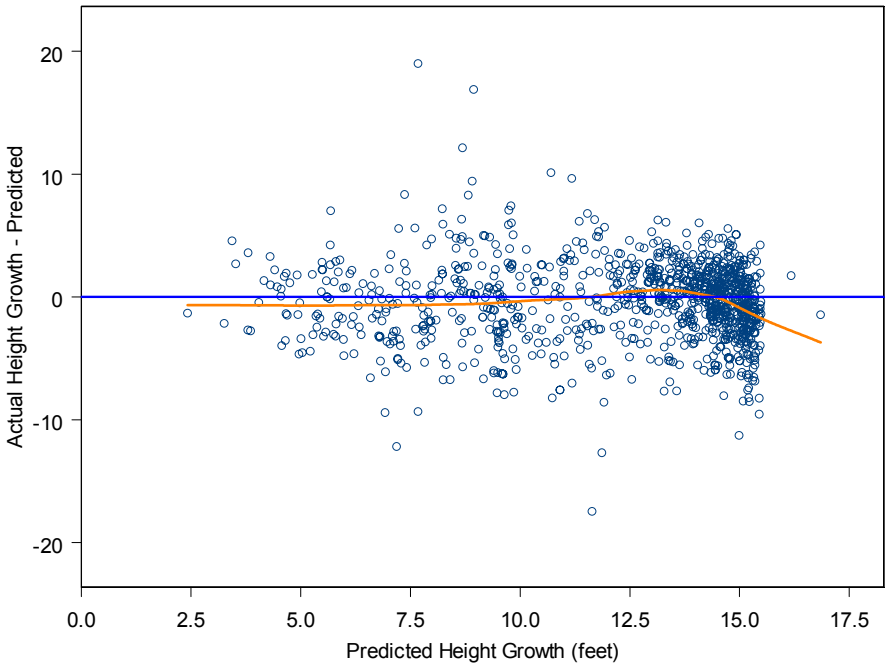
Literature Cited

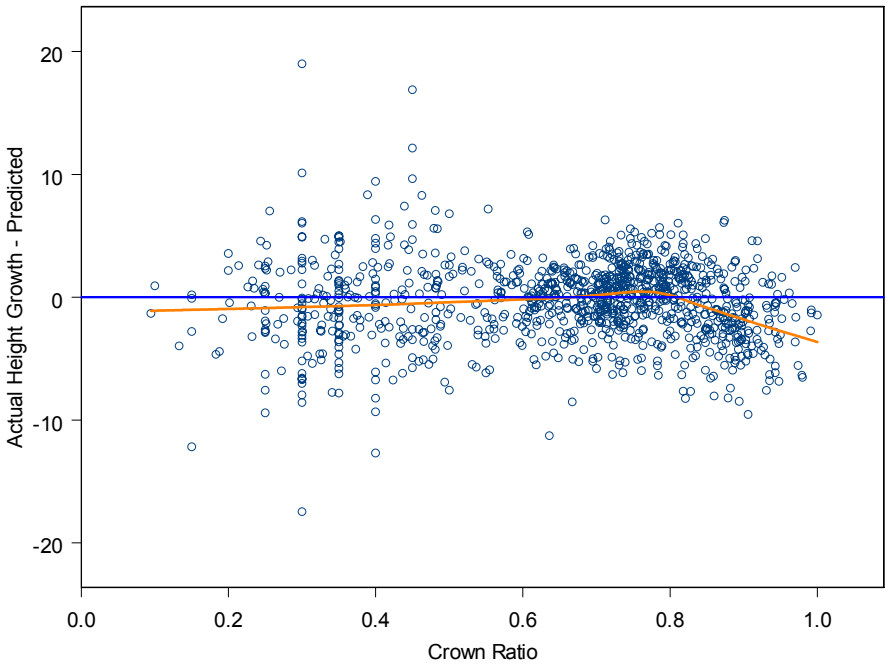
Hann, D.W. 1992. Field procedures for measurement of standing trees. Southwest Oregon Northern Spotted Owl Habitat Project. Department of Forest Resources, Oregon State University.

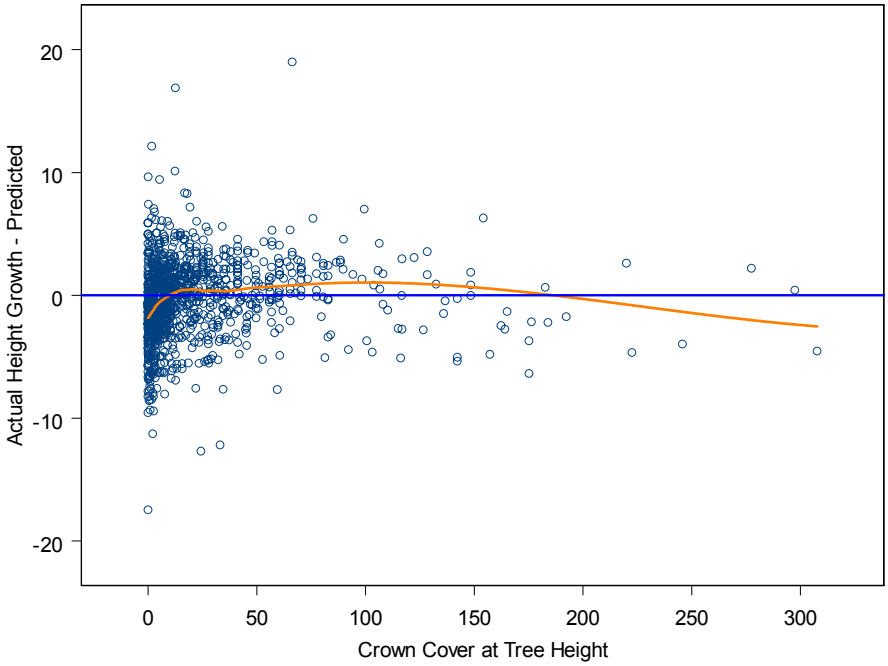
Marshall, D.M. 1998. Unpublished notes from SMC Modeling Technical Advisory Committee. Oregon State University.

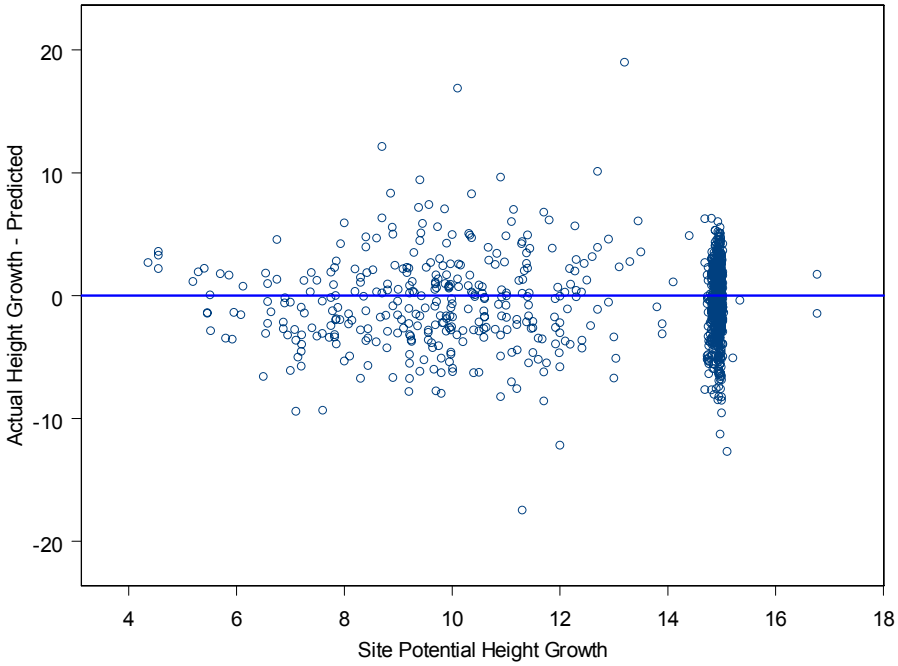
Rinehart, M.L. 1986. Stand Management Cooperative field procedures manual. Stand Management Cooperative, University of Washington.

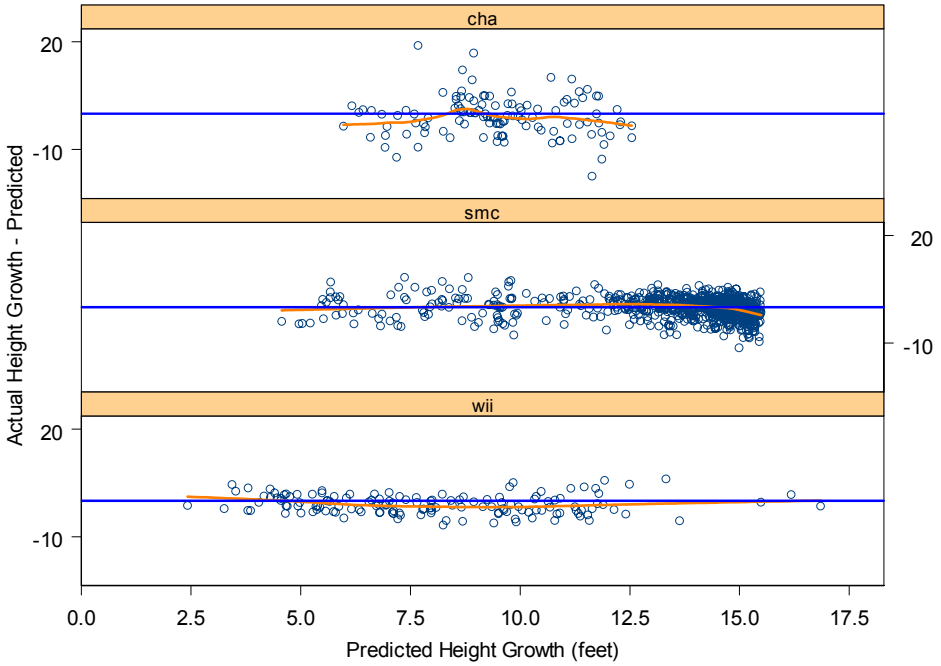
Appendix A. Residual scatterplots for Equation 1 (Loess lines are plotted through each residual cloud.)






Actual Height Growth - Predicted
20
10
0
-10
-20
0
50
100
150
200
250
300
Crown Cover at Tree Height


Actual Height Growth - Predicted
20
10
0
-10
-20
4
6
8
10
12
14
16
18
Site Potential Height Growth


cha
smc
wii
20
-10
20
-10
20
-10
Actual Height Growth - Predicted
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Predicted Height Growth (feet)

Appendix B. Height growth modifier performance across the range of independent variables (modifier is the height growth prediction prior to multiplication by site potential height growth).