Acadian FVS Diameter Growth Equation Fitting
Organon Equation Form

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Data Preparation

We used the diameter at breast height (`dbh`) data in the `ALL_dDBH.csv` file provided by Aaron Weiskittel.

Tree growth observations were limited to:

- trees with observed diameter growth (`dbh` time 1 > `dbh` time 2),
- basal area in larger trees less than total basal area per hectare,
- basal area at time 2 greater than or equal to basal area at time 1, and
- remeasurement intervals between 5 and 10 years inclusive.

This yielded 1479506 observations for modeling. A breakdown by species is shown in Table 1.

Table 1: Species Avaialble for Diameter Growth Equation Fitting

FVS Sp	N Observations
BF	452673
RS	244586
RM	174220
BS	116026
PB	81863
WS	55654
WC	51326
SM	50383
YB	42548
EH	39516
WP	32619
QA	30893
AB	29768

Modified Kuehne Equation Form

We modified the Kuehne[1] diameter growth equation to yield the following:

[1]Kuehne, C., Weiskittel, A., and Kershaw Jr., J.A. 2022. Development and evaluation of refined annualized individual tree diameter and height increment equations for the Acadian Variant of the Forest Vegetation Simulator: Implication for forest carbon estimates. Mathematical and Computational Forestry & Natural-Resource Sciences 14: 9-31.

$$\Delta dbh = e^{\beta_0+\beta_1 log(dbh+1.0)+\beta_2 dbh+\beta_3 log(cr)+\beta_4 bal/log(dbh+1.0)+\beta_5 log(CSI)}$$

The modifications were to drop the squared term on `CSI` (climate site index), to add 1.0 to `dbh` in the log terms of the equation, and to replace the basal area in larger trees (`bal`) terms with a formulation used by Hann[2] involving an interaction with `dbh`.

Fit the Modified Kuehne Equation by Species

The modified equation was fit to species with $\geq$ 20,000 observations. We used an integrated fitting approach and quantile regression to the median. The resulting parameter estimates and MSE values are in Table 2. Two species (`BS` and `YB`) had negative parameter estimates for the `csi` term. The estimates are neglibily small and were set to zero for application.

Fit the Modified Kuehne Equation to All Conifers and All Hardwoods Groups

To accommodate species with inadequate observations, we grouped all available data and formed a conifer group (`OC`) and a hardwood group (`OH`). We fit the modified equation to each group, resulting in the parameter estimates shown in Table 3.

Table 2: Diameter Growth Equation Parameter Estimates

FVS Sp	N Observations	MSE	b0	b1	b2	b3	b4	b5
BF	452673	1.2361831	-2.1435857	0.3593028	-0.0184791	1.0047516	-0.0410973	0.4104913
RS	244586	0.8792822	-1.5602407	0.1025491	-0.0114136	0.7177303	-0.0733104	0.3703701
RM	174220	1.0478926	-2.0742269	0.1344965	-0.0092508	0.6704055	-0.0443568	0.3731337
BS	116026	0.5328071	-0.8058522	-0.1504027	0.0021861	0.8818587	-0.0322017	-0.0288774
PB	81863	0.6925996	-1.4992348	0.0020848	-0.0171510	0.7625551	-0.0656148	0.3339626
WS	55654	1.3386291	-1.3865373	0.2347620	-0.0238776	0.8480158	-0.0861475	0.2881720
WC	51326	0.5772259	-2.1986872	0.3141367	-0.0061004	0.8876820	-0.0189920	0.1375218
SM	50383	1.0591460	-3.6640496	0.6651070	-0.0335220	0.5544203	-0.0898102	0.6356263
YB	42548	1.3931345	-1.0799670	0.3609764	-0.0305255	0.6722657	-0.0667012	-0.0188244
EH	39516	1.2482881	-1.1141883	-0.0193093	-0.0059281	0.7563972	-0.0634549	0.3357535
WP	32619	3.6121192	-0.7180888	0.2856932	-0.0221441	0.6376906	-0.0967224	0.1648024
QA	30893	1.6586426	-1.6835405	0.1627486	-0.0085212	0.3623651	-0.0925568	0.3160373
AB	29768	0.9417206	-2.6919761	0.3500209	-0.0361457	0.7539952	-0.0733272	0.6543146

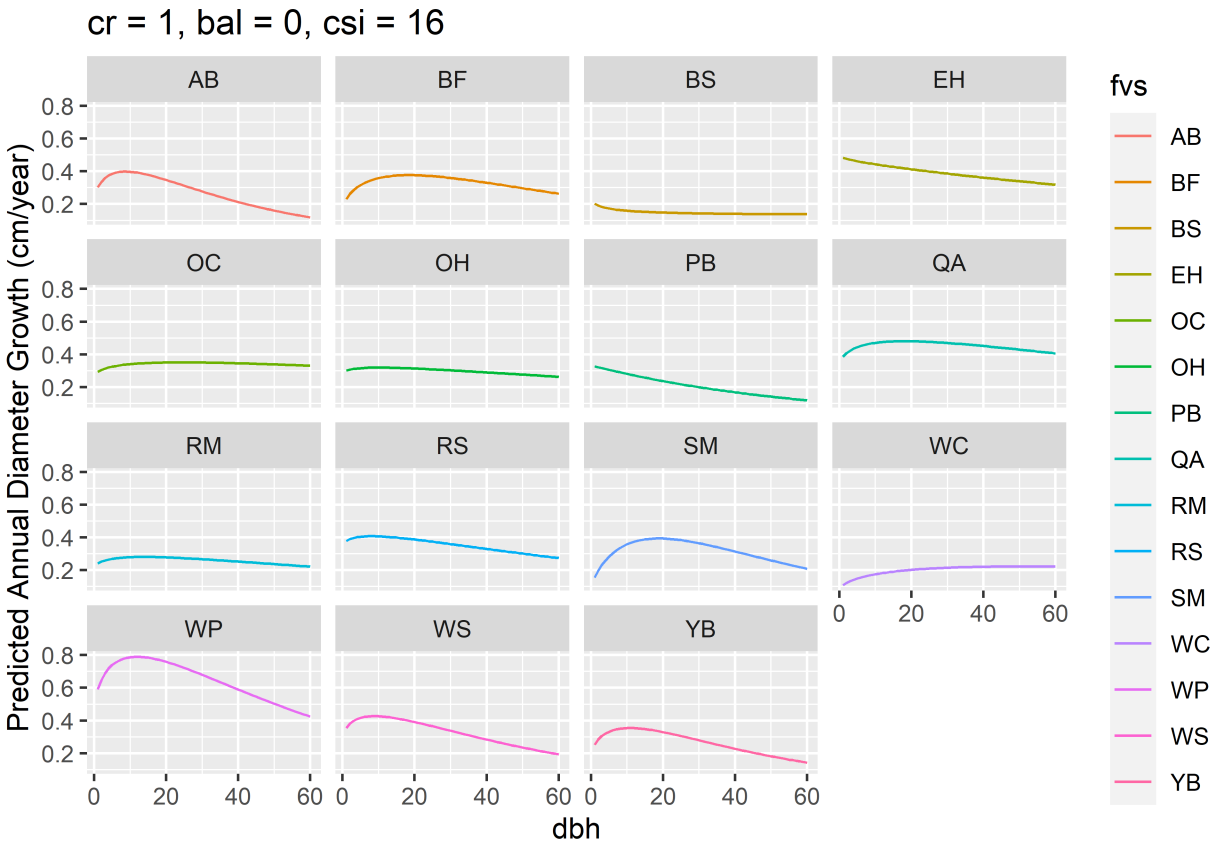
Table 3: Diameter Growth Equation Parameter Estimates for All Conifers and All Hardwoods

FVS Sp	N Observations	MSE	b0	b1	b2	b3	b4	b5
OC	1012234	1.332639	-2.259826	0.1105826	-0.0043717	0.8998574	-0.0461434	0.5717543
OH	464250	1.185672	-2.072092	0.0675099	-0.0061727	0.6355721	-0.0624415	0.4583723

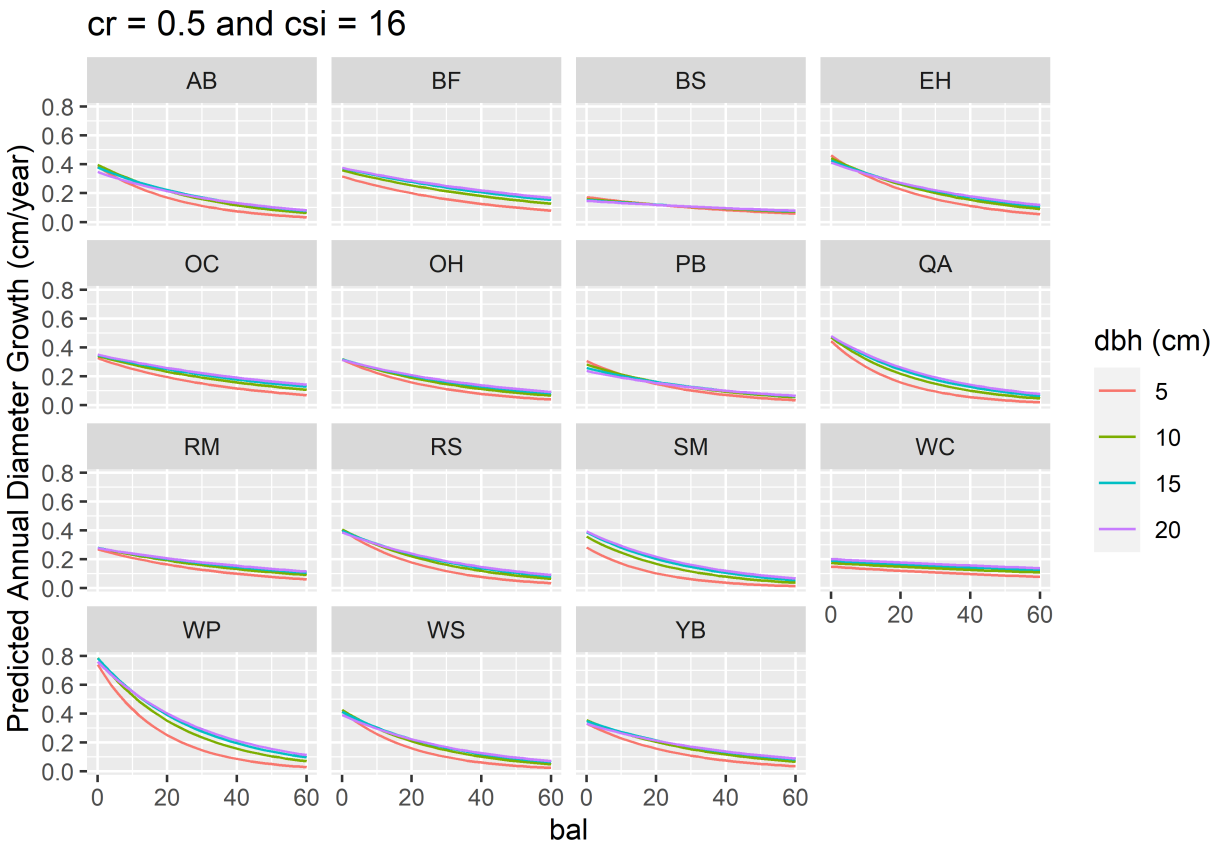
[2]Hann, David W., David D Marshall, Mark L Hanus, and Oregon State University. Forest Research Laboratory. 2006. Reanalysis of the Smc-Organon Equations for Diameter-Growth Rate, Height-Growth Rate, and Mortality Rate of Douglas-Fir. : Corvallis, OR : Forest Research Laboratory, Oregon State University.

Equation Behavior

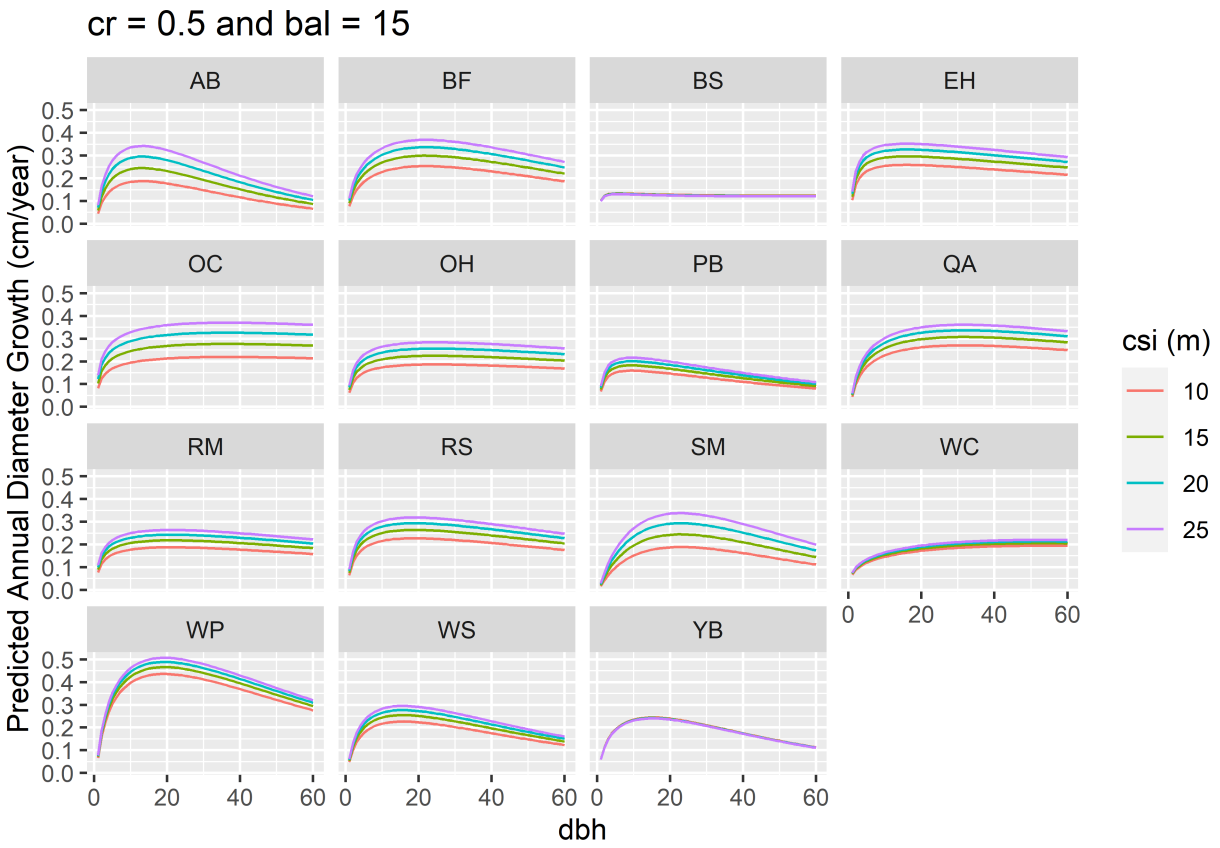
Over DBH for Dominant Tree



Over `bal` for `cr` = 0.5 and `csi` = 16

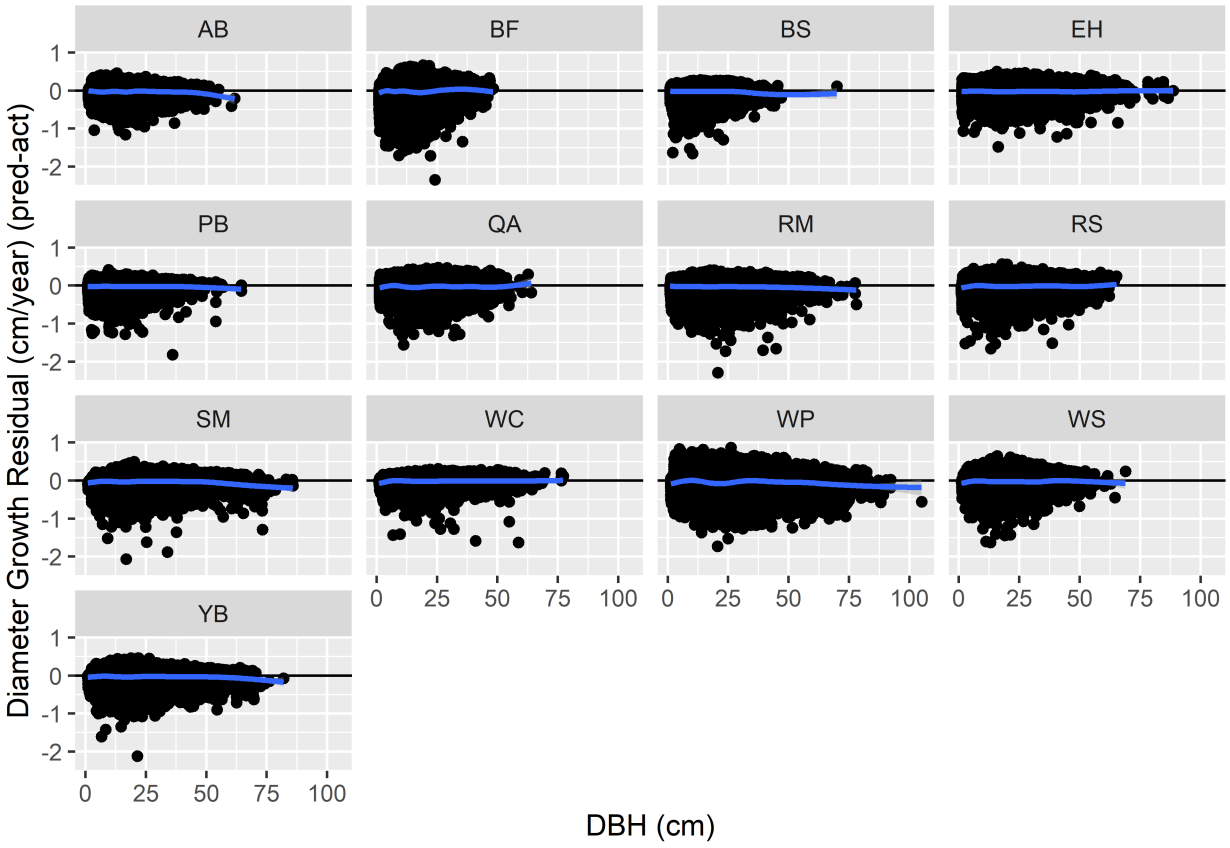


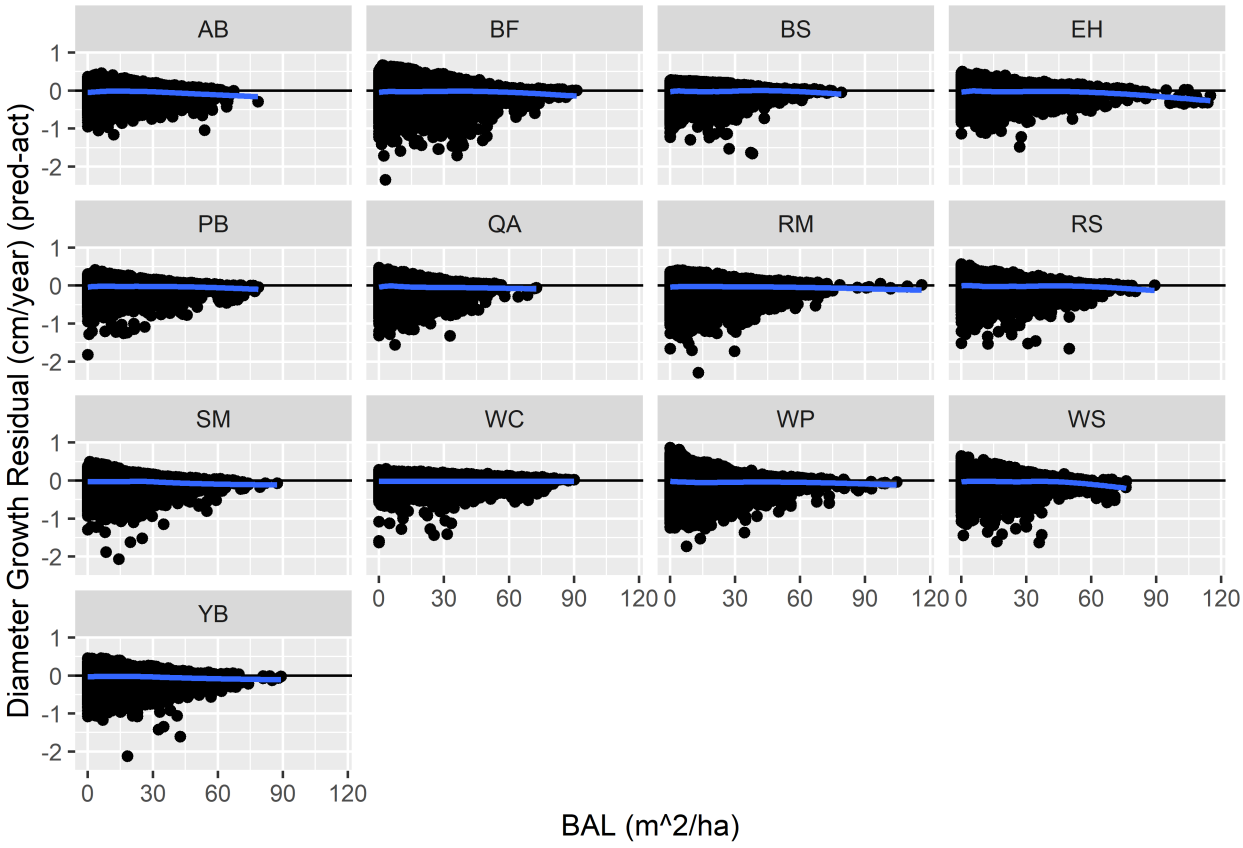
Over `csi` for `cr` = 0.5 and `bal` = 15

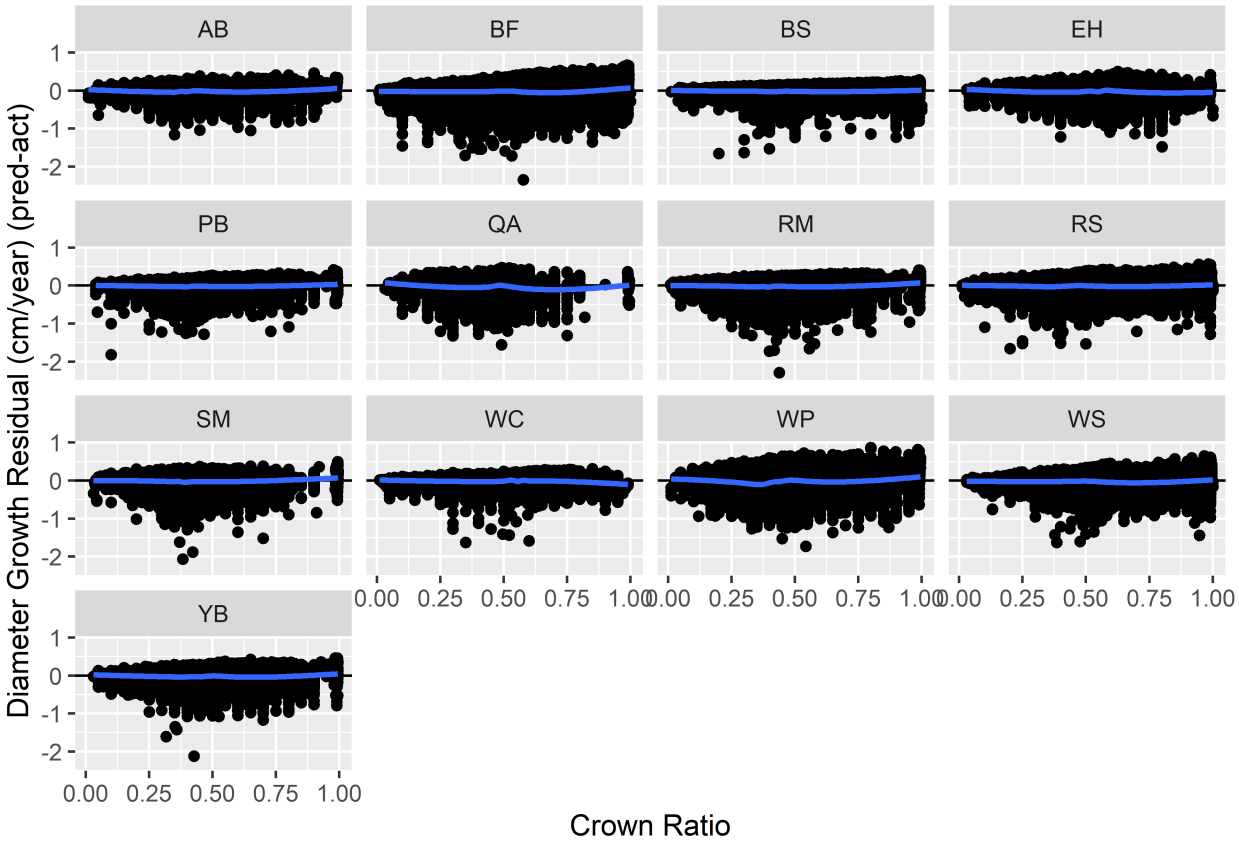


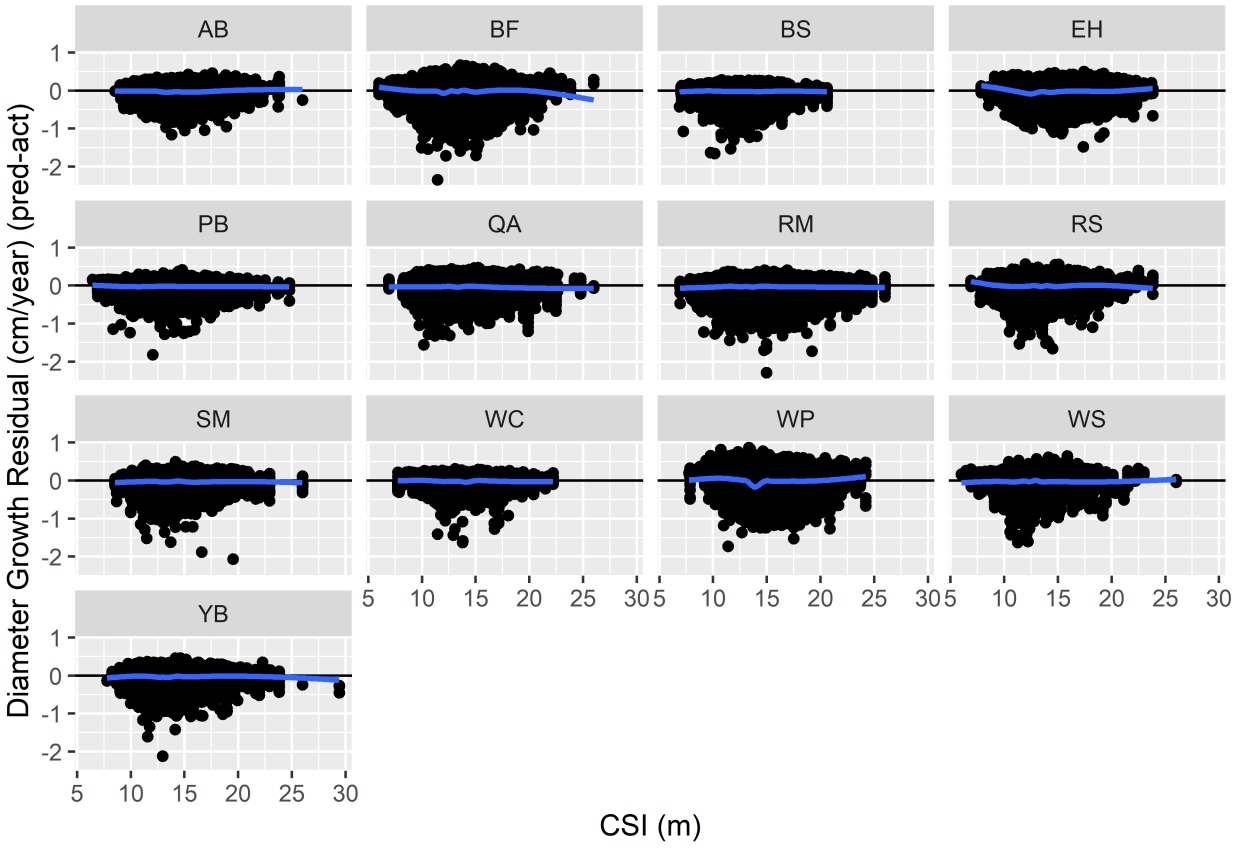
Residual Analysis

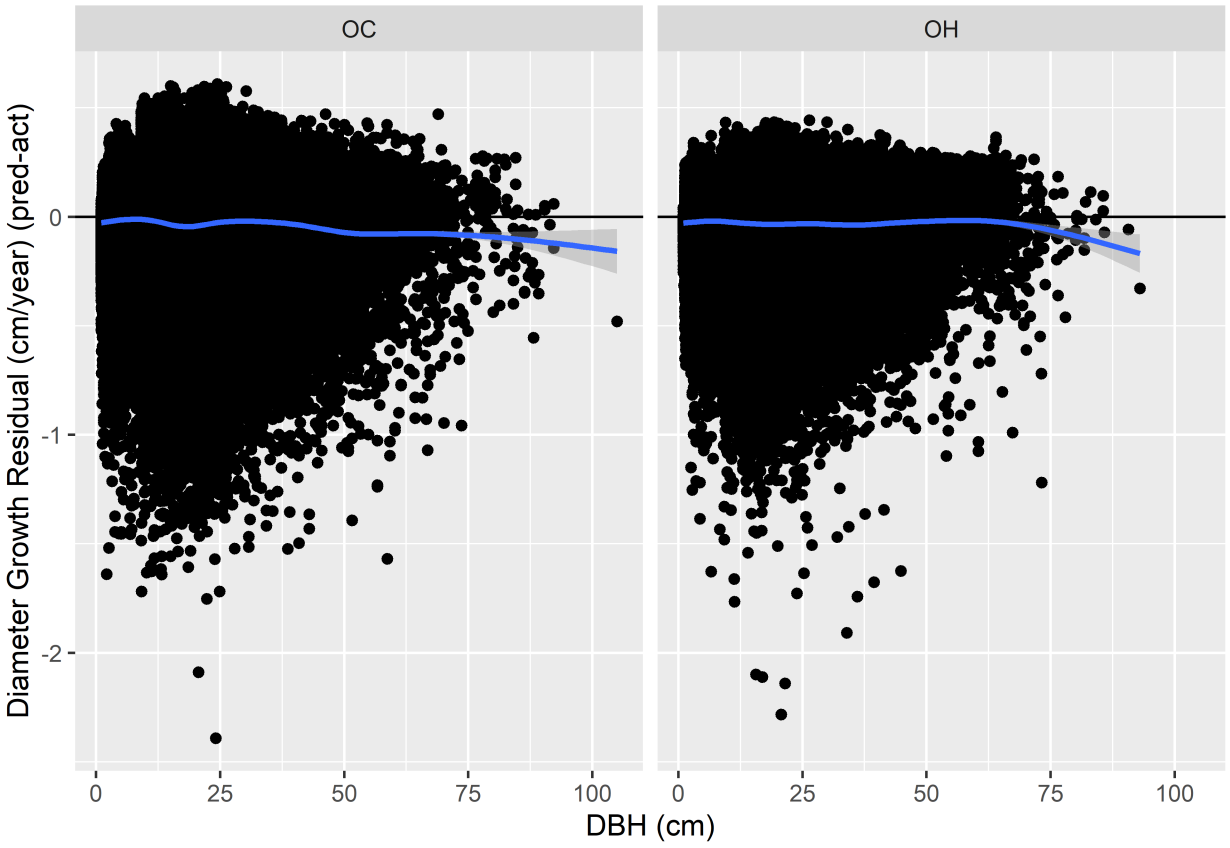
The equation residuals are shown below over explanatory variables.

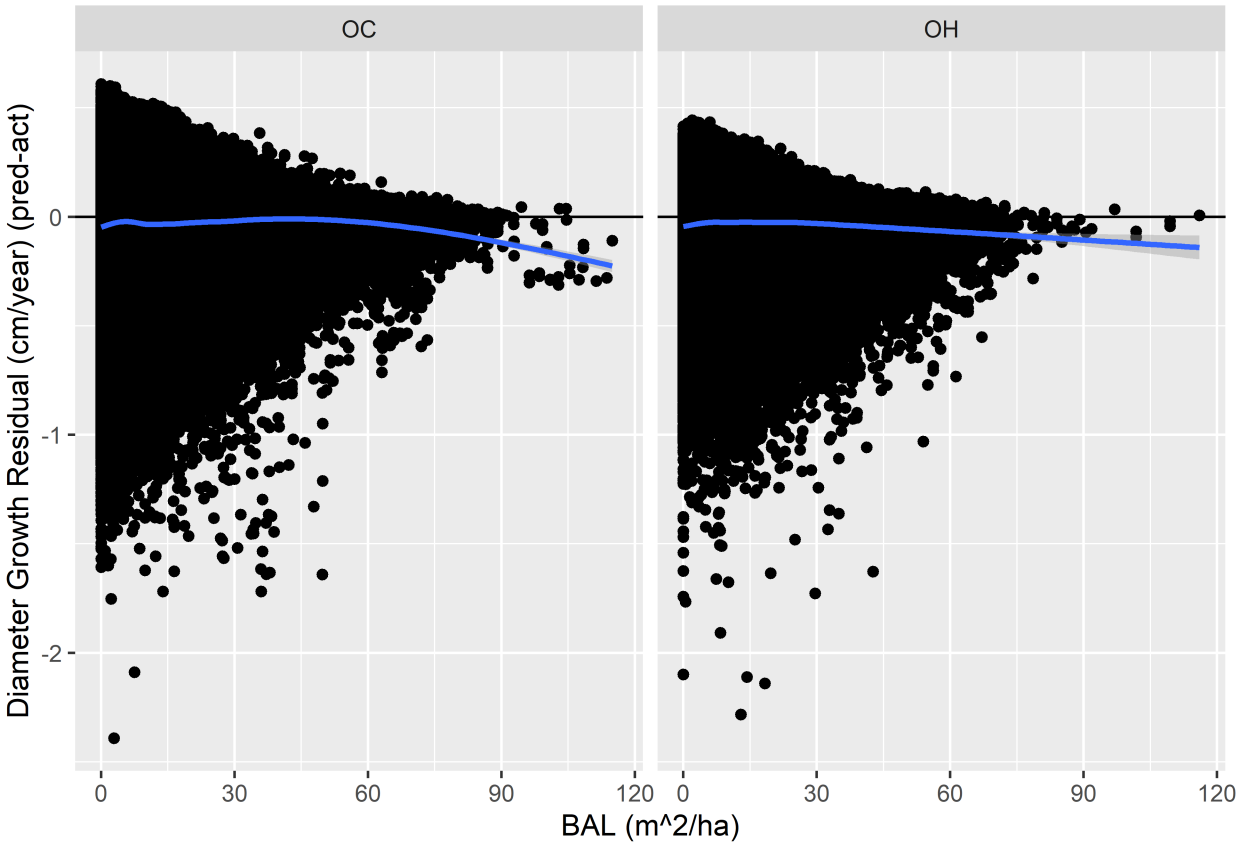

AB
BF
BS
EH
PB
QA
RM
RS
SM
WC
WP
WS
YB
Diameter Growth Residual (cm/year) (pred-act)
DBH (cm)
1
0
-1
-2
0
25
50
75
100

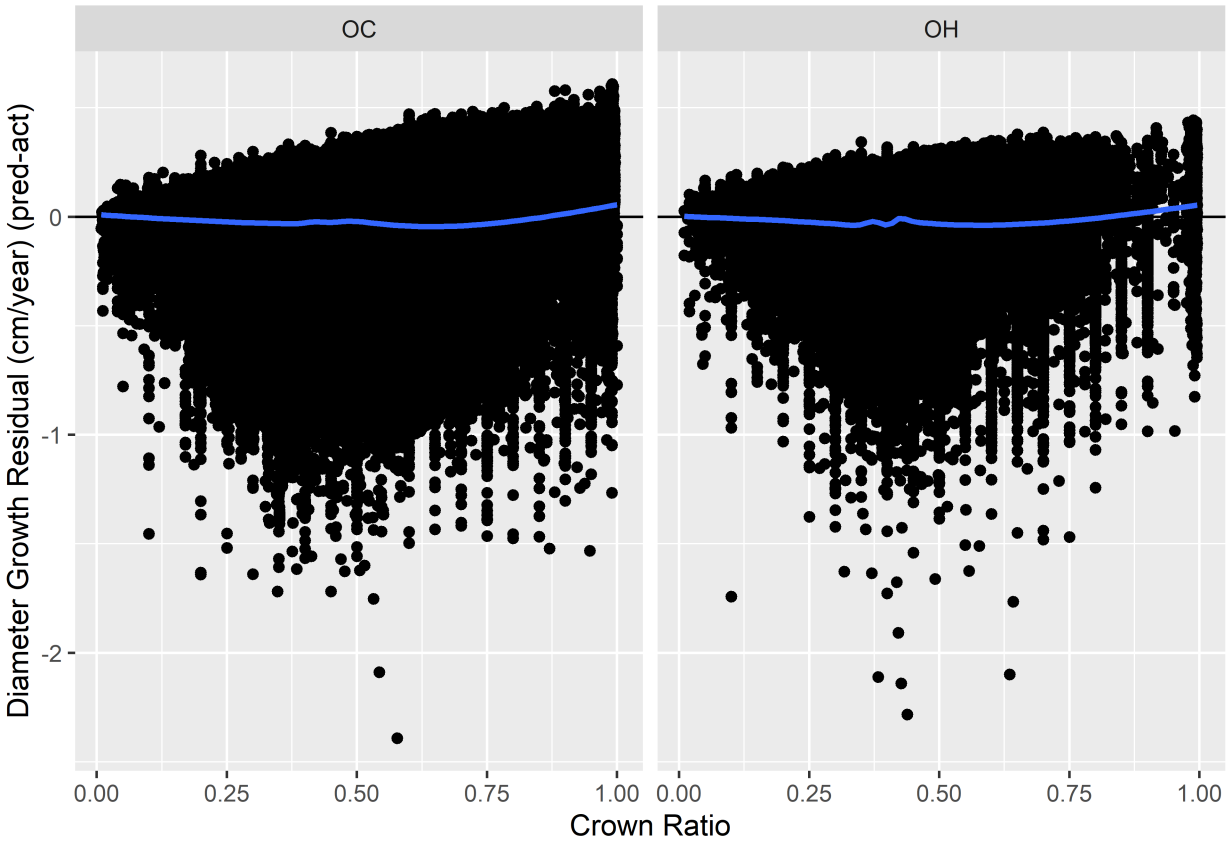

AB
BF
BS
EH
PB
QA
RM
RS
SM
WC
WP
WS
YB
Diameter Growth Residual (cm/year) (pred-act)
1
0
-1
-2
0
30
60
90
120
BAL (m^2/ha)

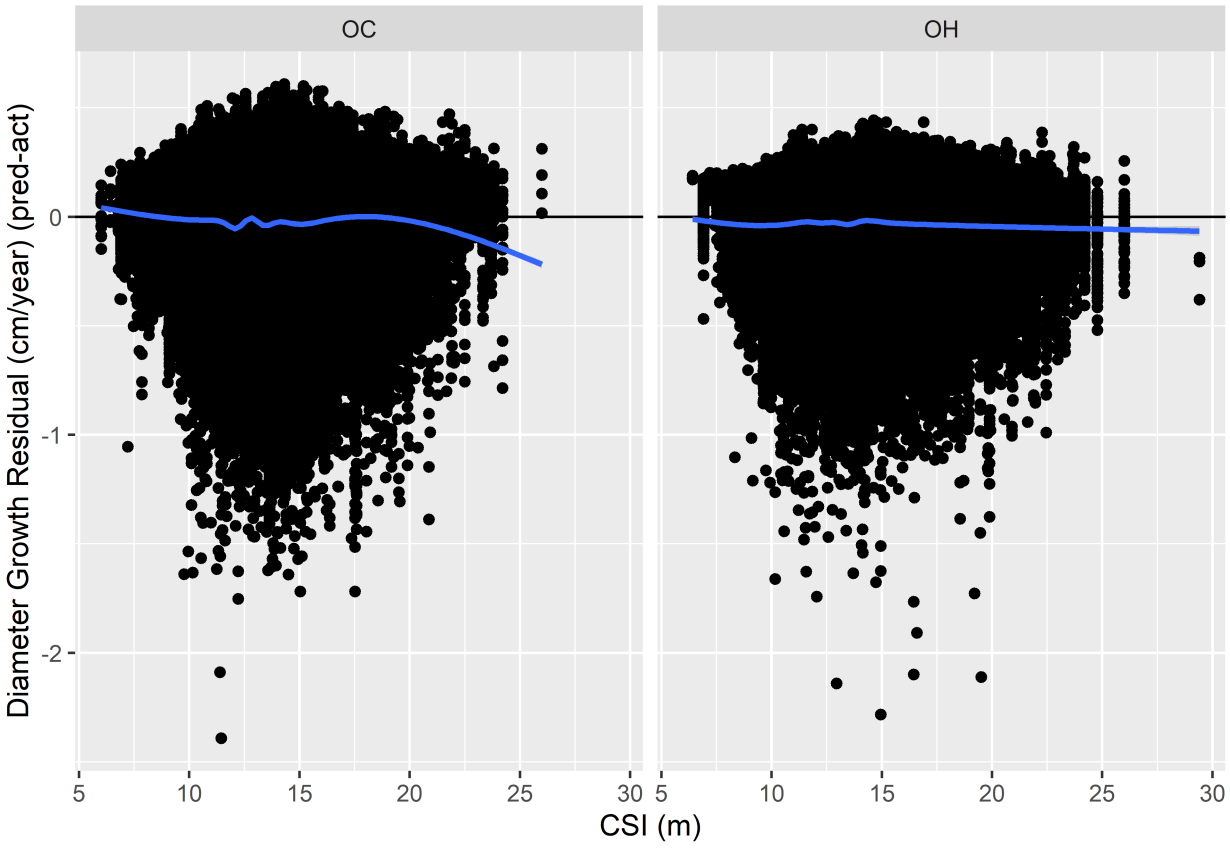

AB
BF
BS
EH
PB
QA
RM
RS
SM
WC
WP
WS
YB
Diameter Growth Residual (cm/year) (pred-act)
1
0
-1
-2
0.00
0.25
0.50
0.75
1.00
Crown Ratio


AB
BF
BS
EH
PB
QA
RM
RS
SM
WC
WP
WS
YB
Diameter Growth Residual (cm/year) (pred-act)
CSI (m)


OC
OH
Diameter Growth Residual (cm/year) (pred-act)
0
-1
-2
0
25
50
75
100
DBH (cm)


OC
OH
Diameter Growth Residual (cm/year) (pred-act)
0
-1
-2
0
30
60
90
120
BAL (m^2/ha)


OC
OH
Diameter Growth Residual (cm/year) (pred-act)
0
-1
-2
0.00
0.25
0.50
0.75
1.00
Crown Ratio


OC
OH
Diameter Growth Residual (cm/year) (pred-act)
0
-1
-2
5
10
15
20
25
30
CSI (m)