Testing Climate SI for Douglas-fir Diameter Growth

Greg Johnson, Aaron Weiskittel, and David Marshall

2026-02-09

Model

$$\Delta dbh = e^{(\beta_0 + \beta_1 log(\frac{(dbh+1)^2}{(cr*ht+1)^{\beta_4}}) + \beta_2 \frac{bal^{\beta_5}}{dbh+2.7} + \beta_3 log(csi+1.37))} \tag{1}$$

where:

- dbh = diameter at breast height (inches),
- bal = basal area per acre in larger trees ($feet^2/ac$),
- cr = crown ratio (fraction of total height),
- ht = total height (feet),
- csi = climate site index (meters), and
- $\beta_0 - \beta_5$ are parameters to be estimated.

Climate site index (csi) was developed by Aaron Weiskittel and represents a CONUS-wide consistent estimate of productivity.

Nonlinear regression was used with an integrated fitting approach such that individual observations can have differing remeasurement intervals. The error to be minimized is ending dbh.

Data

We extracted and processed Forest Inventory and Analysis (FIA) data from 15 states listed in the native range of Douglas-fir in the Silvics of North America.[1]

---

[1]Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 p.

After subsetting the data to censor observations with missing data, limiting the species to Douglas-fir (FIA species code 202), and remeasurement intervals ≥ 5 years we get the observations in Table 1.

Table 1: Douglas-fir Growth Observations by State

State	Observations
AZ	1143
CA	18360
CO	6774
ID	13789
IL	2
MI	42
MT	23645
NM	2440
NV	27
NY	31
OR	68702
PA	11
UT	2348
WA	46594
WY	865

Equation Parameter Estimates

	Coef.	Std. error	t-stat.	p
B0	-14.2584217	0.1271453	-112.14271	0
B1	-0.6704157	0.0036872	-181.82077	0
B2	-0.0978362	0.0074885	-13.06494	0
B3	3.5780455	0.0403965	88.57307	0
B4	2.0777031	0.0082659	251.35707	0
B5	0.5714655	0.0134271	42.56048	0

```
Residual Standard Error: 1.11920758876324 on 184767 degrees of freedom, AIC: 565989.7
```
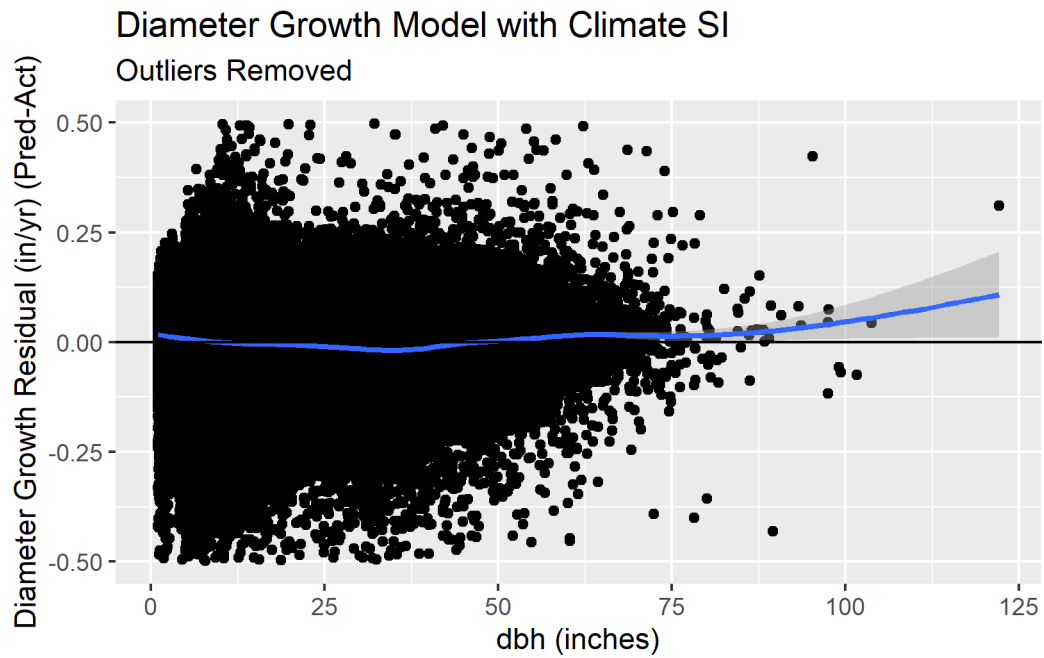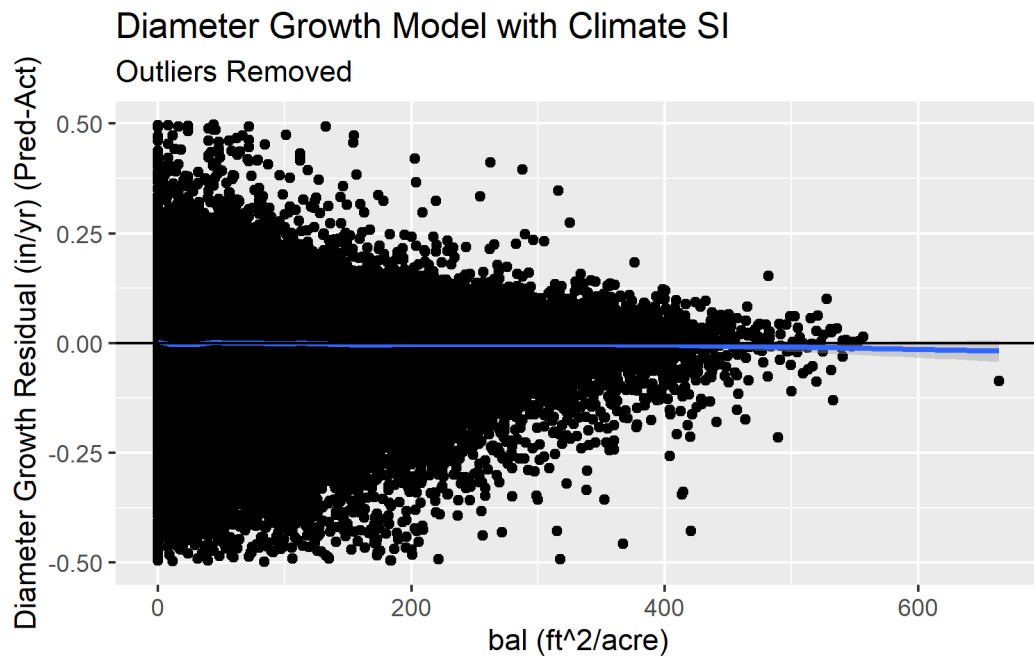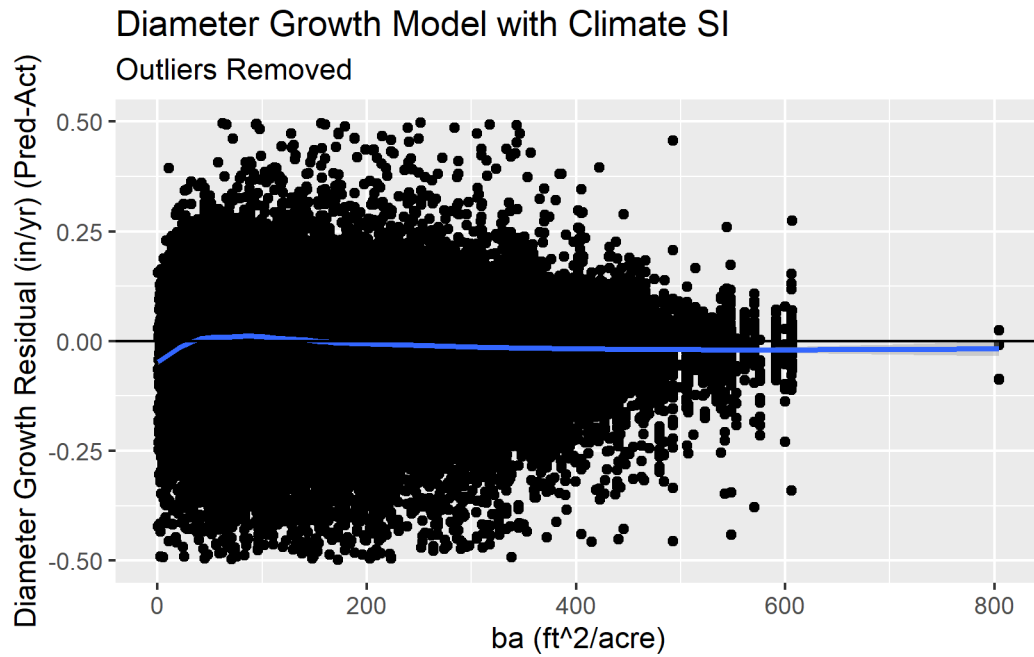
Comparison to Simplified Model without Climate SI

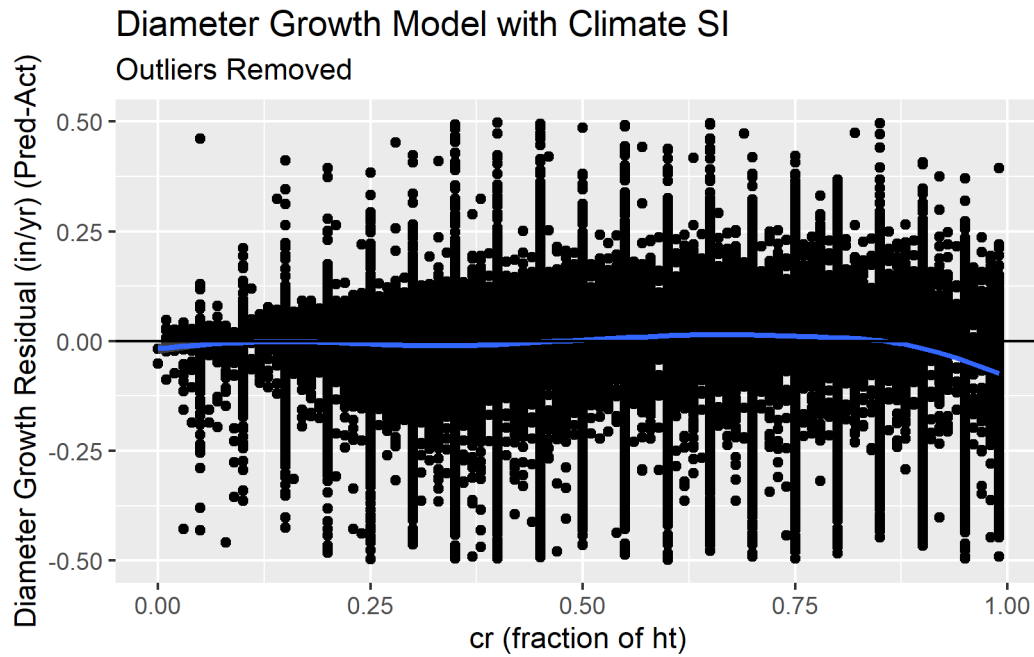|	Coef.	Std. error	t-stat.	p
B0	-3.4527532	0.0248363	-139.02030	0
B1	-0.7036656	0.0038816	-181.28456	0
B2	-0.0880682	0.0079539	-11.07231	0
B4	2.2152039	0.0083456	265.43383	0
B5	0.5636545	0.0158005	35.67311	0

Residual Standard Error: 1.14763670588031 on 186320 degrees of freedom, AIC: 580090.1
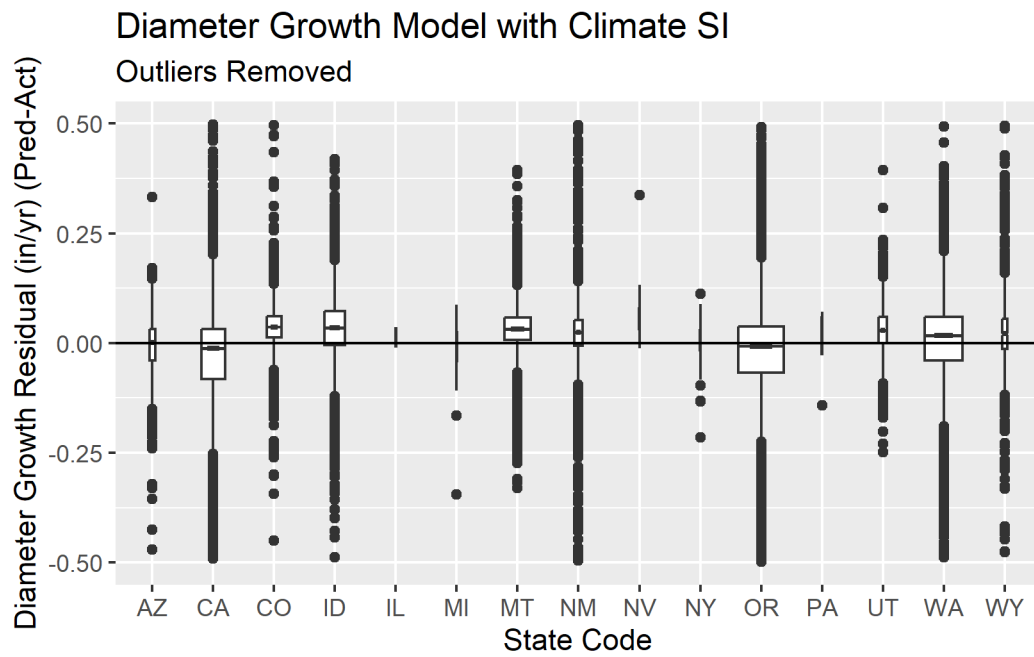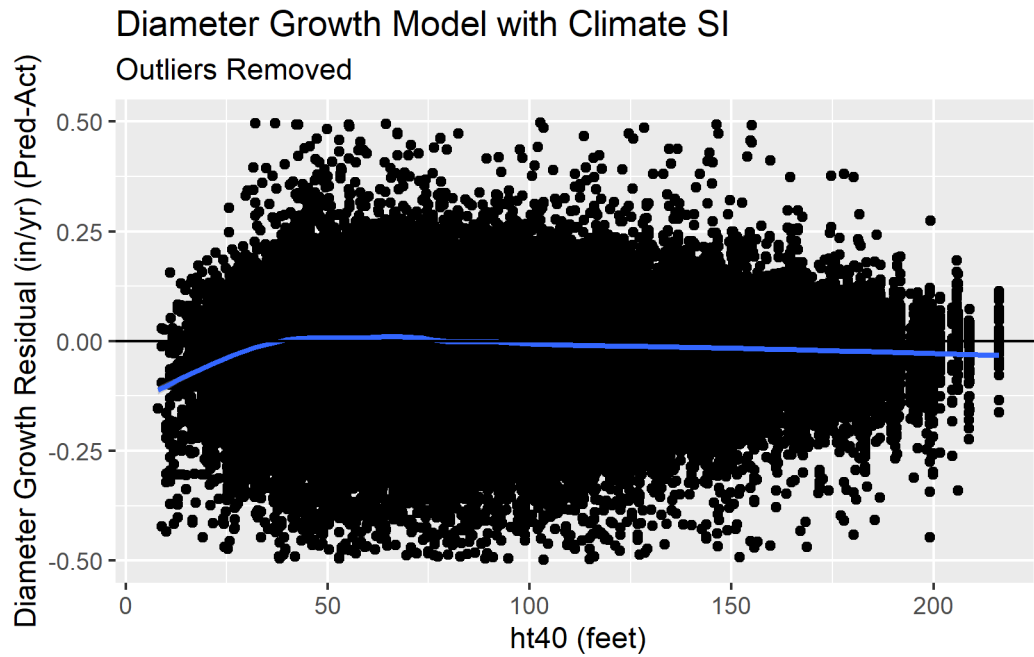
While `csi` improves the fit significantly, it does not remove the geographic residuals patterns in the residuals (see the last graph below).
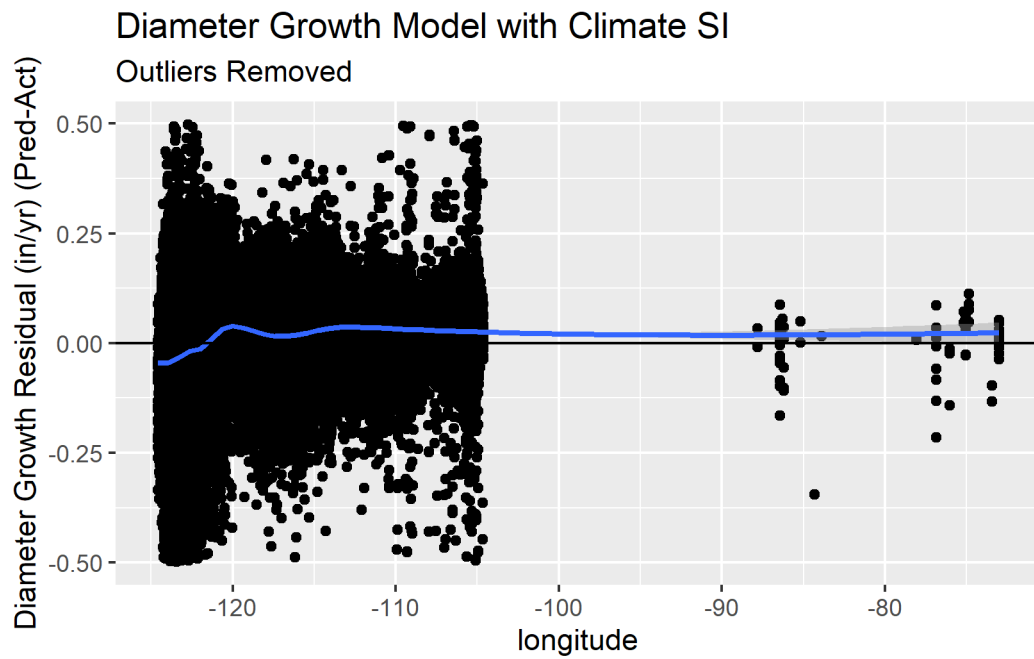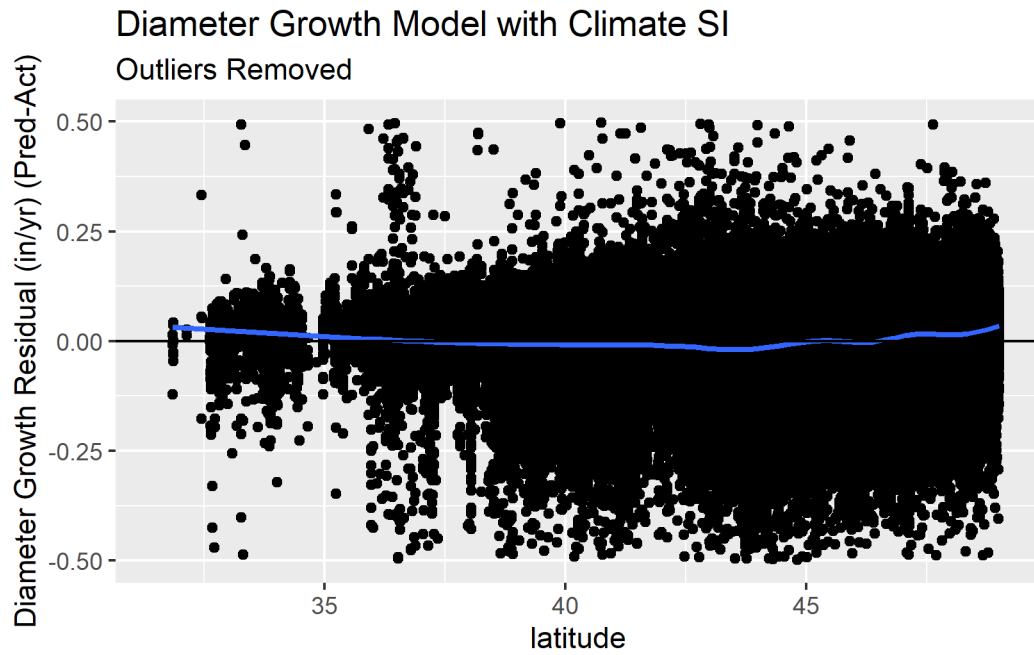
Residual Analysis for Equation 1

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
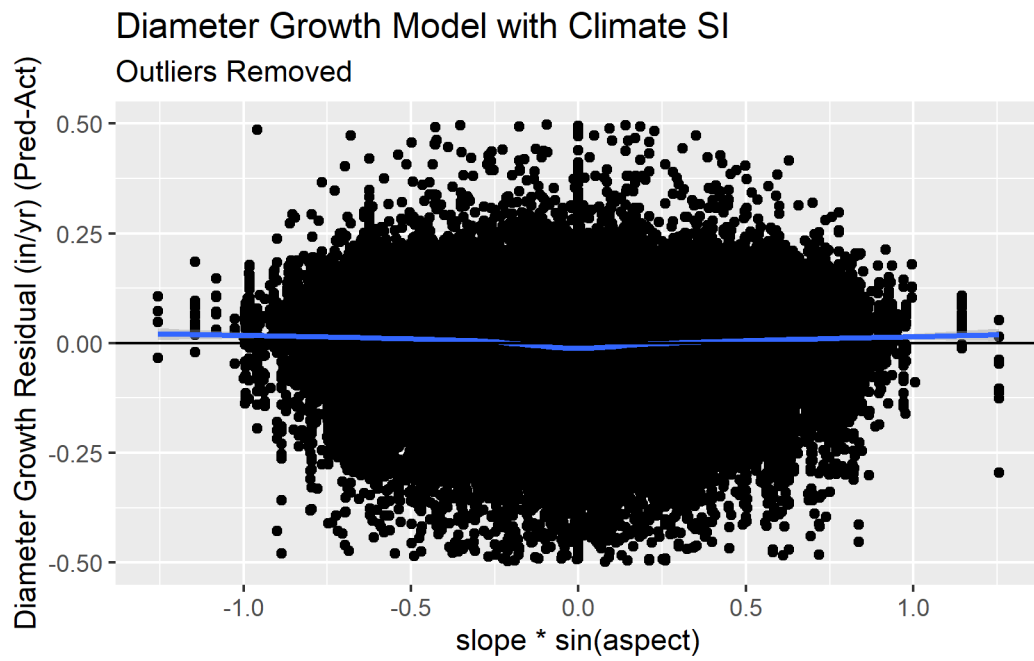### Outliers Removed

6

Diameter Growth Model with Climate SI
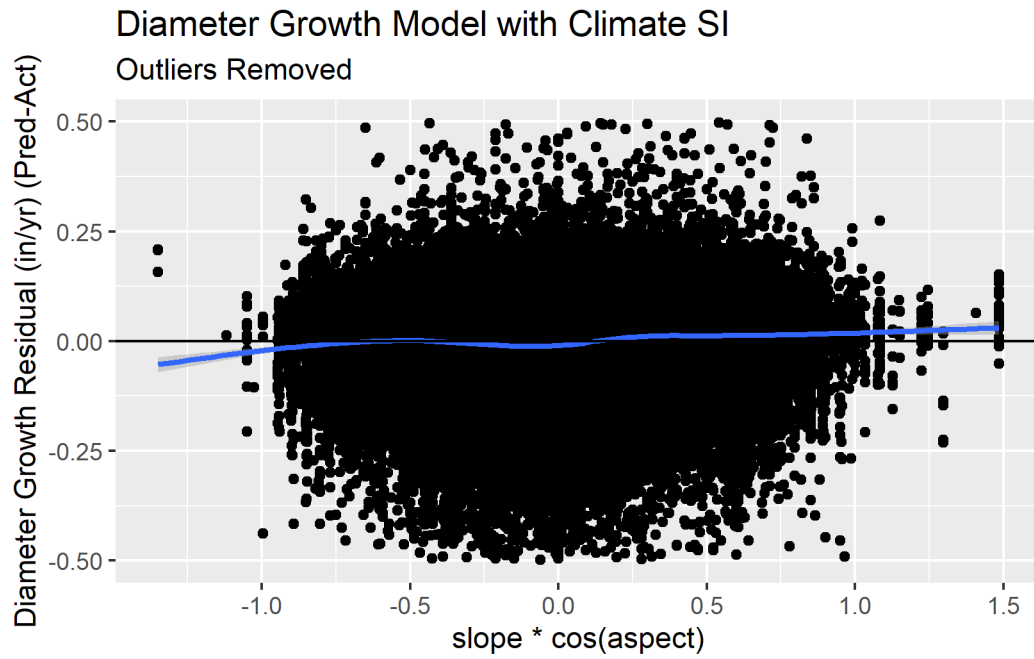Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI
Outliers Removed

Diameter Growth Model with Climate SI