FVS Remodel Project: Oregon and Washington Douglas-fir FIA Data – Do Site Index and Basal Area per Acre Matter?

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2026-01-07

Data

We took the `OR_CHANGEdata_DF` and `WA_CHANGEdata` Douglas-fir data sets provided by David Marshall as a starting point. These data are remeasurement observations from Forest Inventory and Analysis (`FIA`) plots in Oregon and Washington.

We subsetted the data to retain only Douglas-fir (`SPCD` = 202), drop observations with missing values for diameter at breast height (`dbh`), basal area per acre (`ba`), basal area per acre in larger trees (`bal`), crown ratio (`cr`) expressed as a fraction, and site index (`si`) at the beginning and ending measurement points. We also dropped remeasurements with measurement intervals less than 5 years.

The final data set is summarized in Table 1.

Diameter Growth Fitting and Model Comparison

For all regressions in this analysis, we use an integrated fitting approach that allows variable remeasurement intervals by observation. Residuals are annualized for reporting.

We fit the ORGANON diameter growth model to the data:

$\Delta dbh = e^{\beta_0+\beta_1 log(dbh+1)+\beta_2 dbh^2+\beta_3 log(\frac{cr+0.1}{1.2})+\beta_4 log(si+4.5)+\beta_5 \frac{bal^2}{dbh+2.7}+\beta_6 ba^{0.5}}$

The fit statistics for this model are:

	Coef.	Std. error	t-stat.	p
B0	-5.6267475	0.0476125	-118.17799	0
B1	-0.0842869	0.0071684	-11.75819	0

	Coef.	Std. error	t-stat.	p
B2	-0.0002815	0.0000073	-38.57189	0
B3	1.1888063	0.0094312	126.05068	0
B4	0.9622953	0.0097269	98.93114	0
B5	-0.0000571	0.0000008	-76.06450	0
B6	0.0422304	0.0010213	41.35004	0

```
Residual Standard Error: 1.12066867576654 on 116672 degrees of freedom
```

Diameter Growth Residuals with Site Index

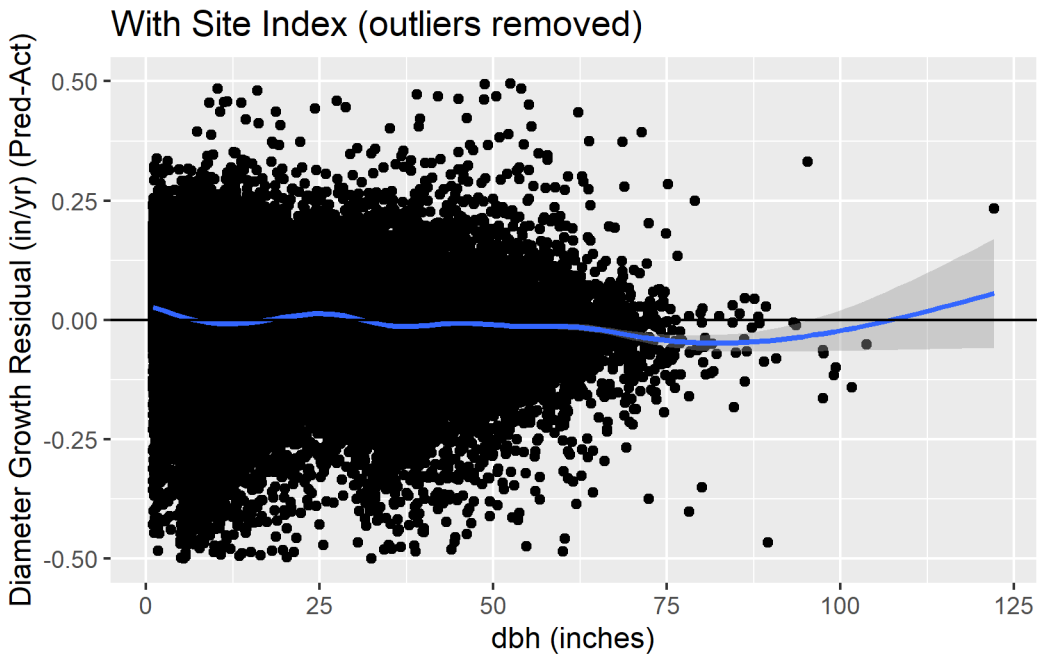
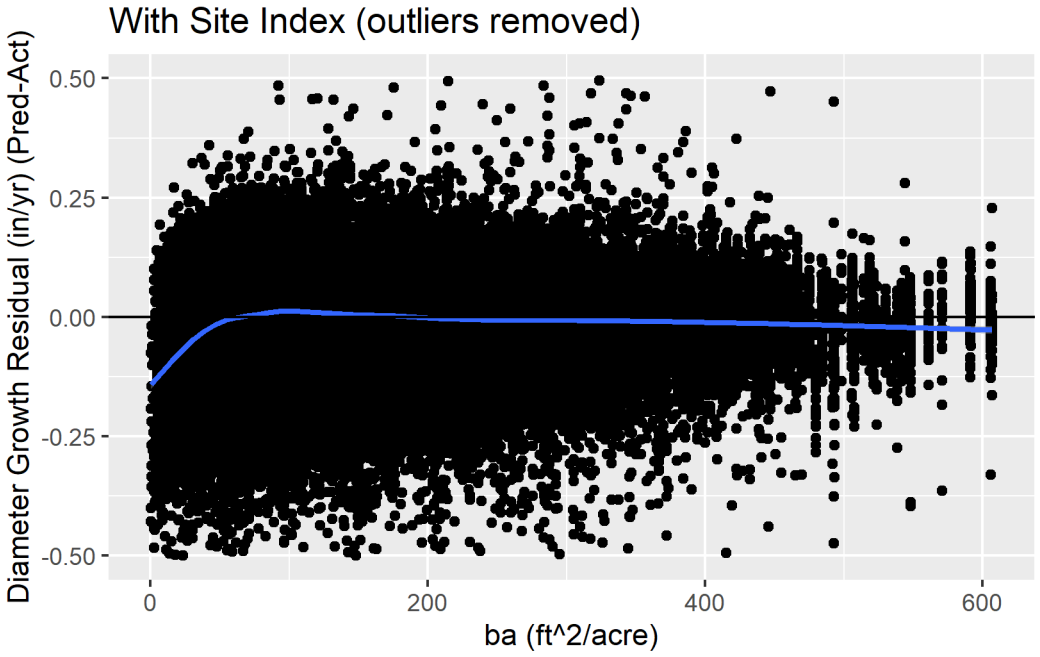
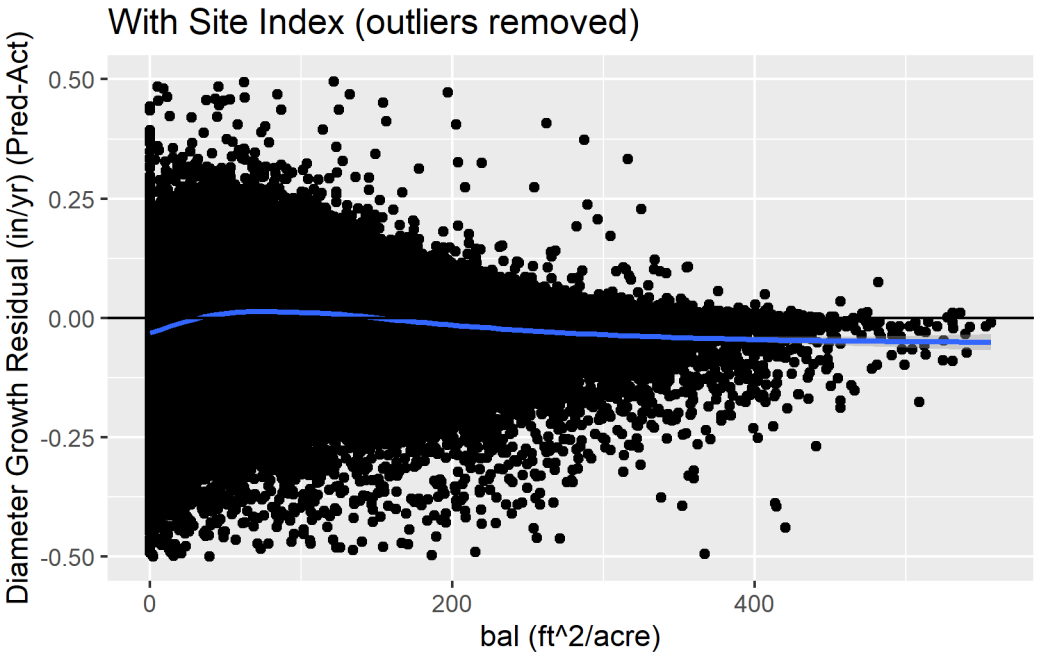
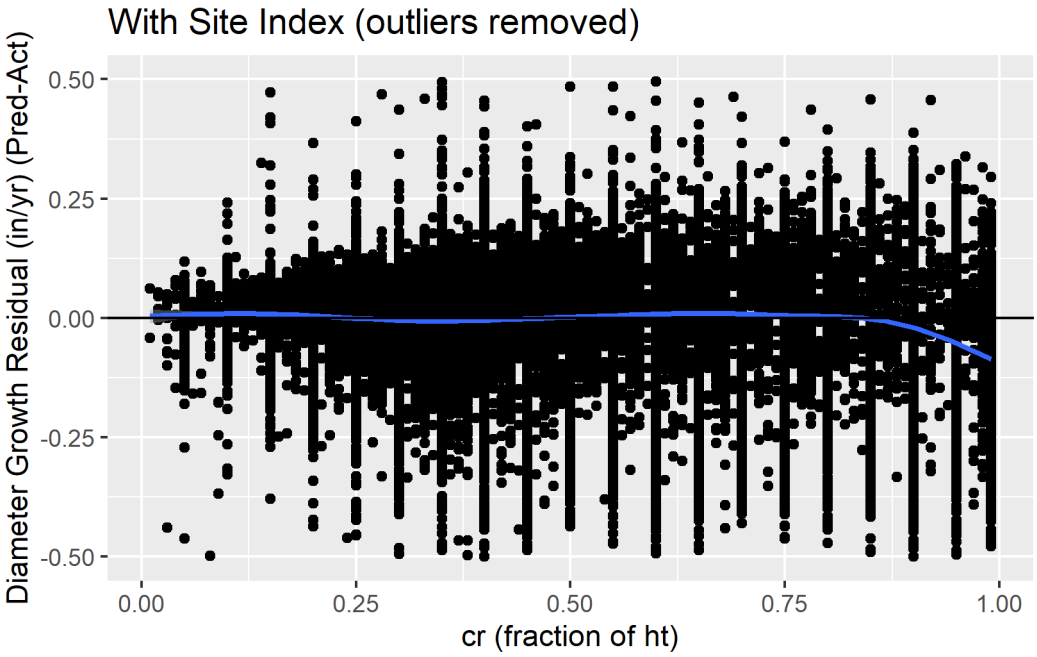


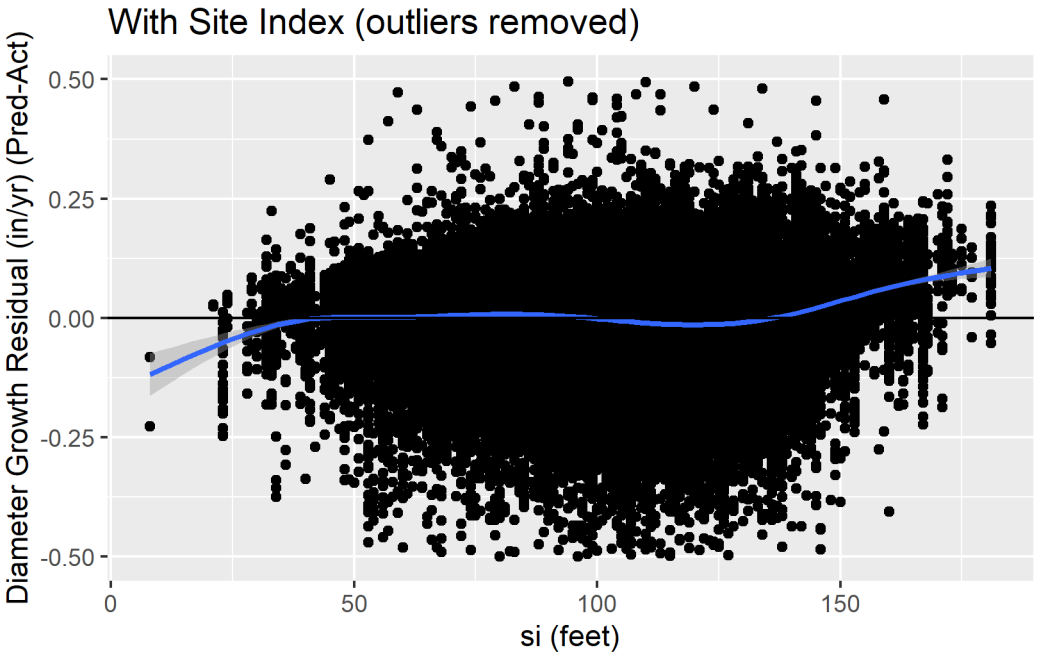
Table 1

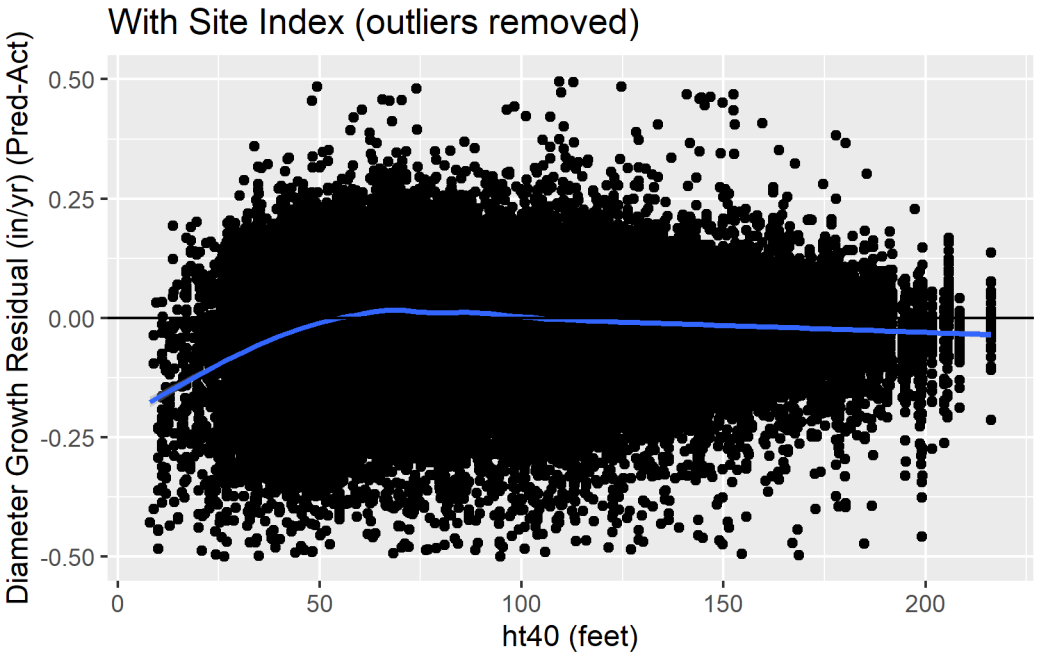
Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
dbh	116679	17	13	1	7.6	23	122
ba	116679	183	100	0.41	107	241	607
bal	116679	93	75	0	36	132	557
cr	116679	0.48	0.2	0.01	0.35	0.62	0.99
si	116679	101	23	8	84	118	181
tpa	116679	433	420	1	181	541	5417
qmd	116679	11	5.7	1	6.9	13	52
ht40	116679	92	35	8	66	114	216
period_length	116679	10	0.44	7.7	9.8	10	13

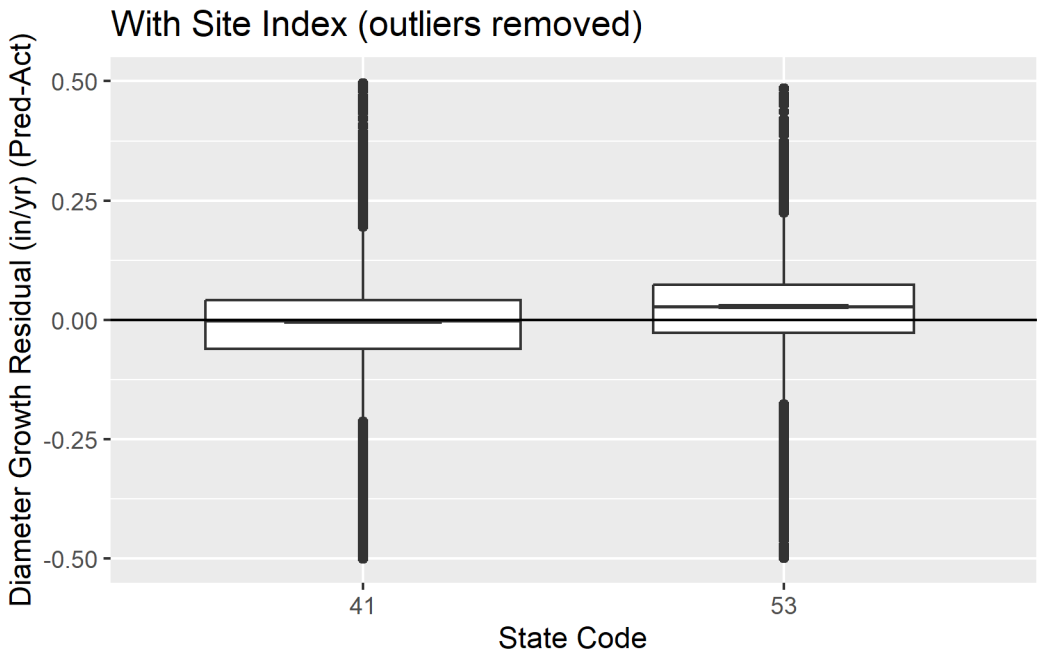



With Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
200
400
bal (ft^2/acre)

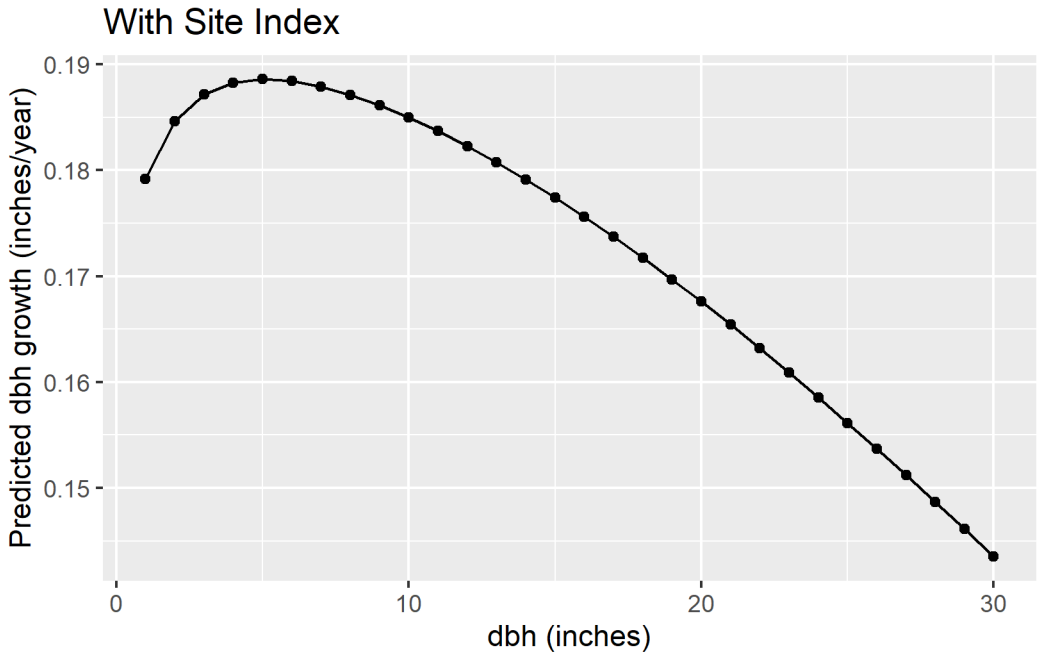

With Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0.00
0.25
0.50
0.75
1.00
cr (fraction of ht)

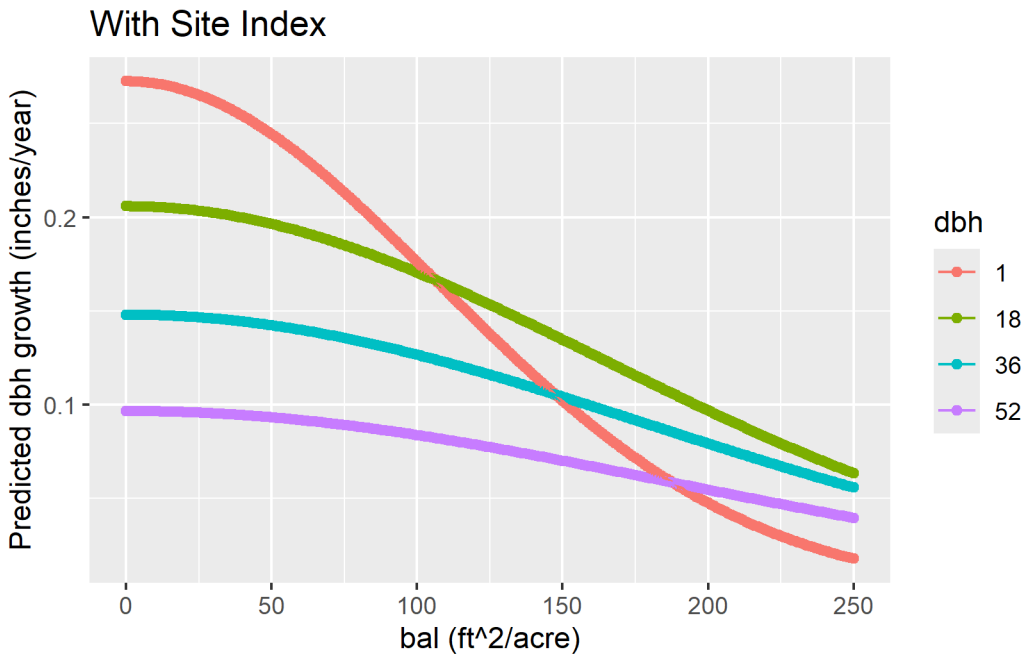

With Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
si (feet)

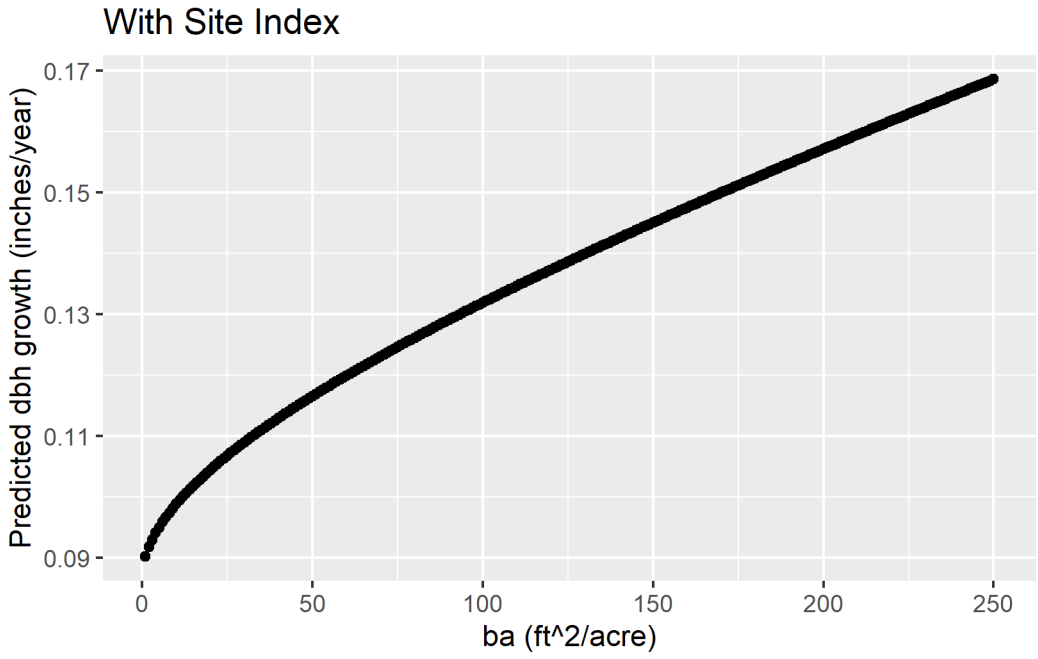

With Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
200
ht40 (feet)

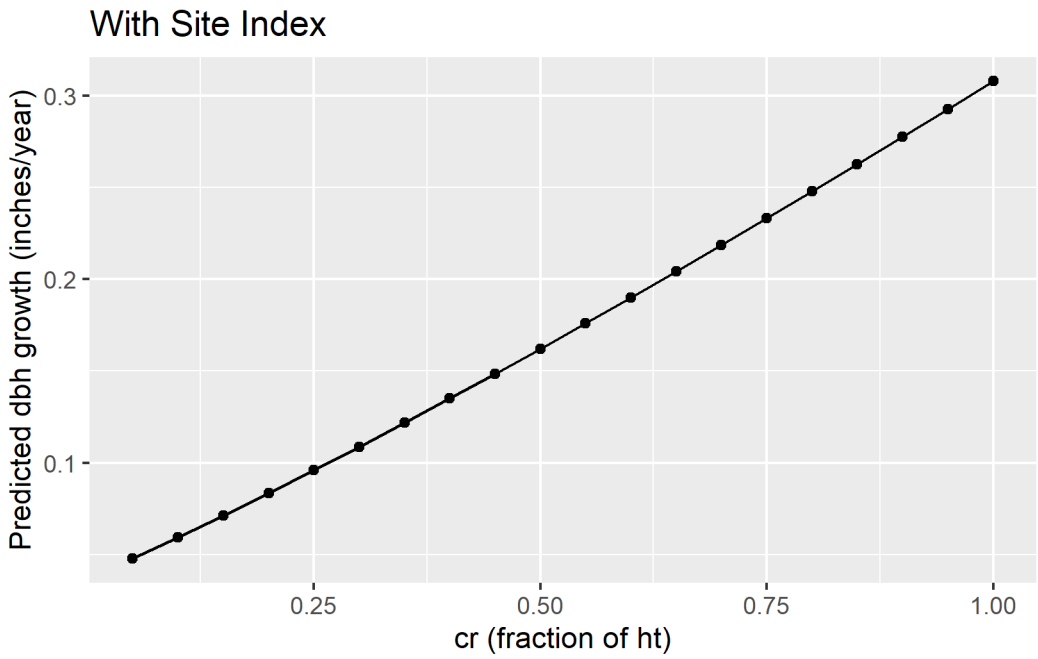


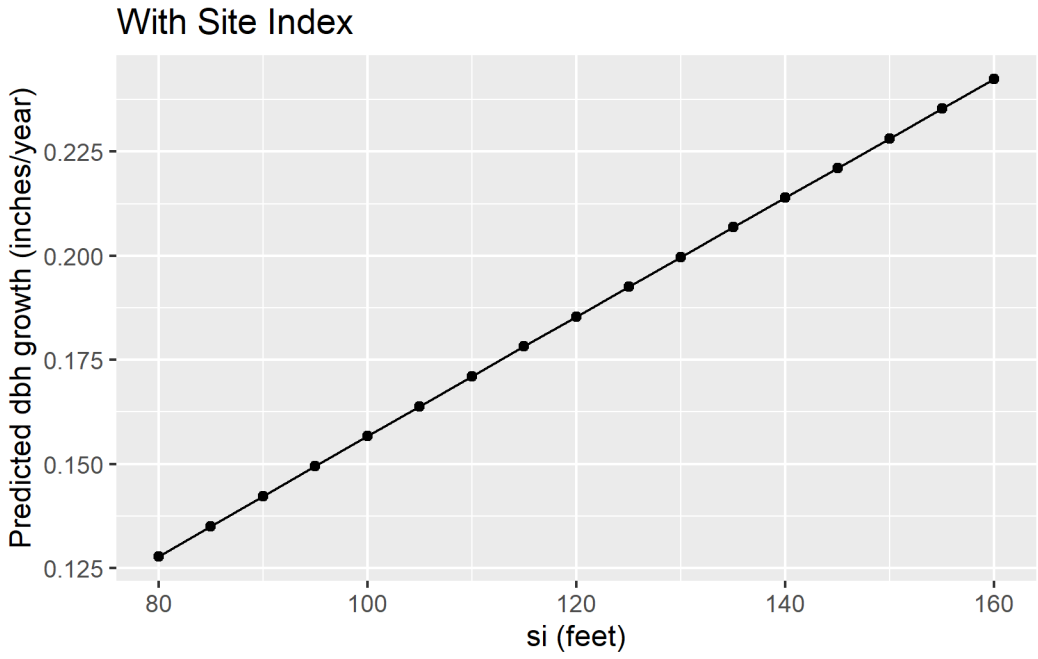
Diameter Growth Equation Performance With Site Index




With Site Index
Predicted dbh growth (inches/year)
0.2
0.1
0
50
100
150
200
250
bal (ft^2/acre)
dbh
1
18
36
52


With Site Index
Predicted dbh growth (inches/year)
0.17
0.15
0.13
0.11
0.09
0
50
100
150
200
250
ba (ft^2/acre)





Diameter Growth Equation Performance Without Site Index

Here we drop the typically weak `si` variable from the equation:

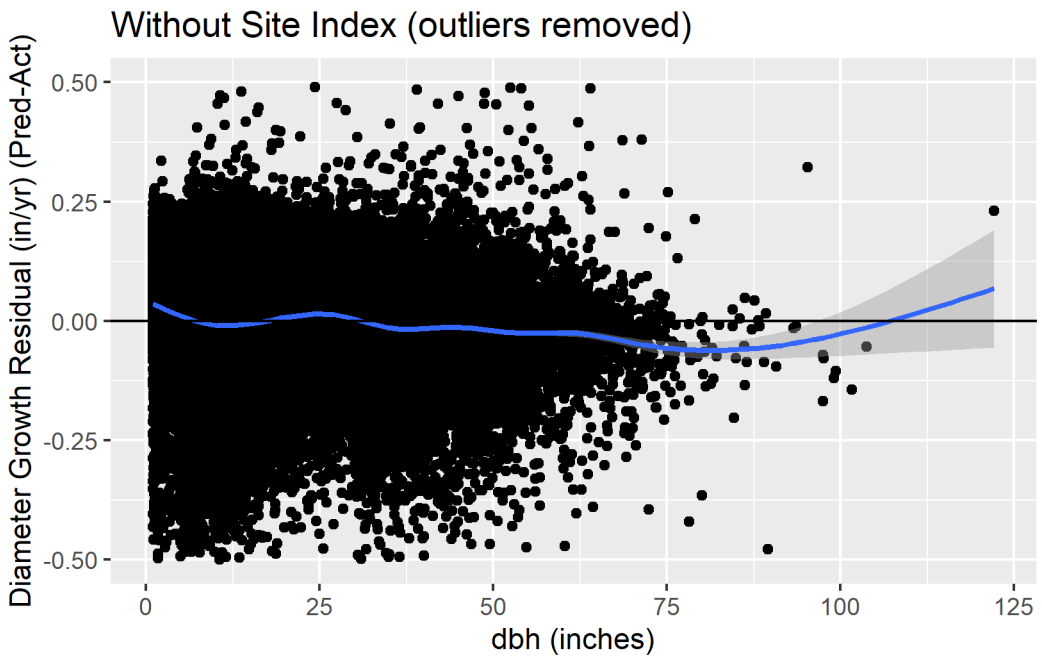
$$\Delta dbh = e^{\beta_0+\beta_1 log(dbh+1)+\beta_2 dbh^2+\beta_3 log(\frac{cr+0.1}{1.2})+\beta_5 \frac{bal^2}{dbh+2.7}+\beta_6 ba^{0.5}}$$

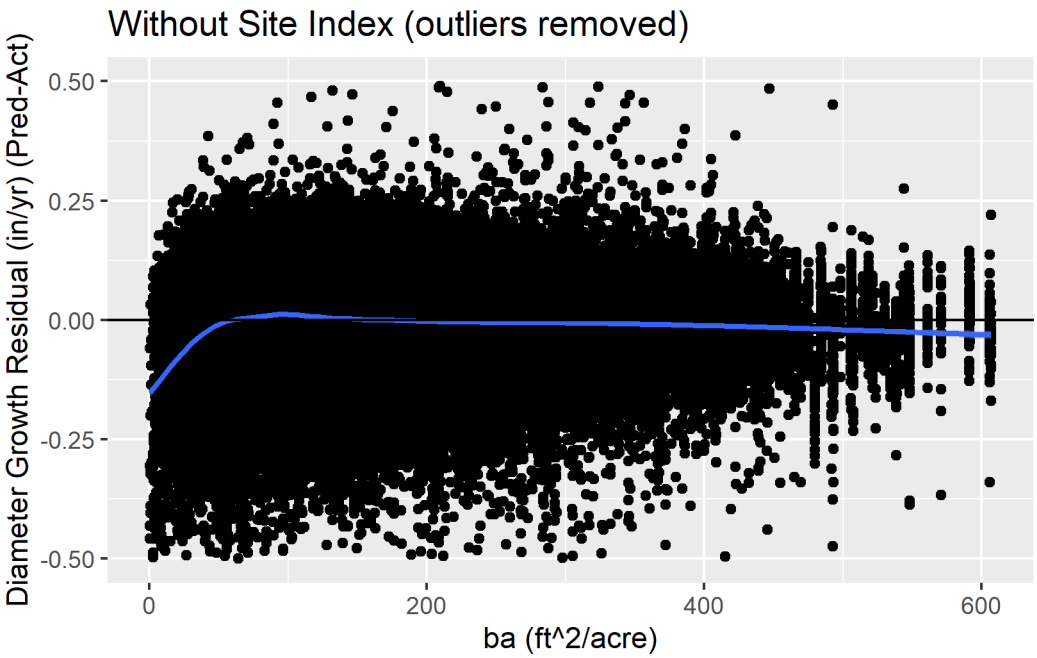
The fit statistics for this model are:

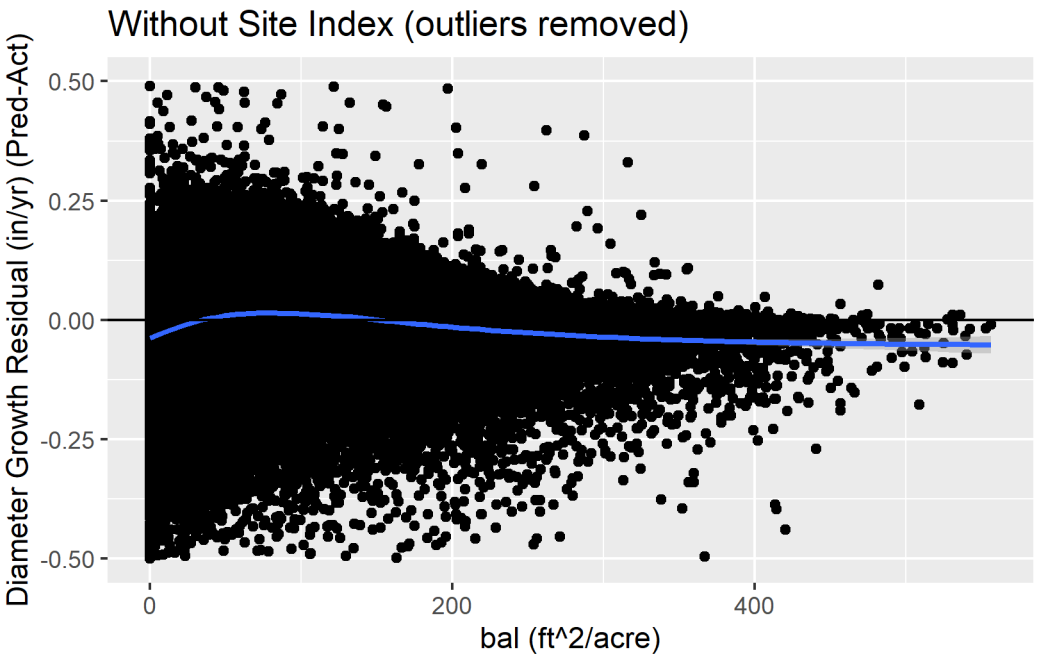
	Coef.	Std. error	t-stat.	p
B0	-1.1862455	0.0162693	-72.91304	0
B1	-0.0922140	0.0076000	-12.13348	0
B2	-0.0003519	0.0000082	-42.80259	0
B3	1.2111490	0.0100025	121.08419	0
B5	-0.0000610	0.0000008	-75.80275	0
B6	0.0510847	0.0010638	48.02223	0

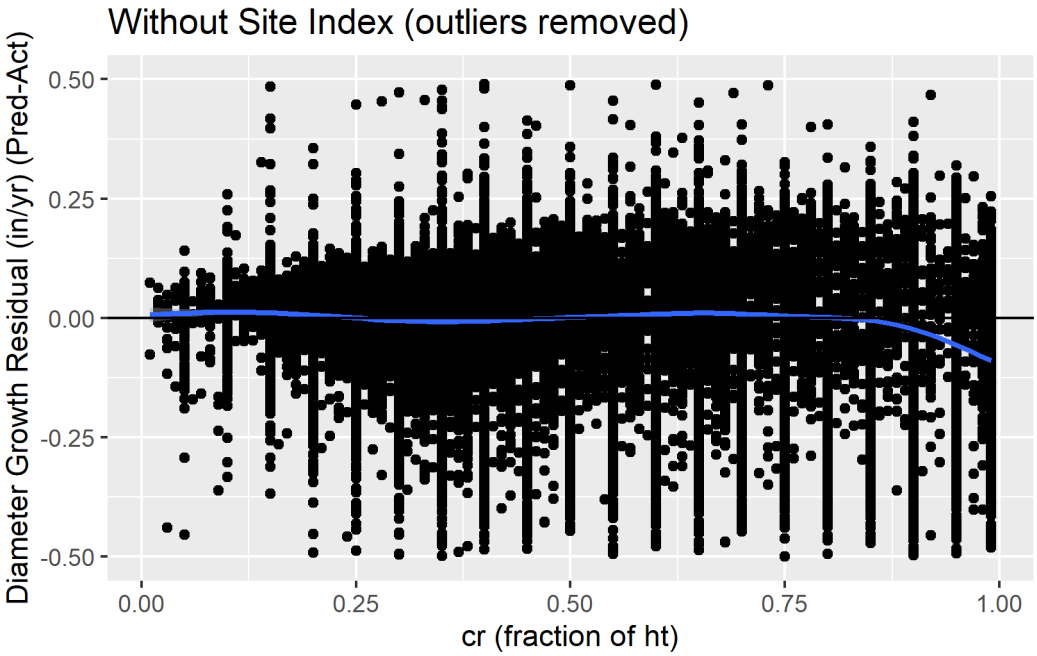
```
Residual Standard Error: 1.17516481607539 on 116673 degrees of freedom
```

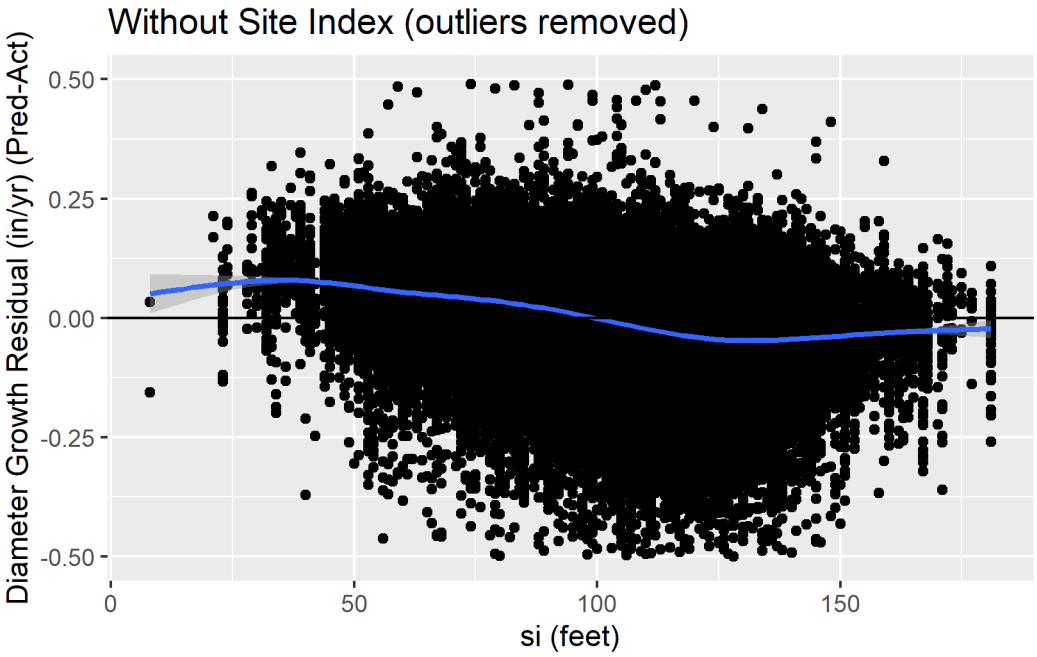
Diameter Growth Residuals Without Site Index

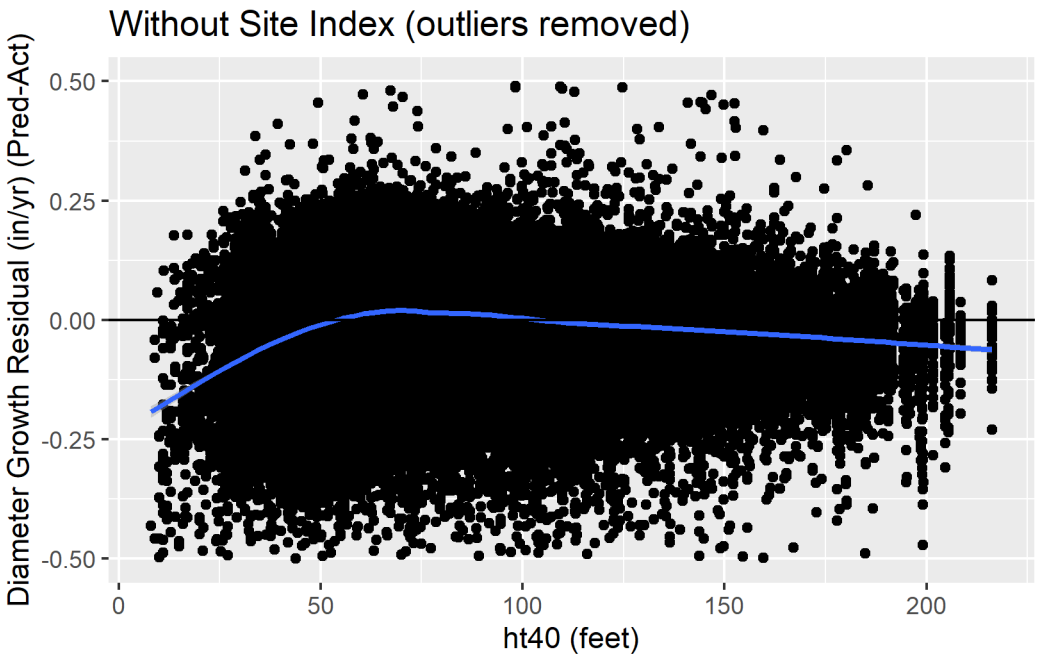


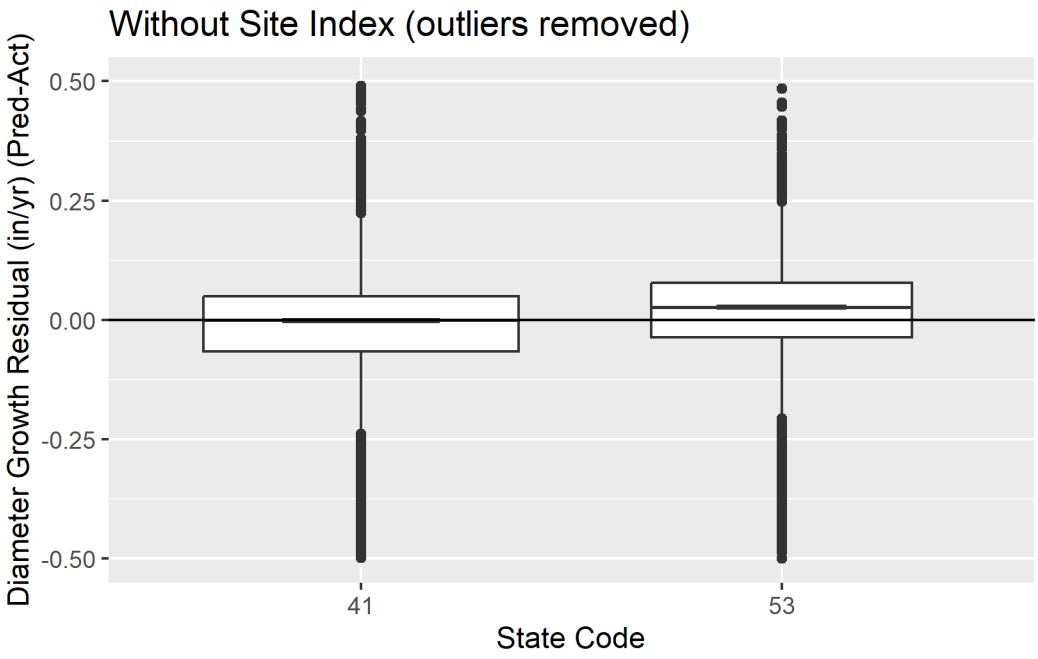

Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
200
400
600
ba (ft^2/acre)


Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
200
400
bal (ft^2/acre)

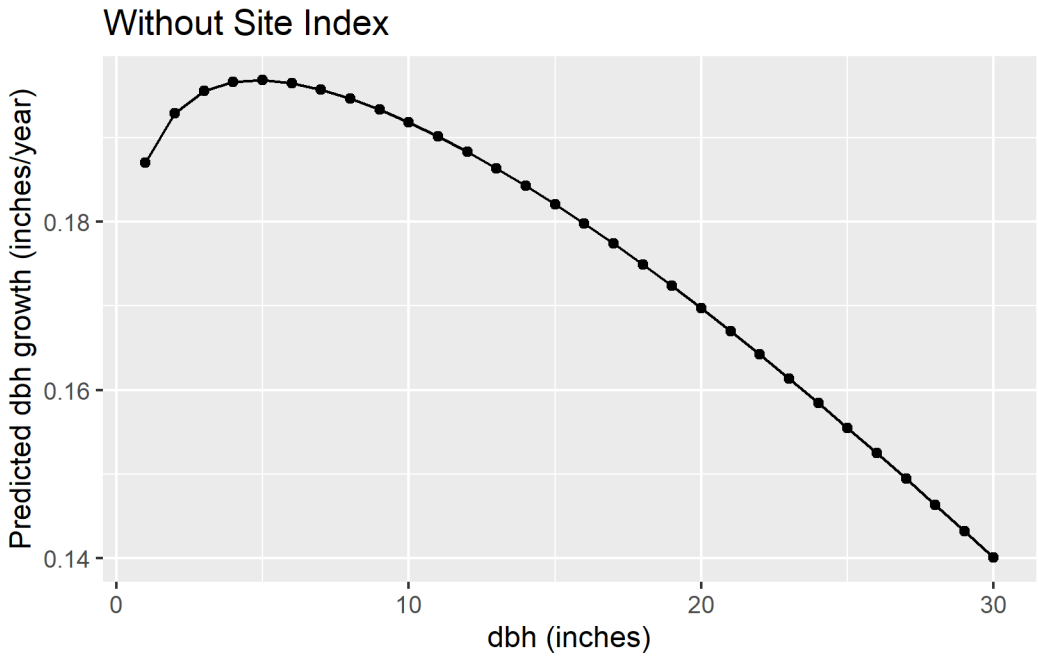

Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0.00
0.25
0.50
0.75
1.00
cr (fraction of ht)

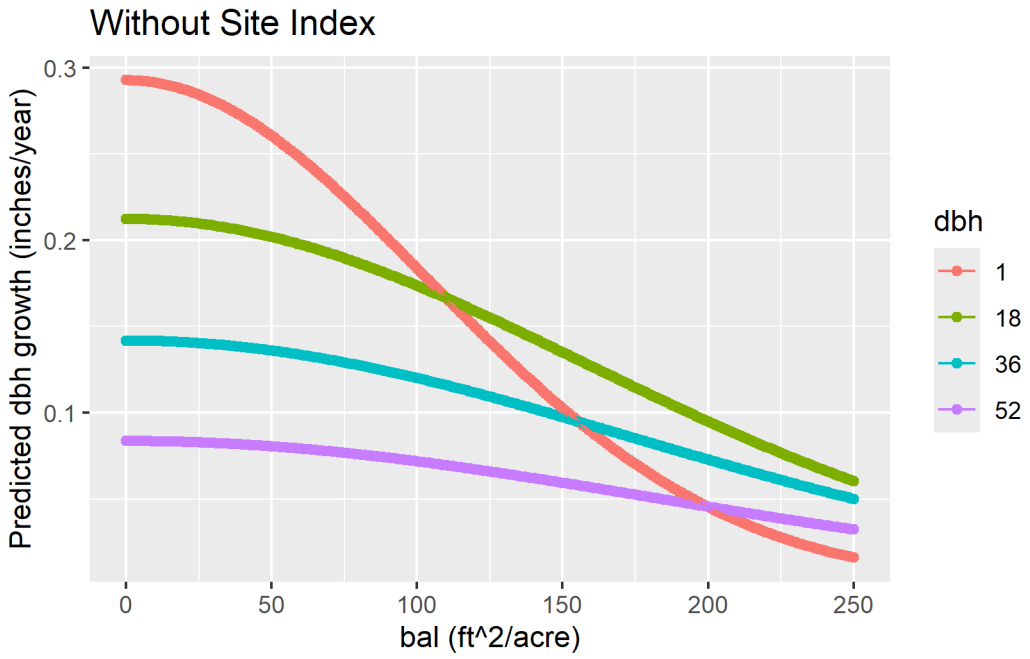

Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
si (feet)

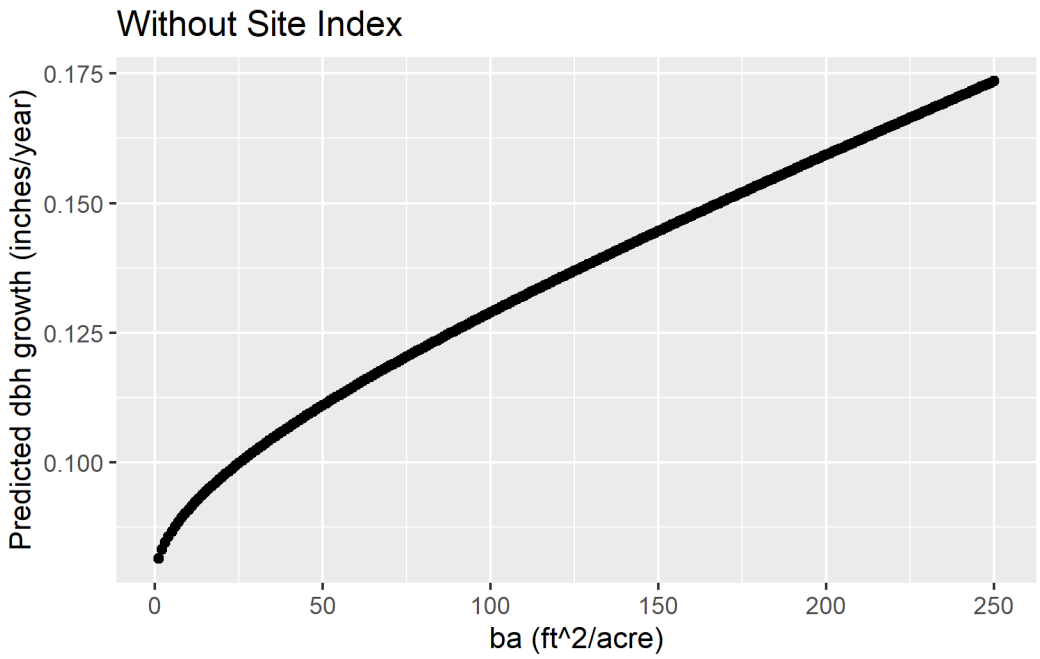

Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
200
ht40 (feet)


Without Site Index (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
41
53
State Code

Diameter Growth Equation Performance Without Site Index







Comparison of Models with and without Site Index

```
Analysis of Variance Table
```

```
Model 1 (without Site Index)
Model 2 (with Site Index)
  Res.Df Res.Sum Sq Df Sum Sq F value    Pr(>F)
1 116673     161127
2 116672     146528  1  14599   11624 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

AIC without Site Index:  368794.601061925
AIC with Site Index:     357715.093972263
```

Both the nested model F test and the AIC comparisons indicate that `si` is adding explanatory value to the model.

Correcting Abiologic Basal Area Term

In the full model (with `si`), the `ba` coefficient is positive. This creates model behavior where diameter growth increases with increasing `ba` – contrary to our expectations. Here we drop the `ba` variable to examine the effect on model fit and behavior.

The following revised model was fit:

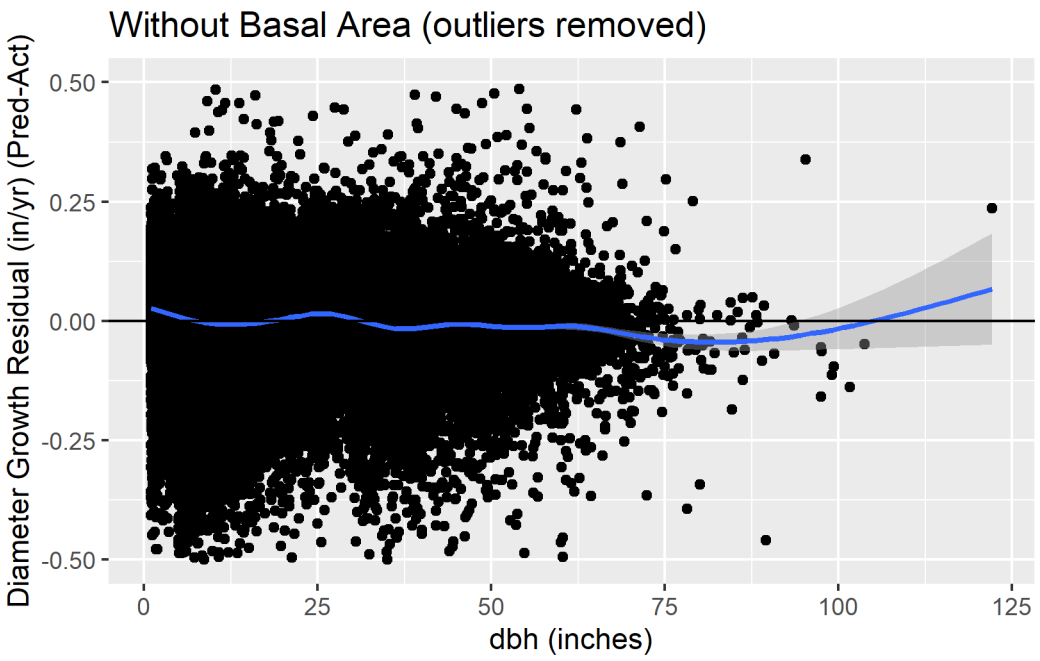
$\Delta dbh = e^{\beta_0+\beta_1 log(dbh+1)+\beta_2 dbh^2+\beta_3 log(\frac{cr+0.1}{1.2})+\beta_4 log(si+4.5)+\beta_5 \frac{bal^2}{dbh+2.7}}$

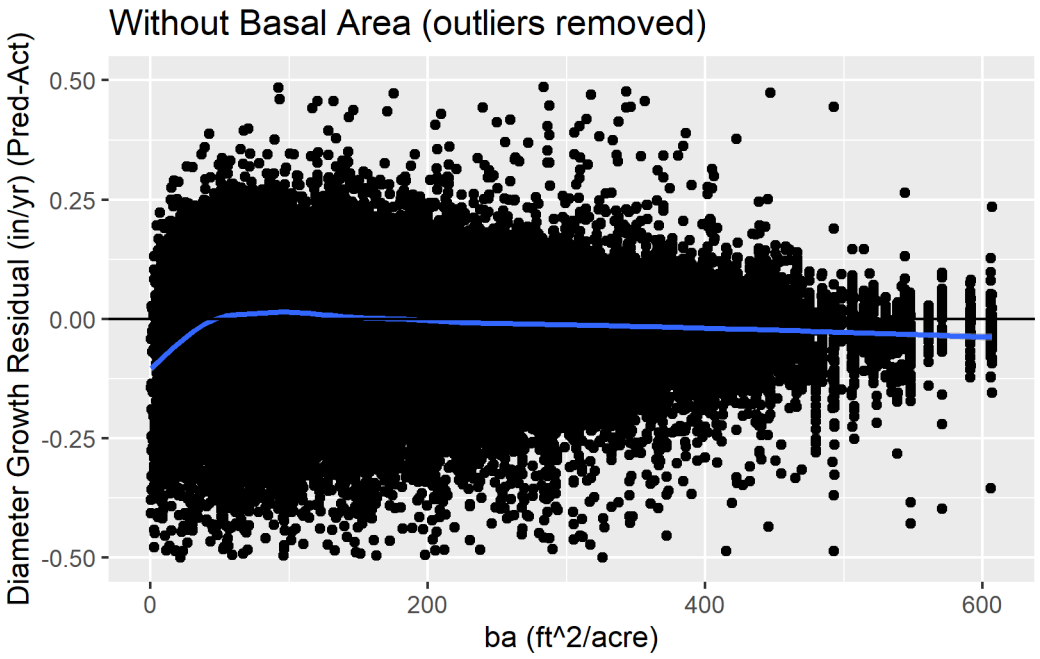
The fit statistics for this model are:

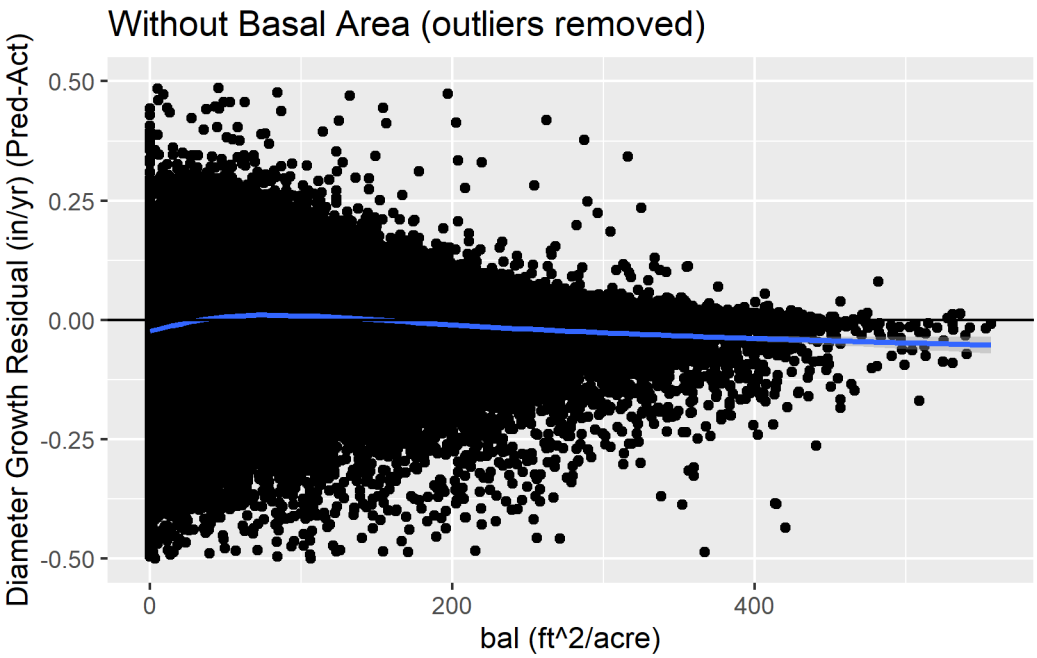
	Coef.	Std. error	t-stat.	p
B0	-5.7207411	0.0480305	-119.106517	0.0e+00
B1	0.0300277	0.0064989	4.620419	3.8e-06
B2	-0.0002441	0.0000072	-33.826817	0.0e+00
B3	1.0902584	0.0089047	122.436438	0.0e+00
B4	1.0025860	0.0097870	102.440533	0.0e+00
B5	-0.0000393	0.0000006	-65.021166	0.0e+00

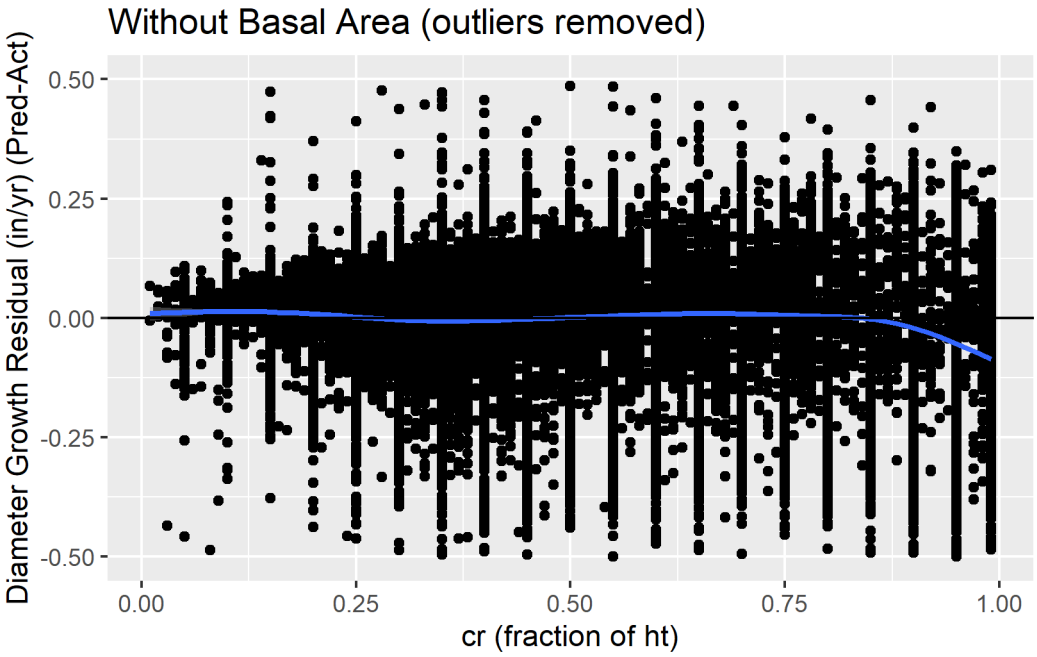
```
Residual Standard Error: 1.12914337485975 on 116673 degrees of freedom
```

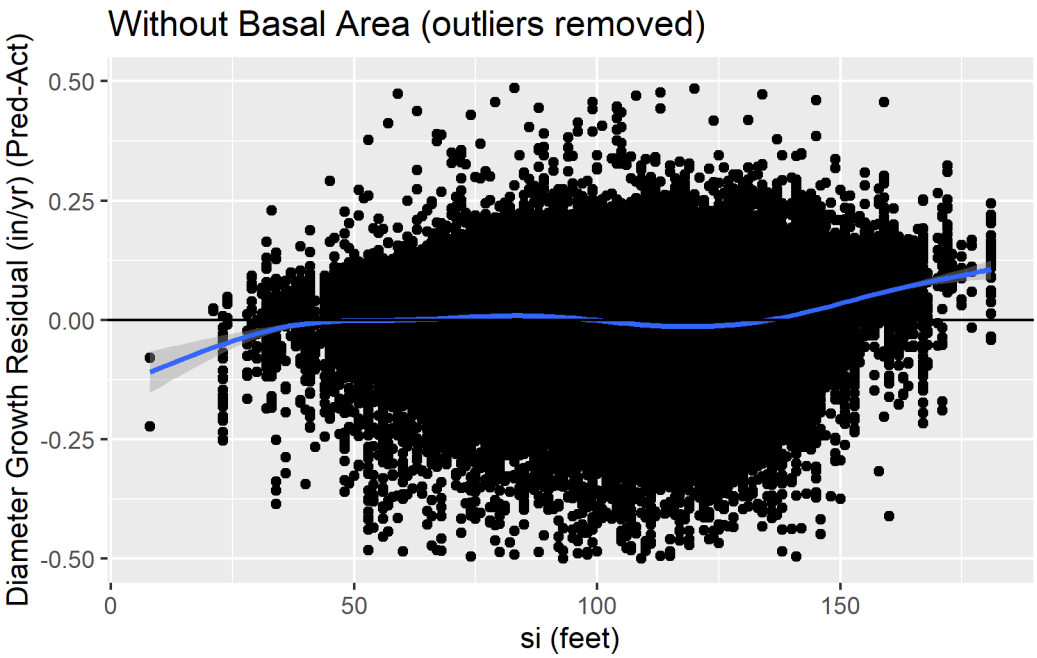
Diameter Growth Residuals Without Basal Area per Acre

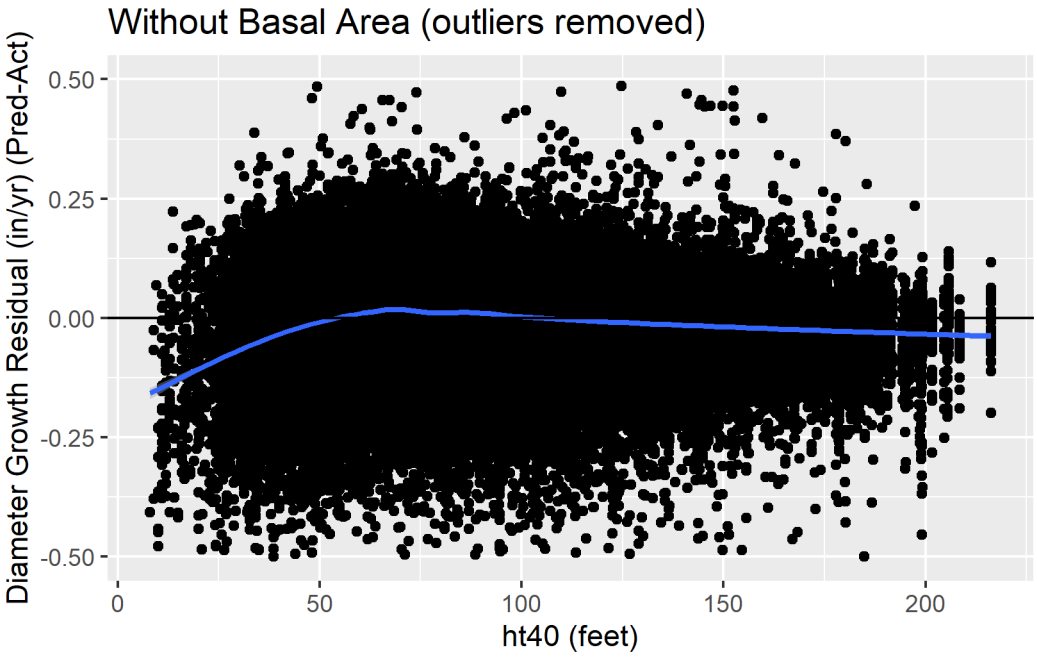




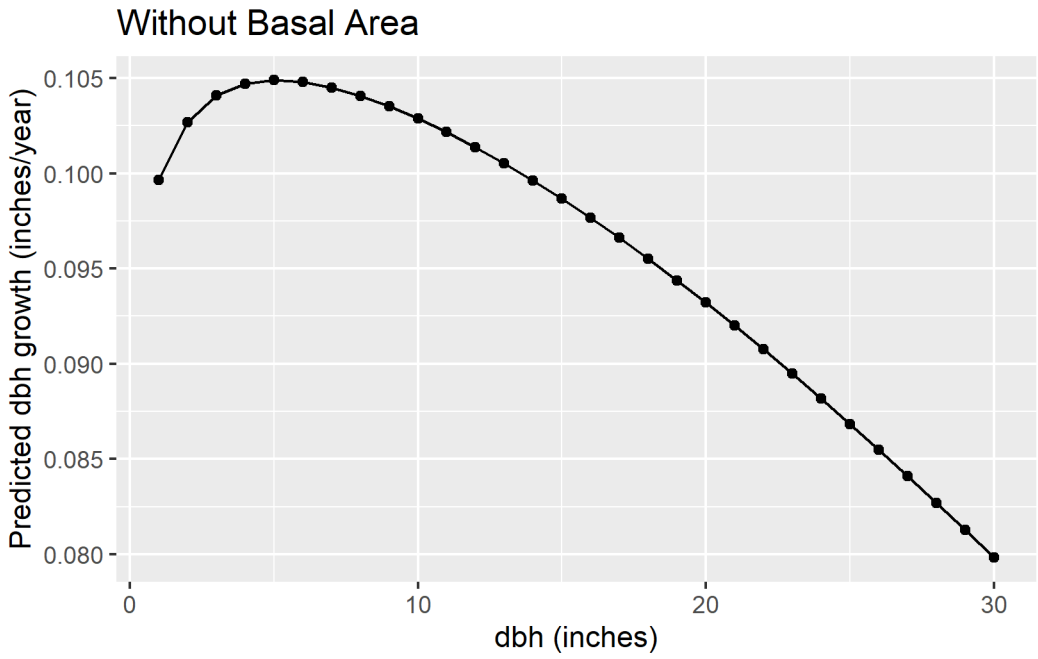

Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
200
400
bal (ft^2/acre)

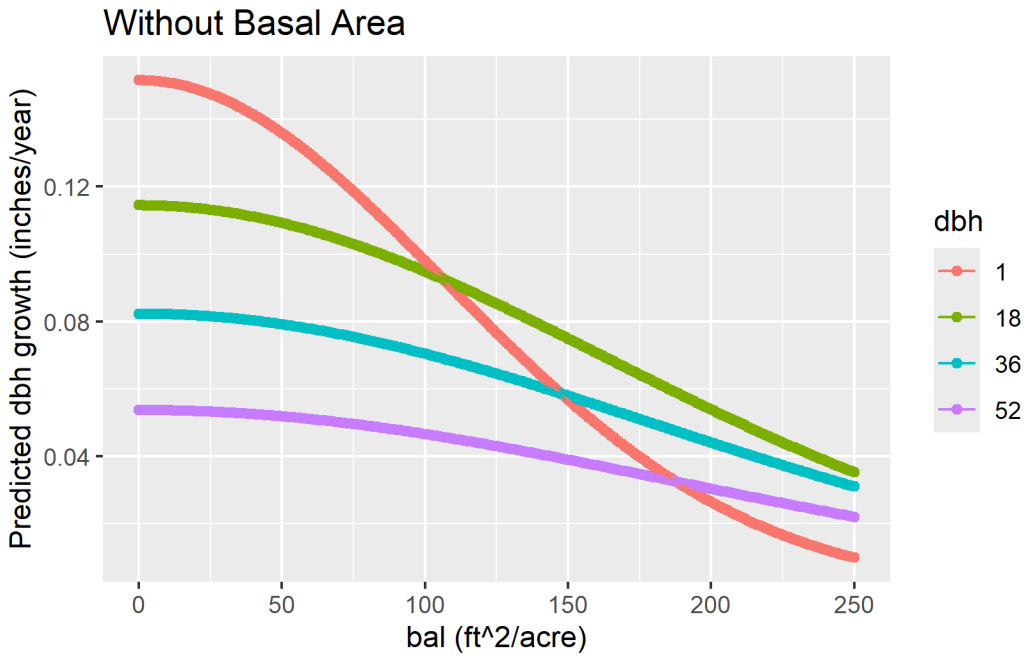

Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0.00
0.25
0.50
0.75
1.00
cr (fraction of ht)

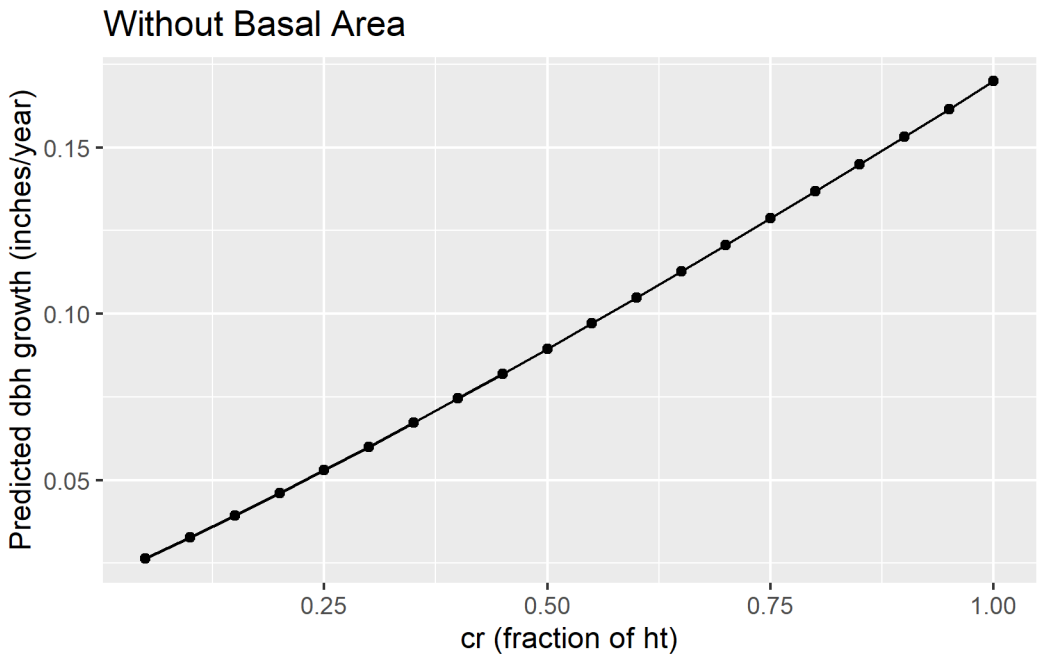

Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
si (feet)

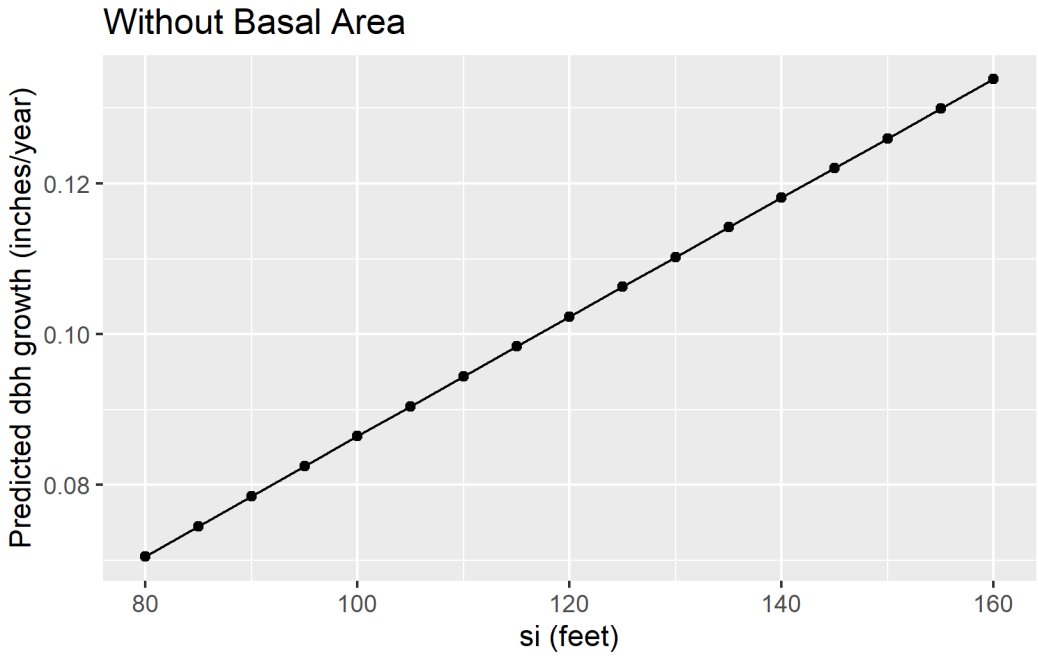

Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
200
ht40 (feet)

Diameter Growth Equation Performance Without Basal Area









Comparison of Models with and without Basal Area

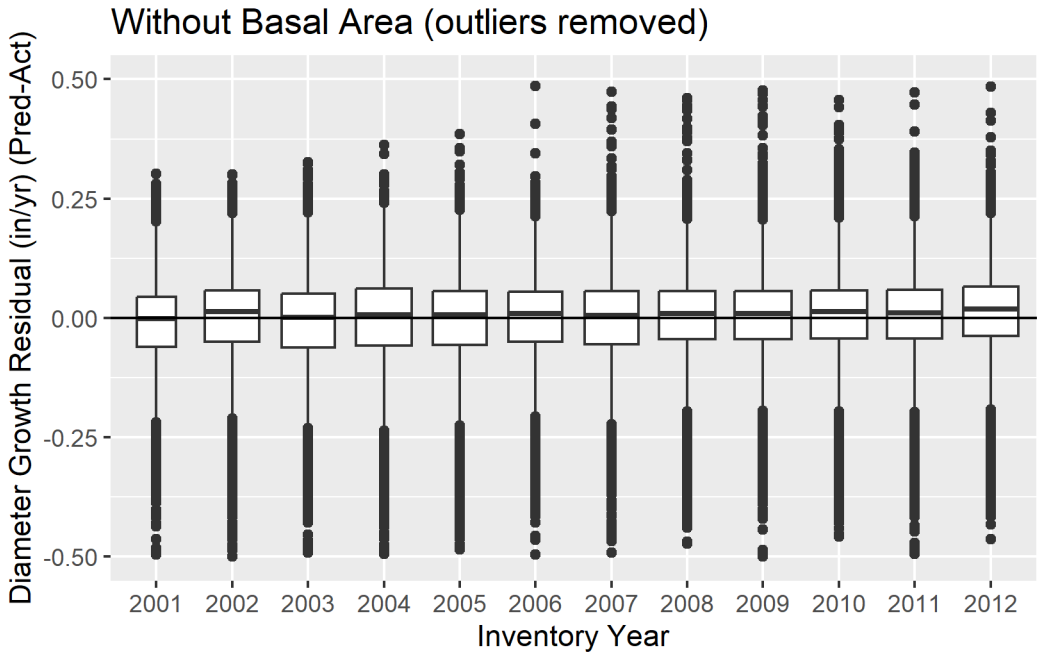
```
Analysis of Variance Table
```

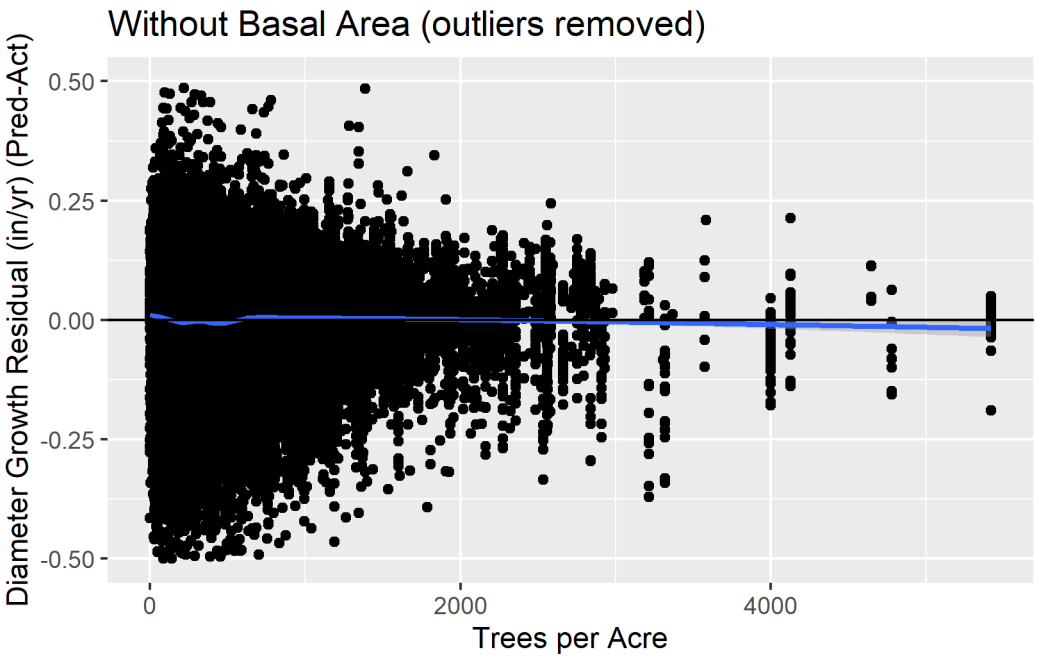
```
Model 1 (without Basal Area)
Model 2 (with Site Index)
  Res.Df Res.Sum Sq Df Sum Sq F value    Pr(>F)
1 116673     148754
2 116672     146528  1 2225.8  1772.3 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

AIC without Basal Area:  359472.150381338
AIC with Site Index:     357715.093972263
```

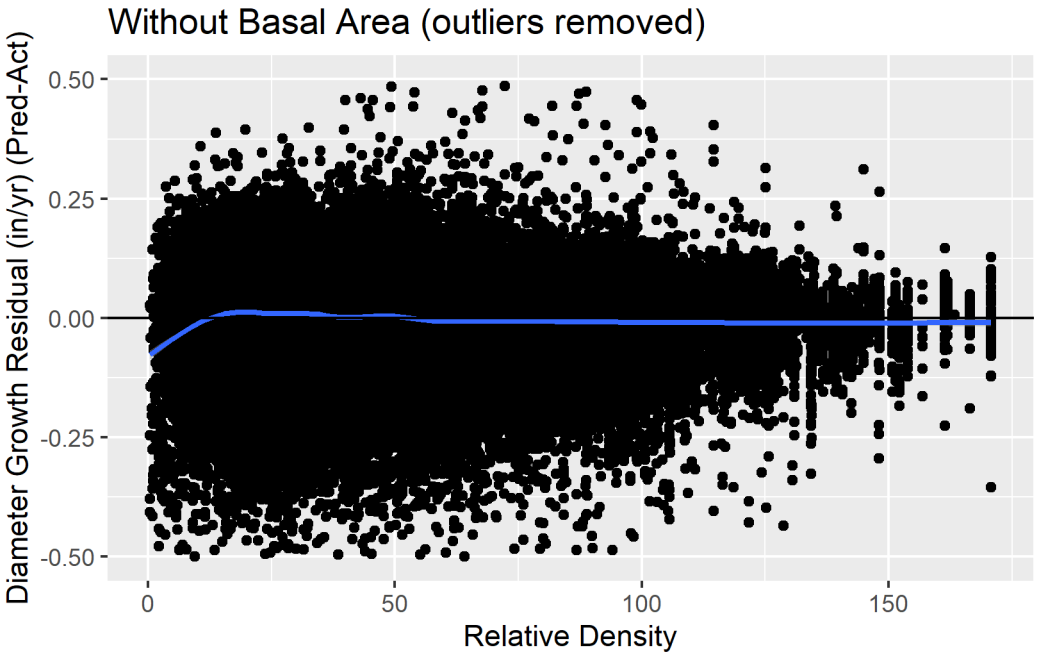
Both the nested model F test and AIC comparisons indicate that adding the `ba` variable is significant. It appears that we will pay a small penalty for dropping `ba` to gain biological consistency.

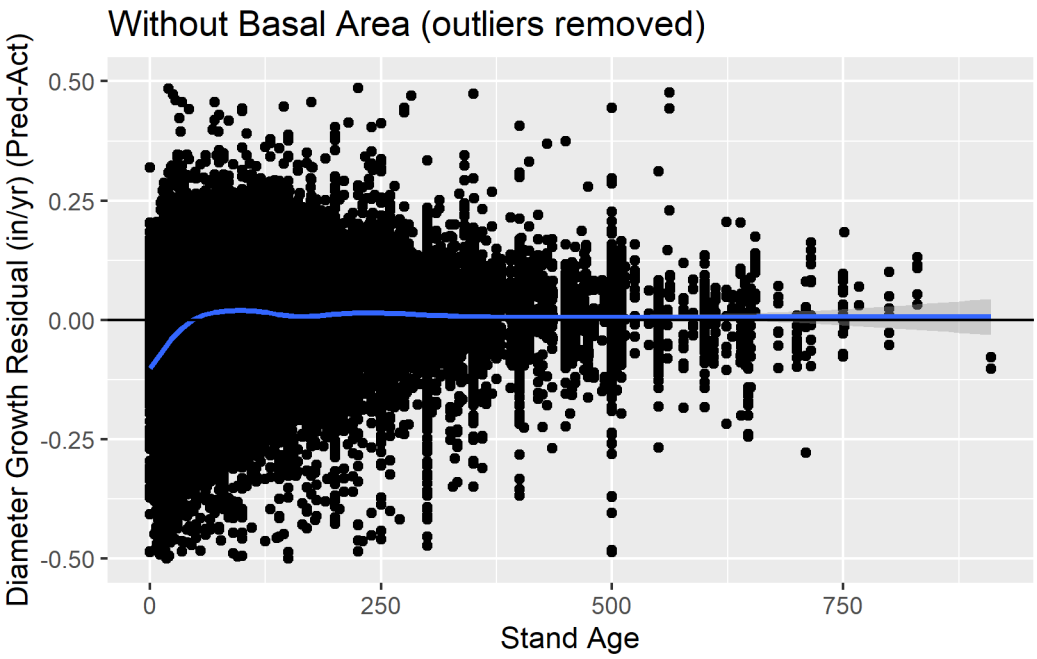
Playing Around with `si` and no `ba` Model

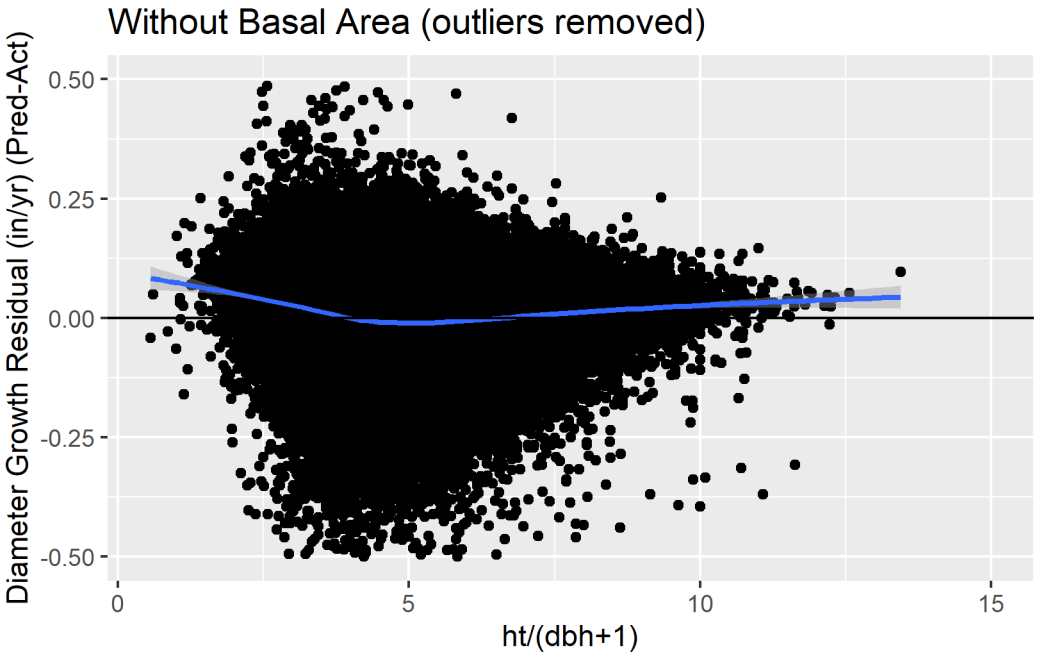
There is a difference in bias between Oregon (41) and Washington (53). There is a positive (over-prediction) for National Forests (owner code 11) and an under-prediction for undifferentiated private (46).




Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
2000
4000
Trees per Acre

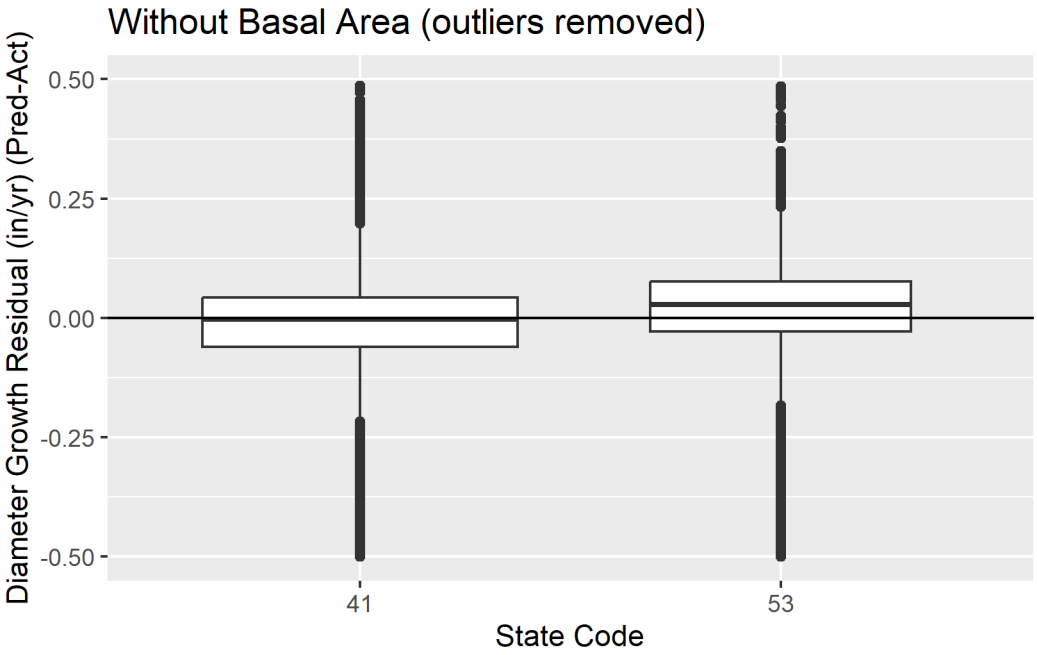

Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
50
100
150
Relative Density


Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
250
500
750
Stand Age


Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
0
5
10
15
ht/(dbh+1)


Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
1
2
3
4
5
Number of Conditions


Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
11
21
22
23
24
25
31
32
33
46
Owner Code


Without Basal Area (outliers removed)
Diameter Growth Residual (in/yr) (Pred-Act)
0.50
0.25
0.00
-0.25
-0.50
41
53
State Code