ORGANON Calibration for Western Hemlock Project

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Height – Diameter Prediction Equation

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Introduction

The ORGANON model (Hann, et al., 1992) uses an equation to predict the height of each tree. The equation is used to estimate height for trees missing height data as a part of the start up process in ORGANON. Currently, the SMC variant of ORGANON uses one of the two following equations (Hanus, Marshall, and Hann, 1999):

$$Height = 4.5 + e^{\beta_0 + \beta_1 DBH^{\beta_2}} \tag{1}$$

$$Height = 4.5 + \left(Ht40 - 4.5\right)\left[\frac{e^{\alpha_0 DBH^{\left(\alpha_1 + \alpha_2 (Ht40 - 4.5)\right)}}}{e^{\left(\alpha_0 D40^{\left(\alpha_1 + \alpha_2 (Ht40 - 4.5)\right)}\right)}}\right] \tag{2}$$

where: Height = total height, DBH = diameter at breast height, Ht40 = height of the 40 largest trees per acre by DBH, and D40 = DBH of the 40 largest trees per acre by DBH. Equation 2 is used for pure (≥ 80% basal area in western hemlock), even-aged stands.

The purpose of this paper is to document the estimation of the coefficients for equations 1 and 2, to western hemlock data.

Champion Dataset

The Champion dataset was constructed from remeasured untreated permanent plots. Only a subset of trees was measured for total height. A summary of the complete dataset appears in the table below:

n = 1,264	**Mean**	**Minimum**	**Maximum**
DBH	11.3	0.0	31.7
HEIGHT	78.6	4.5	146.0
Ht40	89.8	26.6	151.2
D40	15.6	7.3	25.0

Maguire Dataset

Dr. Doug Maguire collected data using the same techniques used for the Willamette dataset. The plots were chosen to represent western hemlock trees from a wide range of site index, densities, and particularly, trees from plots with suppressed diameter classes. Due to the uneven-aged nature of the stands sampled by Maguire, Ht40 and D40 information was not obtained. A summary of the complete dataset appears in the table below:

n = 805	**Mean**	**Minimum**	**Maximum**
DBH	23.5	1.8	65.8
HEIGHT	106.6	9.8	291.8

Rayonier Dataset

The Rayonier dataset was constructed from remeasured untreated permanent plots. Only a subset of trees was measured for total height. A summary of the complete dataset appears in the table below:

n = 25,051	**Mean**	**Minimum**	**Maximum**
DBH	8.0	0.1	29.2
HEIGHT	55.3	5.0	125.0
Ht40	65.3	12.6	125.2
D40	12.3	2.5	24.4

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 total height. All plots are controls, with no known density control or fertilization treatments. A summary of the dataset appears in the table below:

n = 17,984	**Mean**	**Minimum**	**Maximum**
DBH	7.2	0.1	30.6
HEIGHT	58.5	4.6	159.1
Ht40	71.0	20.3	163.2
D40	11.6	3.5	27.0

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. A summary of the dataset appears in the table below:

n = 2,341	Mean	Minimum	Maximum
DBH	13.2	0.1	47.8
HEIGHT	81.6	4.6	152.9
Ht40	85.6	18.0	142.0
D40	20.5	3.5	47.8

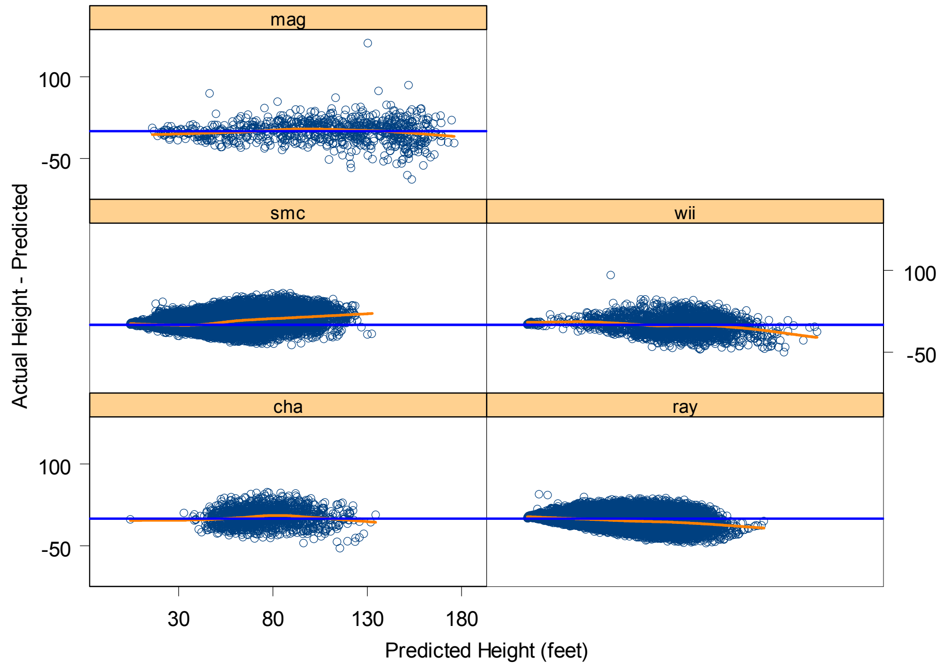
Analysis

Equation 1 was fit to the combined dataset (n = 47,445). The resultant regression was significant and as were all parameter estimates. The following final estimates were obtained:

	Parameter Estimate	se
β_0	5.937920	0.03165090
β_1	-4.438220	0.01555540
β_2	-0.411373	0.00735641

The residual standard error was 14.1386 feet and r^2 = 0. 7468. Appendix A graphs the residuals against the independent variables. Figure 1 shows the residuals plotted over the predictions by data source. For the most part, there appears to be no bias by source with the exception of a tendency to under-predict height for larger trees in the SMC dataset. In fact, source effects where significant. Given the overall good performance however, the source differences were not pursued.

Figure 1. Height prediction residuals by data source (mag = Maguire, smc = SMC, wii = Willamette, cha = Champion, ray = Rayonier).

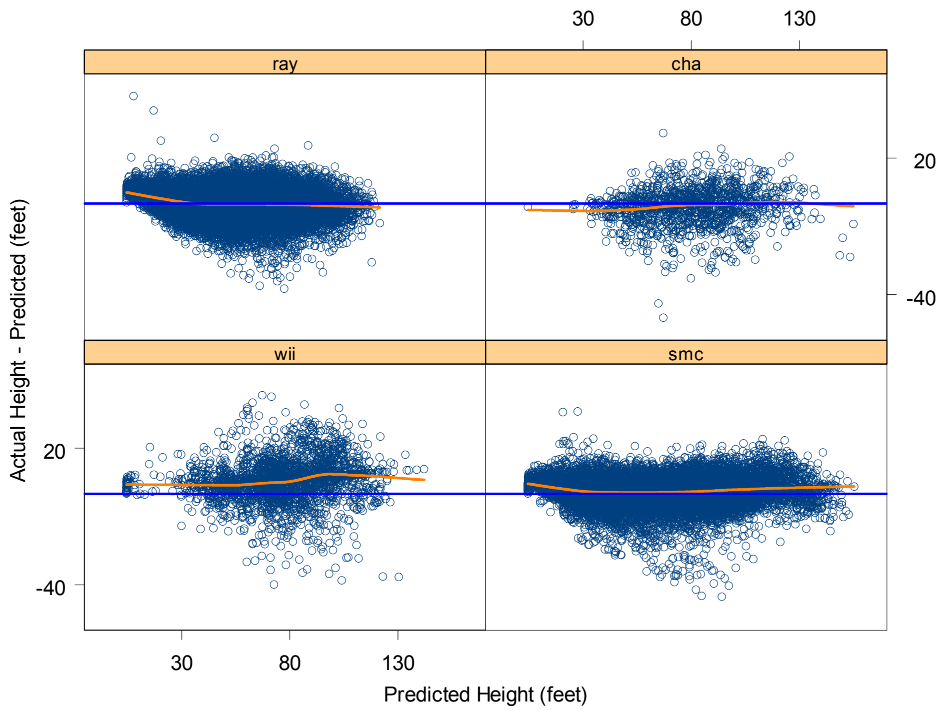


Equation 2 was fit to the combined dataset excluding the Maguire data (n = 46,640). The resultant regression was significant and as were all parameter estimates. The following final estimates were obtained:

	Parameter Estimate	**se**
α_0	-3.58277000	0.0308676000
α_1	-1.67394000	0.0121630000
α_2	0.00743516	0.0000901282

The residual standard error was 6.2591 feet and r^2 = 0.9464. Appendix B graphs the residuals against the independent variables. Figure 2 shows the residuals plotted over the predictions by data source. There appears to be no bias by source with the exception of a consistent under-prediction of Willamette heights. This bias appears to be an artifact of the large number of trees in the Willamette dataset with heights close to their plot's Ht40. A fit made to the Willamette dataset alone did not improve this bias. It may be that the temporary plots yielded a sample size too small for this purpose. Since all other data sources were permanent plots, there was no opportunity to explore this further.

Figure 2. Height prediction residuals for Equation 2 (ray = Rayonier, cha = Champion, wii = Willamette, smc = SMC).



Discussion

Figures 3 and 4 compare the predictions of Equations 1 and 2 respectively with the current ORGANON SMC-variant's equations. SMC and Equation 1 are similar for small trees (under 50 feet), but depart for larger trees. The present dataset has strong representation in trees 50 to 130 feet tall. We tend to favor Equation 1's predictions over those made by the SMC-variant.

SMC and Equation 2 are similar across the range of predictions. The substantially reduced residual variation around Equation 2's regression argues strongly for its use whenever possible (relatively pure, even-aged stands of western hemlock).

Hanus, Hann, and Marshall (1999) pointed out that a height – diameter equation based on undamaged trees would be more appropriate for use as a difference equation and bounding height/diameter. Unfortunately, the inconsistency in recording damage among the datasets used here precluded this approach. Therefore, Equation 1 in this paper represents the average height for a given diameter of all trees.

Figure 3. Equation 1 height predictions compared with SMC-variant height predictions.

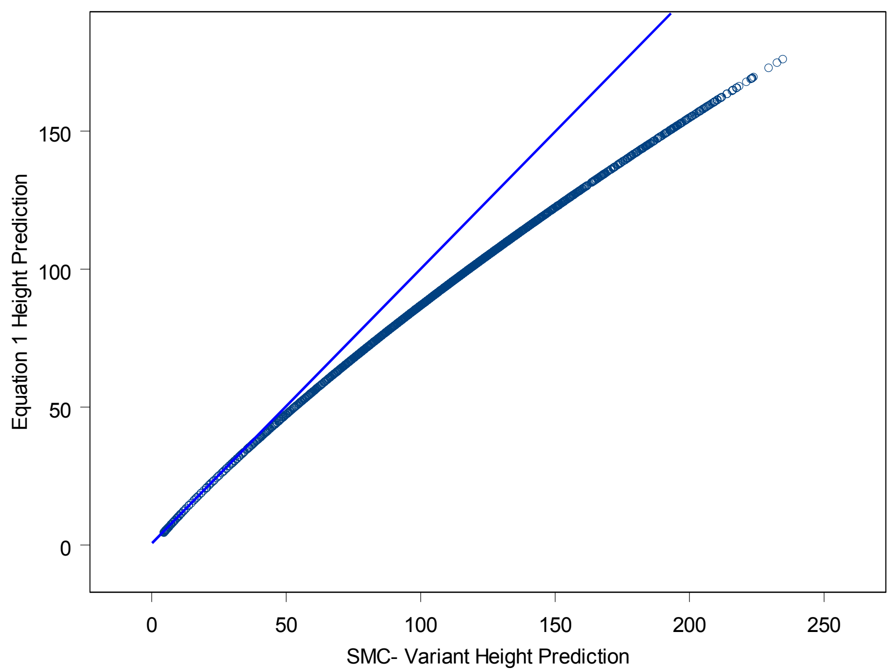
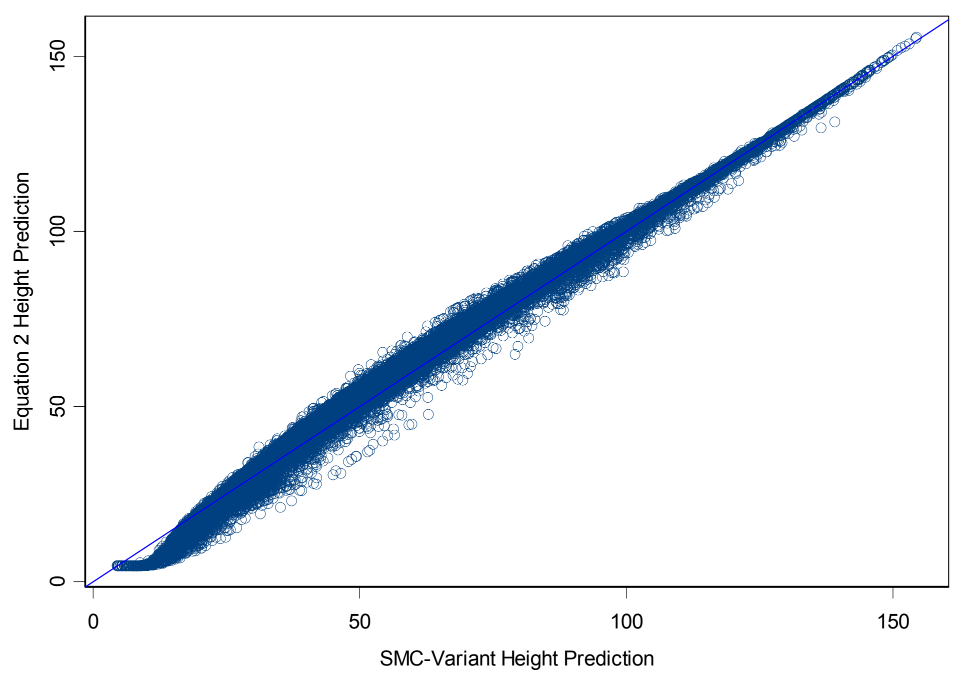


Figure 4. Equation 2 height predictions compared with SMC-variant height predictions.



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.

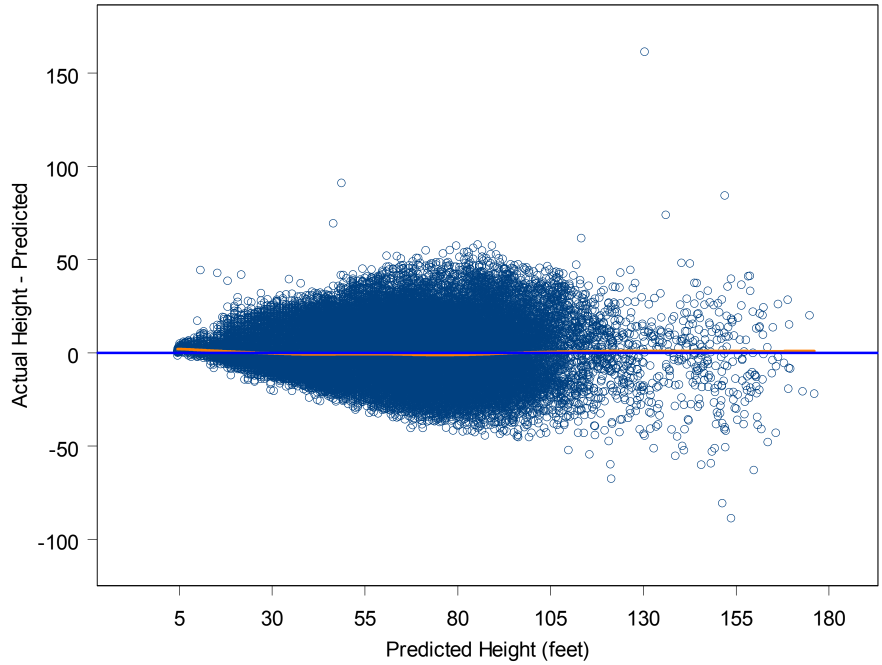
Hanus, M.L., D.W. Hann, and D.D. Marshall. 1999. Predicting height for undamaged and damaged trees in southwest Oregon. Forest Research Lab., Oregon State University, Corvallis, Oregon. Research Contribution 27. 22p.

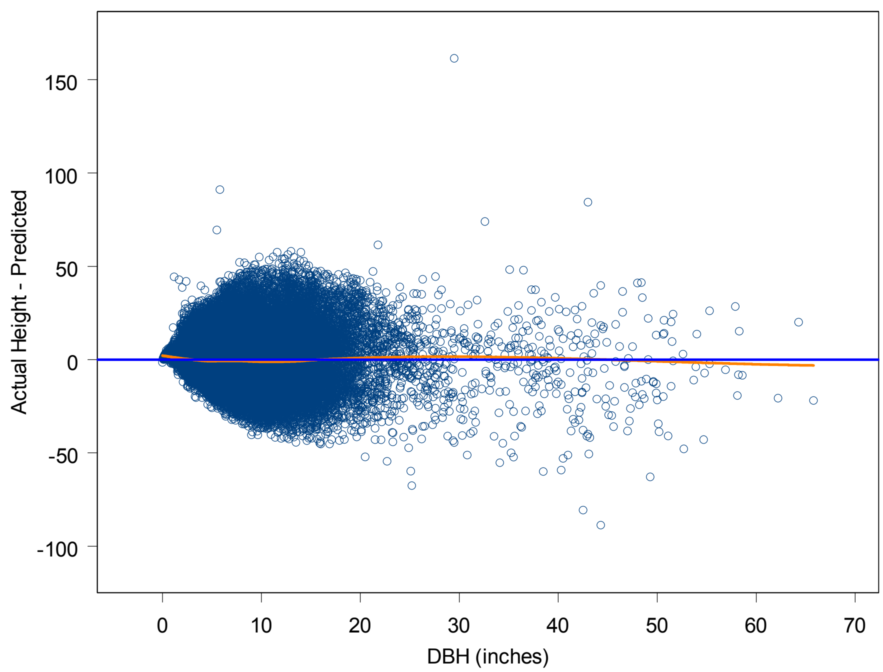
Hanus, M.L., D.D. Marshall, and D.W. Hann. 1999. Height-diameter equations for six species in the coastal regions of the Pacific Northwest. Forest Research Lab., Oregon State University, Corvallis, Oregon. Research Contribution 25. 11p.

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

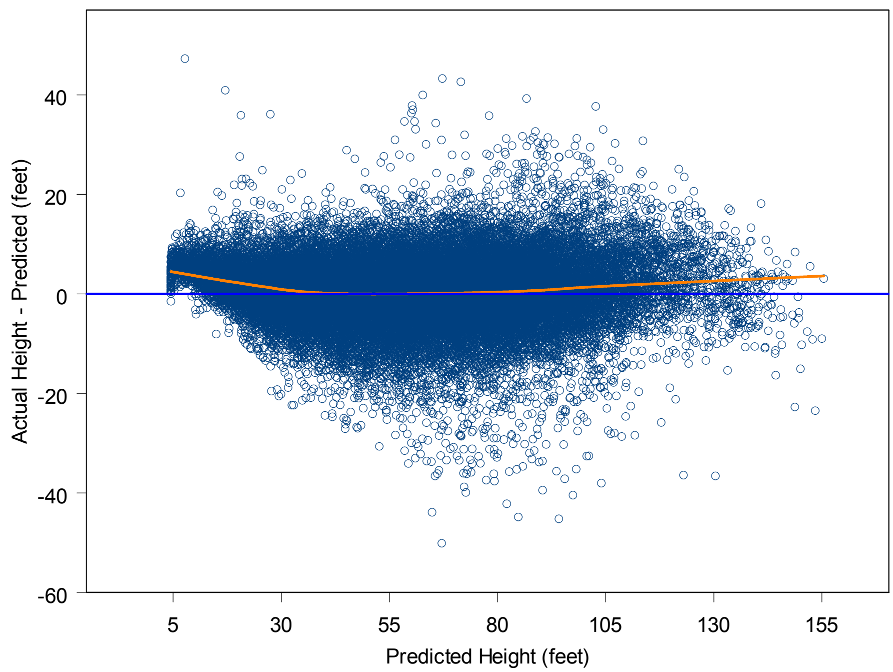
Rinehart, M.L. 1986. Stand Management Cooperative field procedures manual. Stand Management Cooperative, University of Washington.

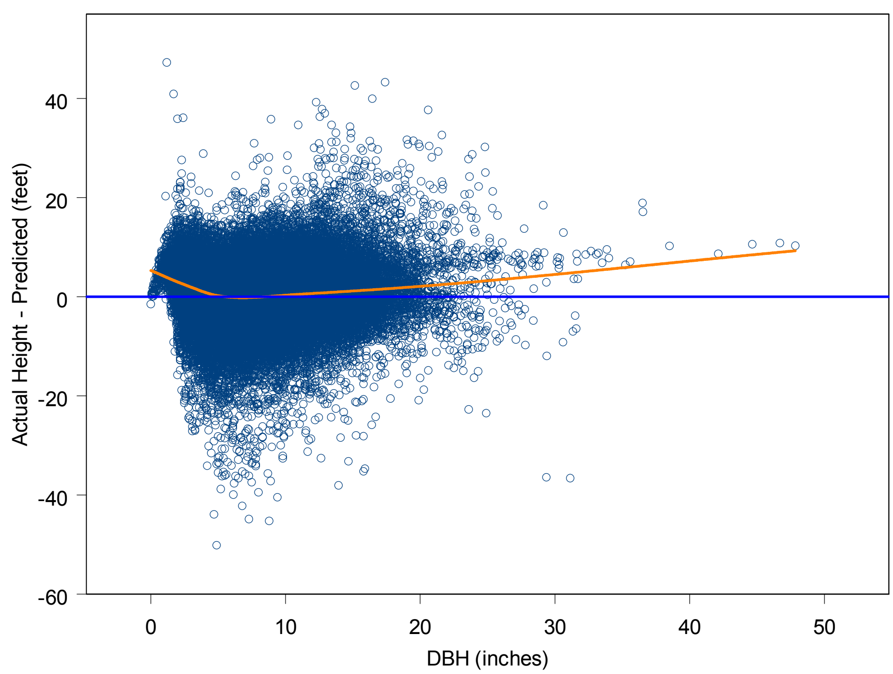
Appendix A. Residual scatterplots for Equation 1 (Loess lines are plotted through each residual cloud.)

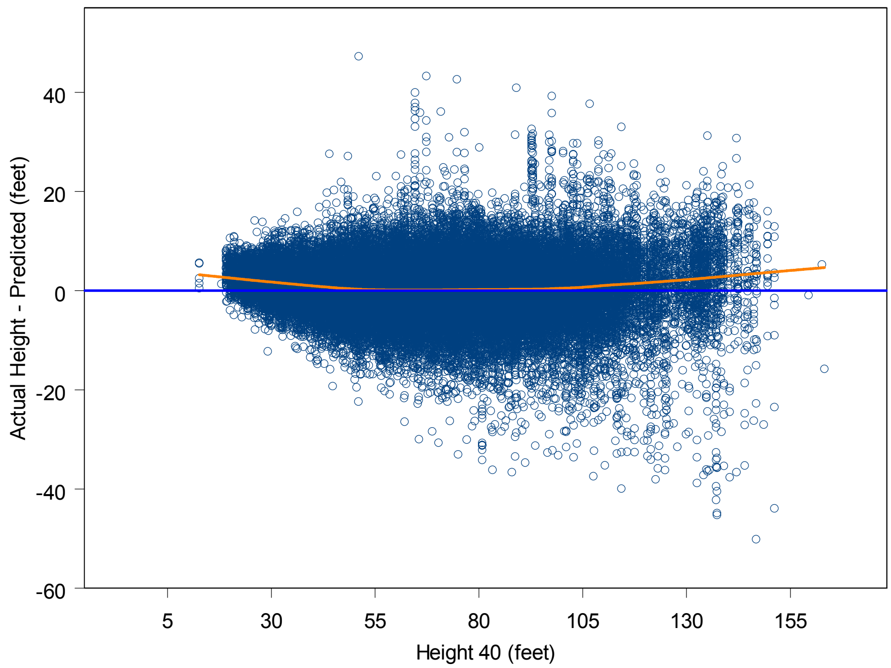


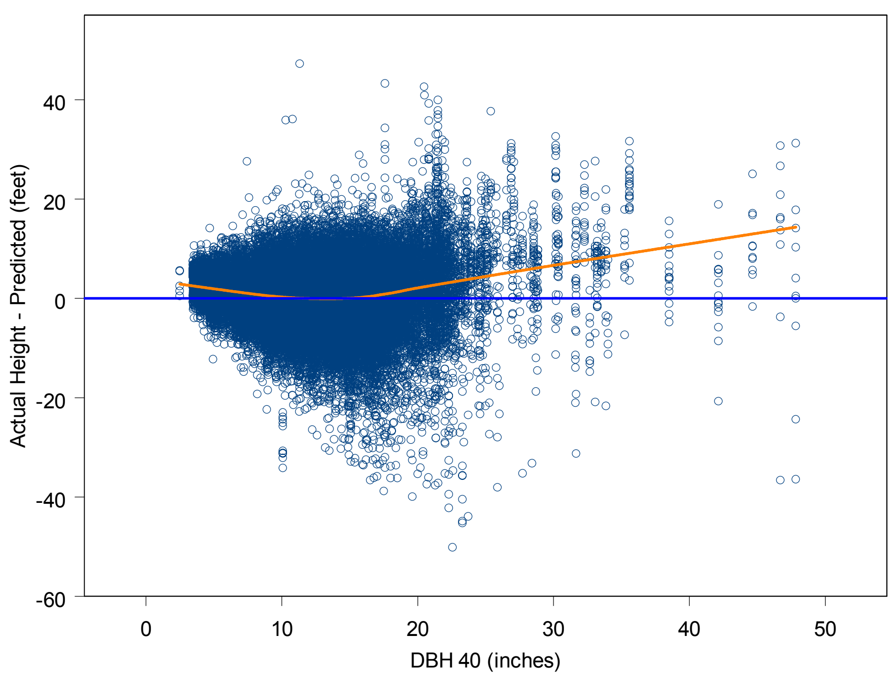


Appendix B. Residual scatterplots for Equation 2 (Loess lines are plotted through each residual cloud.)






40
20
0
-20
-40
-60
Actual Height - Predicted (feet)
5
30
55
80
105
130
155
Height 40 (feet)


40
20
0
-20
-40
-60
Actual Height - Predicted (feet)
0
10
20
30
40
50
DBH 40 (inches)