MACHINE LEARNING TO OPTIMIZE STAND DENSITY AS A FUNCTION OF MANAGEMENT OBJECTIVES AND SITE RESOURCES

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OVERVIEW

- IFC Max SDI Summary
- Westside Project Overview
- Data
- Modeling Approach
- Variable Selection
- Results

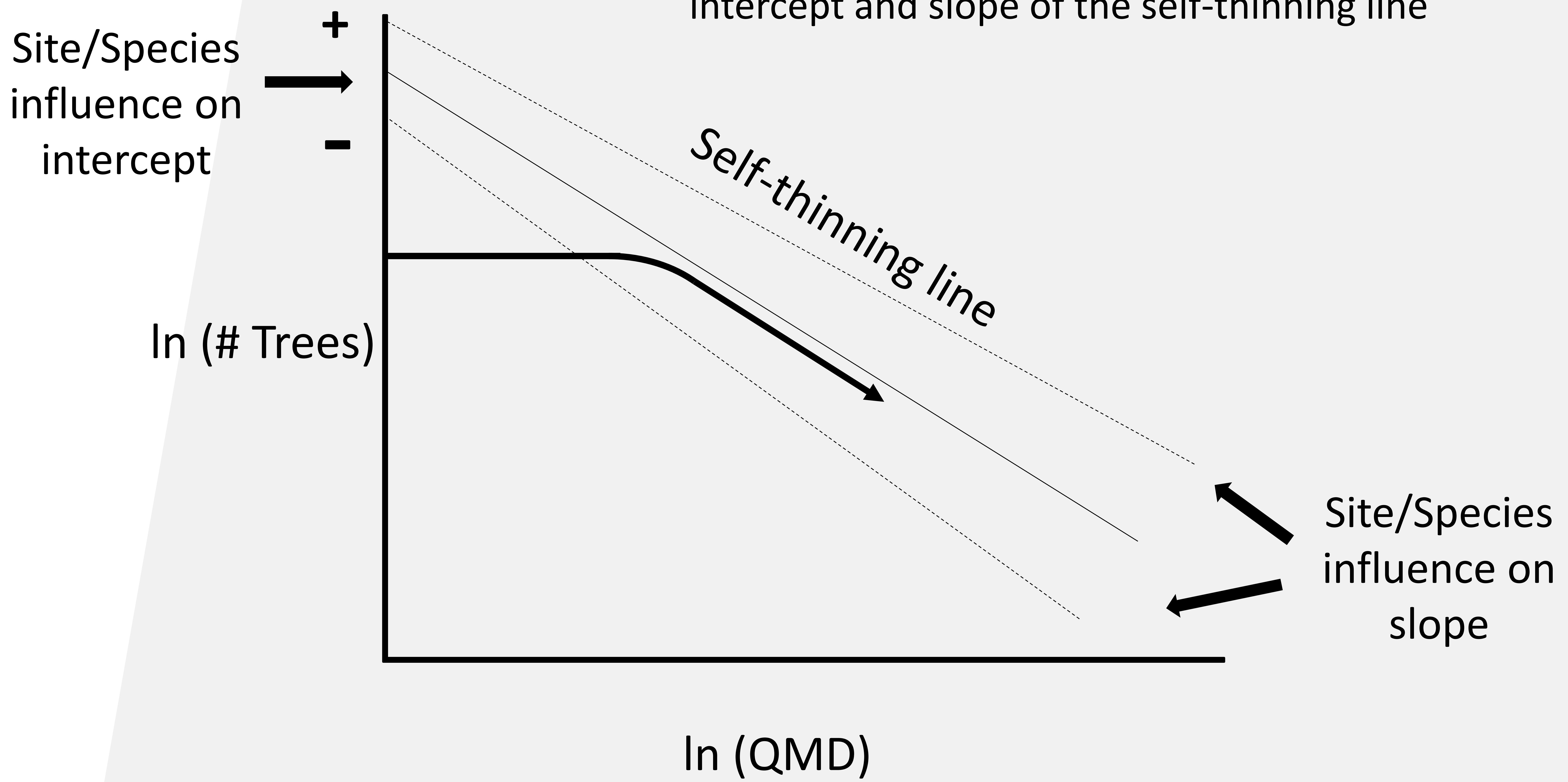
MAXIMUM STAND DENSITY INDEX

DESCRIBES CARRYING CAPACITY

- Density – function of the number of trees and their size
  - Maximum – the limit on # trees that can exist
  - % of max (relative density) predict key phases of stand development
    - Establishment (density indp.)> Crown Closure (onset) > Self Thinning (density depn.)
- Stand Density Index (SDI) modeled as a function of TPA and QMD
  - $SDI = N\left(\frac{QMD}{10}\right)^b$ >>>>> $\log(N) = \beta_0 + \beta_1 \log(QMD)$
- Site and Species effects on slope and intercept of the self-thinning line

$$lnN = (\beta_0 + \ k_i) + (\beta_1 + \ k_i)lnQMD$$

Where k_i is the site/species effect on the intercept and slope of the self-thinning line



IFC – MAXIMUM STAND DENSITY INDEX

INLAND MODEL

Influence of site characteristics and species composition

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Site sensitive maximum stand density index models for mixed conifer stands across the Inland Northwest, USA

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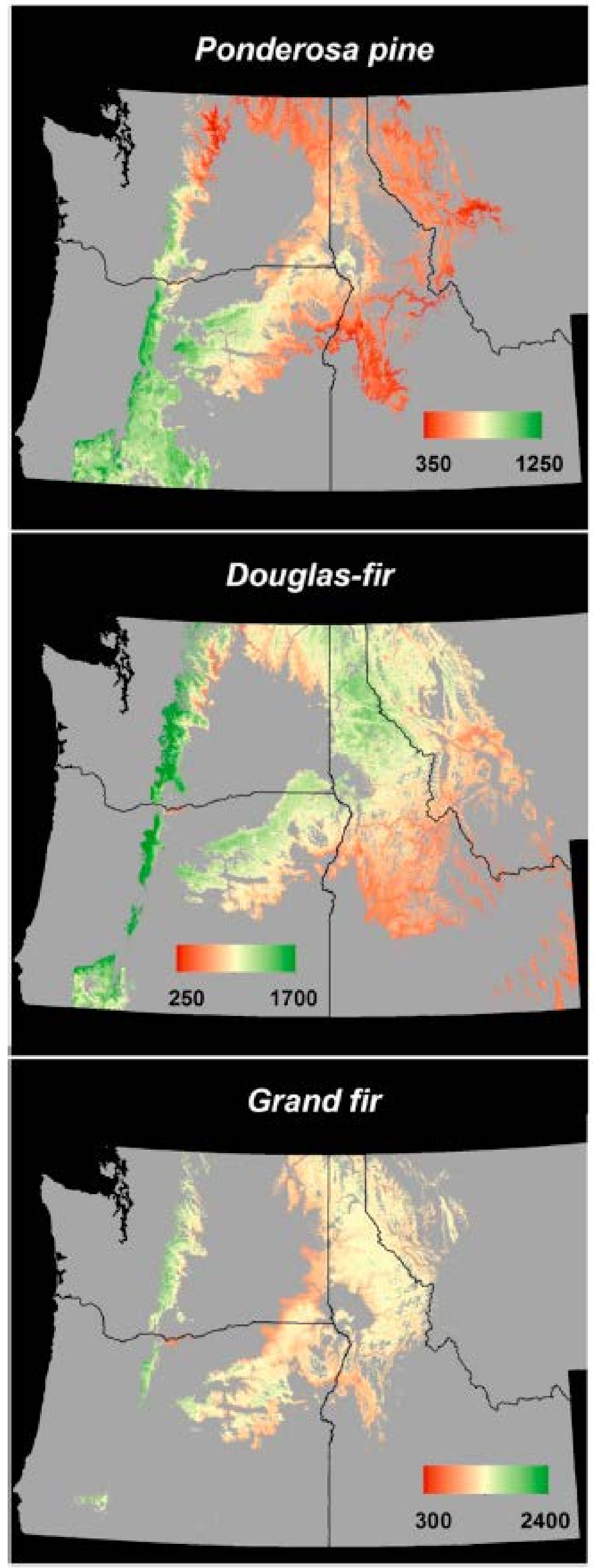


MAX SDI – WESTSIDE

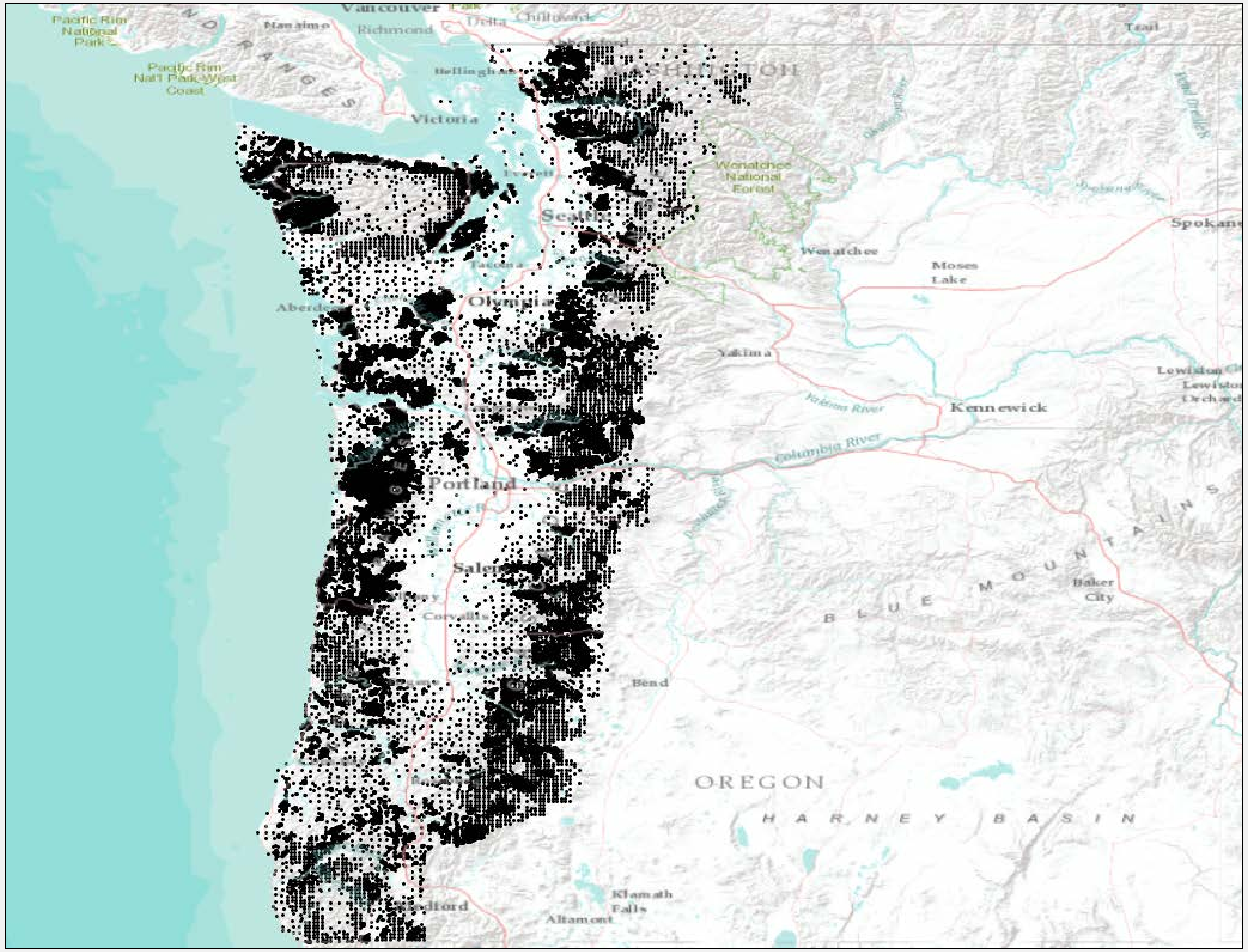
APPROACH

Explore and model the influence of site characteristics and species composition on stand carrying capacity in Westside PNW forests. Cascade crest, west to the coast in Oregon and Washington.

- Focus on important conifer species
- Incorporate effects of species mixing (BA proportion)
- Topography – slope and aspect transformations, elevation
- Influence of soils and volcanic ash
- Climatic Variables
- Current Predictions based on past climate (1961-1990)
- Future climate scenarios

DATA

- Sources – IFC members
  - Hancock, Olympic Resource Management, Roseburg Resources Co.
  - WA DNR, ORDF, USFS (FIA and FSVEG)
- n = **188,159** initial records in area of interest
  - Plot level data where plot coordinates available
  - Stand level using stand centroid (~10% of data)
- QMD and TPA of each record
- Species BA proportions (DF, WH, RC, RA, Hwd, Conf)
- Topography extraction from 30m DEM
  - Transformations with R-terrain (slope & aspect)
- ClimateNA – 247 variables (Annual, Month, Season)
- Geology and Soil layers

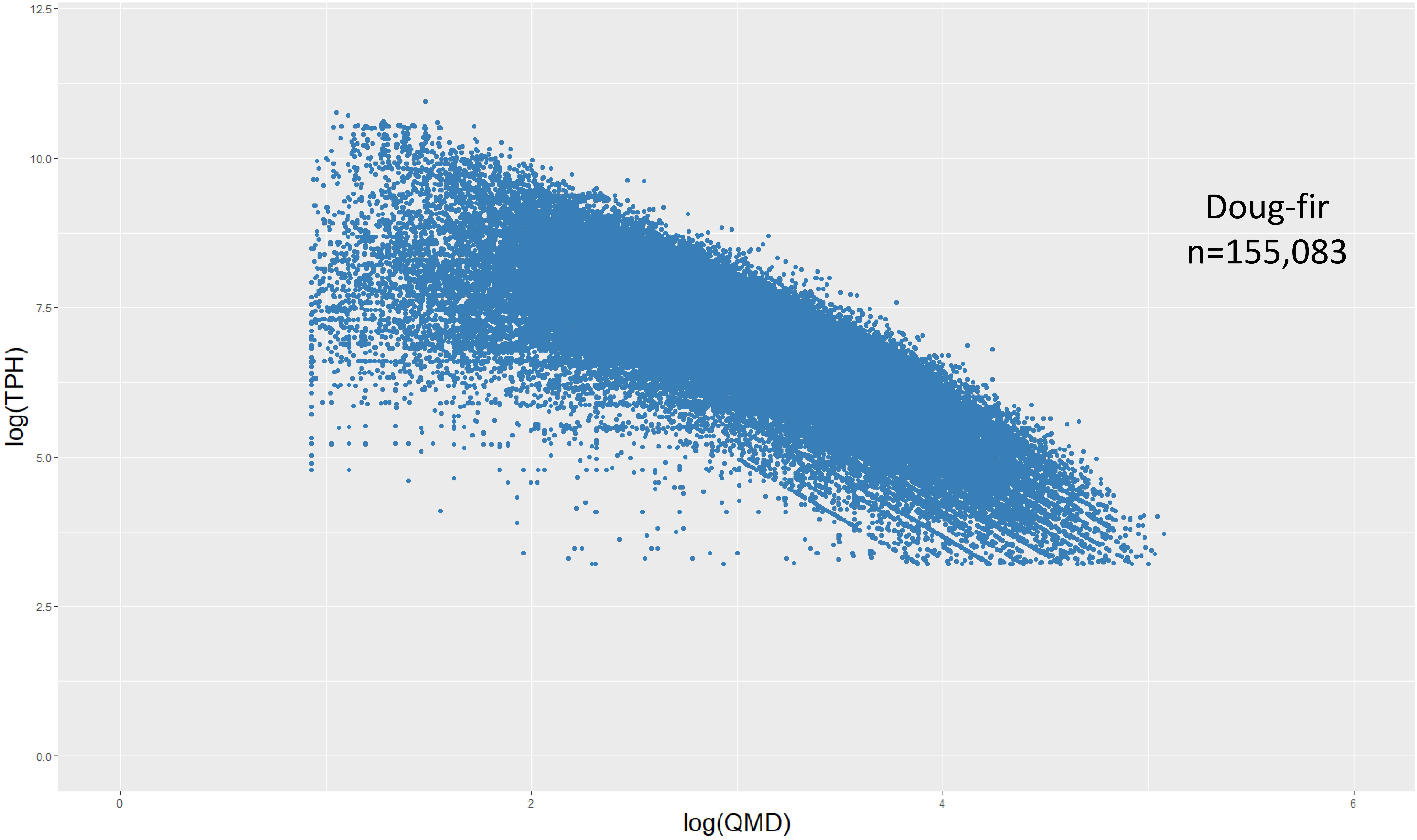


log(TPH)
log(QMD)
11
9
7
5
3
1
2
3
4
5
Species
DF
WH
RC
RA
OtherH
OtherC

DOUGLAS-FIR

MODELING APPROACH

- 155,083 plots with at least 10% Doug-fir by BA
- Data cleaning
  - Missing expansion factors, at least 10 TPA (24.7 TPH), QMD at least 1 inch (2.54 cm), questionable data
- Use Linear Quantile Mixed Models to determine the 95% quantile line of log(TPH)~log(QMD)
  - Mixed model where each record has random intercept, giving each record a unique 95% max SDI value
- Use Random Forest with SDI values to find variable importance
  - Ensemble of many trees
- Stochastic Frontier Analysis with selected variables

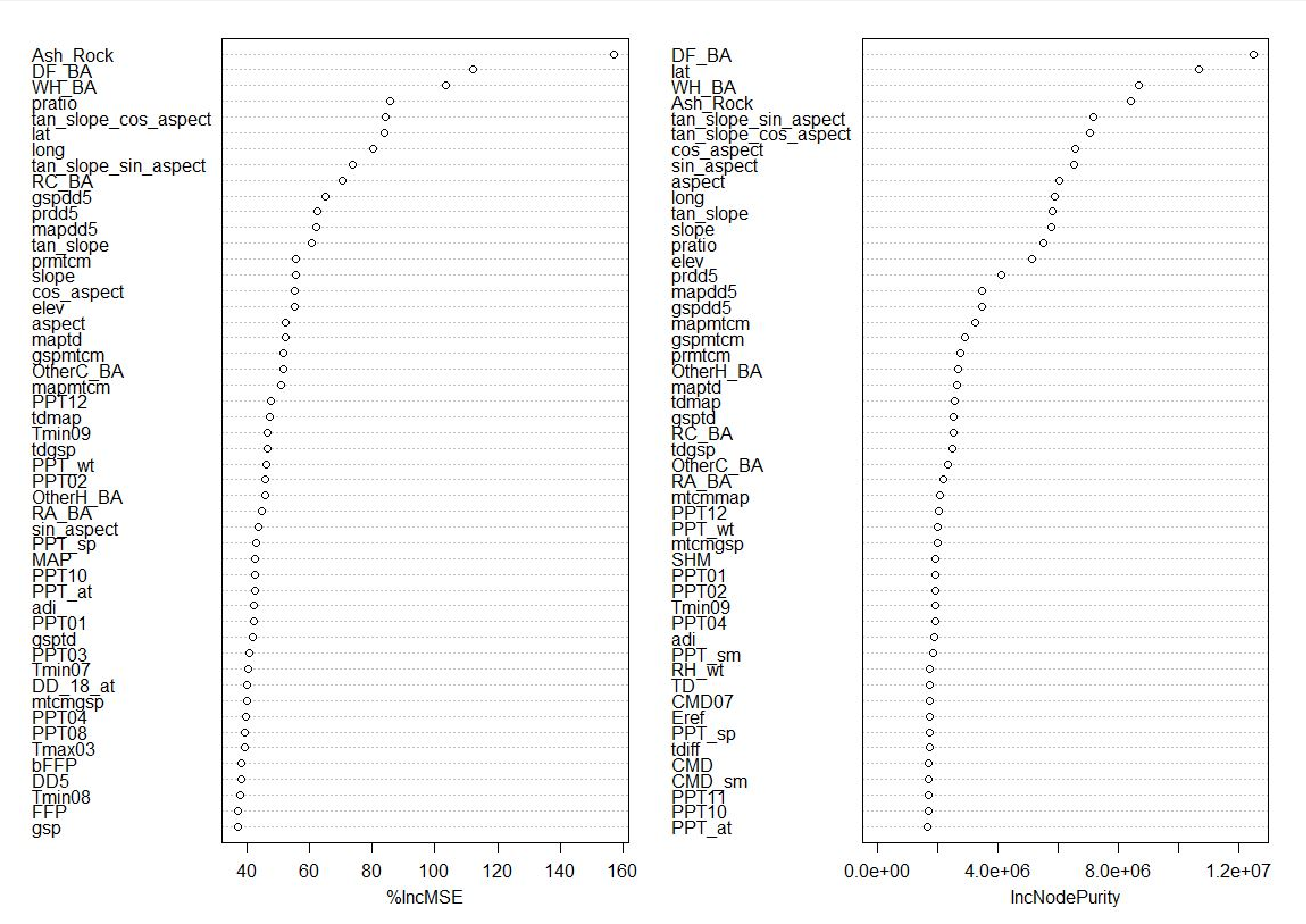


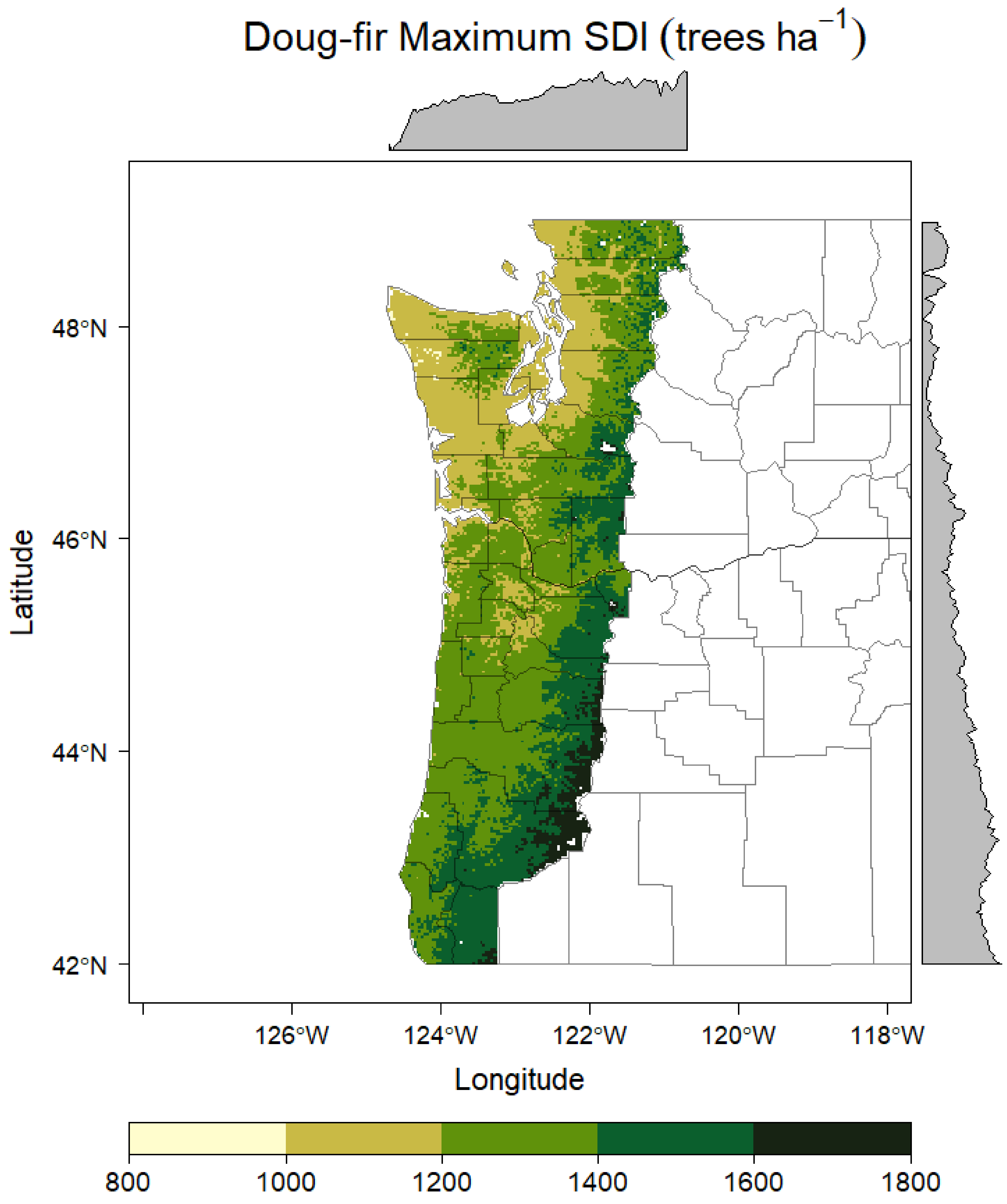
Doug-fir
n=155,083
log(TPH)
log(QMD)
12.5
10.0
7.5
5.0
2.5
0.0
0
2
4
6

DOUGLAS-FIR VARIABLE SELECTION

RANDOM FOREST

- Geographic Location
- Topography
- Other Species' BA
  - Base model as pure DF
  - Coef for Species BA proportion (+)
    - WH, RA, RC, OtherC, OtherH
- Timing of precip
- Interaction of precip and temp

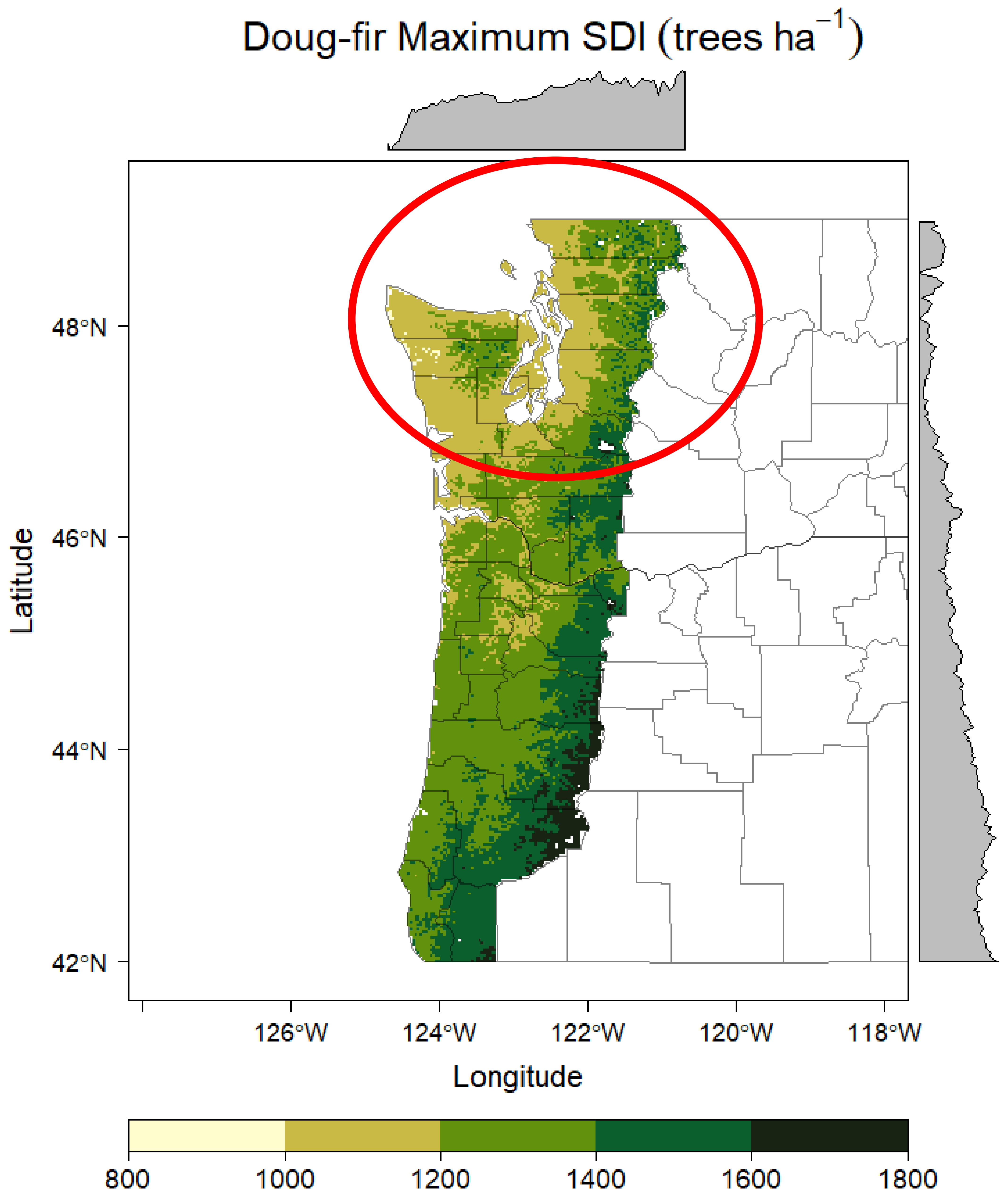


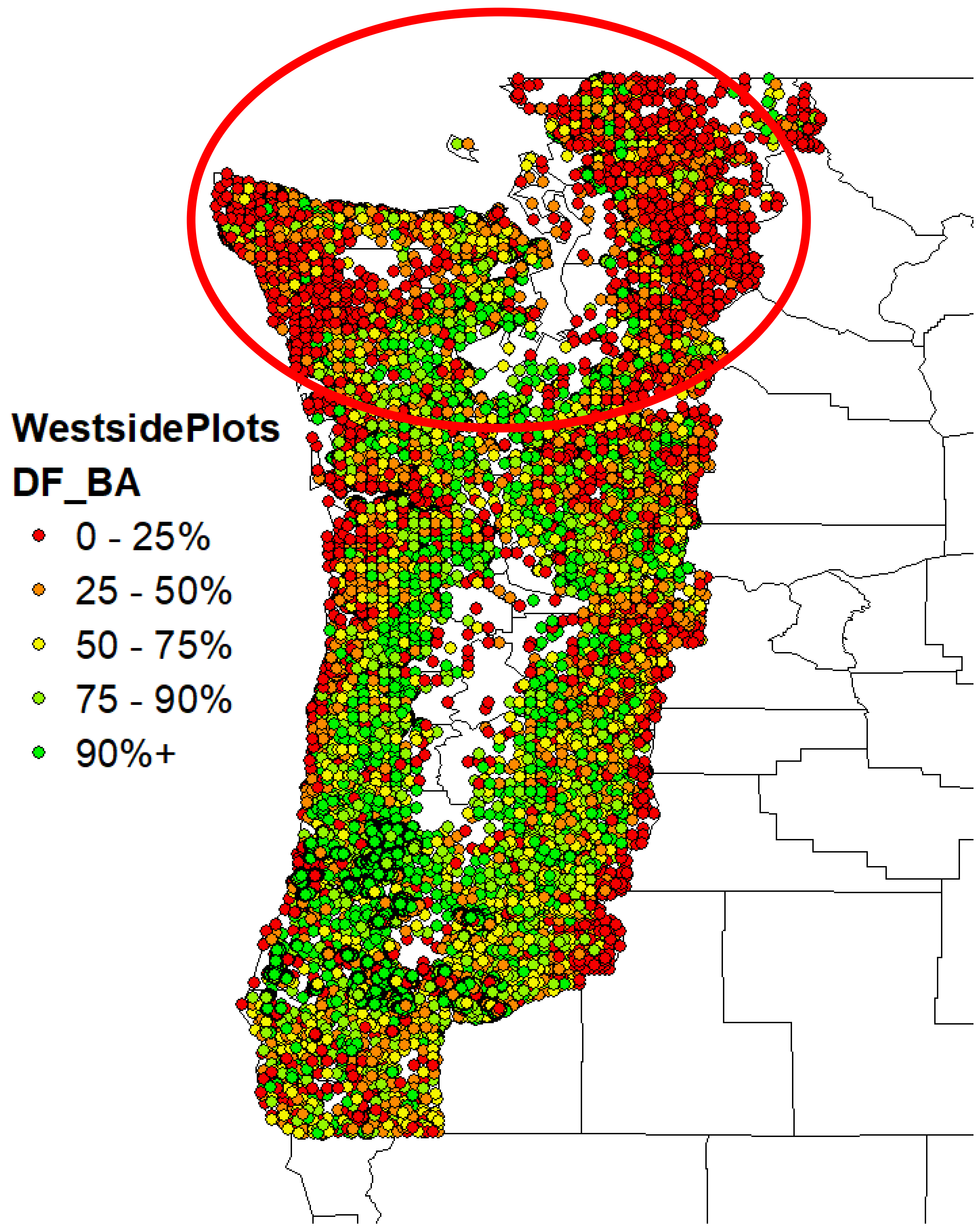


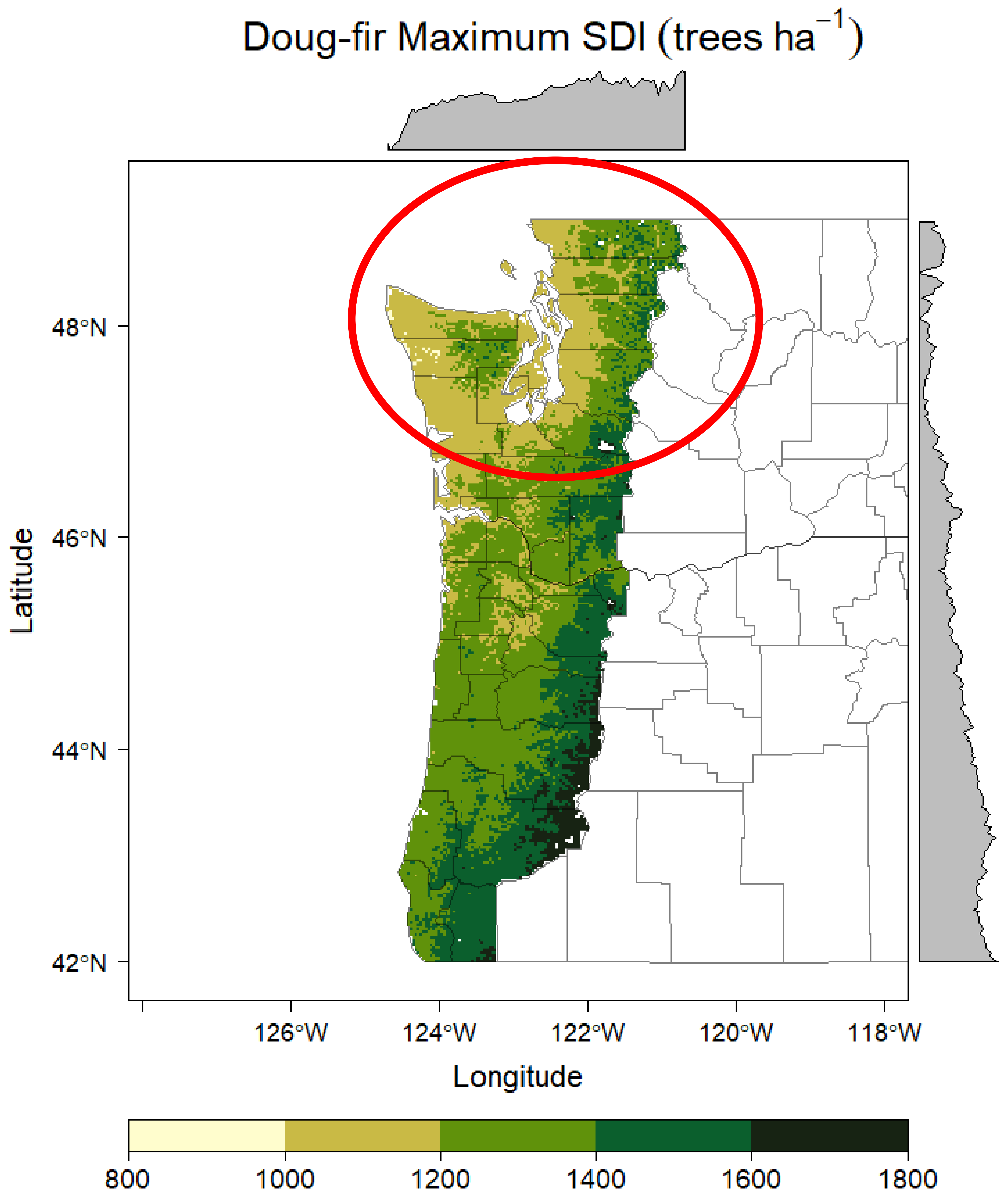
n=155,083

Min	25%	50%	75%	95%
839	1203	1301	1415	1579

Max SDI	Source
1360-1470	Reineke, 1933
1450	Long, 1985
1451	Weiskittel et al, 2009
1376	Woodall et al, 2005
1478	Long et al, 1988
1815 (BC,CAN)	Comeau et al, 2010
1491 (GB)	Comeau et al, 2010


Doug-fir Maximum SDI (trees ha^{-1})
48°N
46°N
44°N
42°N
Latitude
126°W
124°W
122°W
120°W
118°W
Longitude
800
1000
1200
1400
1600
1800


WestsidePlots
DF_BA
0 - 25%
25 - 50%
50 - 75%
75 - 90%
90%+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48°N
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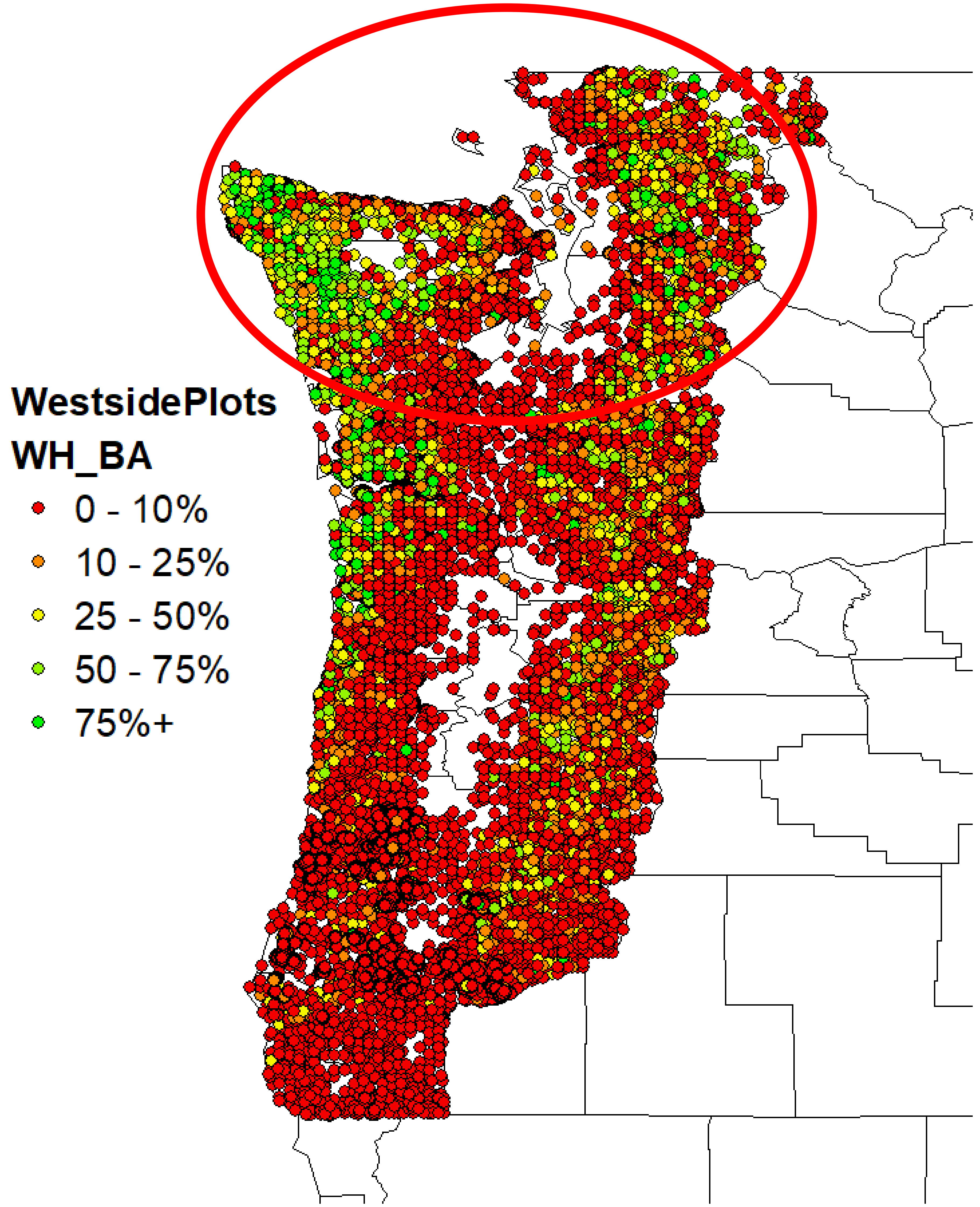
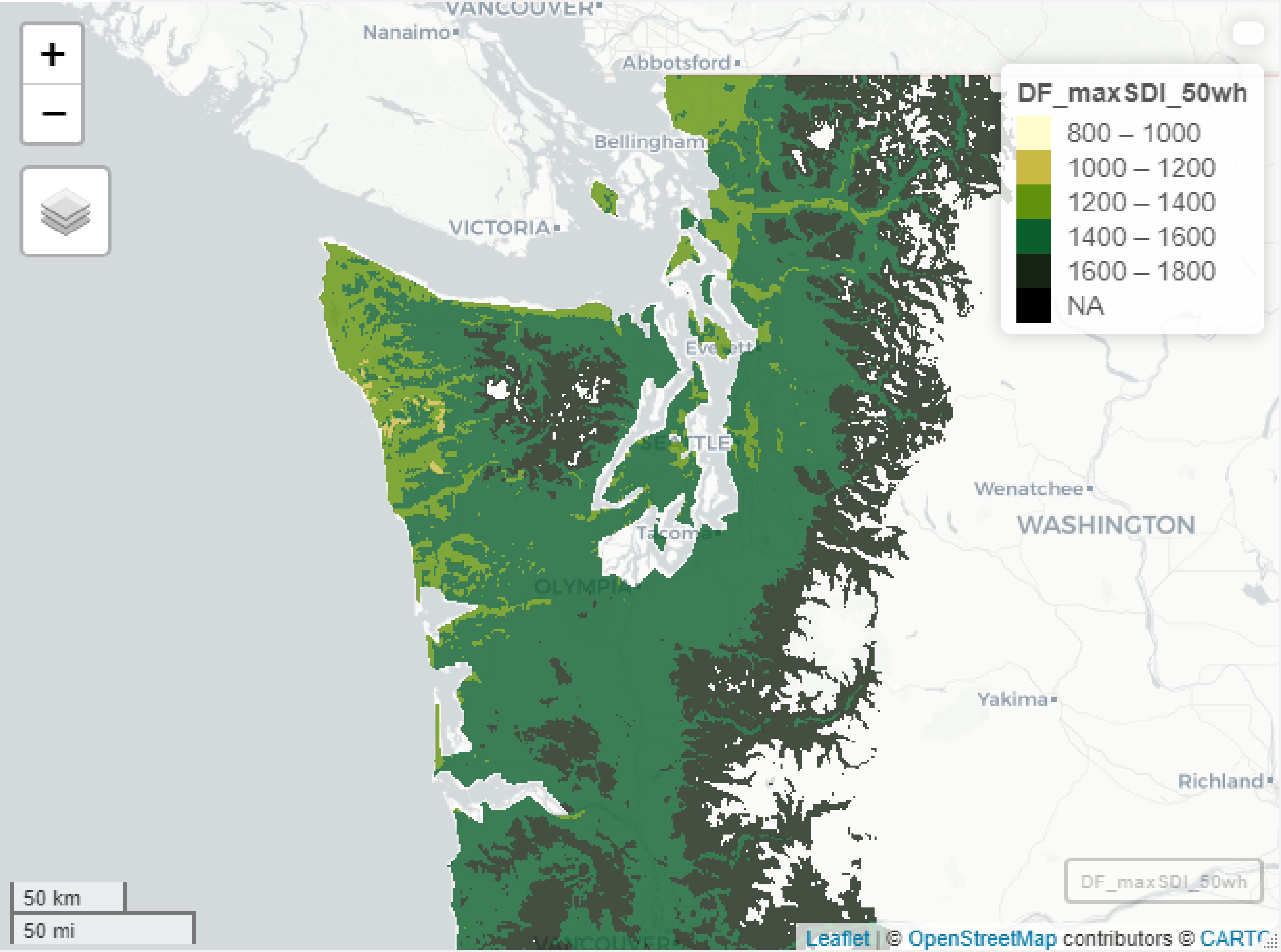
122°W
120°W
118°W
Longitude
800
1000
1200
1400
1600
1800


WestsidePlots
WH_BA
0 - 10%
10 - 25%
25 - 50%
50 - 75%
75%+



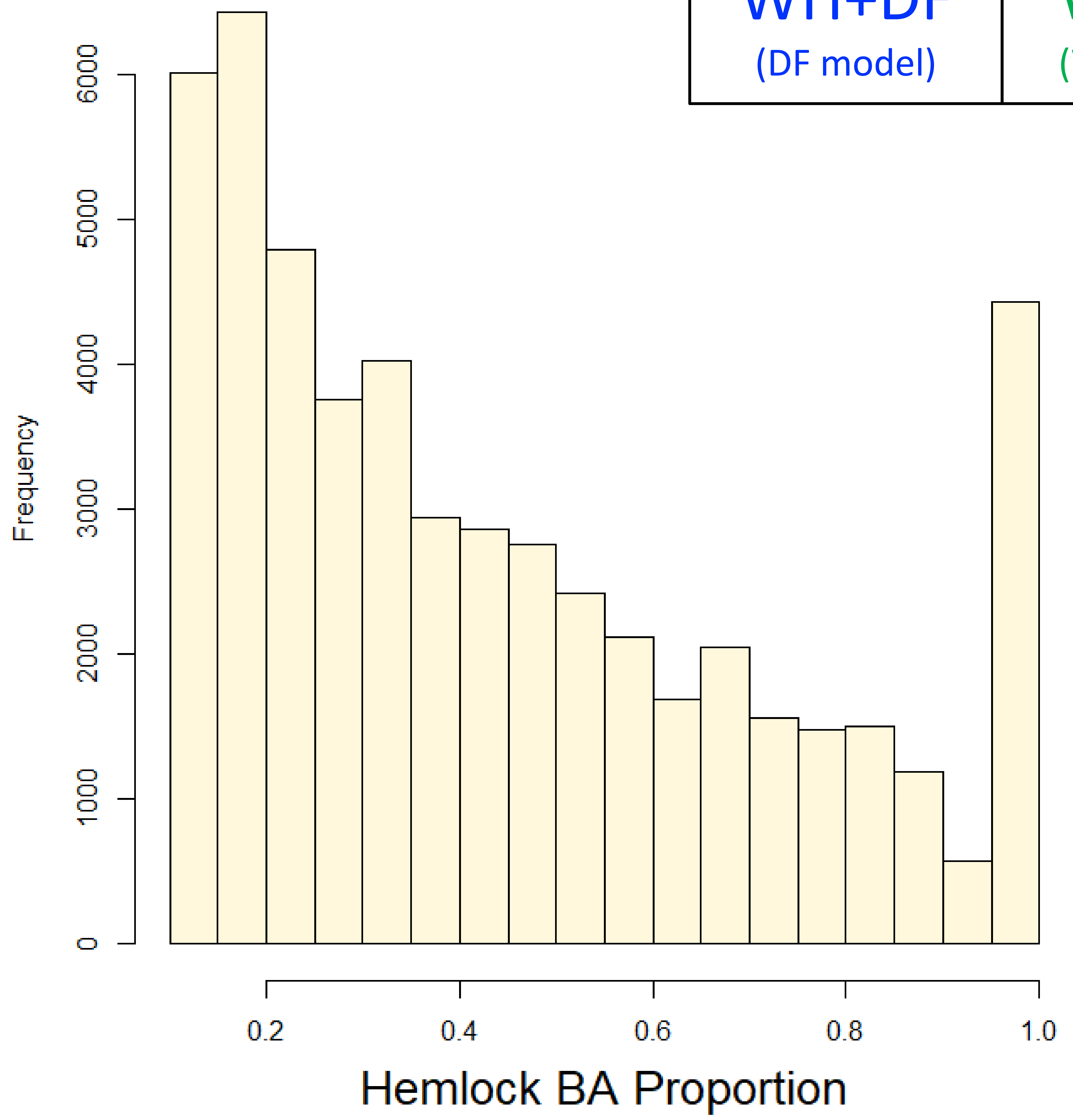
50% Western Hemlock BA Proportion in model

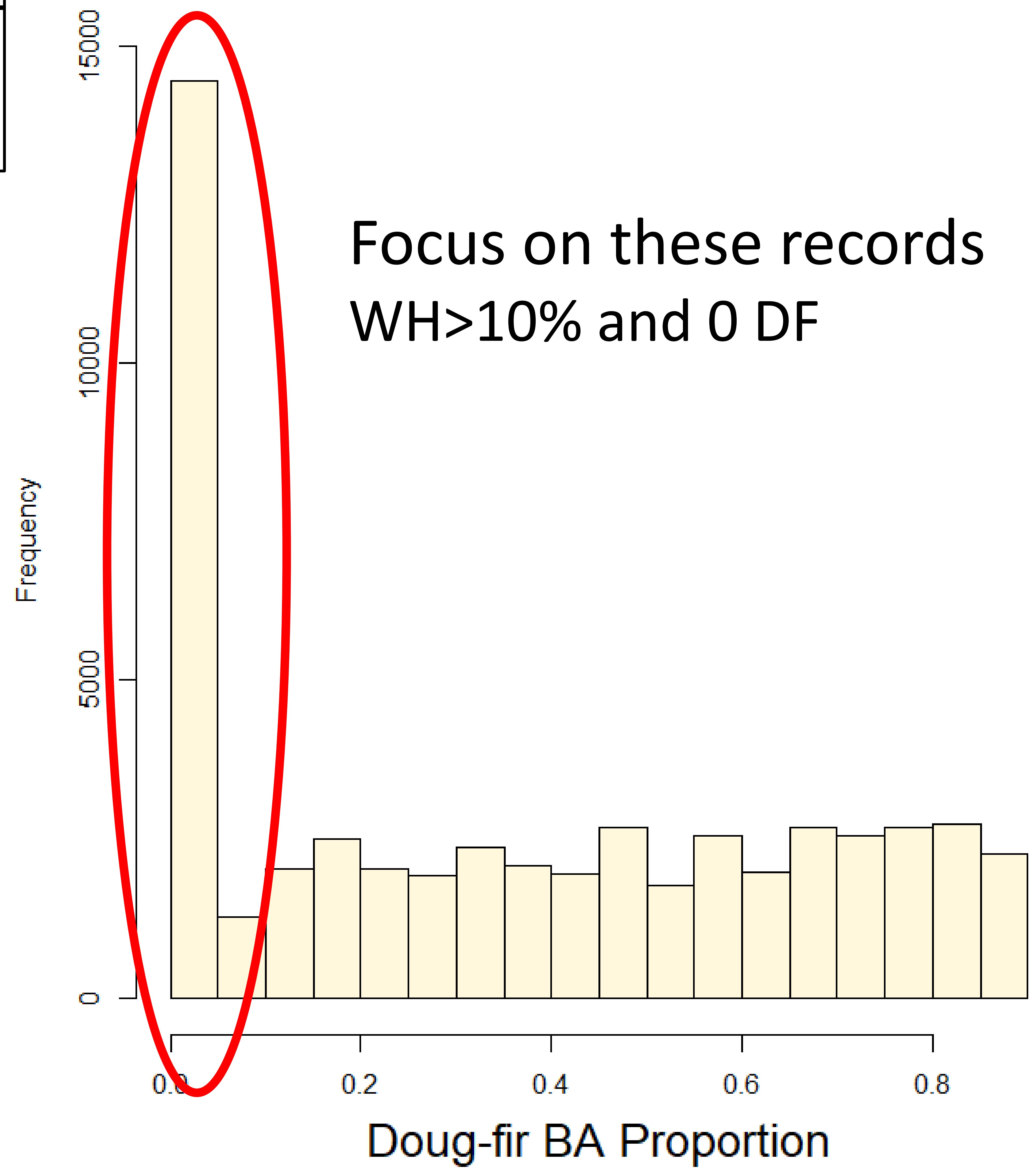
WESTERN HEMLOCK

MODELING APPROACH

- 52,578 plots with at least 10% W. Hemlock by BA
- Data Cleaning same as DF
- During modelling process, records without Doug-fir responded different than records with Doug-fir
  - Plots with DF tended to be dominated by DF (~37% had >50% Doug-fir BA)
  - DF BA proportion was extremely influential in model, lowering Hemlock maxSDI significantly
- Removed plots with DF BA, leaving 13,737 records of Hemlock plots
  - Wetter, less droughty locations
- Random Forest on calculated 95% quantile SDI (LQMM) for Variable Selection
- Stochastic Frontier Analysis

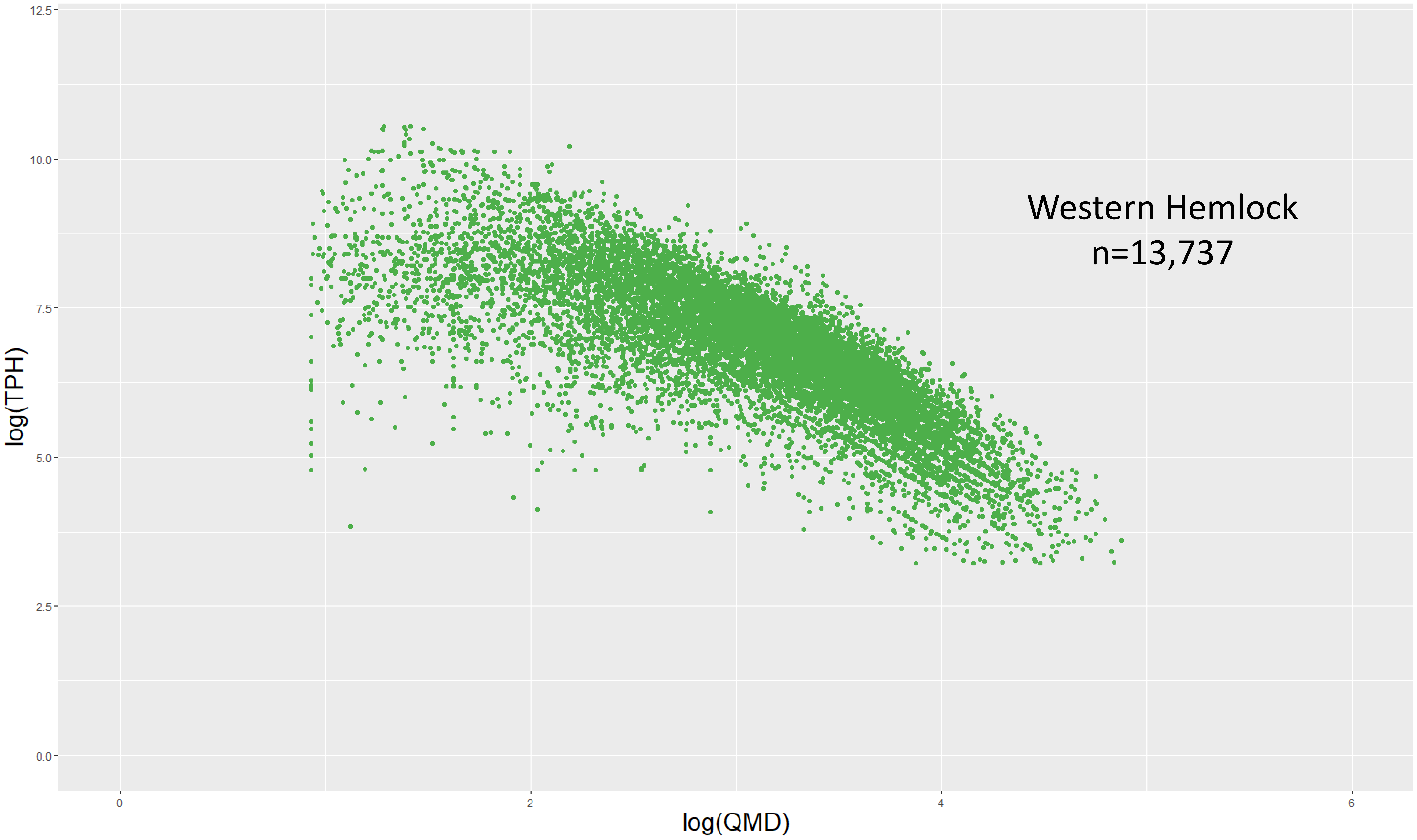
DF-WH (DF model)	DF+WH (DF model)
WH+DF (DF model)	WH-DF (WH model)





Focus on these records

WH>10% and 0 DF

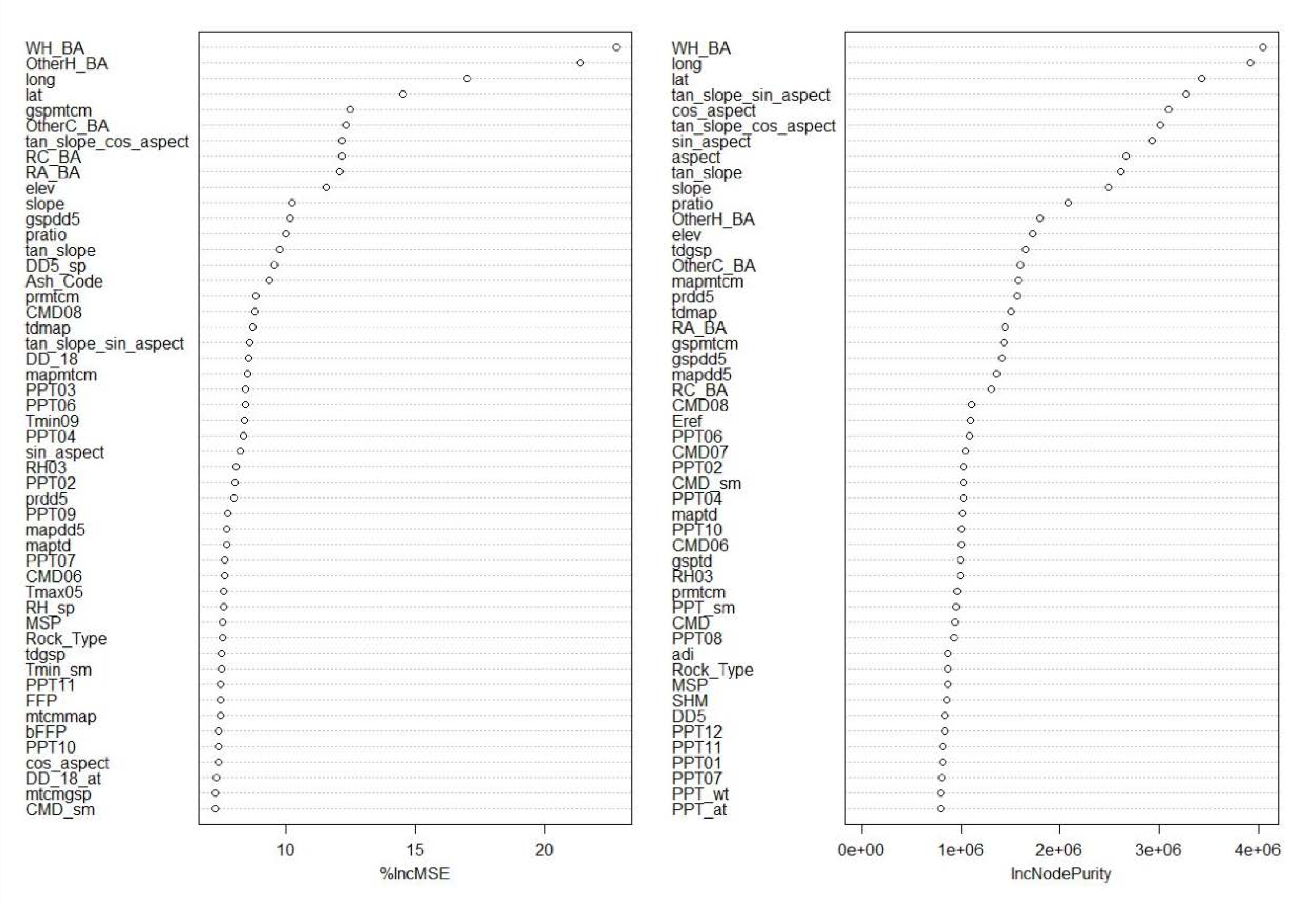


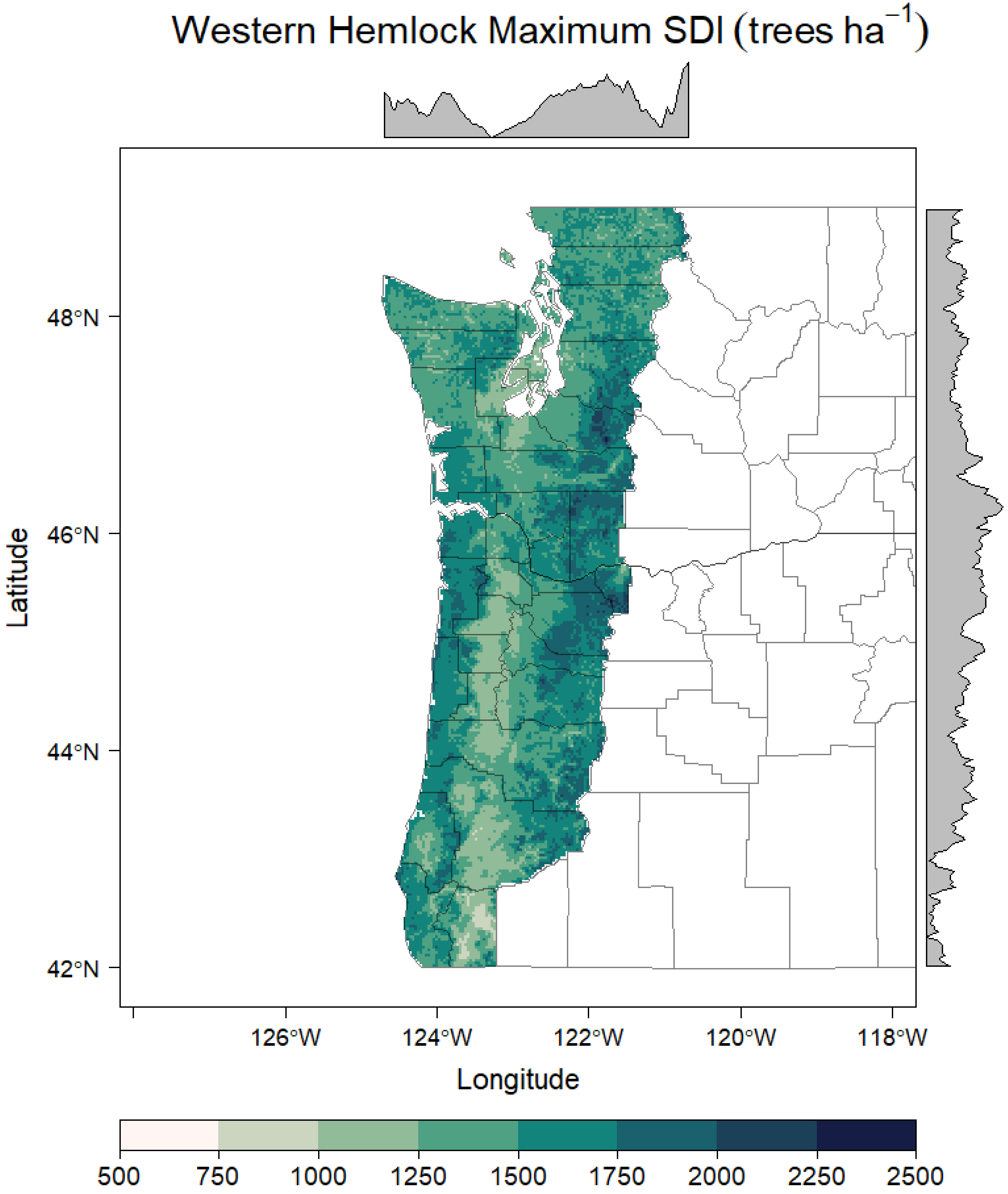
Western Hemlock
n=13,737
log(TPH)
log(QMD)
12.5
10.0
7.5
5.0
2.5
0.0
0
2
4
6

WESTERN HEMLOCK VARIABLE SELECTION

RANDOM FOREST

- Geographic Location
- Topography
- Other Species’ BA
  - Base model as pure WH
- Timing of precip
- Interaction of precip and cool temps
- Relative Humidity





n=13,137

Min	25%	50%	75%	99%
890	1355	1500	1654	1973

Max SDI	Source
1688	Weiskittel et al, 2009
1950	Long, 1985
2100	Hyink et al, 1987

FUTURE SCENARIOS

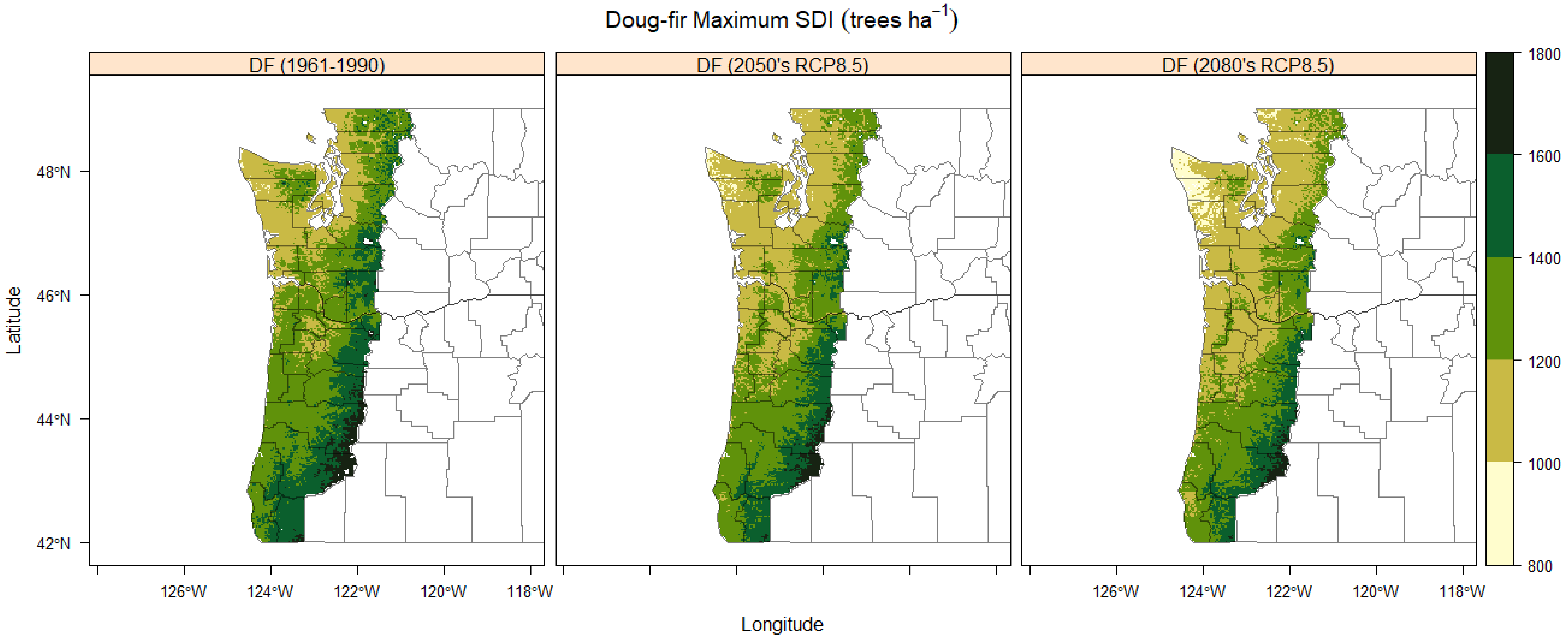
RUN MODEL WITH CLIMATE PROJECTIONS

"Historical climate data are necessary for understanding relationships between climate and biological response of organisms, or general patterns of ecological adaptations to local climate environments. Such insight can be used to build mechanistic or statistical models…"

- Under changing patterns on precipitation, temperature
- Atmosphere-Ocean Global Circulation Models (AOGCMs)
  - Ensemble of 15 GCMs from the Climate Model Intercomparison Project 5 (CMIP5)
- Representative Concentration Pathways (RCPs)
  - RCP4.5 – emission peak in 2040's and decline
  - RCP8.5 – emissions continue to increase throughout the century
- Doug-fir ran with future changes in ratio of Growing Season Precip to Annual Precip and interaction of precip and cool temps
- W. Hemlock ran with future changes in precip ratio, RH and interaction of precip and cool temps

DOUGLAS-FIR

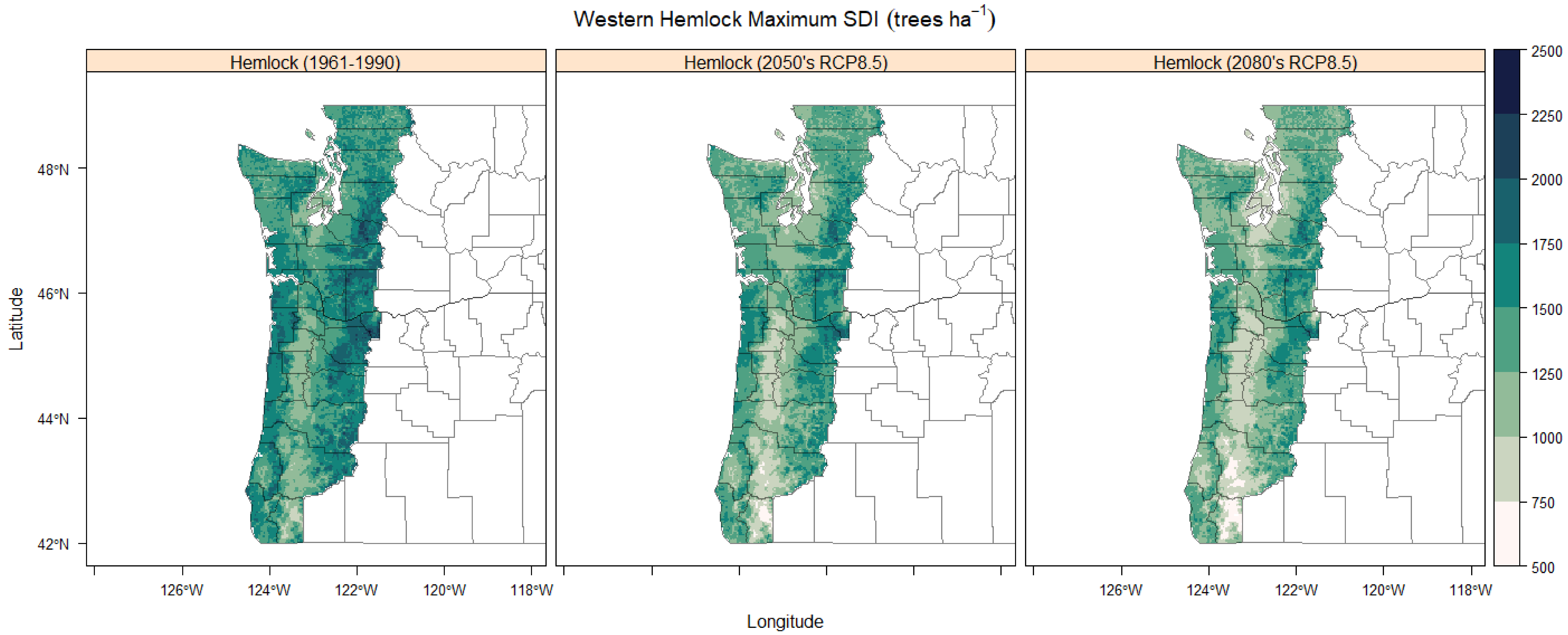
FAIRLY RESILIENT – 6% AVG DROP (LOCATION SPECIFIC)



Historic	2050's RCP 8.5	2080's RCP8.5
1579 (95%q maxSDI)	1513 (95%q maxSDI)	1480 (95%q maxSDI)

WESTERN HEMLOCK

LESS RESILIENT – 13% AVG DROP (LOCATION SPECIFIC)

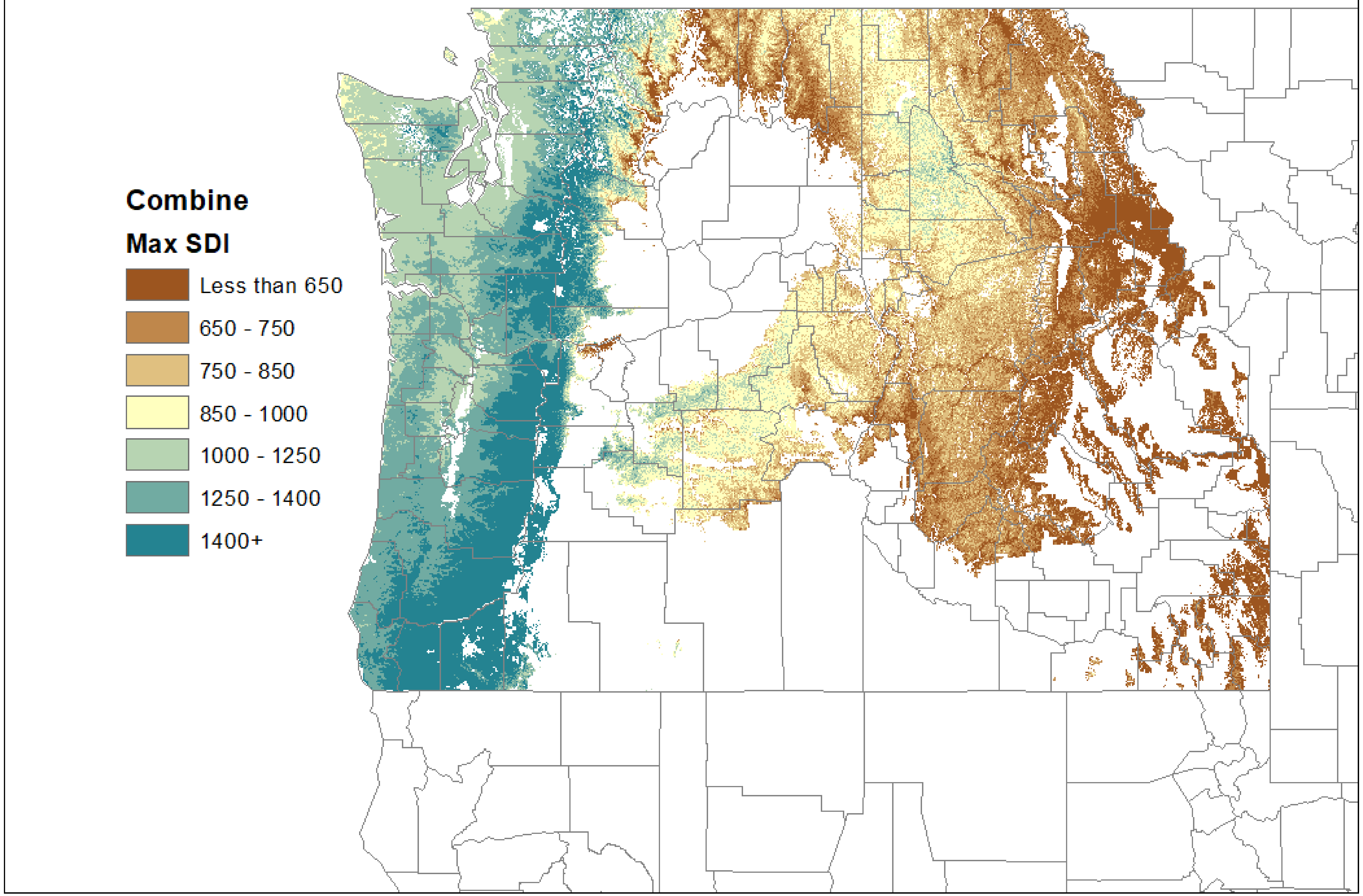


Historic	2050's RCP 8.5	2080's RCP8.5
1973 (99%q maxSDI)	1783 (99%q maxSDI)	1720 (99%q maxSDI)

CONTINUED WORK

- Continue exploring variable importance in DF and WH
- Examine future scenarios further
- Other Species
- Other Modeling Approaches
  - Quantile Regression
  - Non-parametric ensemble approach – RF, GBM
- Explore diameter distributions and cutoffs where data available
- Combining regional models

Douglas-fir


Combine
Max SDI
Less than 650
650 - 750
750 - 850
850 - 1000
1000 - 1250
1250 - 1400
1400+

ACKNOWLEDGMENTS

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