ESTIMATING SITE PRODUCTIVITY OF DOUGLAS-FIR AND PONDEROSA PINE STANDS IN IDAHO WITH A GEOGRAPHICALLY WEIGHTED REGRESSION

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OUTLINE

- Background
  - Need for site productivity information in Idaho
- Past Studies
- Data
  - Site index Data
  - Climate data
  - Soil data
- Methods
- Results
  - Multiple linear regression
- Next Steps

BACKGROUND – SITE PRODUCTIVITY IN IDAHO

- Previous Site Productivity
  - Idaho previously related productivity to habitat type and land classification which can change over time (Pfiser, 1980)
  - There are many other factors that influence tree productivity
    - We’re trying to use these factors identified in previous projects to create a site productivity map for Idaho

STUDY OBJECTIVE

- We want to create a 90 meter Site Index Map for the State of Idaho
  - Using geophysical variables and climate factors instead of habitat types
  - Generate maps for multiple species
    - Initially Douglas-fir and Ponderosa Pine

PRIOR STUDIES

- Milner and Monserud:
  - Milner had equations for Ponderosa Pine and Douglas-fir trees

$$\text{PP } SI = 59.6 + (4.787 + 0.012544 \cdot A - 1.141 \cdot \text{Ln}A + 11.44/A^2) \cdot (H\text{-}4.5 - 121.4 \cdot [1\text{-EXP}(-0.01756 \cdot A)] ** 1.483)$$

(Milner, 1992)

$$\text{DF } SI = 57.3 + (7.06 + 0.02275 \cdot A - 1.858 \cdot \text{Ln}A + 5.496/A^2) \cdot (H\text{-}4.5 - 114.6 \cdot [1\text{-EXP}(-0.01462 \cdot A)] ** 1.179)$$

(Milner, 1992)

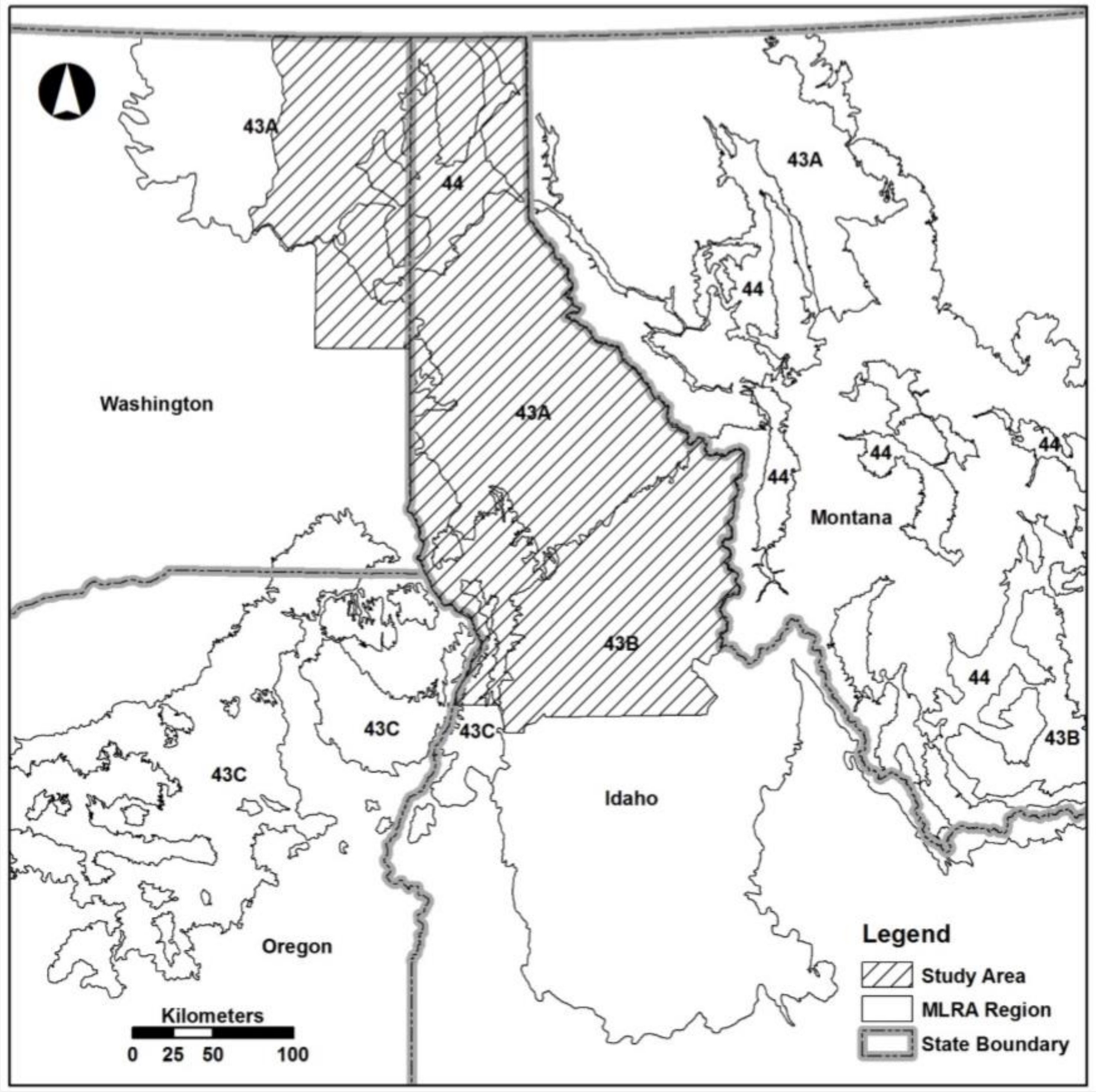
  - Monserud developed equations for generating site index productivity using habitat types.
    - Equation for DF using habitat type

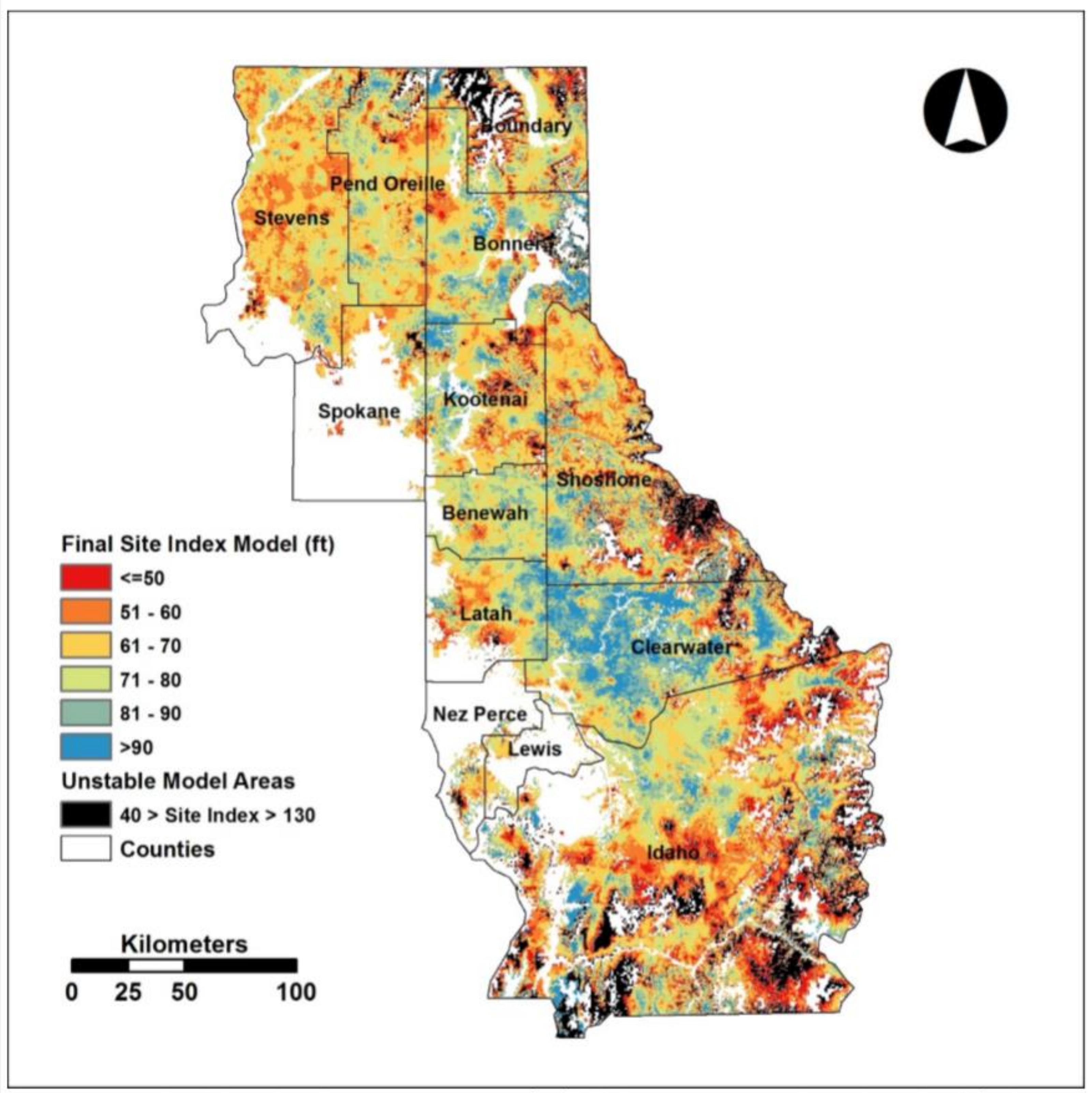
$$\hat{S} = 38.878 - 2.805(\ln A)^2 + 0.0216 \cdot A \cdot \ln A + 0.4305 \cdot H + 28.415 \cdot H/A.$$

(Monserud, 1984)

PRIOR STUDIES

- Site Index Model for Northern Idaho and Northeast Washington created by Mark Kimsey in 2014
  - This project used geophysical variables instead of traditional habitat conditions

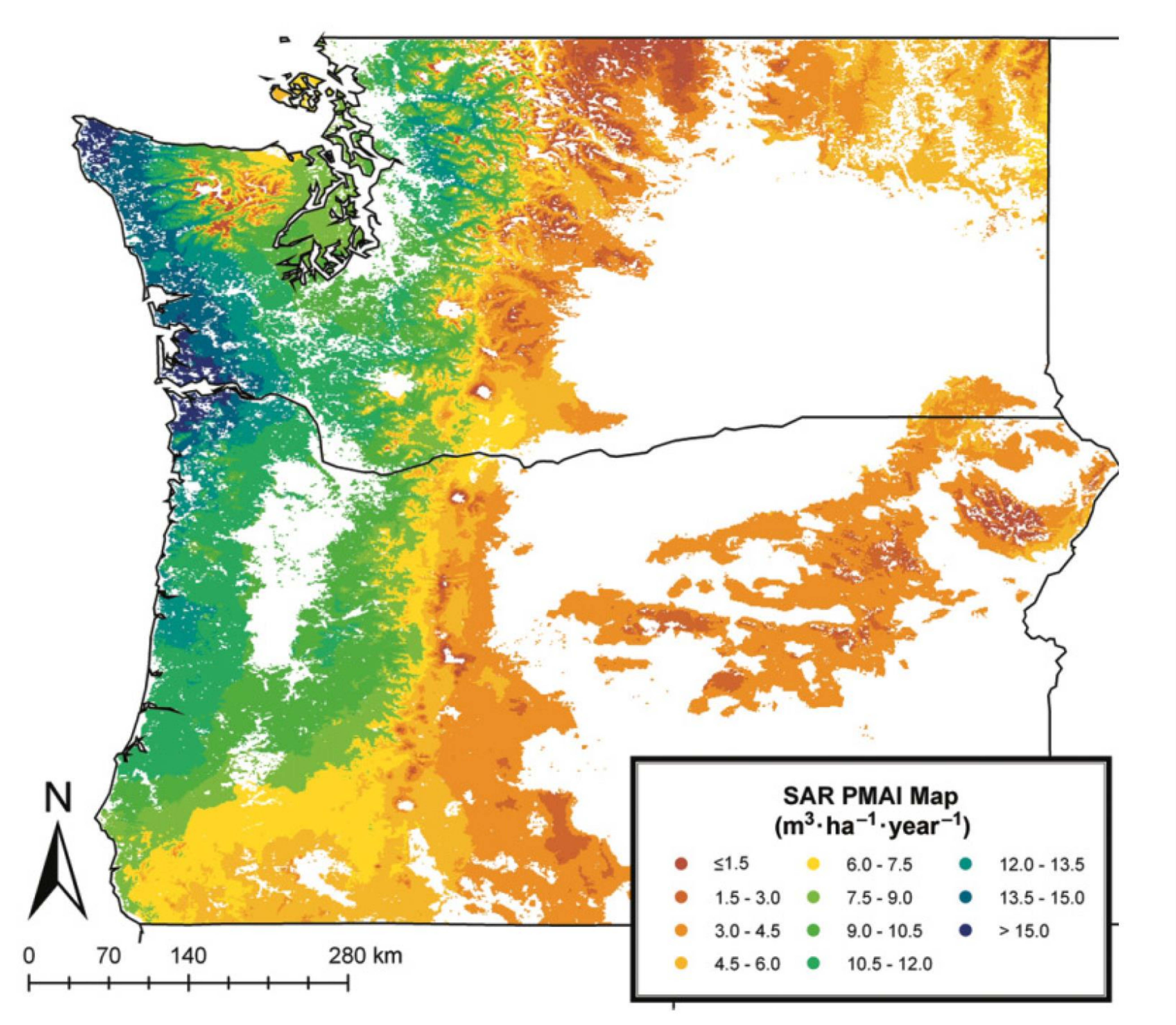




(Kimsey, 2014)

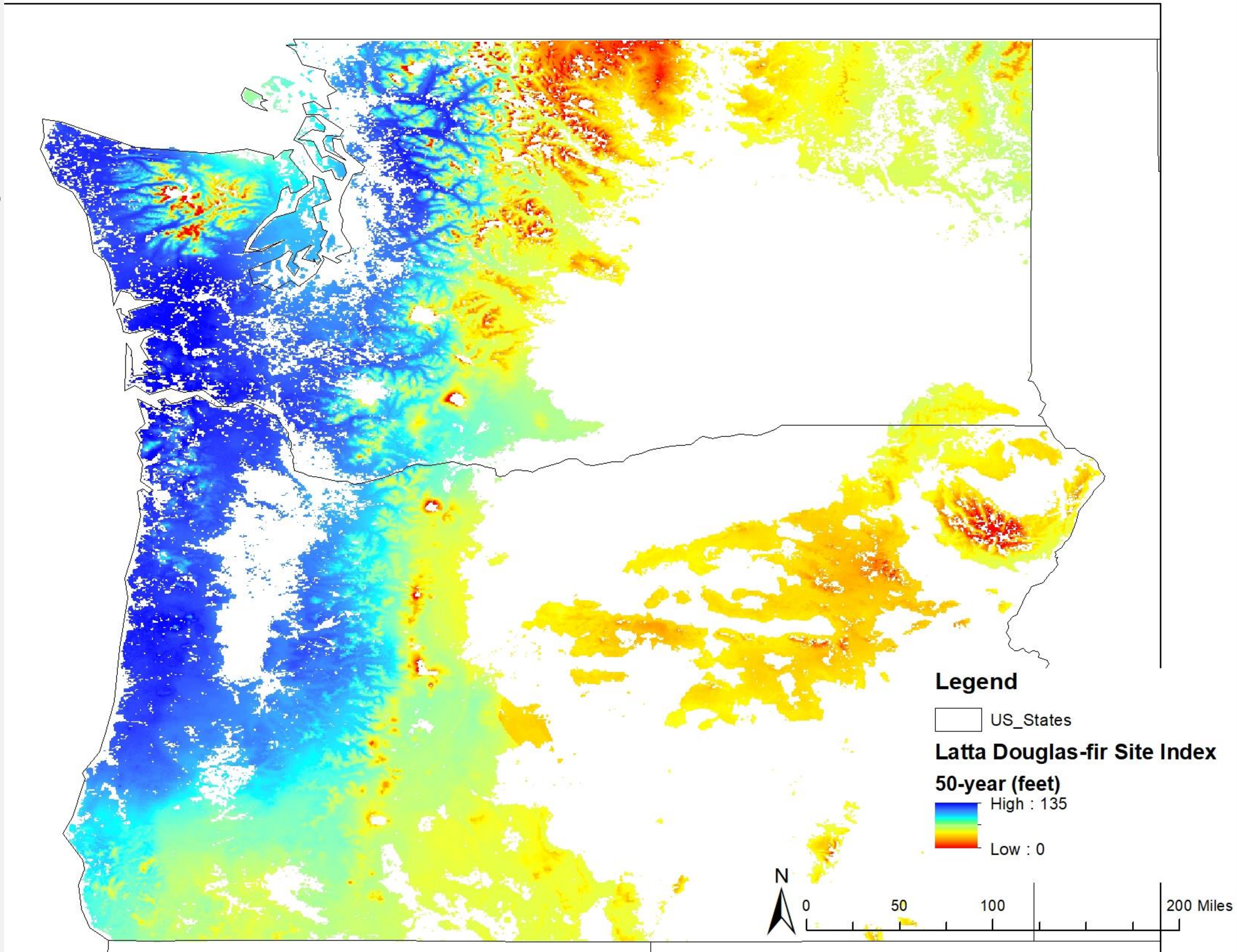
PRIOR STUDIES

- Greg Latta 2009- imputation of forest productivity in US PNW (specifically Oregon and Washington)
- Similar data to Kimsey in that it used localized regression techniques
  - but focused on climate interaction as opposed to geophysical
  - And the error term as opposed to the coefficients



PRIOR STUDIES

- Greg Latta 2009- potential impacts of climate change on forests in US PNW (specifically Oregon and Washington)
- Could also be solved for site index (instead of culmination Mean Annual Increment)

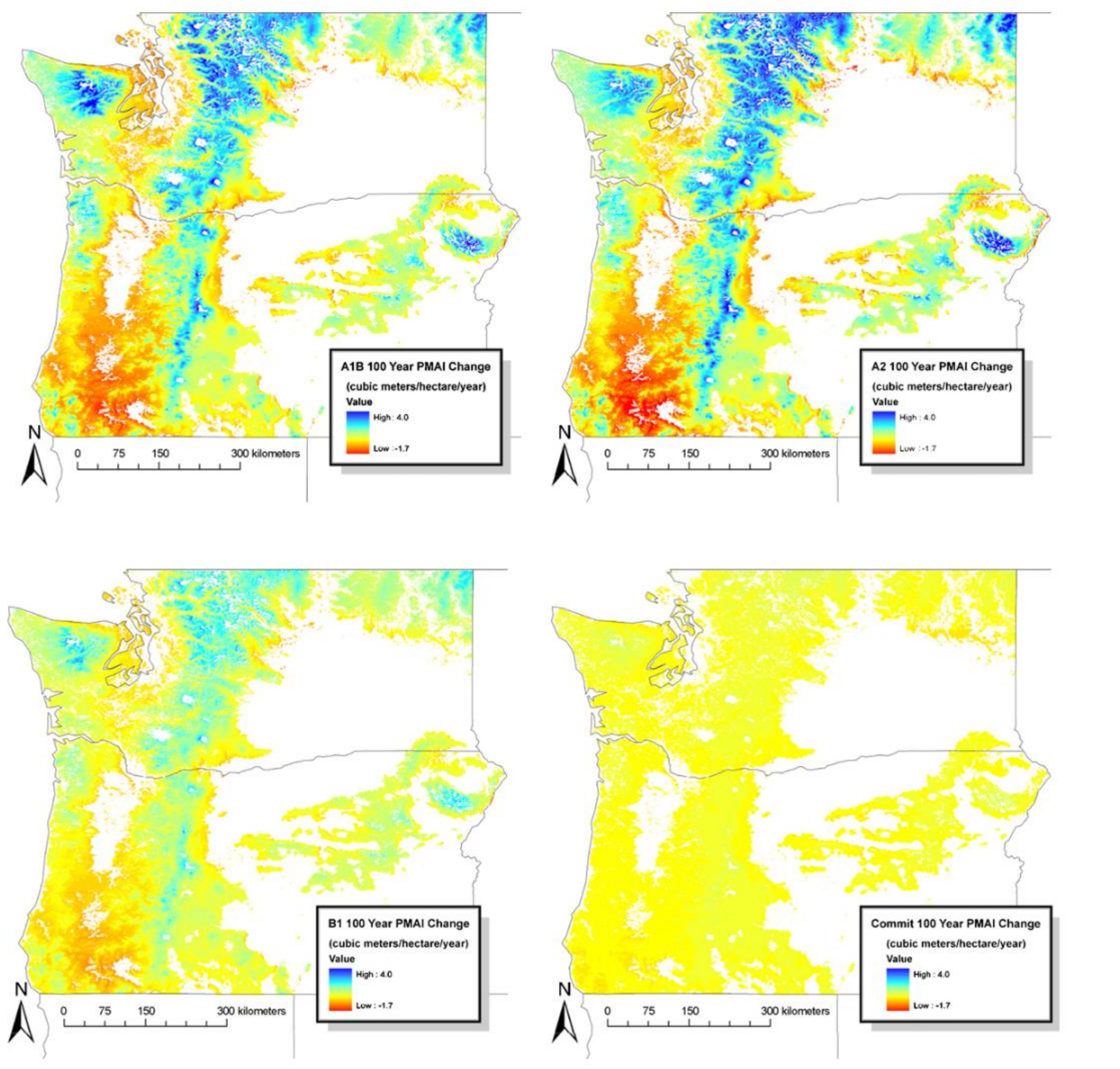


PRIOR STUDIES

- Latta et al. (2010)- potential impacts of climate change on forests in US PNW (specifically Oregon and Washington)
- Similar data to Kimsey in that it used localized regression techniques
  - but focused on climate interaction as opposed to geophysical
  - And the error term as opposed to the coefficients

- Used the model to evaluate different scenarios to determine changes in productivity
  - All scenarios show productivity gains in high elevations

PRIOR STUDIES



- Latta et al. (2010) Results
- Each map represents a different IPCC AR4 SRES scenario
  - A1B and A2 were economic focuses
  - B1 and Commit were more environmentally focused

Note: IPCC – International Panel on Climate Change
AR4 – The IPCC 4th Climate Assessment Report
SRES – IPCC Special Report on Emissions Scenarios

DATA – FORESTS IN IDAHO

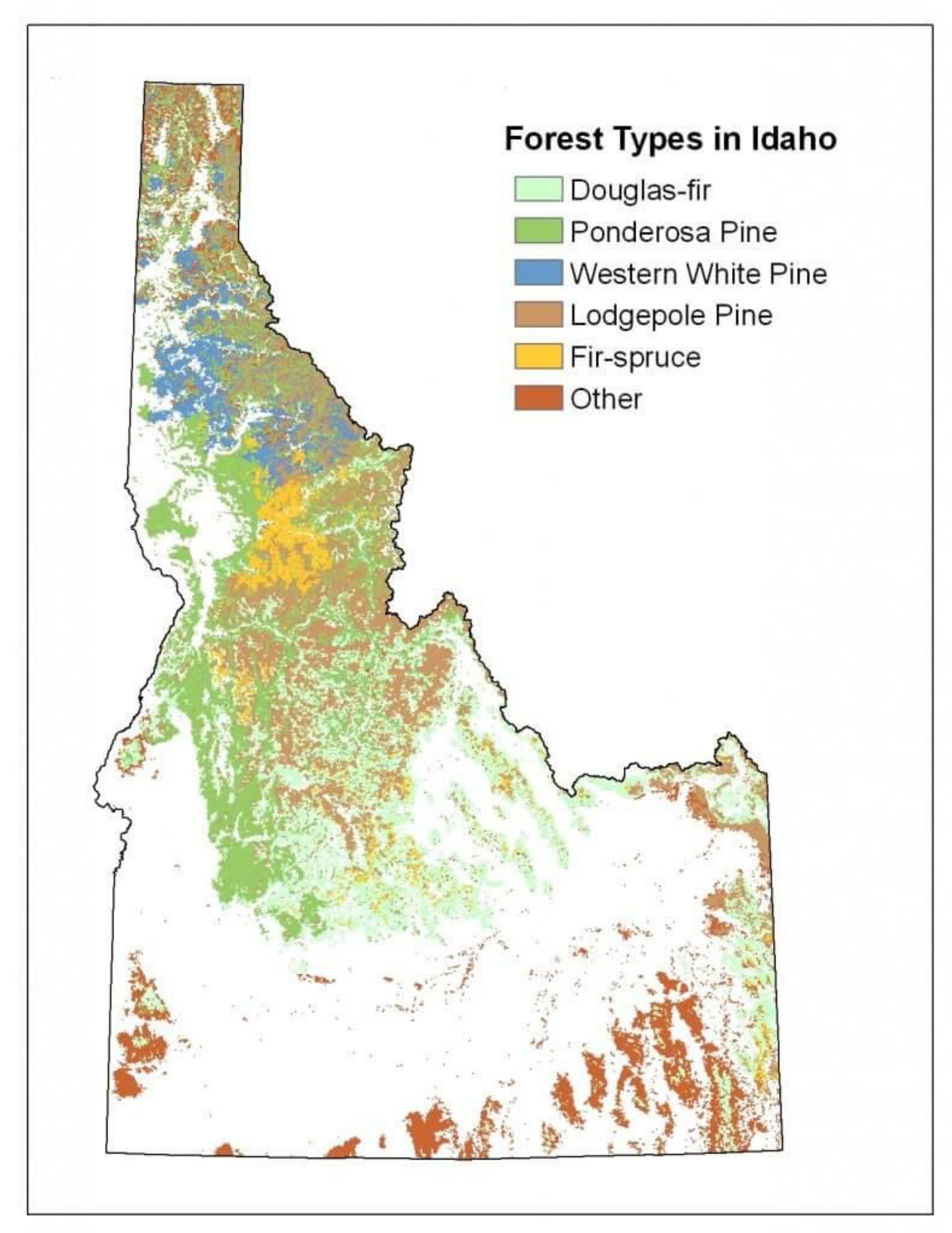
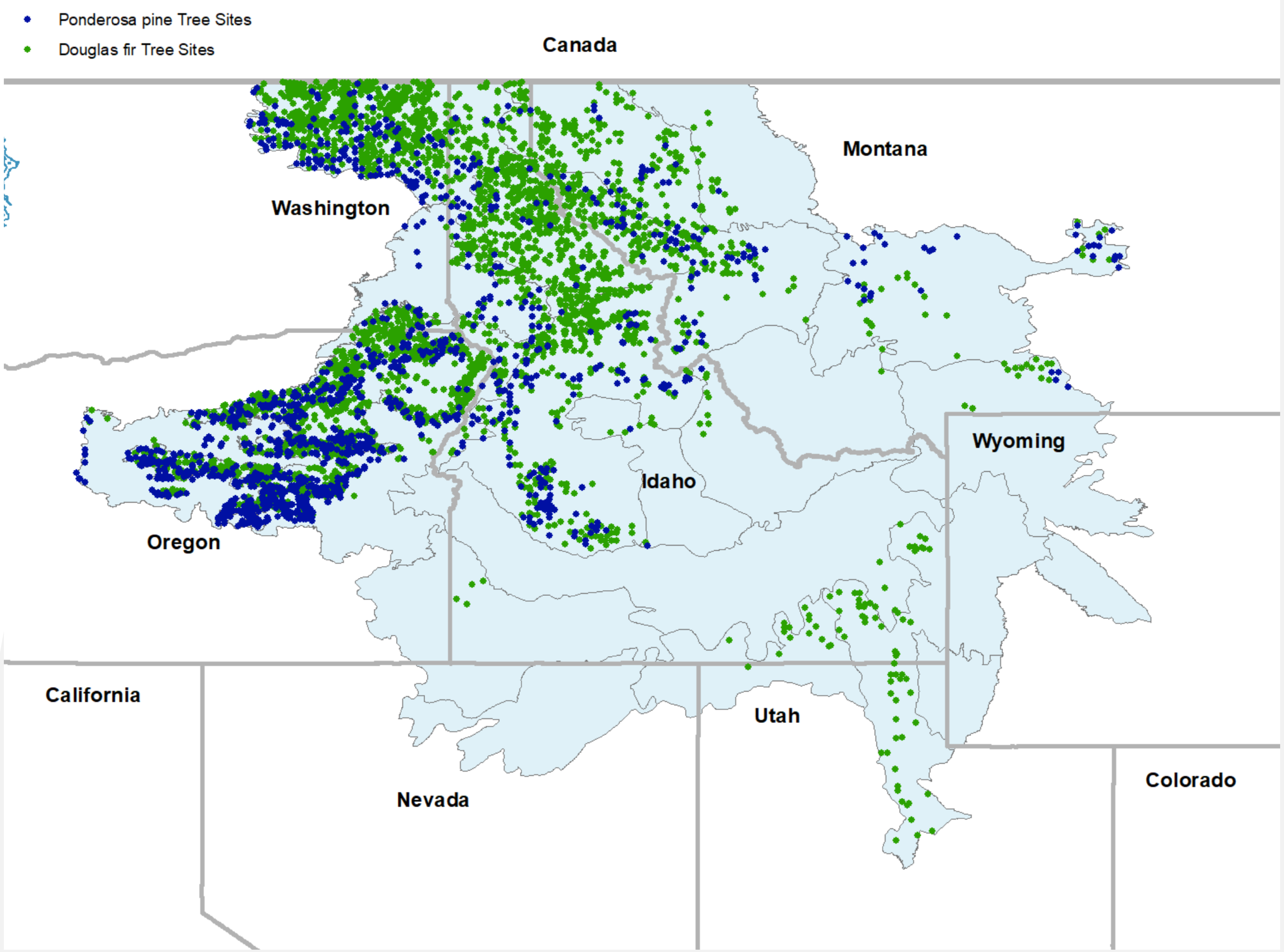


Image taken from: Idaho Forest Product Commission
https://idahoforests.org/content-item/forest-types-in-idaho/

DATA – SITE INDEX

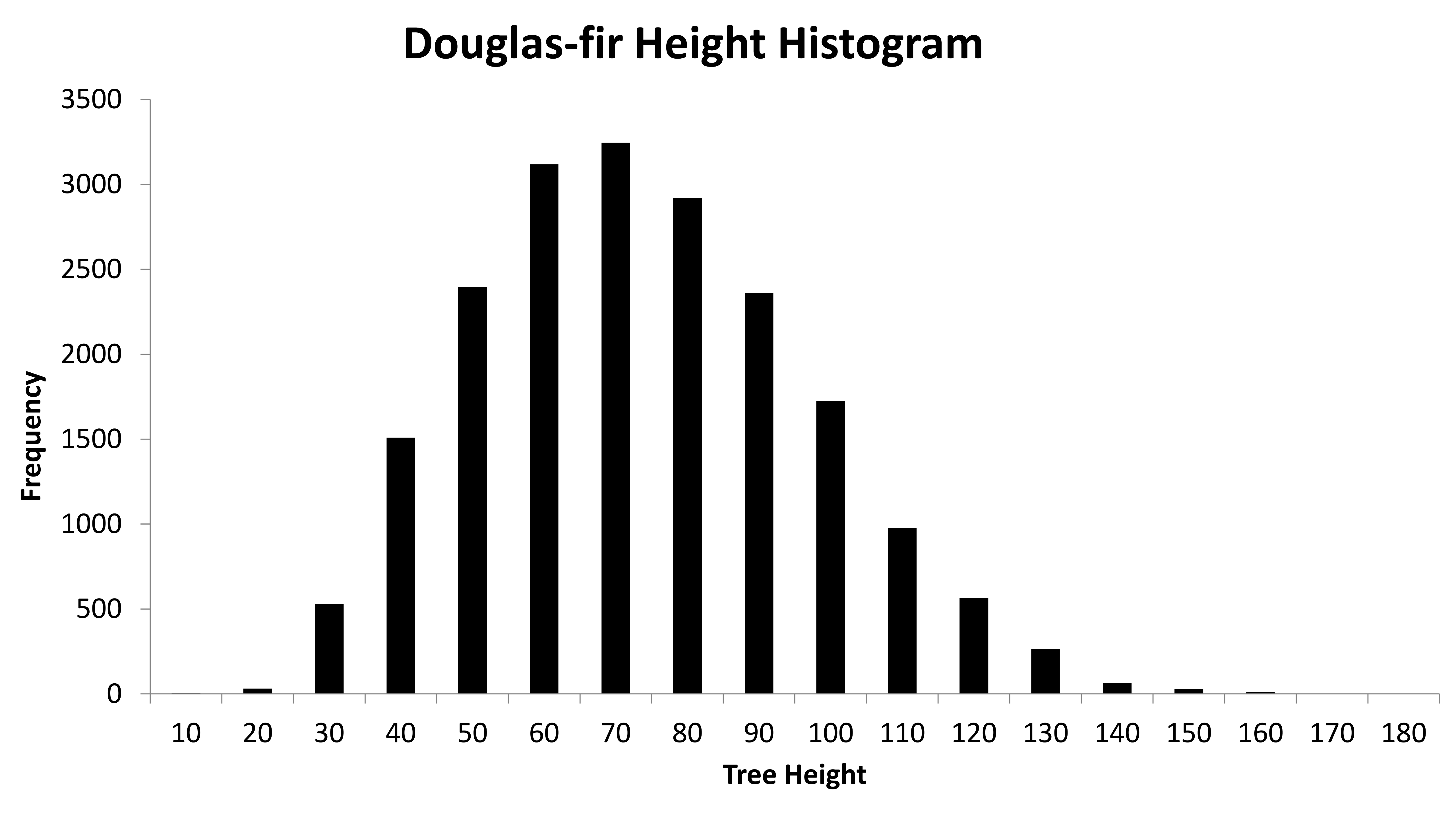
- USFS Forest Inventory and Analysis (FIA) data
  - Douglas-fir: 19,751 trees
  - Ponderosa Pine: 8,228 trees
- Douglas-fir -most prevalent forest type in Idaho (Monserud, 1984)
  - Reference species due to its ability to reproduce and grow across different conditions in the PNW (Kimsey, 2014)
- Ponderosa Pine: regionally important conifer species (Kimsey, 2014)

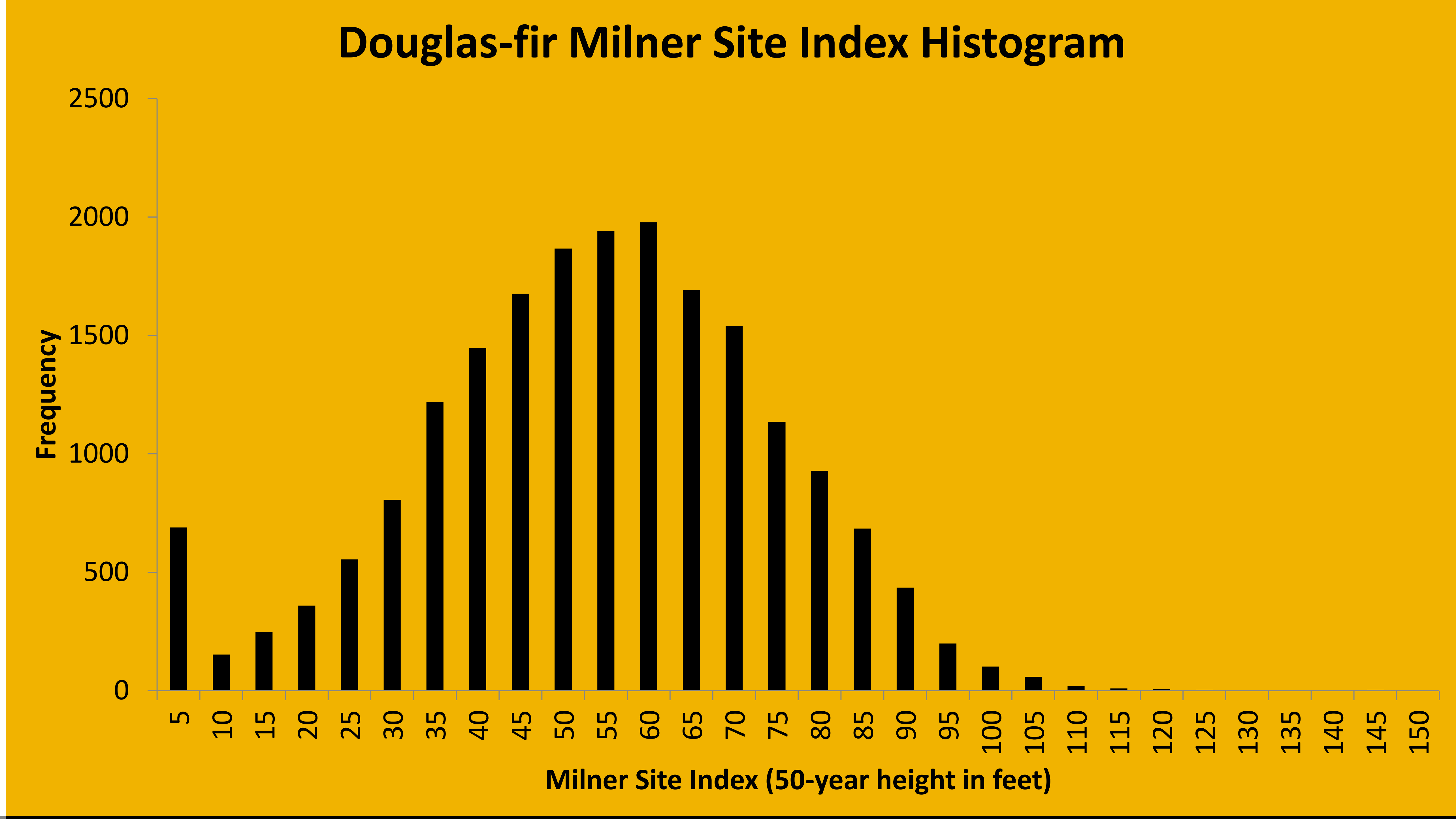
DATA – FORESTS IN IDAHO

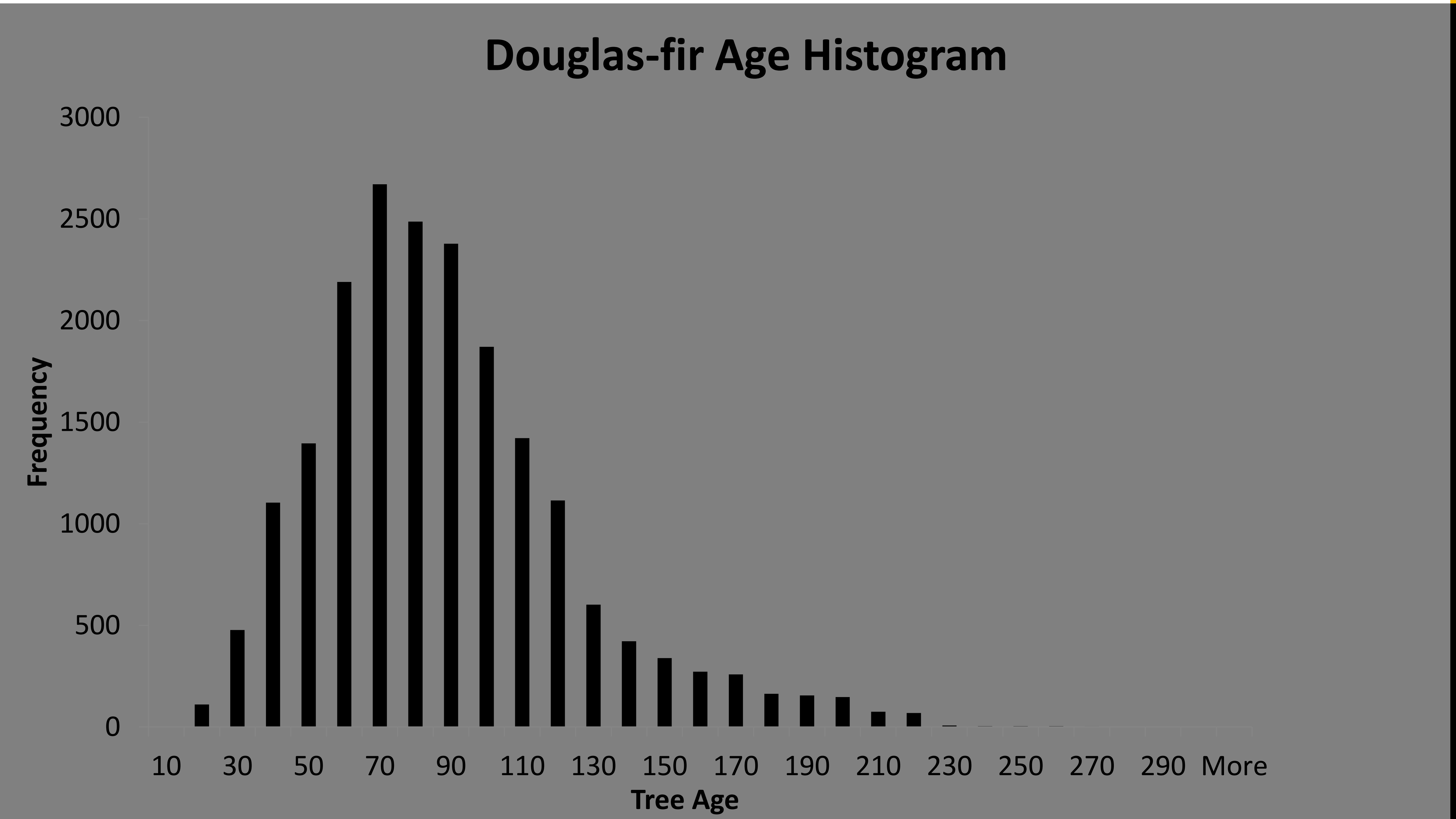


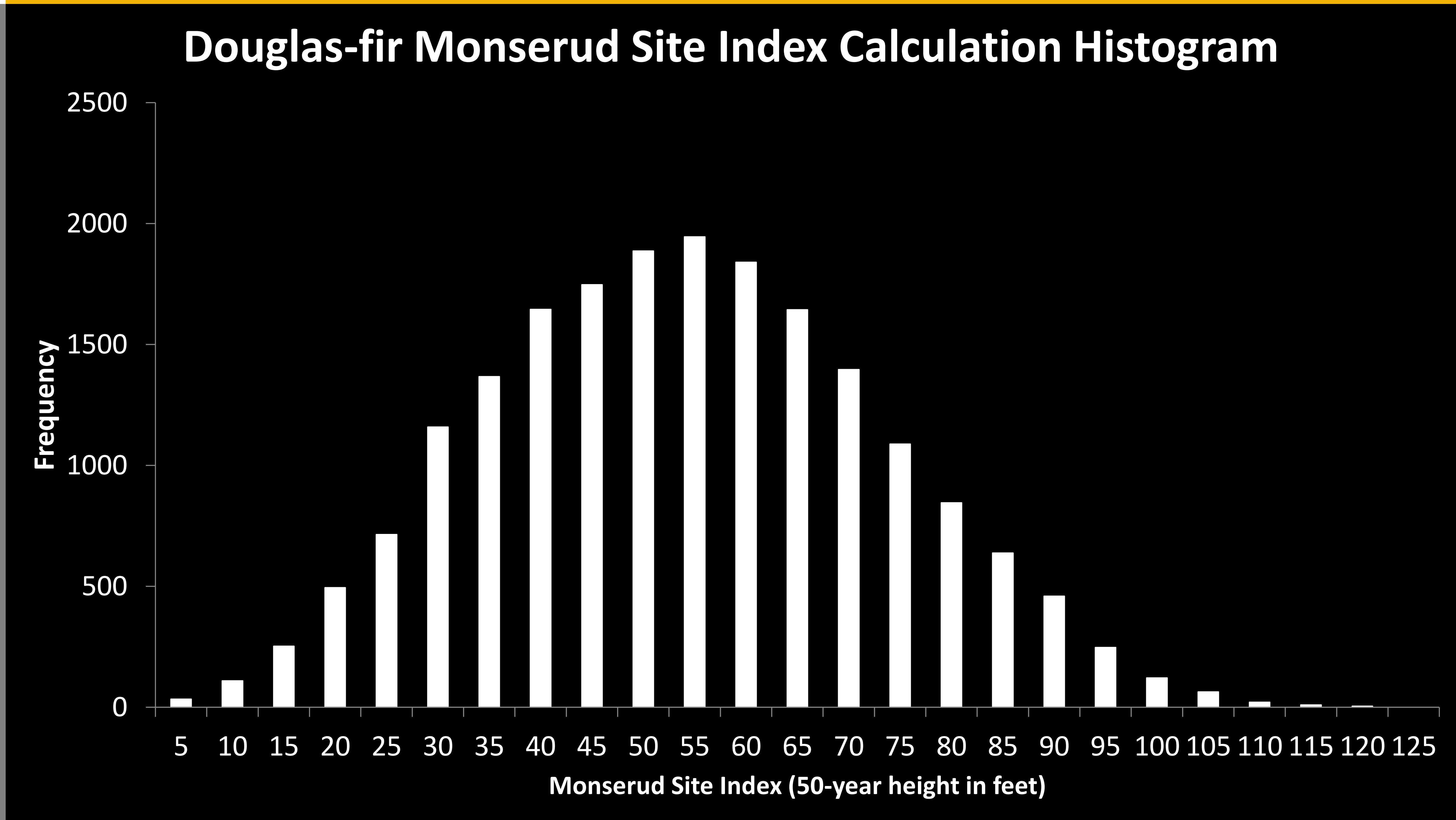
DATA – SITE INDEX

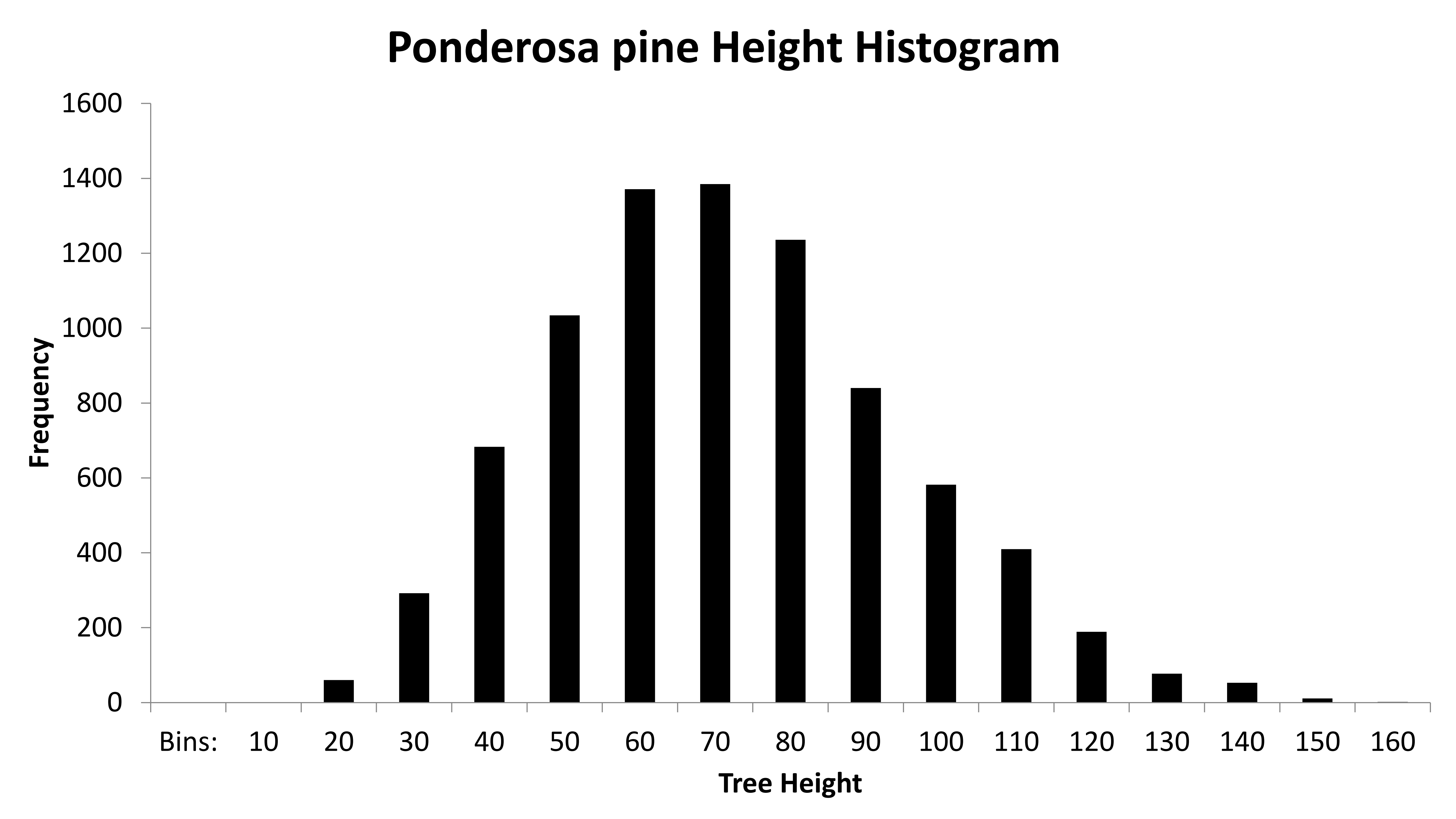
- Data Gathered:
  - Elevation
  - Available water holding capacity (0-25cm)
  - Mean Annual Temperature
  - Total Annual Precipitation
  - Slope
  - Aspect
  - Latitude and Longitude
  - Tree Height
  - Tree Age

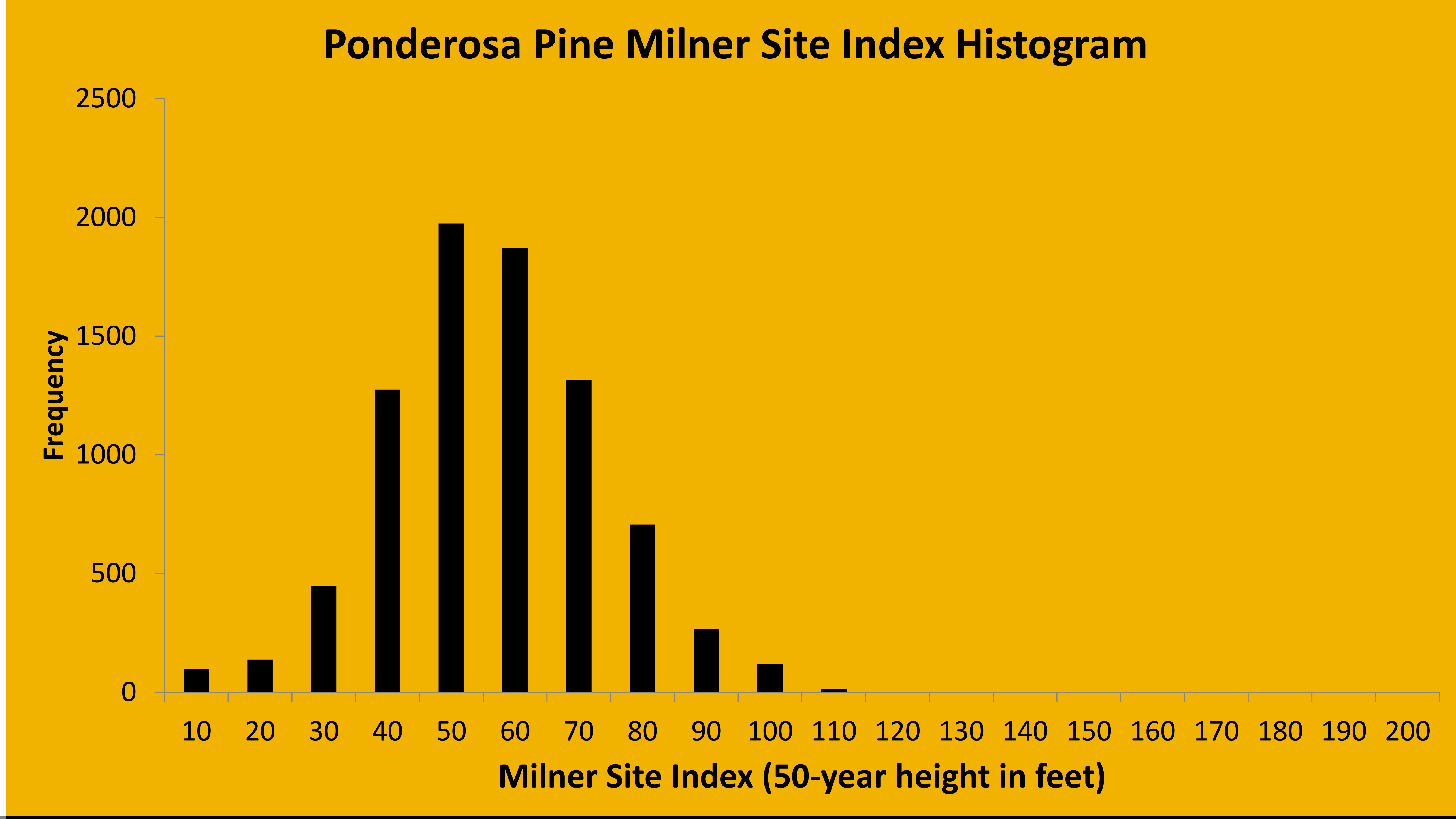

Douglas-fir Height Histogram
Frequency
Tree Height
0 500 1000 1500 2000 2500 3000 3500
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

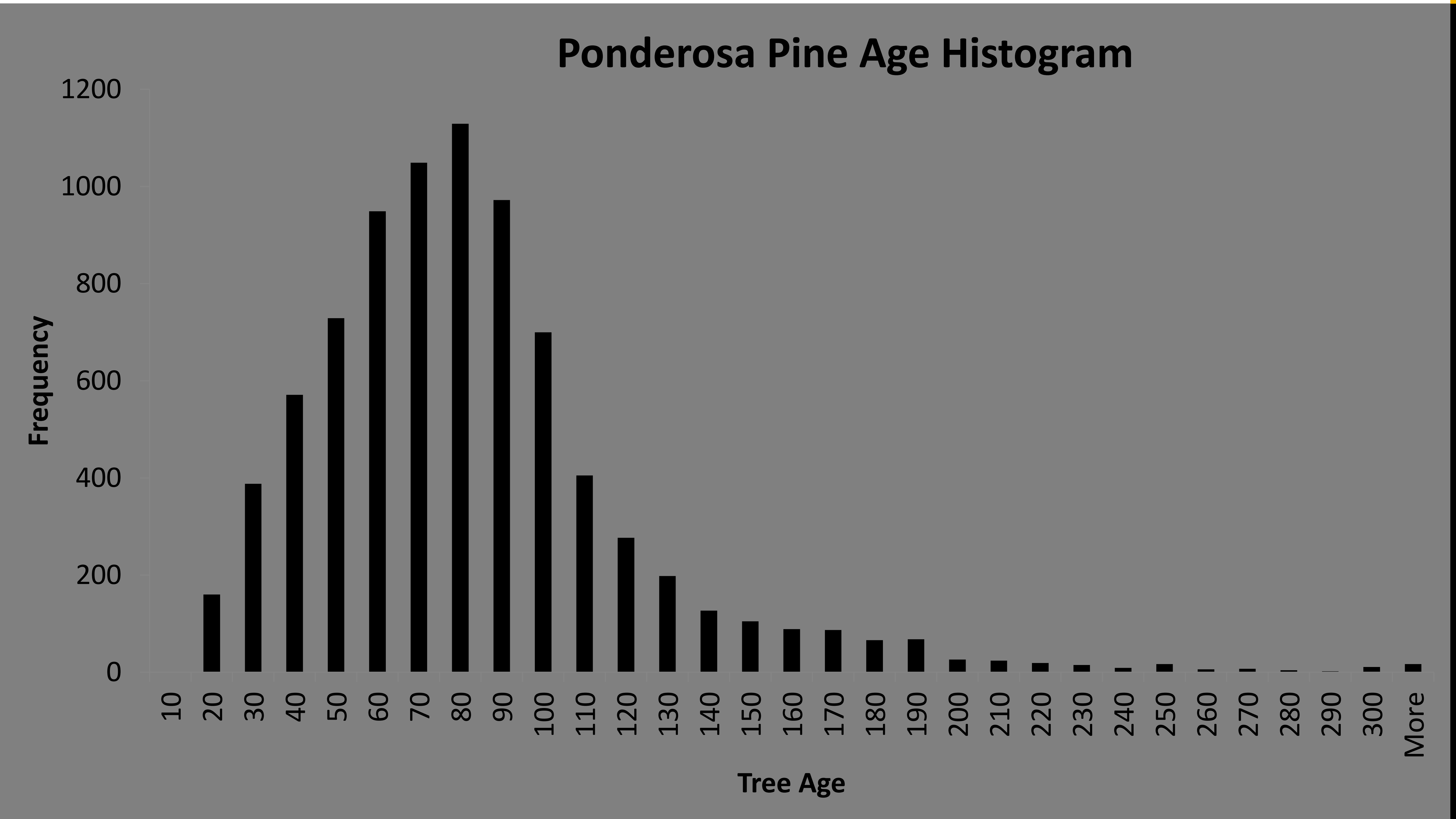

Douglas-fir Milner Site Index Histogram
Frequency
Milner Site Index (50-year height in feet)
0 500 1000 1500 2000 2500
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150

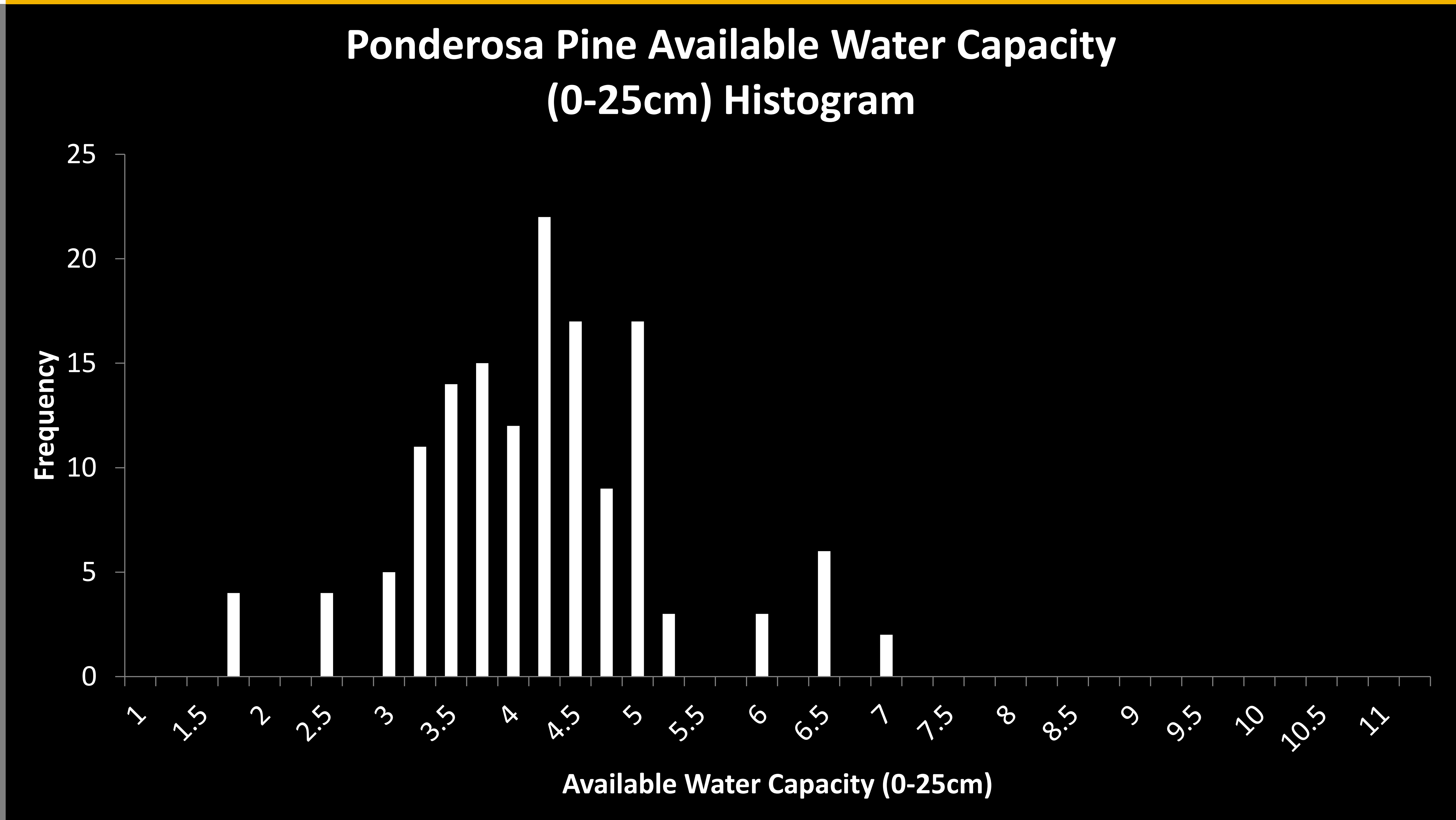

Douglas-fir Age Histogram
Frequency
Tree Age
0 500 1000 1500 2000 2500 3000
10 30 50 70 90 110 130 150 170 190 210 230 250 270 290 More


Douglas-fir Monserud Site Index Calculation Histogram
Frequency
Monserud Site Index (50-year height in feet)
0 500 1000 1500 2000 2500
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125


Ponderosa pine Height Histogram
Frequency
1600
1400
1200
1000
800
600
400
200
0
Bins: 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
Tree Height


Ponderosa Pine Milner Site Index Histogram
Frequency
2500
2000
1500
1000
500
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Milner Site Index (50-year height in feet)


Ponderosa Pine Age Histogram
Frequency
1200
1000
800
600
400
200
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 More
Tree Age


Ponderosa Pine Available Water Capacity
(0-25cm) Histogram
Frequency
25
20
15
10
5
0
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11
Available Water Capacity (0-25cm)

DATA – SITE INDEX

- Data Selection:
  - DF Dataset: 19751
  - PP Dataset: 8228
- Histogram Removal:
  - Points removed based on previous study bounds
    - Points with no data

- Study Constraints:
  - **Milner (PP)**
    - Age: 50-100 years
    - SI: 41-84 feet
  - **Milner (DF)**
    - Age: 50-100 years
    - SI: 27-91 feet
  - **Monserud (DF):**
    - Age: 10-200 years
    - SI: 40-90 feet

DATA – SITE INDEX

DF Descriptive Statistics

DF Dataset: 13095

	Min	Max	Mean	Median	STDV
Age:	12	200	75.964	72	30.4551
Ann. PPT.:	231.36	2298.05	740.555	687.18	250.513
Ann. Temp:	0.13	10.43	5.93072	6.06	1.47471
AWC:	0.9	11.25	4.33169	4.37	1.38295
Elevation:	749	1931	1262.74	1313	297.294
HT:	20	134	75.9646	75	20.8311
Milner:	27.5559	91.367	60.3892	58.986	12.2824
Monserud:	40.0283	90.997	59.8527	58.0791	12.7131
Slope:	0	61	34.3947	33	16.2789

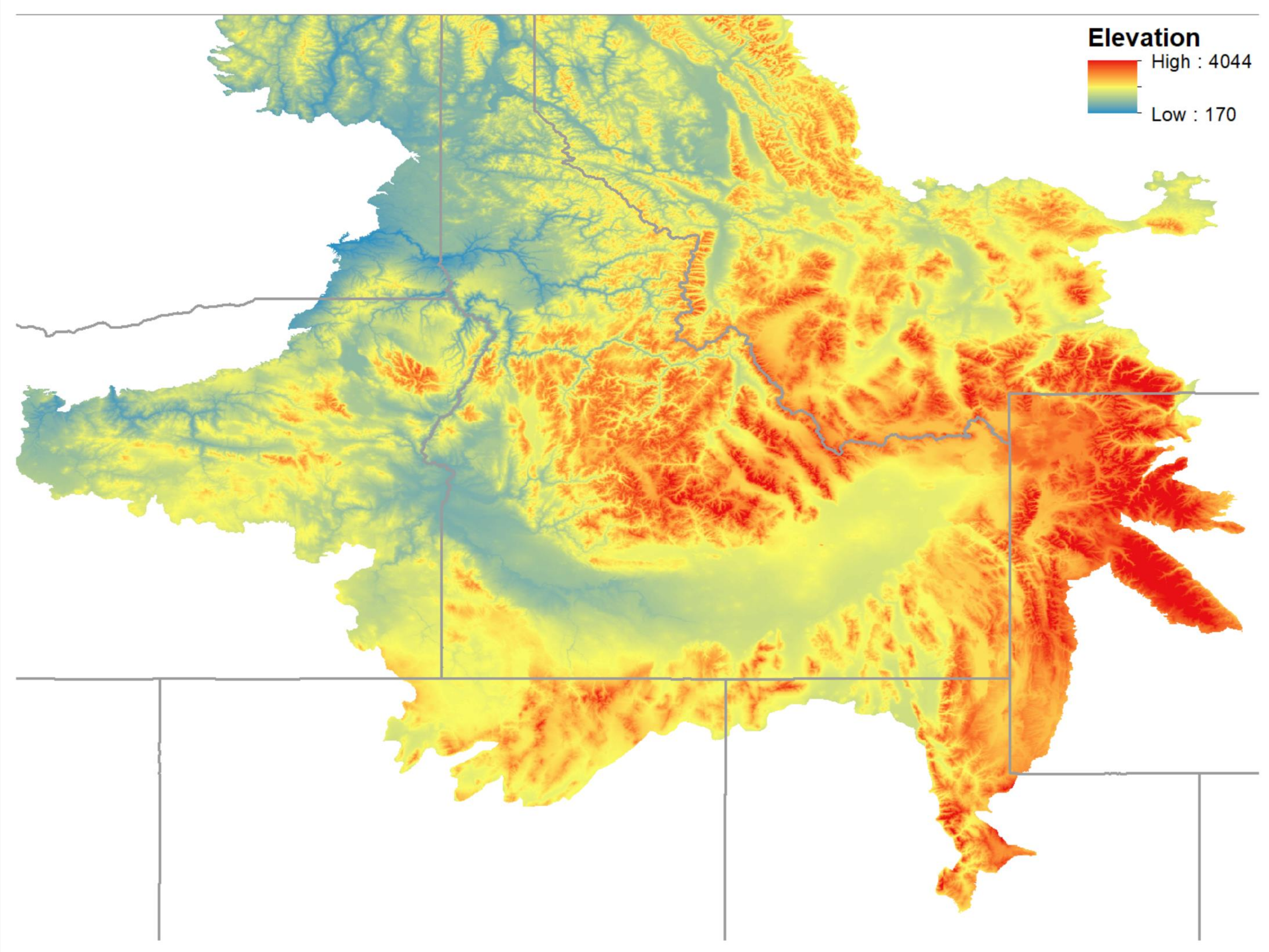
PP Descriptive Statistics

PP Dataset: 3416

	Min	Max	Mean	Median	STDV
Age:	50	100	72.9994	73	13.7082
Ann. PPT.:	275.81	1501.03	558.584	527.8	154.673
Ann. Temp:	2.92	10.38	6.78452	6.65	1.13356
AWC:	0.9	9.15	4.14999	4.37	1.27817
Elevation:	455	2255	1310.76	1365	317.09
HT:	40	125	73.2301	72	14.5956
Milner:	41.0047	84.9629	55.3655	53.4367	10.2266
Slope:	0	119	23.7427	20	18.0487

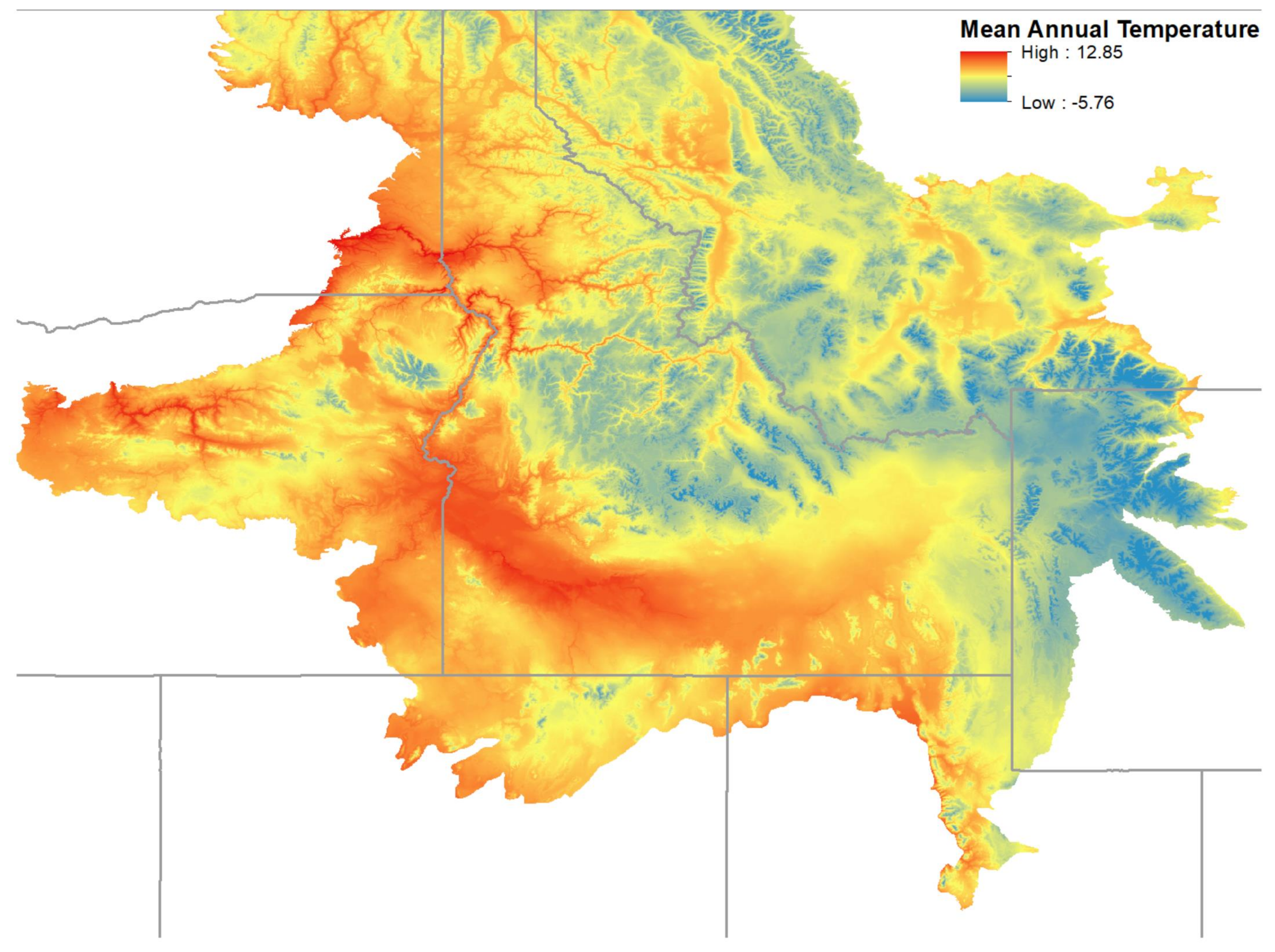
DATA – ELEVATION

- Elevation (DEM 800m)



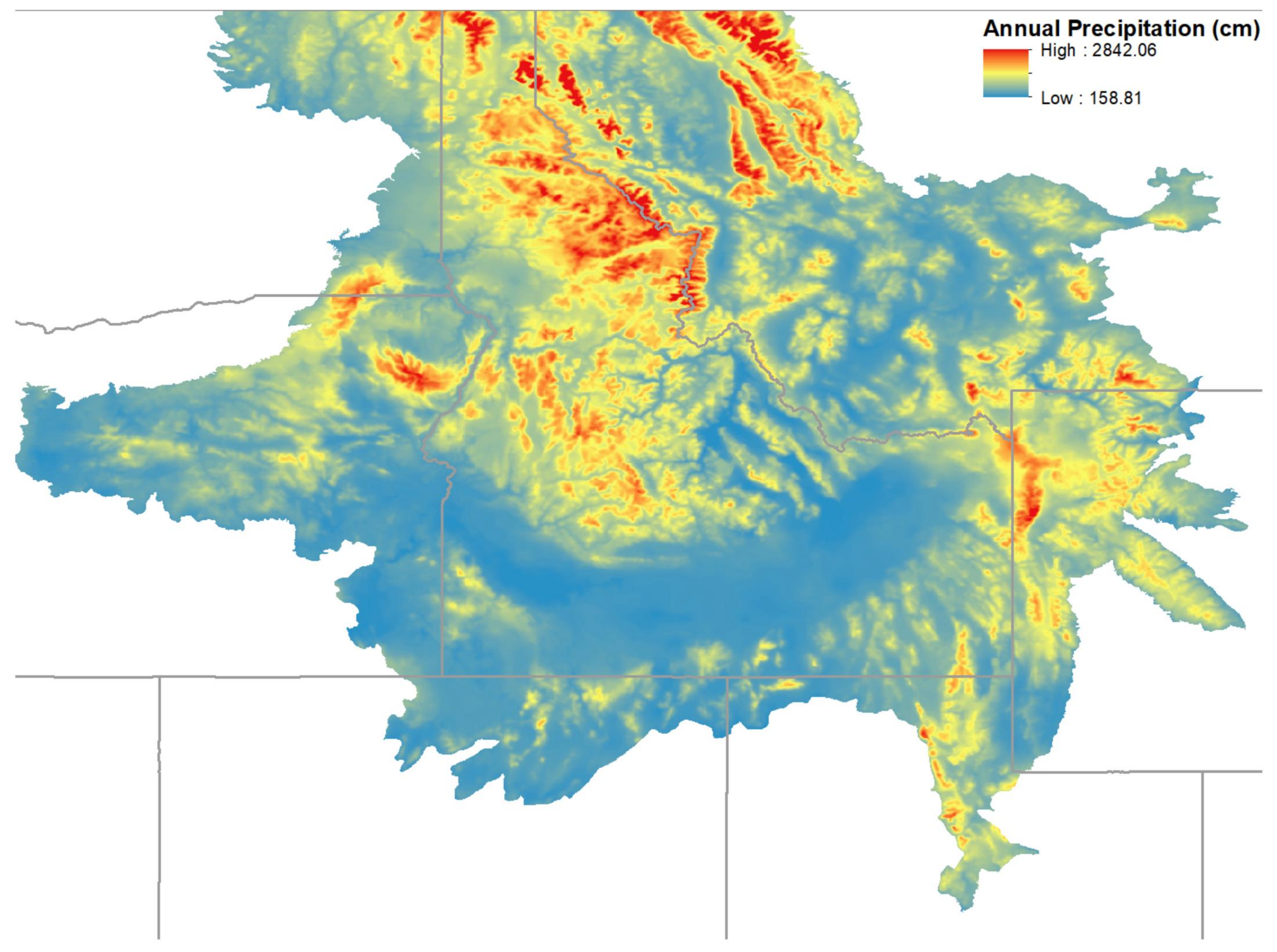
DATA – CLIMATE

- Mean Annual Temperature (°C)



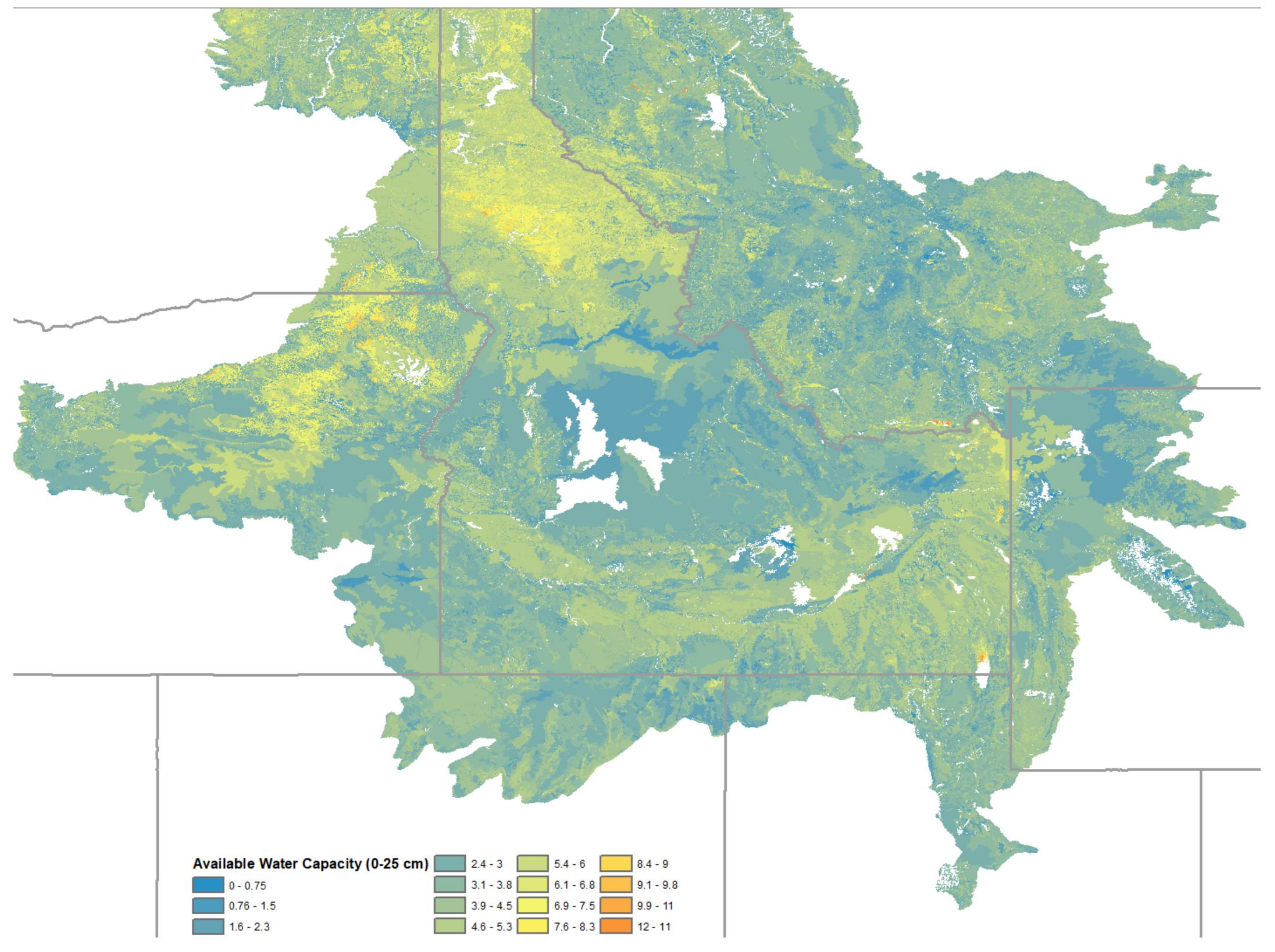
DATA – CLIMATE

- Annual Precipitation



DATA – SOIL

- Available Water Capacity (0-25 cm)



DATA – CLIMATE

- Climate Moisture Index: Measure of precipitation in excess of evapotranspiration

$$[1] \quad ET_m = 0.0135(T_m + 17.78)SR_m\left(\frac{238.8}{595.5 - 0.55T_m}\right)$$

(Latta, 2009)

$$[2] \quad CMI = \sum_{m=1}^{mgs}[P_m - (days_m ET_m/10)]$$

(Latta, 2009)

- **No Map**: Greg was working on a 90 meter pixel-based map but is slow. The slope and aspect components of CMI are muted when looking at 800 meter vs 90 meter

METHODS - MULTIPLE LINEAR REGRESSION

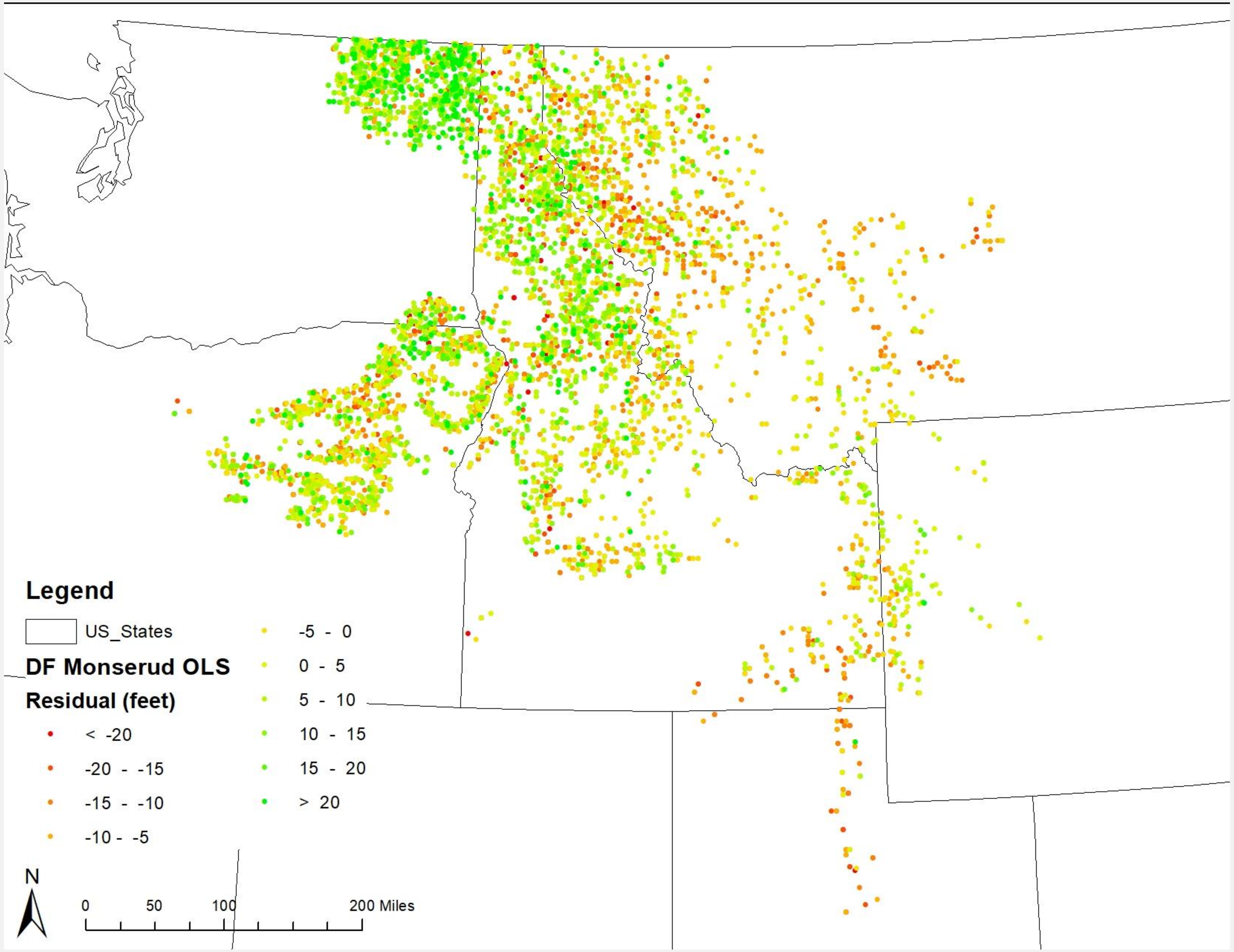
- OLS Regression
  - Using:
    - Average Annual Temperature
    - Total Annual Precipitation
    - July, August, September Climate Moisture Index
    - Available Water Capacity (0-25cm)
- Evaluate Error Map
  - Determine if we have spatial autocorrelation

RESULTS - MULTIPLE LINEAR REGRESSION

OLS Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	22.71248	2.834	8.01	0.000
AVG_TEMP	4.253668	0.551	7.71	0.000
AVG_TEMP*AVG_TEMP	-0.13862	0.040	-3.44	0.001
ANN_PRECIP	0.014711	0.003	4.25	0.000
ANN_PRECIP*ANN_PRECIP	-4.46E-06	0.000	-3.21	0.001
CMI_JAS	-0.001	0.022	-0.05	0.964
CMI_JAS*CMI_JAS	-0.00035	0.000	-4.81	0.000
SOIL_AWS	1.641759	0.575	2.86	0.004
SOIL_AWS*SOIL_AWS	-0.25015	0.044	-5.64	0.000
AVG_TEMP*ANN_PRECIP	0.000509	0.000	1.42	0.155
AVG_TEMP*CMI_JAS	0.002703	0.002	1.09	0.275
AVG_TEMP*SOIL_AWS	-0.00036	0.066	-0.01	0.996
ANN_PRECIP*CMI_JAS	2.48E-05	0.000	1.68	0.094
ANN_PRECIP*SOIL_AWS	0.000518	0.000	1.38	0.167
CMI_JAS*SOIL_AWS	0.010448	0.003	4.16	0.000

R-squared	0.195
S.E. of regression	11.458
Mean dependent var	59.925
Moran's I (Inverse Distance)	0.616
Zscore	90.146



METHODS - LOCALIZED REGRESSION

- OLS Regression
- Error Map
- Localized Regression Technique
  - Geographical Weighted Regression
  - Simultaneous Autoregressive Regression
- Comparisons
  - between SI calculations derived from Milner and Monserud
  - Between our approach and Kimsey and Latta in NE Washington

FUTURE DIRECTION – *OTHER RESULTS/ISSUES*

- Data Issues
  - We did not have actual plot locations (so fuzzed and swapped)
  - WE did not apply an elevation correction to PRISM climate data
    - PRISM elevation may differ from FIA plot elevation
- Potential Uses for Site Index Maps
  - Growth Models
  - Forest Action Plan
  - Climate Change

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