University of Idaho
College of Natural Resources

INLAND NORTHWEST SEEDLING GROWTH & SURVIVAL MODEL

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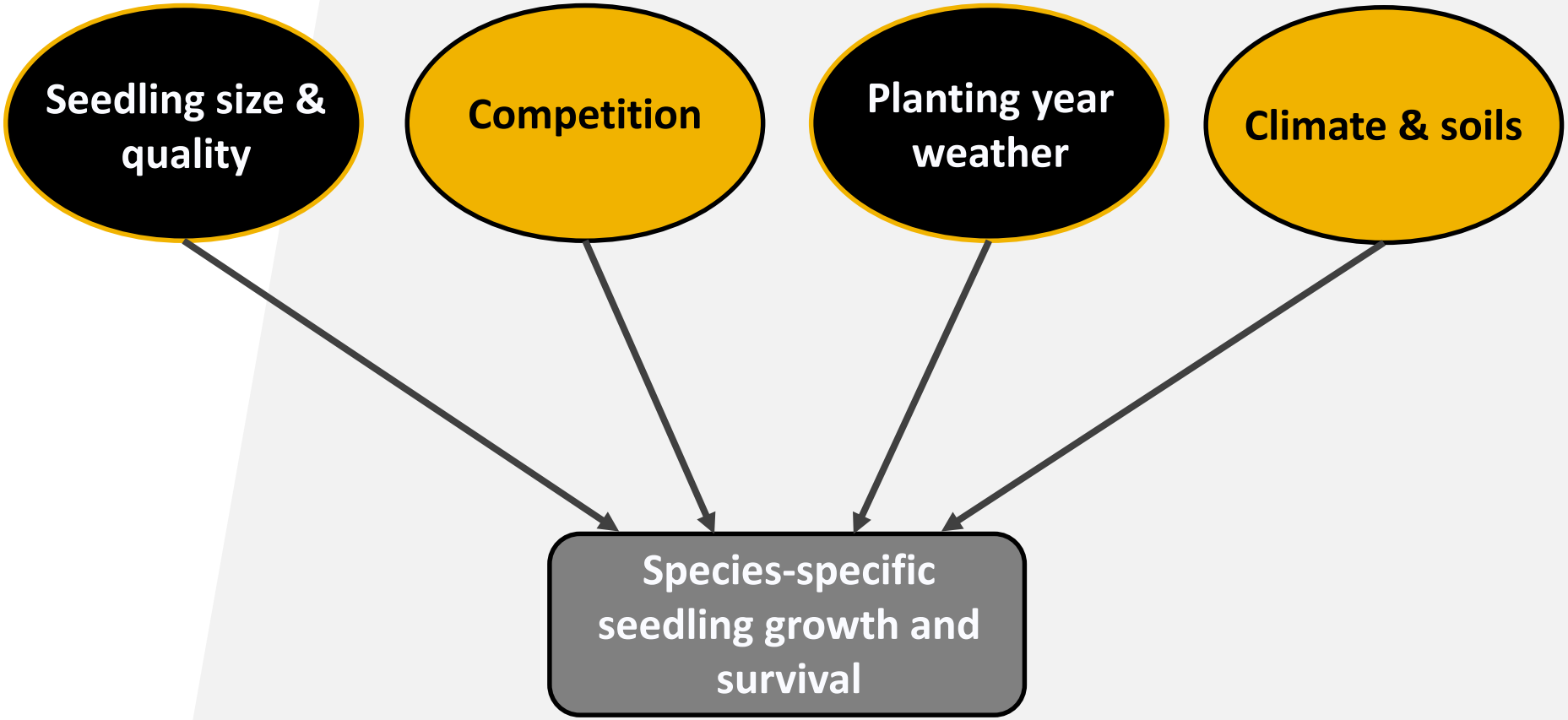
WHY DO WE NEED A SEEDLING MODEL?

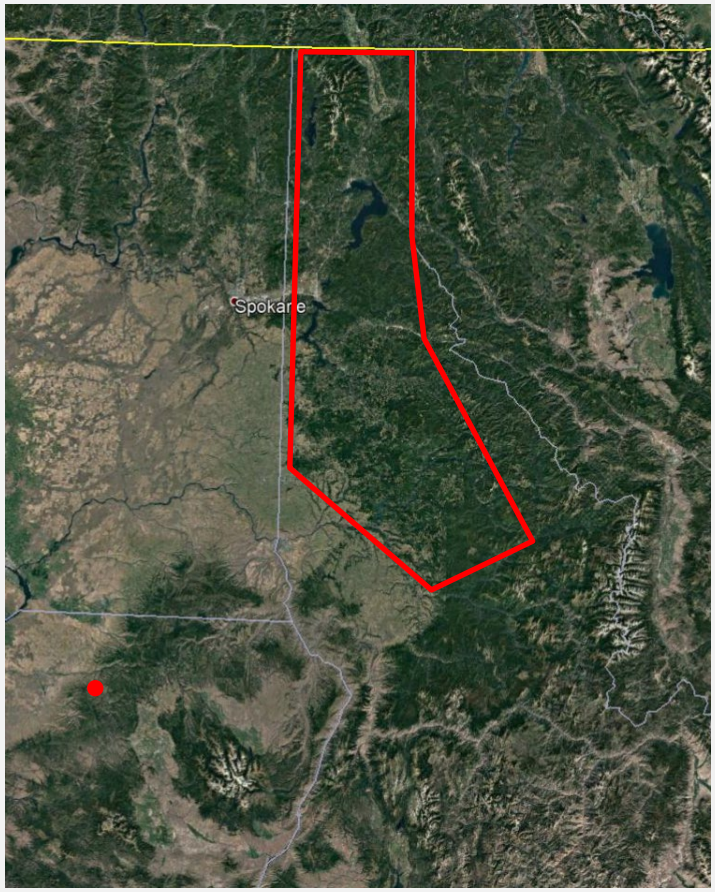
- Available G&Y models do not account for modern reforestation practices:
  - Lack ability to predict individual seedling growth & survival
  - Poorly account for competition from non-tree vegetation
  - Do not account for seedling variability from the nursery
  - Variable weather, soils, and climate of the INW influences seedling success
- Assist in developing precision silvicultural prescriptions

MODEL STRUCTURE



STUDY SITES PRIMARILY NORTHERN IDAHO

	Western Larch	Douglas-fir
Study Sites	31	25
Seedlots	58	39
Elevation Range	2,822-4,355 ft	2,822-4,276 ft
Habitat Types	Moist Grand fir-Western hemlock	Moist Grand fir-Western hemlock
Land Ownership	PotlatchDeltic, Hancock, Molpus, Stimson, UIdaho	PotlatchDeltic, Hancock, UIdaho, USFS
1 year observations	6,752	3,402
2 year observations	1,129	1,014



SEEDLING VARIABLES

Seedling Variable	Western Larch	Douglas-fir
	Mean (Range)	
Initial height (cm)	30.1 (8.5 – 56.0)	29.2 (8.8 – 57.8)
Initial caliper (mm)	3.9 (0.3 – 6.9)	4.0 (1.2 – 6.7)
Root growth potential (# new white roots)	13.2 (1.4 – 56.5)	30.6 (7.4 – 68.0)

SEEDLING QUALITY: ROOT GROWTH POTENTIAL

- "…defined as a seedling's ability to grow roots when placed into an environment which is highly favorable for root growth (ie. Warm, moist, well-lit)" (Ritchie & Tanaka 1990)

- Assesses seedling vitality (free of disease, injury, or stress)

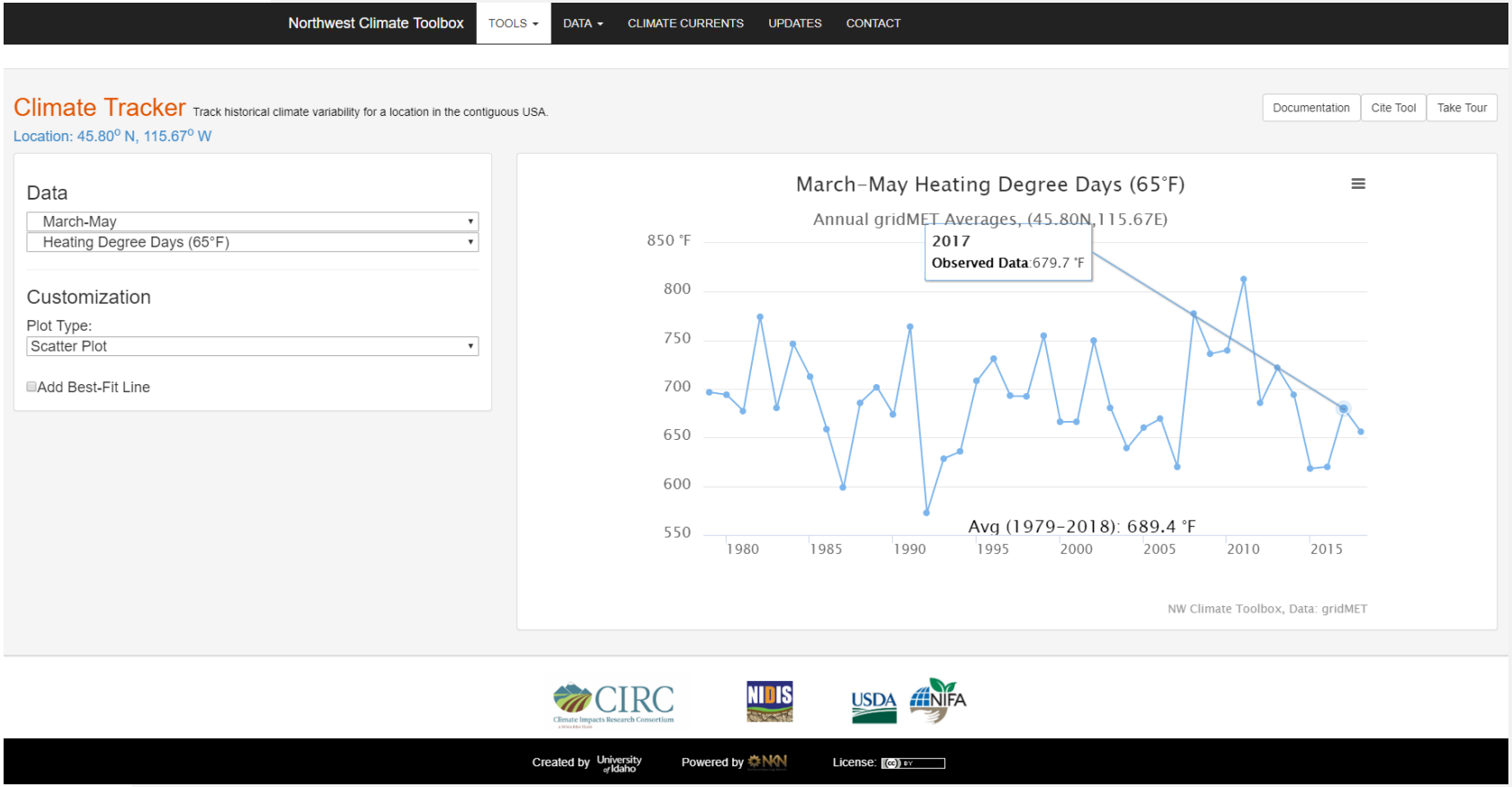
COMPETITION VARIABLES

Competition Variable	Western Larch	Douglas-fir
	Mean (Range)	
Forb (%)	12.2 (0 – 100)	18.0 (0 – 100)
Shrub (%)	3.4 (0 – 100)	7.5 (0 – 90)
Grass (%)	1.9 (0 – 100)	3.4 (0 – 90)
Slash (%)	27.4 (0 – 100)	22.7 (0 – 100)

PLANTING YEAR WEATHER VARIABLES

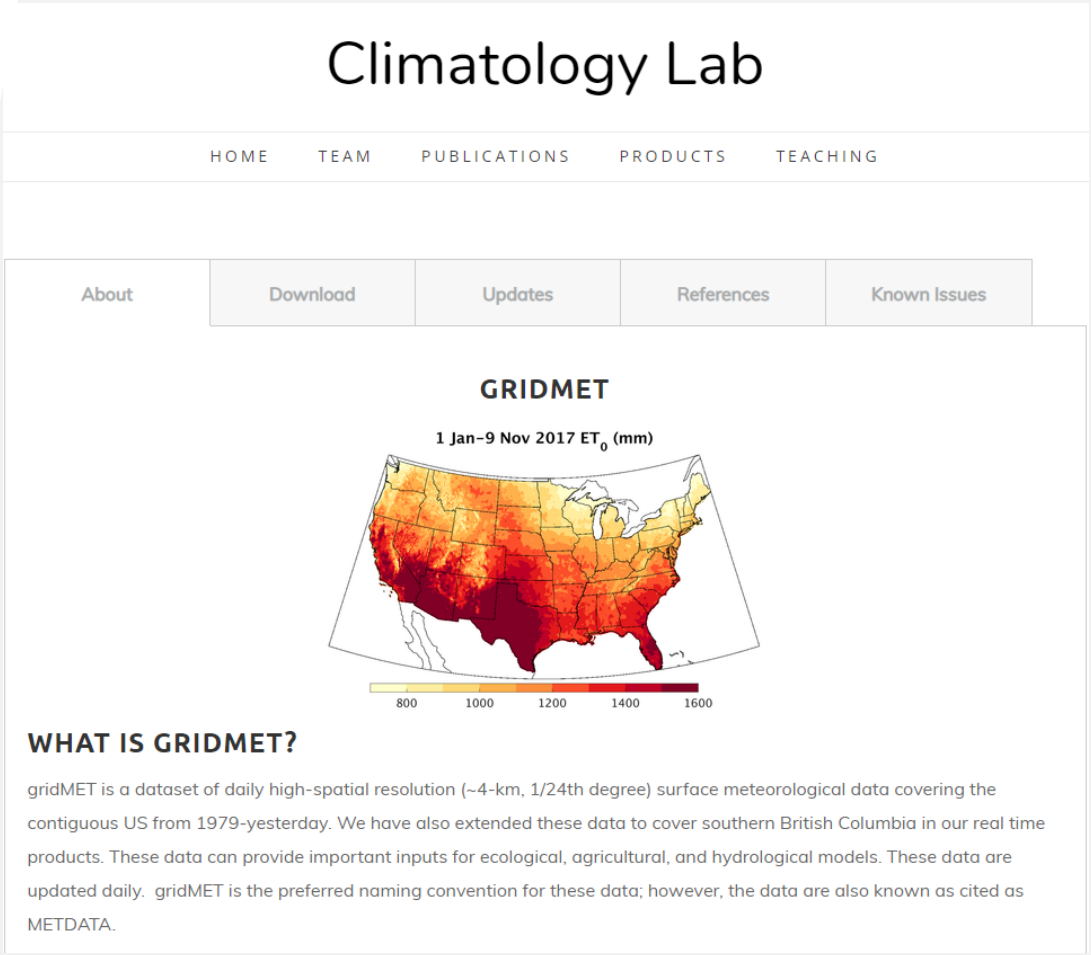
Weather Variable	Western Larch	Douglas-fir
	Mean (Range)	
March precipitation (mm)	82.8 (46.9 – 252.3)	110.2 (61.0 - 308.5)
March minimum temperature (°C)	-1.8 (-3.3 - -0.2)	-1.8 (-3.4 - -0.2)
March maximum temperature (°C)	7.7 (6.6 – 9.2)	8.2 (4.7 – 9.2)
March average temperature (°C)	2.9 (2.0 – 4.5)	3.2 (1.7 – 4.5)
June precipitation (mm)	45.8 (27.8 – 82.4)	42.9 (27.8 – 82.4)
June minimum temperature (°C)	6.9 (5.7 – 8.0)	7.0 (5.6 – 8.0)
June maximum temperature (°C)	20.5 (18.1 – 22.6)	21.3 (18.3 – 22.6)
June average temperature (°C)	13.7 (12.2 – 15.3)	14.1 (12.8 – 15.3)
August maximum temperature (°C)	27.0 (24.0 – 29.8)	27.6 (24.7 – 29.8)
August max vapor pressure deficit (kPa) (*Difference between amount of moisture in the air and how much moisture the air can hold when saturated*)	3.0 (2.5 – 3.4)	3.1 (2.6 – 3.4)
Heating degree days March-May 18.3 °C (°C) (*Number of degrees that a day's average temp is **below** 18.3 °C*)	290.4 (256.8 – 348.6)	286.5 (256.8 – 354.9)
Cooling degree days June-Aug. 18.3 °C (°C) (*Number of degrees that a day's average temp is **above** 18.3 °C*)	11.2 (0.0 – 26.8)	9.5 (0.4 – 26.8)

WEATHER FROM CLIMATE TRACKER



https://climatetoolbox.org/tool/historical-climate-tracker

CLIMATE TRACKER BASED ON GRIDMET

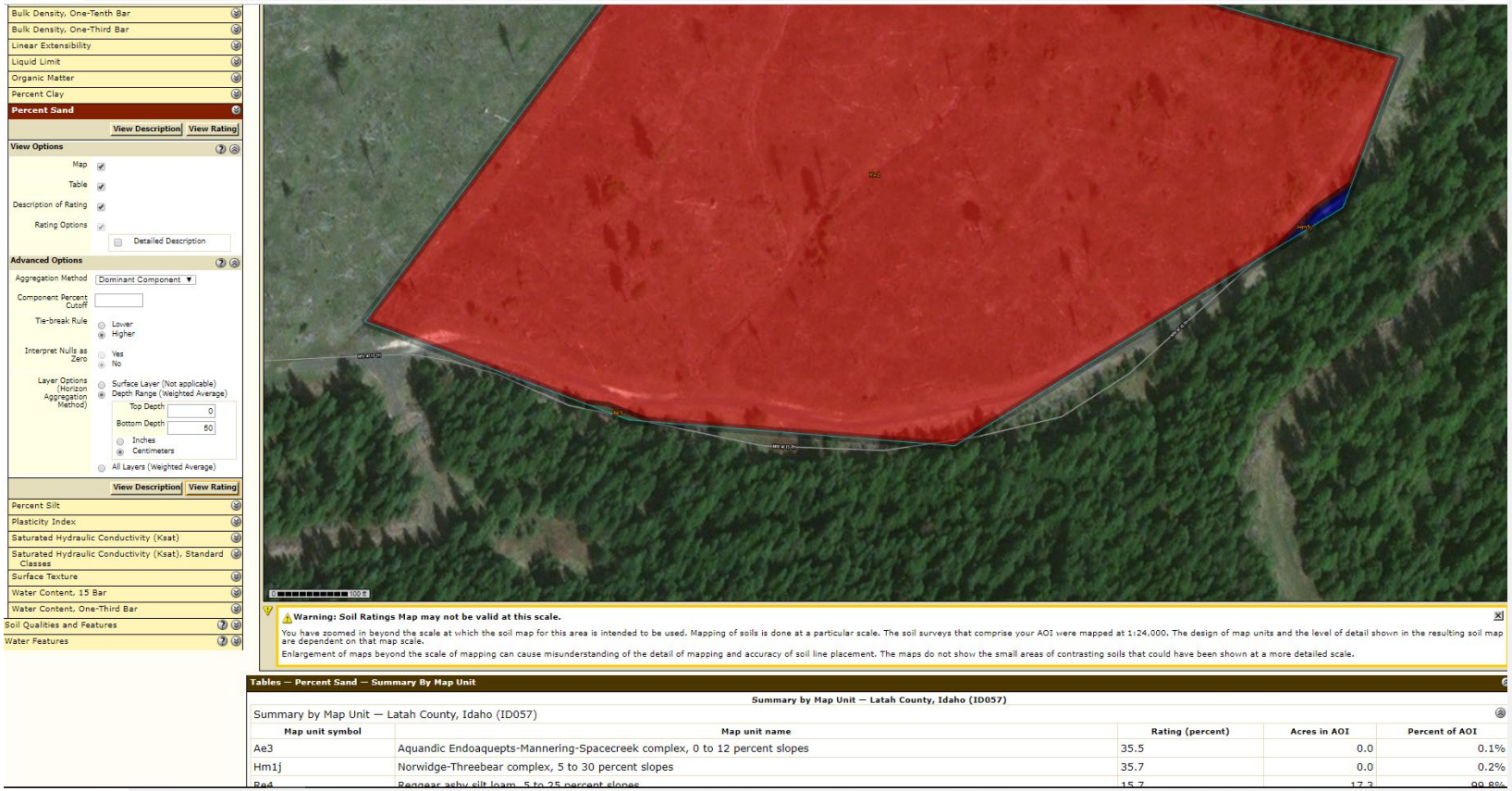


http://www.climatologylab.org/gridmet.html

SITE VARIABLES

Site Variable	Western Larch	Douglas-fir
	Mean (Range)	
Available water supply 0-50 cm (cm)	11.2 (4.6-15.5)	11.9 (8.9-15.5)
Bulk density top 50 cm (g/cm^3)	0.64 (0.20 – 1.16)	0.47 (0.20 – 1.52)
Soil organic matter (%)	4.8 (1.8 – 11.3)	3.5 (2.0 – 8.0)
Sand 0-50 cm (%)	37.4 (15.7 – 50.6)	30.9 (19.7 – 50.6)
Precipitation (mm) May-September. 30-year norm (1980-2010)	246.0 (204.5 – 318.3)	262.7 (219.5 – 328.2)
Max temperature (°C) May-September. 30-year norm (1980-2010)	22.2 (18.9 – 24.1)	22.5 (20.4 – 24.1)
Min temperature (°C) May-September. 30-year norm (1980-2010)	6.2 (5.2 – 7.5)	6.1 (4.9 – 7.5)

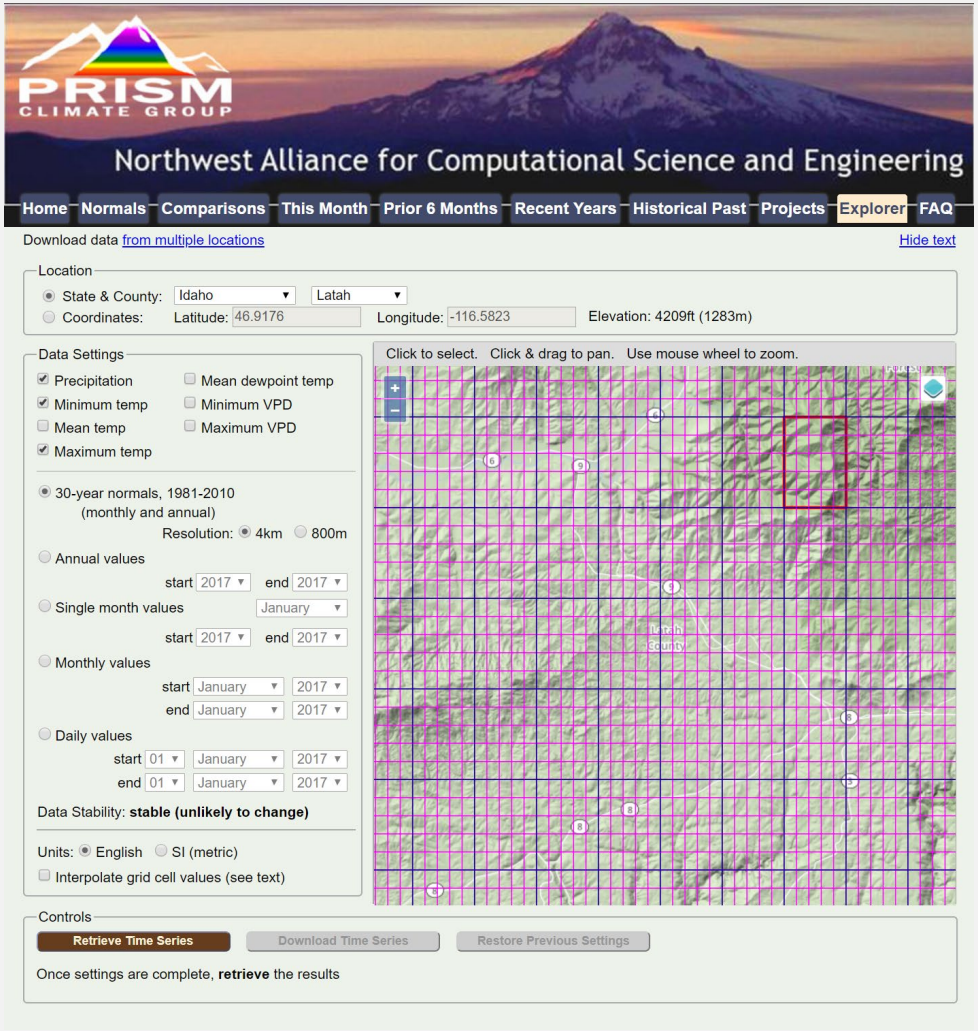
SOILS DATA FROM WEB SOIL SURVEY



UI Experimental Forest

https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

LONG-TERM CLIMATE DATA FROM PRISM



http://www.prism.oregonstate.edu/

SURVIVAL MODEL FORM

$$Survival = \frac{e^{a+b\times SEEDLING+c\times COMP+d\times WEATHER+e\times SITE}}{1+e^{a+b\times SEEDLING+c\times COMP+d\times WEATHER+e\times SITE}}$$

$$b \times \textbf{\textit{SEEDLING}} = b_1 ht_0 + b_2 cal_0 + b_3 RGP_{count}$$

$$c \times \textbf{\textit{COMP}} = c_1 Forb + c_2 Shrub + c_3 Grass + c_4 Slash$$

$$d \times \textbf{\textit{WEATHER}} = d_1 Precip_{June} + d_2 HDD_{March\text{-}May} + d_3 VPDmax_{Aug}$$

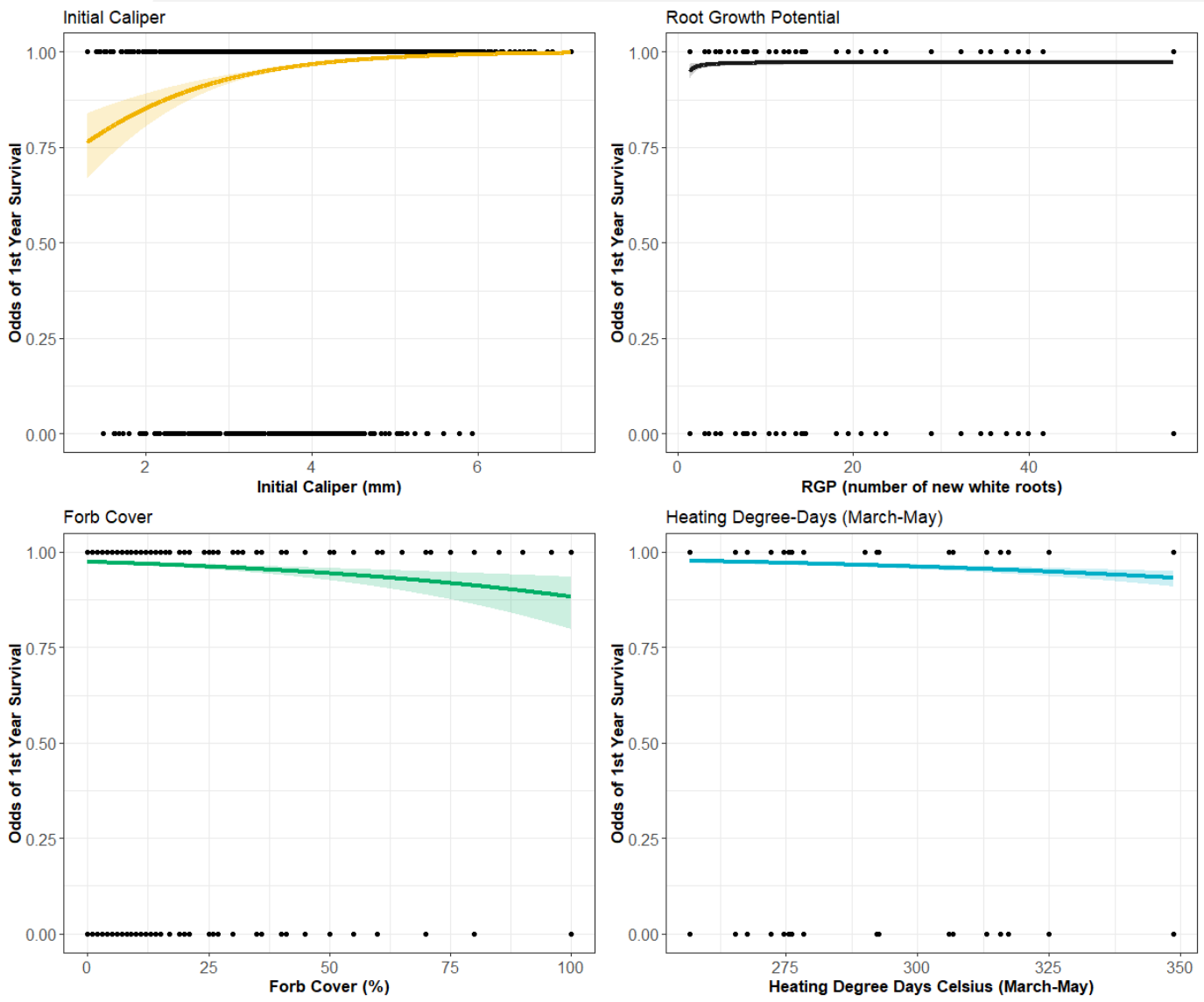
$$e \times \textbf{\textit{SITE}} = e_1 Sand_{50} + e_2 MaxTemp_{May\text{-}Sept}$$

Logistic regression with binary response (1=alive, 0=dead)
Removed damaged or browsed seedlings

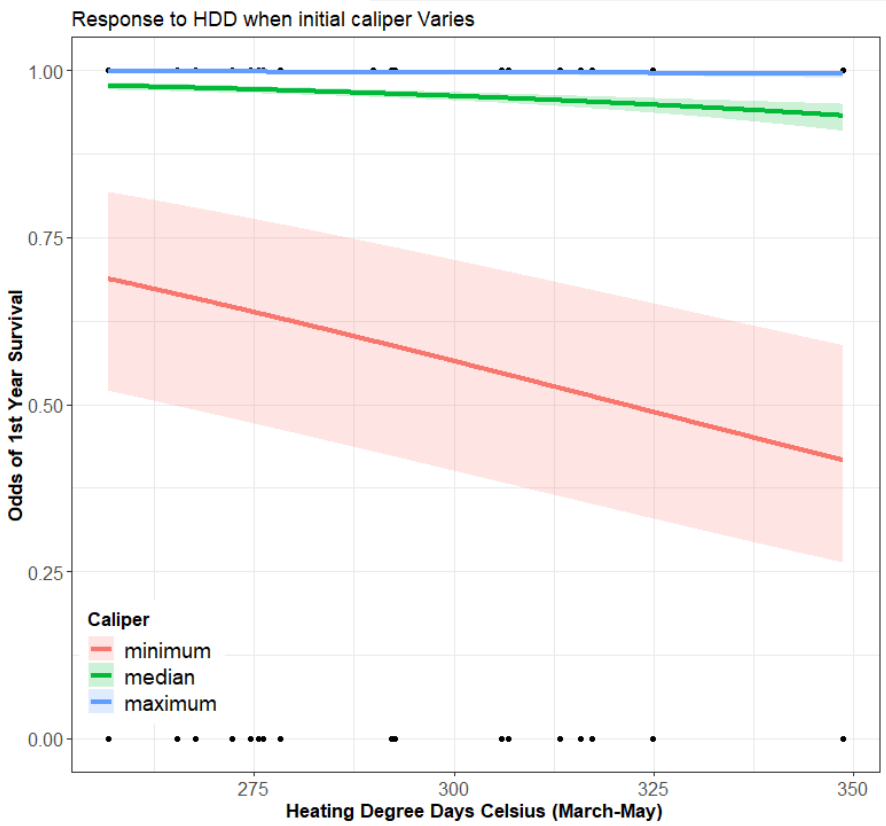
1-YEAR SURVIVAL MODEL PARAMETERS

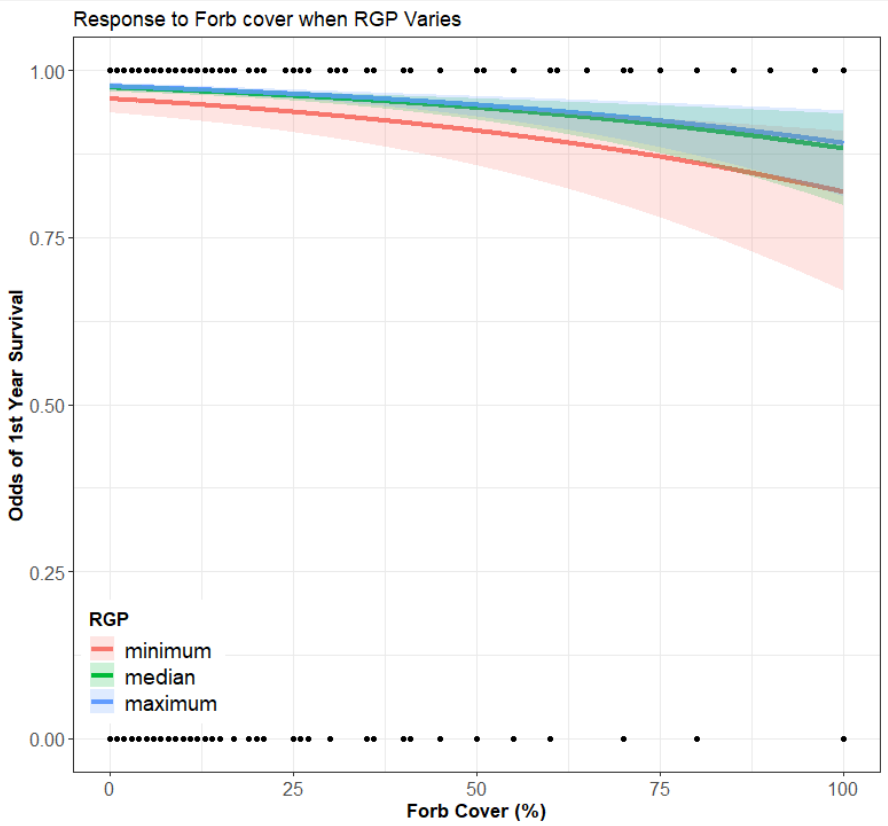
Parameter	Western Larch	Douglas-fir
Intercept	4.353815	27.769755
Ht_0 (initial height)	- -0.035715	-
Cal_0 (initial diameter)	+ 0.819334	-
RGP_{count}^{-1}	+ -0.859206	- 17.054616
Forb (%)	- -0.016115	-
Shrub (%)	-	-
Grass (%)	-	-
Slash (%)	-	-
June precipitation	+ 0.014390	+ 0.044786
Spring heating degree-days	- -0.012270	- -0.059624
August max VPD (kPa)	-	- -1.584204
Sand upper 50 cm (%)	-	- -0.101531
May-Sept max temperature	-	-

WESTERN LARCH 1ST YEAR SURVIVAL

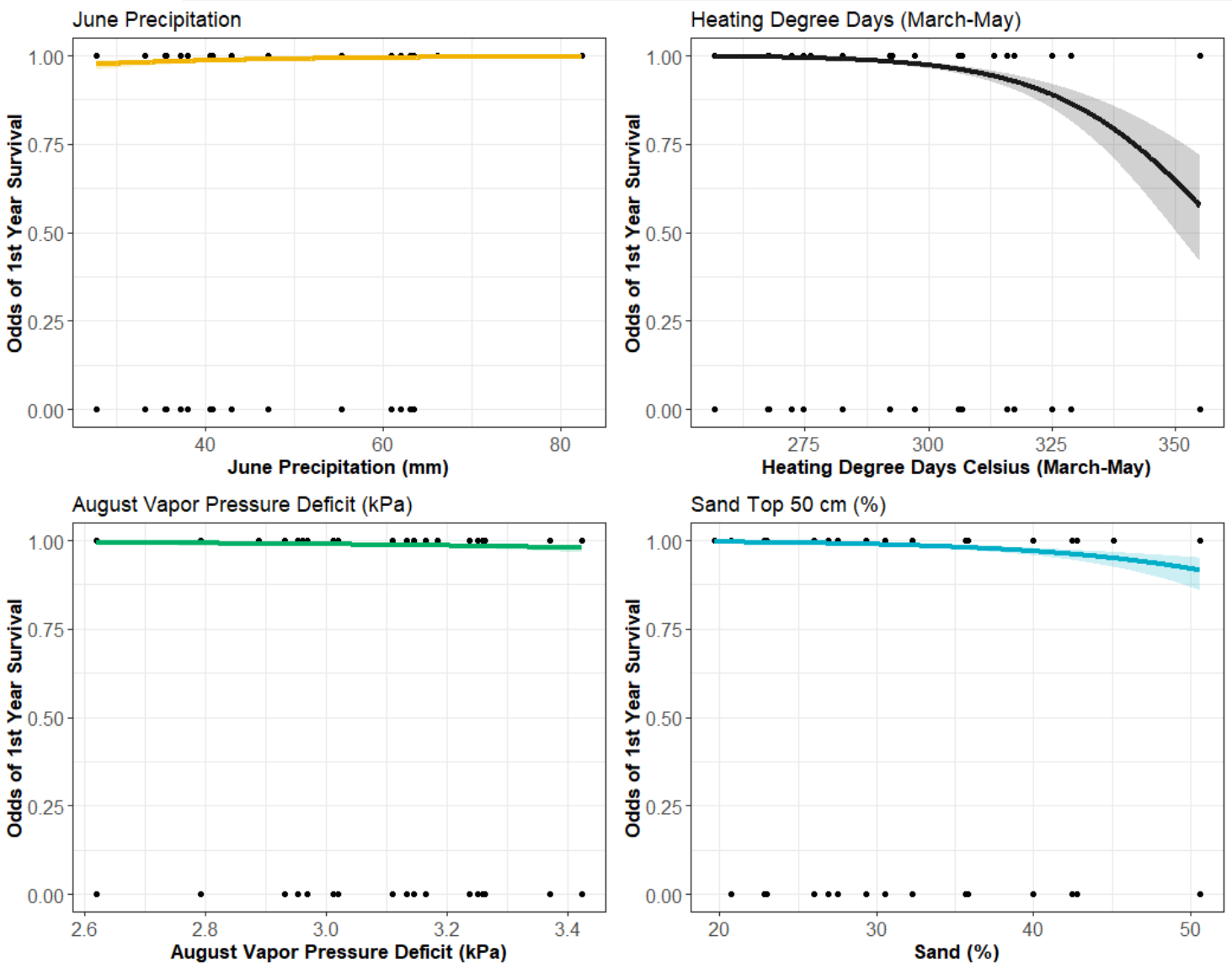


WL SURVIVAL – INTERACTING FACTORS

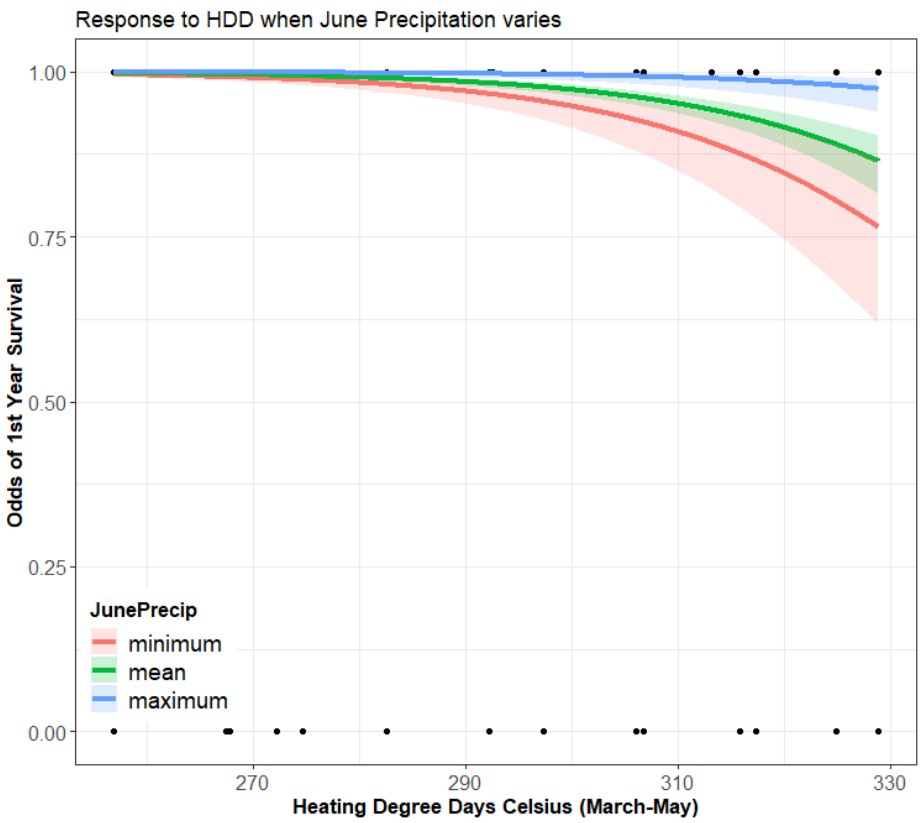


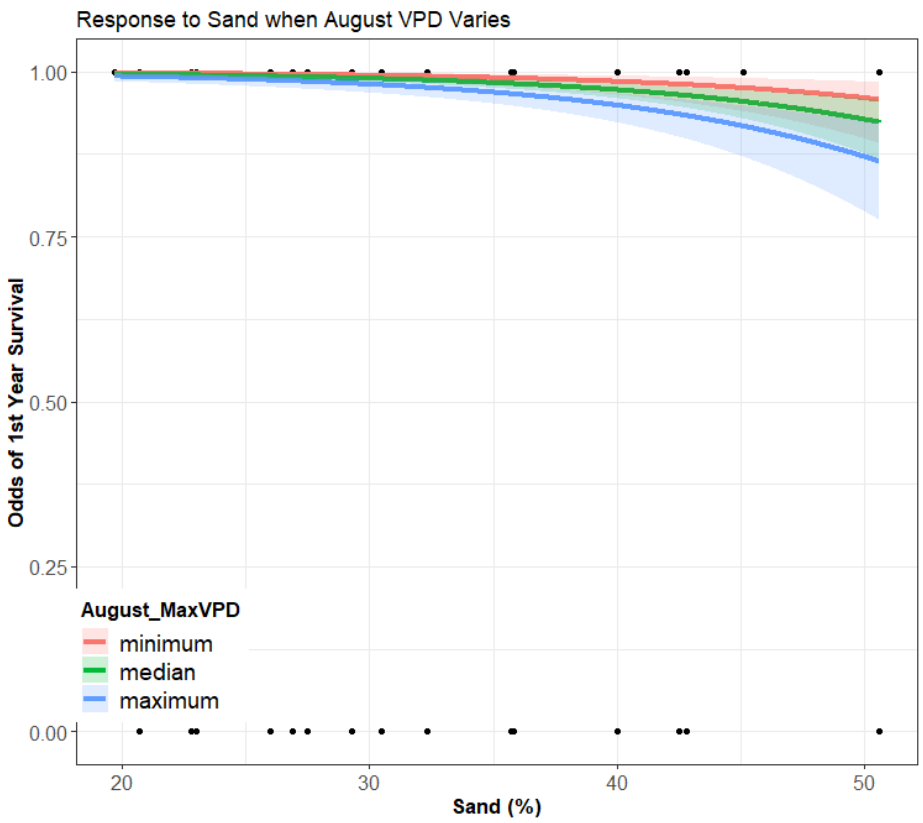


DOUGLAS-FIR 1ST YEAR SURVIVAL



DF SURVIVAL – INTERACTING FACTORS





CALIPER GROWTH MODEL FORM

$$\ln(cal_1 - cal_0) = a + b \times \boldsymbol{SEEDLING} + c \times \boldsymbol{COMP} + d \times \boldsymbol{WEATHER} + e \times \boldsymbol{SITE}$$

$$b \times \boldsymbol{SEEDLING} = b_1 ht_0 + b_2 cal_0 + b_3 RGP_{count}$$

$$c \times \boldsymbol{COMP} = c_1 Forb + c_2 Shrub + c_3 Grass + c_4 Slash$$

$$d \times \boldsymbol{WEATHER} = d_1 Precip_{March} + d_2 HDD_{Mar\text{-}May}$$

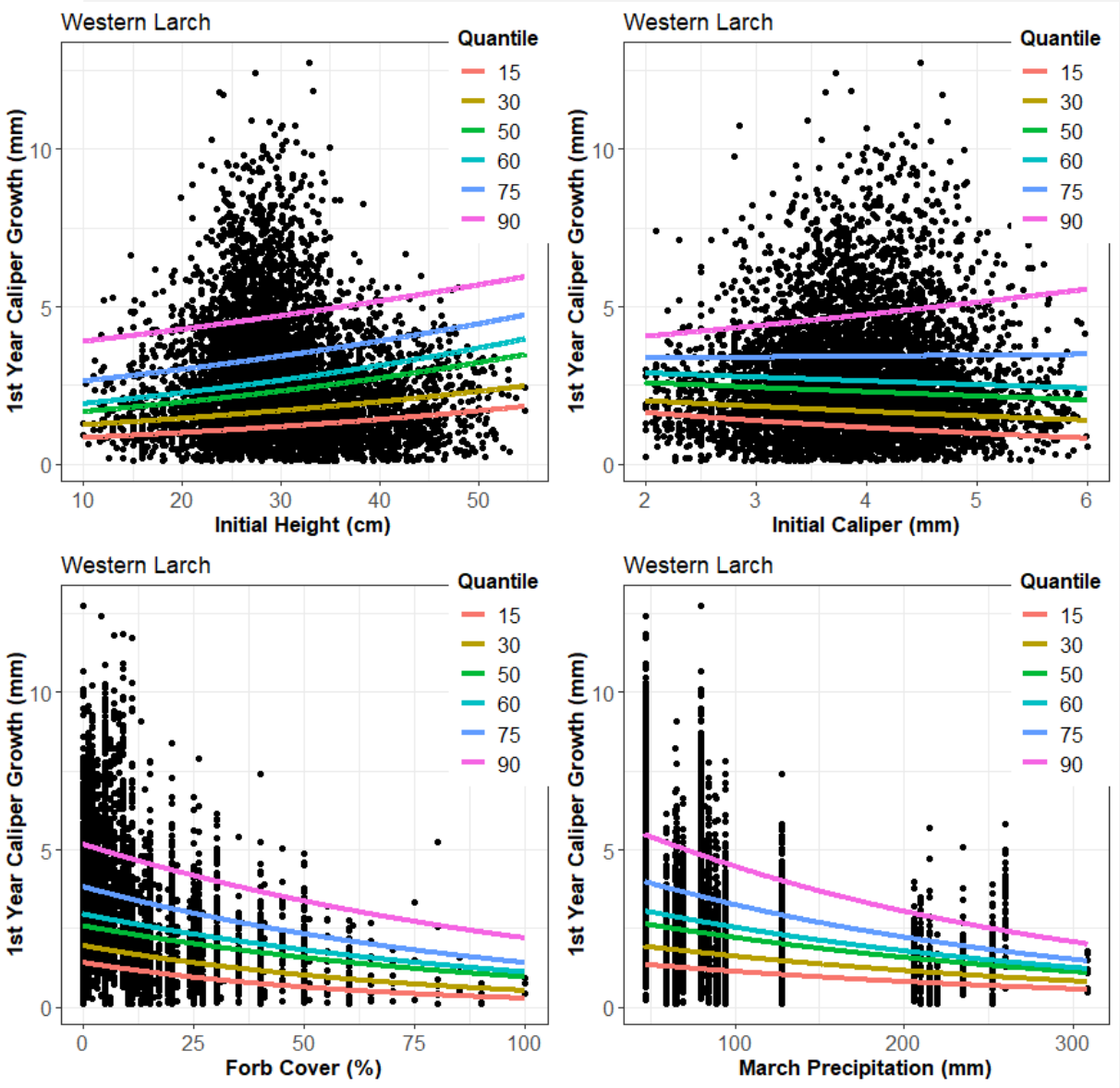
$$e \times \boldsymbol{SITE} = e_1 Sand_{50} + e_2 ASW_{0\text{-}50}$$

Fit with quantile regression (15th, 30th, 45th, 60th, 75th, 90th quantiles [percentiles])

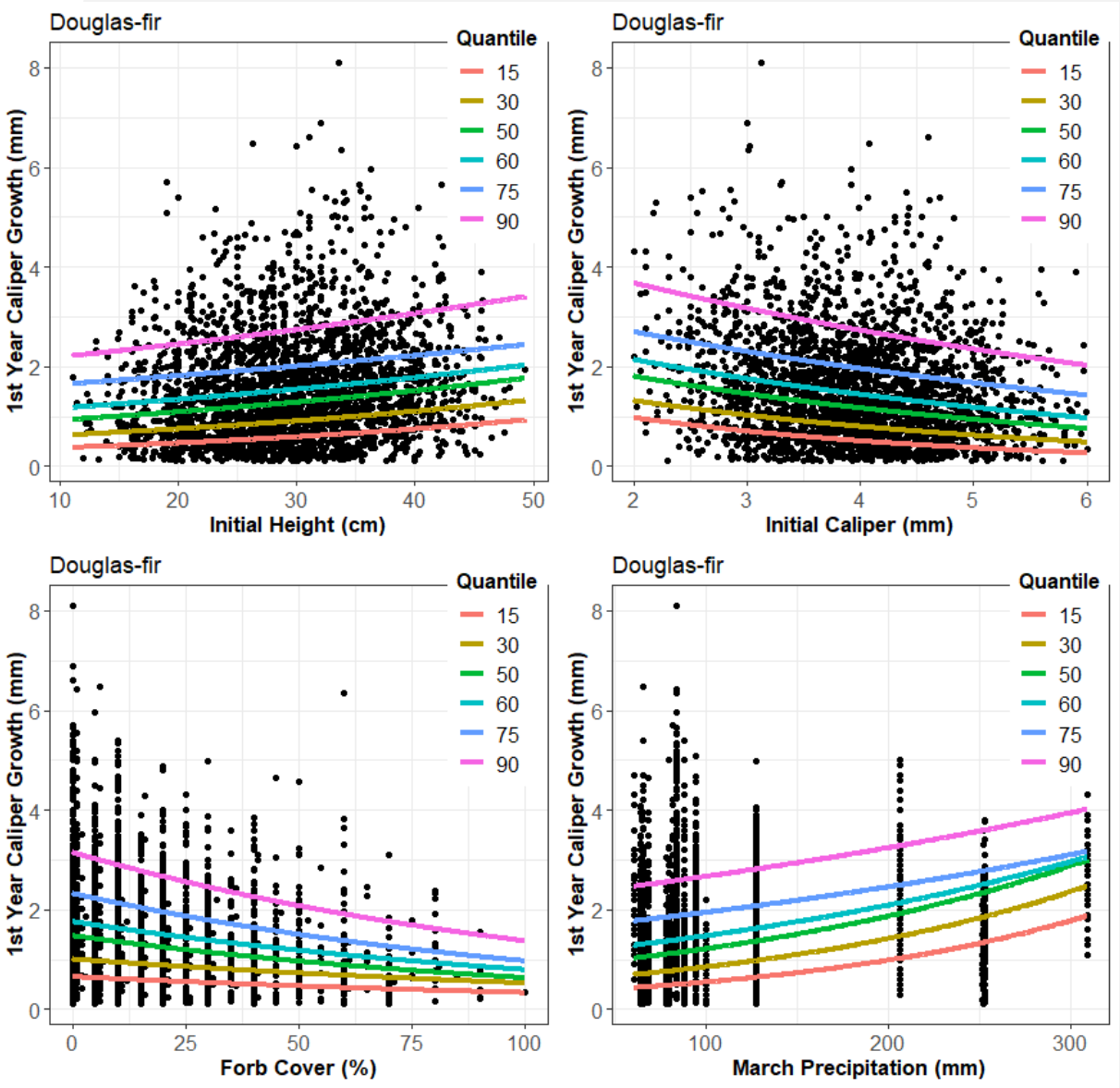
MEDIAN 1-YEAR CALIPER MODEL PARAMETERS

Parameter	Western Larch	Douglas-fir
Intercept	-	1.62162
Ht_0 (cm)	+ 0.01646	+ 0.01649
Cal_0 (mm)	- -0.05984	- -0.21839
RGP_{count} (count of new roots)	- -0.01048	- -0.00855
Forb (%)	- -0.00994	- -0.00855
Shrub (%)	- -0.01368	- -0.01232
Grass (%)	- -0.00550	-
Slash (%)	-	+ 0.00711
March precipitation (mm)	- -0.00337	+ 0.00434
Spring heating degree-days (°C)	+ 0.00400	- -0.00799
Sand upper 50 cm (%)	-	-
Available soil water 0-50 cm (cm)	-	+ 0.07084

WESTERN LARCH 1 YEAR CALIPER GROWTH



DOUGLAS-FIR 1 YEAR CALIPER GROWTH



WESTERN LARCH EXAMPLE (50TH PERCENTILE)

HT_0	Cal_0	RGP	Forb	Shrub	Grass	March precip	June precip	HDD
31.8	2.0	15	10	0	5	90	40	290
22.0	1.9	15	40	5	15	90	40	290
30.2	3.4	15	10	0	0	90	40	290
27.1	1.8	15	20	10	5	90	40	290
32.4	4.1	15	60	0	5	90	40	290
28.7	3.8	15	20	0	0	90	40	290

WESTERN LARCH EXAMPLE (50TH PERCENTILE)

HT_0	Cal_0	RGP	Forb	Shrub	Grass	March precip	June precip	HDD	Surv
31.8	2.0	15	10	0	5	90	40	290	0.84
22.0	1.9	15	40	5	15	90	40	290	0.81
30.2	3.4	15	10	0	0	90	40	290	0.95
27.1	1.8	15	20	10	5	90	40	290	0.82
32.4	4.1	15	60	0	5	90	40	290	0.93
28.7	3.8	15	20	0	0	90	40	290	0.96

WESTERN LARCH EXAMPLE (50TH PERCENTILE)

HT_0	Cal_0	RGP	Forb	Shrub	Grass	March precip	June precip	HDD	Surv	Calg (mm)
31.8	2.0	15	10	0	5	90	40	290	0.84	0.92
22.0	1.9	15	40	5	15	90	40	290	0.81	0.30
30.2	3.4	15	10	0	0	90	40	290	0.95	0.84
27.1	1.8	15	20	10	5	90	40	290	0.82	0.62
32.4	4.1	15	60	0	5	90	40	290	0.93	0.19
28.7	3.8	15	20	0	0	90	40	290	0.96	0.67

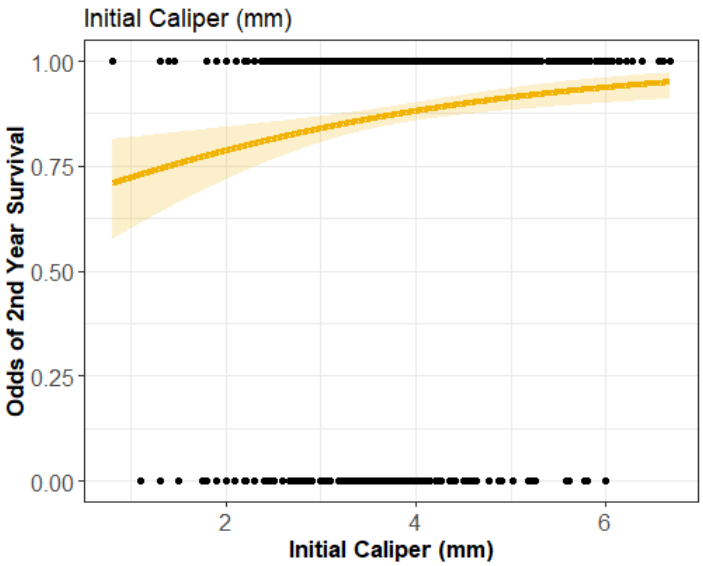
WESTERN LARCH EXAMPLE (50TH PERCENTILE)

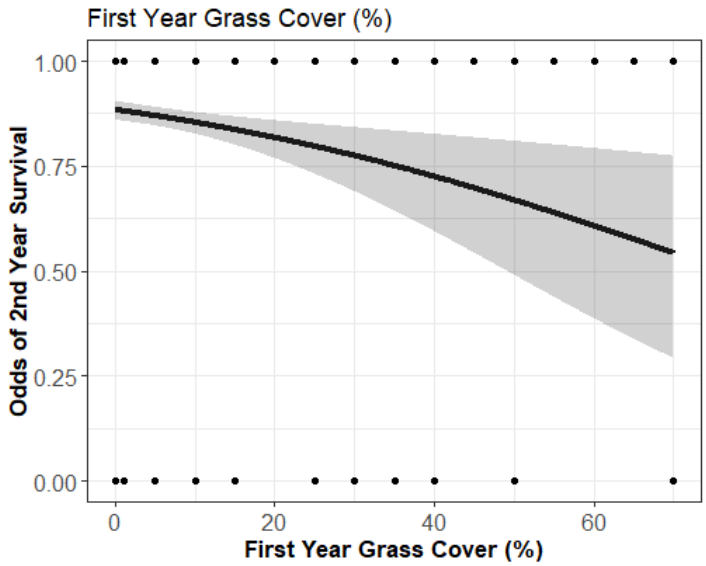
HT_0	Cal_0	RGP	Forb	Shrub	Grass	March precip	June precip	HDD	Surv	Calg (mm)
31.8	2.0	15	10	0	5	90	40	290	0.84	0.92
22.0	1.9	15	40	5	15	90	40	290	0.81	0.30
30.2	3.4	15	10	0	0	90	40	290	0.95	0.84
27.1	1.8	15	20	10	5	90	40	290	0.82	0.62
32.4	4.1	15	60	0	5	90	40	290	0.93	0.19
28.7	3.8	15	20	0	0	90	40	290	0.96	0.67
								AVERAGE:	**0.84**	**0.92**

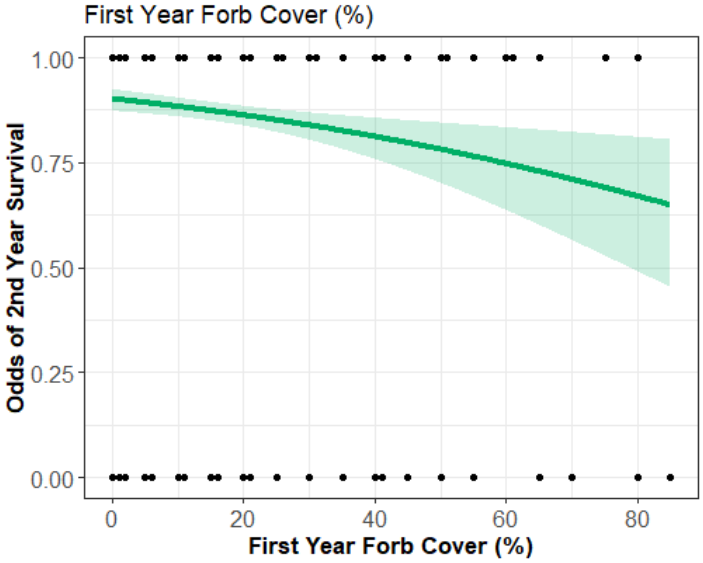
2-YEAR SURVIVAL MODEL PARAMETERS

Parameter	Western Larch	Douglas-fir
Intercept	-	12.139152
Ht_0 (initial height)	-	- -0.050704
Cal_0 (initial diameter)	+ 0.348039	-
RGP_{count}	-	
Forb (%)	- -0.018821	
Shrub (%)	-	- -0.017286
Grass (%)	- -0.026557	-
Slash (%)	-	-
June precipitation	+ 0.221188	-
Spring heating degree-days	- -0.033953	- -0.017681
Sand upper 50 cm (%)	- -0.307795	- -0.119052

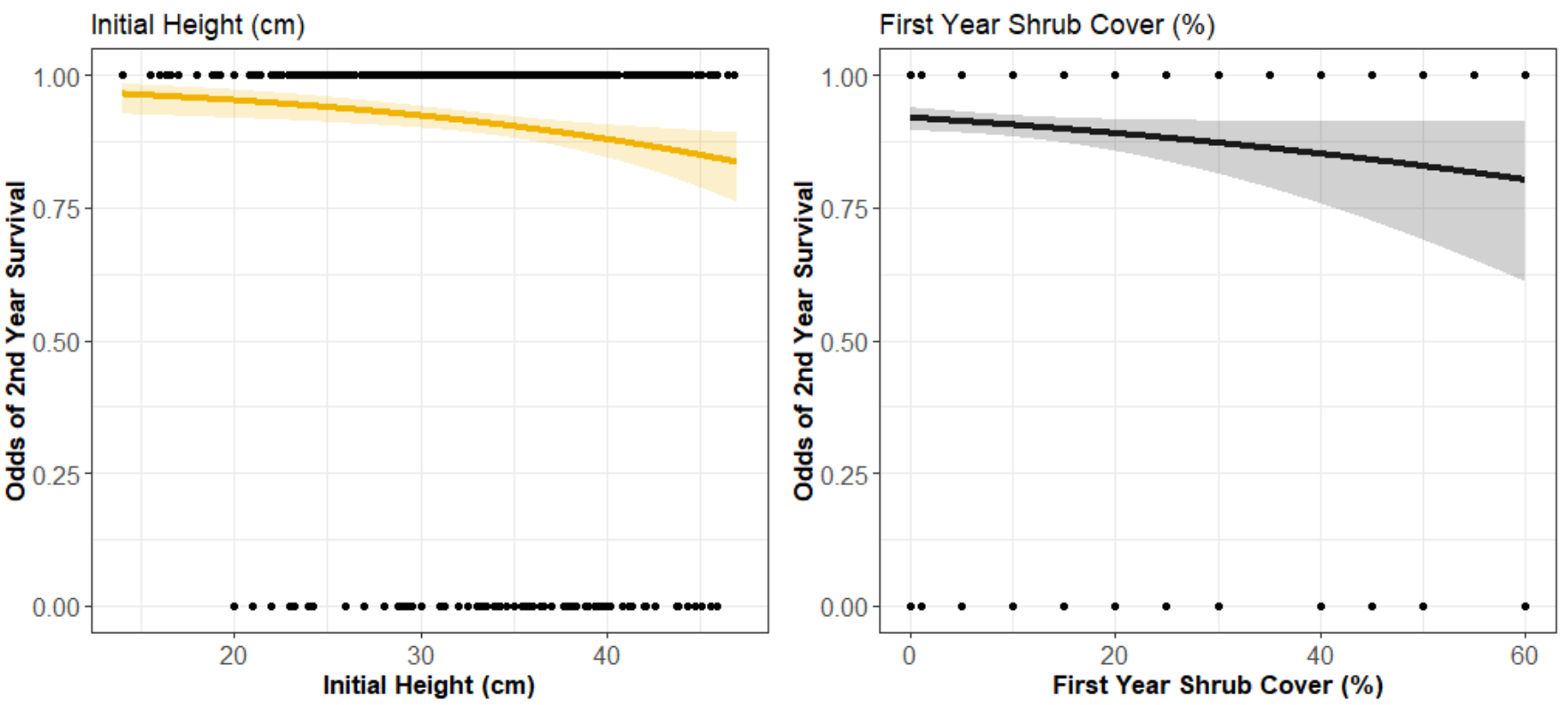
WESTERN LARCH 2-YEAR SURVIVAL







DOUGLAS-FIR 2-YEAR SURVIVAL



SUMMARY

- First year growth and survival is a start to better understand drivers of DF and WL seedling performance in the INW.
- Model is unique: includes initial seedling size, seedling quality, competition, planting-year weather, and site characteristics all easily measured or obtained from public sources.
- More precipitation in June and cooler spring temps (lower heating degree days) resulted in greater survival for both WL and DF.
- Larger caliper seedlings and greater competition from forbs, shrubs, and grasses led to lower caliper growth during the first season.
- Greater March precipitation led to less WL caliper growth but greater DF caliper growth demonstrating different species sensitivity to weather.

NEXT STEPS

- Work with cooperators to measure additional seedlings planted in 2019
- Remeasure first year seedlings to increase number of observations for 2nd year modeling
- Track growth and survival through age 5
- Obtain individual seedling data from broad range of site productivity and geography
- Expand model to additional species: Ponderosa pine, lodgepole pine, and western white pine

ACKNOWLEDGEMENTS

- PotlatchDeltic Corporation
- Hancock Forest Management
- Stimson Lumber Company
- Molpus Timberland Investment
- USDA Forest Service RMRS
- UIdaho Experimental Forest
- Lori Mackey (CFNSR)
- Numerous field crew members