Supplement S2. Vegetation and Land Cover Classification System and Background Materials to Link State Transitions to Douglas-Fir Site Index and MC1 Climate Drivers

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Each section of this supplement is comprised of a previously unpublished report generated by different members of the research team during the course of this project.

Section 1 is reprinted in modified form from:
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Section 2 is authored by Bart Johnson.

Sections 3-6 are authored by Peter Gould and Connie Harrington.

1. SWCNH State-and-Transition Model Community Types

The full successional plus managed states vegetation system was built based on Yospin et al. 2015.

Cover Type Classification. We reduced diverse species and species assemblages to eleven successional cover types. In general, we grouped species that were phylogenetically or ecologically related. Each group has local and regional archetypes. The first is a group of xeric, broadleaf deciduous trees. Deciduous oaks (*Quercus* spp.) are the archetype, with Oregon white oak (*Quercus garryana)* and California black oak (*Quercus kelloggii)* the current local dominants. The group also includes chinquapin (*Chrysolepis spp.*). We grouped mesic broadleaf deciduous trees that are frequently found in riparian forest or on mesic slopes. In the Willamette Valley, the archetype for this group is Oregon big leaf maple (*Acer macrophyllum*), but it also includes many other genera (*Alnus*, *Cornus*, *Fraxinus*, *Malus*, *Populus*, *Prunus*, *Salix*). Our archetype for less mesic needleleaf evergreen species was Douglas-fir (*Pseudotsuga menziesii*). The archetype for more mesic needleleaf evergreen species was grand fir (*Abies grandis*), but this group also includes the genera *Thuja* and *Tsuga*. Finally, there are two community types that are not abundant in the Willamette Valley now, but could be in the future with climate change: an evergreen oak community, represented by Pacific madrone (*Arbutus menziesii) and potentially including* tanoak (*Lithocarpus densiflorus*) and evergreen oak (*Quercus*) species; and a xeric evergreen needle-leaf community, represented by ponderosa pine.

OA (Oak Savanna)
Open broadleaf deciduous communities, typically oak. May include other species, but must have canopy cover below 25%. This group includes most prairie and savanna.

OW (Oak Woodland)
Broadleaf deciduous woodland, typically oak. May include other species. Must have canopy cover between 25% and 60%.

OD (Oak over Douglas-fir)
Xeric woodlands of broadleaf deciduous trees growing above needleleaf evergreens.

DO (Douglas-fir over oak)
Woodlands and low-density forests of needleleaf evergreen trees growing above xeric broadleaf deciduous trees.

DD (Dry Douglas-fir)
Less mesic deciduous woodlands and low-density forests. These may contain a wide variety of species, but Douglas-fir typically dominates.

BM (Bigleaf Maple)
Mesic broadleaf deciduous forest, big leaf maple usually dominates. This may include a substantial component of mesic needleleaf evergreen trees.

DM (Douglas-fir and Maple)
Mesic mixed needleleaf evergreen and broadleaf deciduous forest. The typical needleleaf evergreen species is Douglas-fir, but there is also a large grand fir component. The typical broadleaf deciduous species is big leaf maple. The needleleaf evergreen component must be dominant over the broadleaf deciduous component.

DG (Douglas-fir and Grand fir)
Mesic needleleaf evergreen forest. Grand fir is the dominant species, but there may be substantial quantities of Douglas-fir and big leaf maple.

M (Madrone)
Systems dominated by evergreen broadleaf species, typified by Pacific madrone. This includes prairie, savanna and woodland systems, but must not include a substantial Douglas-fir component.

MD (Madrone over Douglas-fir)
Systems dominated by evergreen broadleaf species, with a substantial component of Douglas-fir in the understory.

P (Pine)
Systems dominated by xeric evergreen species, typified by ponderosa pine. This includes prairie, savanna and woodland systems.

CTSS
The **ctss** (cover type, structural stage) description of a STM state is a concatenation of five components.

First is the "row" or "climax community type":

oa	Deciduous oak savanna
ow	Deciduous oak woodland
od	Deciduous oak over Douglas-fir
do	Douglas-fir over oak
dd	Less mesic Douglas-fir
bm	Big leaf maple
dm	More mesic Douglas-fir
dg	Douglas-fir and grand fir
m	Madrone
md	Madrone over Douglas-fir
p	Xeric evergreen needle leaf

Next is size class:

gfp	Grass-forb, post-disturbance
gf	Grass-forb
sh-	Low density shrub
y	young (<5" diameter-at-breast-height [dbh])
p	pole (5-10" dbh)
s	small (10-20" dbh)
l	large (>20" dbh)

Canopy closure is next, although it is only included for size classes **p**, **s** and **l**:

o	Open canopy (<25% canopy cover
m	Medium closure (25 – 60% canopy cover)
c	Closed canopy (>60% canopy cover)

Next is the canopy layering, included only for size classes **s** and **m**:

1	Single canopy layer
2	More than one canopy layer

Finally, there may be "**rf**" appended, indicating that the state has reduced fuels

2. List of Land Use/Land Cover and Vegetation Types

LULC and Vegetation States in SWCNH Envision			
last modified, 10/12/2013			
Note that only the vegclass number is available as an attribute reference in Envision.			
Legend	**Vegclass**	**ctss**	**Description**
	LULC (Land Use/Land Cover) Classes		
	1	-	Residential 0 - 4 DU/ac
	2	-	Residential 4 - 9 DU/ac
	3	-	Residential 9 - 16 DU/ac
	4	-	Residential > 16 DU/ac
	6	-	Commercial
	7	-	Commercial/Industrial
	8	-	Industrial
	10	-	Residential and commercial
	11	-	Urban non-vegetated unknown
	18	-	Railroad
	19	-	Primary roads
	20	-	Secondary roads
	21	-	Light duty roads
	24	-	Rural non-vegetated unknown
	29	-	Main channel non-vegetated
	33	-	Water
	40	-	Snow/ice
	42	-	Barren
	49	-	Urban tree overstory
	66	-	Hybrid poplar
	67	-	Grass seed
	68	-	Row crop
	71	-	Grains
	72	-	Nursery
	73	-	Berries & Vineyards
	74	-	Double cropping
	75	-	Hops
	76	-	Mint
	78	-	Sugar beet seed
	83	-	Hay
	85	-	Pasture
	88	-	Bare/fallow
	89	-	Flooded/marsh
	90	-	Field crop
	91	-	Turfgrass/park
	92	-	Orchard
	93	-	Christmas trees
	95	-	Woodlot

LULC and Vegetation States in SWCNH Envision			
	Current Unmanaged Successional Vegetation Classes		
	200	oagf	Oak savanna, grass-forb stage (upland prairie)
	201	oay	Oak savanna, saplings
	202	oapo	Oak savanna, pole-sized trees
	203	oaso1	Oak savanna, small trees, one layer
	204	oalo1	Oak savanna, large trees, one layer
	209	oagfp	Oak savanna, grass-forb stage, post-disturbance (upland prairie)
	210	owpm	Oak woodland, pole-sized trees
	211	owsm1	Oak woodland, small trees, one layer
	212	owlm1	Oak woodland, large trees, one layer
	220	odsm2	Oak-fir woodland, small trees, two layers
	221	odlm2	Oak-fir woodland, large trees, two layers
	230	dogf	Douglas-fir w/oak, grass-forb stage
	231	doy	Douglas-fir w/oak, saplings
	232	dopm	Douglas-fir w/oak, pole-sized trees, medium to closed canopy
	233	dosm2	Douglas-fir w/oak, small trees, medium to closed canopy, two layers
	234	dolm2	Douglas-fir w/oak, large trees, medium to closed canopy, two layers
	239	dogfp	Douglas-fir w/oak, grass-forb stage, post-disturbance
	240	ddgf	Douglas-fir, grass-forb stage
	241	ddy	Douglas-fir, saplings
	242	ddpo	Douglas-fir, pole-sized trees, open canopy
	243	ddso1	Douglas-fir, small trees, open canopy, one layer
	244	ddlo1	Douglas-fir, large trees, open canopy, one layer
	245	ddpm	Douglas-fir, pole-sized trees, medium to closed canopy
	246	ddsm2	Douglas-fir, small trees, medium to closed canopy, two layers
	247	ddlm2	Douglas-fir, large trees, medium to closed canopy, two layers
	259	ddgfp	Douglas-fir, grass-forb stage, post-disturbance
	260	dmgf	Mesic mixed Douglas-fir & broadleaf deciduous, grass-forb stage
	261	dmy	Mesic mixed Douglas-fir & broadleaf deciduous, saplings
	262	dmpm	Mesic mixed Douglas-fir & broadleaf deciduous, pole-sized trees, medium canopy
	263	dmsm1	Mesic mixed Douglas-fir & broadleaf deciduous, small trees, medium canopy, one layer
	264	dmlm1	Mesic mixed Douglas-fir & broadleaf deciduous, large trees, medium canopy, one layer
	265	dmpc	Mesic mixed Douglas-fir & broadleaf deciduous, pole-sized trees, closed canopy
	269	dmgfp	Mesic mixed Douglas-fir & broadleaf deciduous, grass-forb stage, post-disturbance
	270	dgsc2	Mesic needleleaf evergreen, small trees, closed canopy, two layers
	271	dglc2	Mesic needleleaf evergreen, large trees, closed canopy, two layers
	280	bmgf	Mesic broadleaf deciduous, grass-forb stage
	281	bmy	Mesic broadleaf deciduous, saplings
	282	bmpm	Mesic broadleaf deciduous, pole-sized trees, medium canopy
	285	bmsc1	Mesic broadleaf deciduous, small trees, closed canopy, one layer
	286	bmlc1	Mesic broadleaf deciduous, large trees, closed canopy, one layer
	289	bmgfp	Mesic broadleaf deciduous, grass-forb stage, post-disturbance

LULC and Vegetation States in SWCNH Envision			
	Reduced Fuels States - Current Managed Successional Vegetation Classes		
	300	oagfrf	Oak savanna, grass-forb stage, reduced fuels(upland prairie)
	301	oayrf	Oak savanna, saplings, reduced fuels
	302	oaporf	Oak savanna, pole-sized trees, reduced fuels
	303	oaso1rf	Oak savanna, small trees, one layer, reduced fuels
	304	oalo1rf	Oak savanna, large trees, one layer, reduced fuels
	308	owgfrf	Oak woodland, grass-forb stage, reduced fuels
	309	owyrf	Oak woodland, saplings, reduced fuels
	310	owpmrf	Oak woodland, pole-sized trees, medium canopy, reduced fuels
	311	owsm1rf	Oak woodland, small trees, one layer, reduced fuels
	312	owlm1rf	Oak woodland, large trees, one layer, reduced fuels
	318	oagfprf	Oak savanna, grass-forb stage, post-disturbance, reduced fuels (upland prairie)
	319	owgfprf	Oak woodland, grass-forb stage, post-disturbance, reduced fuels
	320	odsm2rf	Oak-fir woodland, small trees, two layers, reduced fuels
	321	odlm2rf	Oak-fir woodland, large trees, two layers, reduced fuels
	333	dosm2rf	Douglas-fir w/oak woodland, small trees, two layers, reduced fuels
	334	dolm2rf	Douglas-fir w/oak woodland, large trees, two layers, reduced fuels
	339	dogfprf	Douglas-fir w/oak, grass-forb stage, post-disturbance, reduced fuels
	340	ddgfrf	Douglas-fir, grass-forb stage, reduced fuels
	341	ddyrf	Douglas-fir, saplings, reduced fuels
	342	ddporf	Douglas-fir woodland, pole-sized trees, reduced fuels
	343	ddso1rf	Douglas-fir woodland, small trees, one layer, reduced fuels
	344	ddlo1rf	Douglas-fir woodland, large trees, one layer, reduced fuels
	346	ddsm2rf	Douglas-fir woodland, small trees, two layers, reduced fuels
	347	ddlm2rf	Douglas-fir woodland, large trees, two layers, reduced fuels
	359	ddgfprf	Douglas-fir, grass-forb stage, post-disturbance, reduced fuels
	362	dmpmrf	Mesic mixed Douglas-fir & broadleaf deciduous woodland, pole-sized trees, reduced fuels
	363	dmsm1rf	Mesic mixed Douglas-fir & broadleaf deciduous woodland, small trees, one layer, reduced fuels
	364	dmlm1rf	Mesic mixed Douglas-fir & broadleaf deciduous woodland, large trees, one layer, reduced fuels
	369	dmgfprf	Mesic mixed Douglas-fir & broadleaf deciduous, grass-forb stage, post-disturbance, reduced fuels
	370	dgsc2rf	Mesic needleleaf evergreen woodland, small trees, two layers, reduced fuels
	371	dglc2rf	Mesic needleleaf evergreen woodland, large trees, two layers, reduced fuels
	380	bmgfrf	Mesic broadleaf deciduous, grass-forb stage, reduced fuels
	381	bmyrf	Mesic broadleaf deciduous, saplings, reduced fuels
	382	bmpmrf	Mesic broadleaf deciduous woodland, pole-sized trees, reduced fuels
	385	bmsc1rf	Mesic broadleaf deciduous woodland, small trees, one layer, reduced fuels
	386	bmlc1rf	Mesic broadleaf deciduous woodland, large trees, one layer, reduced fuels
	389	bmgfprf	Mesic broadleaf deciduous, grass-forb stage, post-disturbance, reduced fuels

LULC and Vegetation States in SWCNH Envision			
	Plantation Conifer Sequence		
	440	ddgfpl	Douglas-fir, grass-forb stage, plantation
	441	ddypl	Douglas-fir, saplings, plantation
	442	ddpopl	Douglas-fir, pole-sized trees, open canopy, plantation
	443	ddsc1pl	Douglas-fir, small trees, closed canopy, one layer, plantation
	444	ddlc1pl	Douglas-fir, large trees, closed canopy, one layer, plantation
	447	ddgc1pl	Douglas-fir, giant trees, closed canopy, one layer, plantation
	448	ddgc2pl	Douglas-fir, giant trees, closed canopy, two layers, plantation
	Emerging Future Successional Vegetation Classes		
	499	pgf	Pine savanna, grass-forb stage (upland prairie)
	500	py	Pine savanna, saplings
	501	ppo	Pine savanna, pole-sized trees
	502	pso1	Pine savanna, small trees, one layer
	503	plo1	Pine savanna, large trees, one layer
	504	ppm	Pine woodland, pole-sized trees
	505	psm2	Pine woodland, small trees, two layers
	506	plm2	Pine woodland, large trees, two layers
	509	pgfp	Pine savanna, grass-forb stage, post-disturbance
	520	mgf	Madrone, grass-forb stage
	521	my	Madrone, saplings
	525	mpm	Madrone, pole-sized trees, medium canopy
	526	msm1	Madrone, small trees, medium canopy, one layer
	527	mlm1	Madrone, large trees, medium canopy, one layer
	529	mgfp	Madrone, grass-forb stage, post-disturbance
	540	mdsm2	Mixed madrone & Douglas-fir, small trees, medium canopy, two layers
	541	mdlm2	Mixed madrone & Douglas-fir, large trees, medium canopy, two layers
	Reduced Fuels States - Emerging Future Successional Vegetation Classes		
	599	pgfrf	Pine savanna, grass-forb stage, reduced fuels (upland prairie)
	600	pyrf	Pine savanna, saplings, reduced fuels
	601	pporf	Pine savanna, pole-sized trees, open canopy, reduced fuels
	602	pso1rf	Pine savanna, small trees, one layer, reduced fuels
	603	plo1rf	Pine savanna, large trees, one layer, reduced fuels
	605	psm1rf	Pine woodland, small trees, one layer, reduced fuels
	606	plm1rf	Pine woodland, large trees, one layer, reduced fuels
	609	pgfprf	Pine woodland, grass-forb stage, post-disturbance, reduced fuels (upland prairie)
	620	mgfrf	Madrone, grass-forb stage, reduced fuels
	621	myrf	Madrone, saplings, reduced fuels
	625	mpmrf	Madrone, pole-sized trees, reduced fuels
	626	msm1rf	Madrone, small trees, medium canopy, one layer, reduced fuels
	627	mlm1rf	Madrone, large trees, medium canopy, one layer, reduced fuels
	629	mgfprf	Madrone, grass-forb stage, post-disturbance, reduced fuels
	640	mdsm2rf	Mixed madrone & Douglas-fir, small trees, medium canopy, two layers, reduced fuels
	641	mdlm2rf	Mixed madrone & Douglas-fir, large trees, medium canopy, two layers, reduced fuels

3. Plot Selection for Calculation of State-and-Transition Probabilities for the CNH Project

Peter Gould and Connie Harrington, PNW Research Station

December 7, 2011

Note: this work was completed between August and October 2010. The work is summarized here.

Introduction

The purpose of this document is to describe the process of selecting plots to populate the transition probabilities for a state-and-transition model (STM). The goal was to identify a set of plots to represent each state. The plots were then projected using the forest vegetation simulator (FVS) and the future condition of each plot was once again classified into a state. The transition probabilities were calculated as the proportion of plots that moved from one state to another.

Data Sources

Bart Johnson's Joint Fire Sciences plots: primarily oak dominated in Willamette Valley

GAP plots from Jane Kurtis (?): primarily oak dominated in Willamette Valley

PNW Integrated database: Data from western Oregon from several sources including FIA (pre 2000), National Forest Inventories (i.e., CVS plots), and BLM plots.

Citation:
Hiserote and Waddell, 2005 Hiserote, B., Waddell, K., 2005. The PNW-FIA integrated database user guide (version 2.0). Data are available at:
http://www.fs.fed.us/pnw/fia/publications/data/data.shtml.

PNW FIA Annual Inventory: Data from recently measured FIA plots in western Oregon (2001-2008).

Citation:
US Forest Service, Forest Inventory and Analysis. FIA Datamart. http://apps.fs.fed.us/fiadb-downloads/datamart.html. Accessed 2010-09-01.

Plot Selection

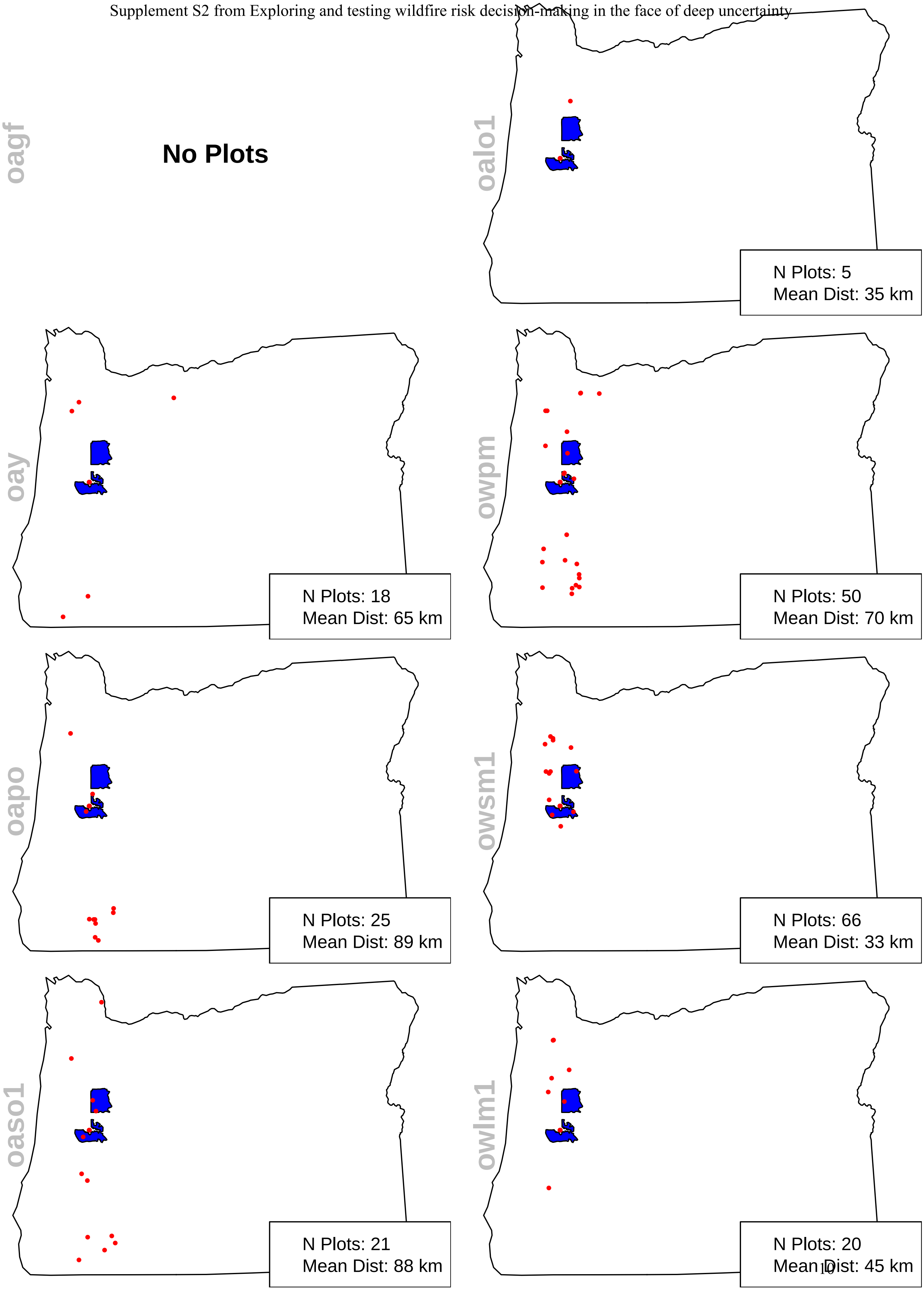
Plots were selected using the following algorithm to identify the plots that were most representative of the study areas:

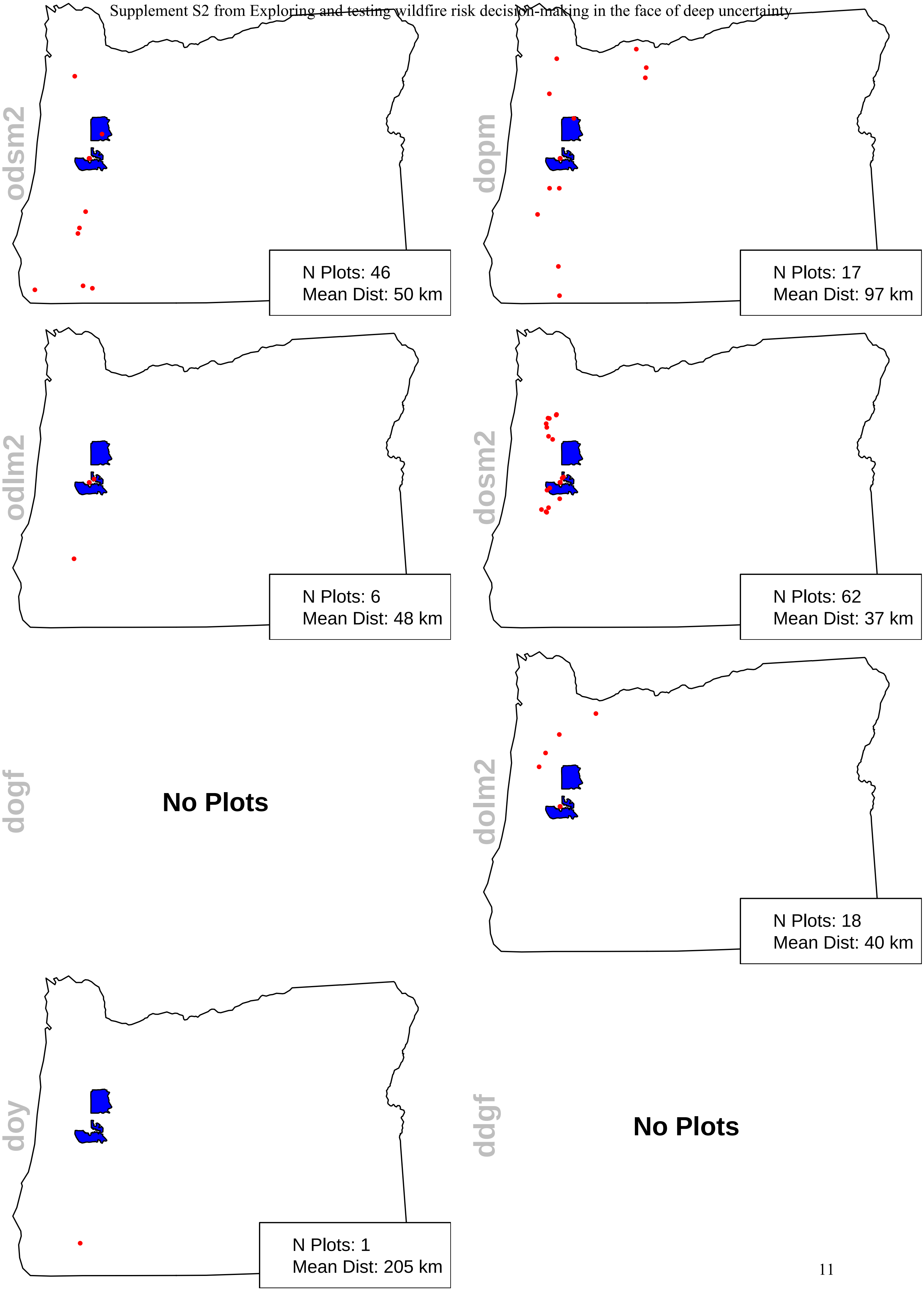
1. Each plot was classified into a state based on the STM critiera.

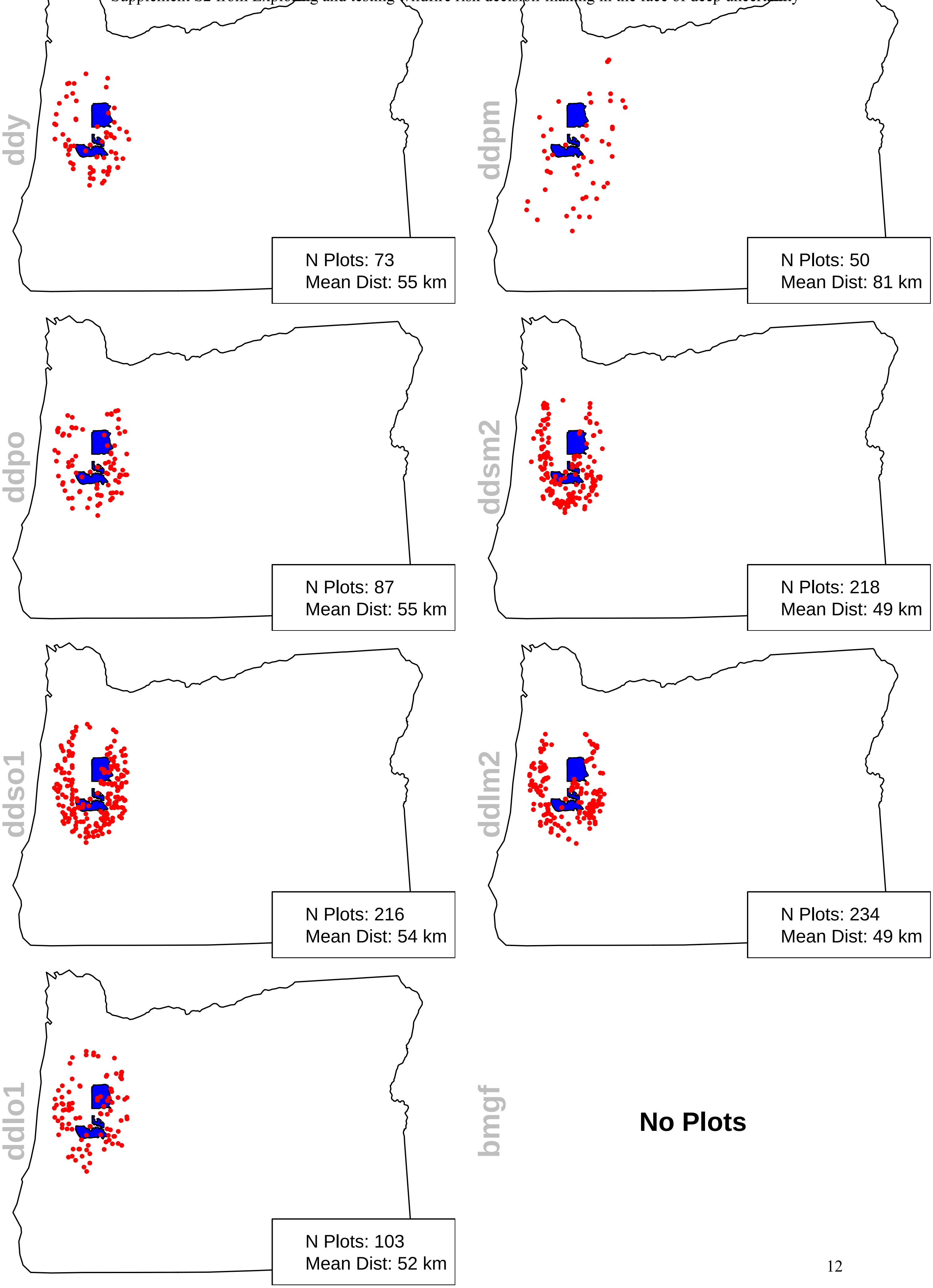
2. The distance from each plot to a centroid at 44.05N, 123.09W (Eugene, OR) was calculated. The distance was weighted so that the E-W distance was 1.7 times the N-S distance. The weighting reflects the greater uniformity of the Willamette Valley in the N-S direction versus the E-W direction.
3. All plots within 100 weighted km of Eugene, OR were selected (44.05N, 123.09W).
4. If fewer than 50 plots were selected for a state, then additional plots were selected by finding the closest plots to the centroid (44.05N, 123.09W) until 50 plots were located or no more plots were available.

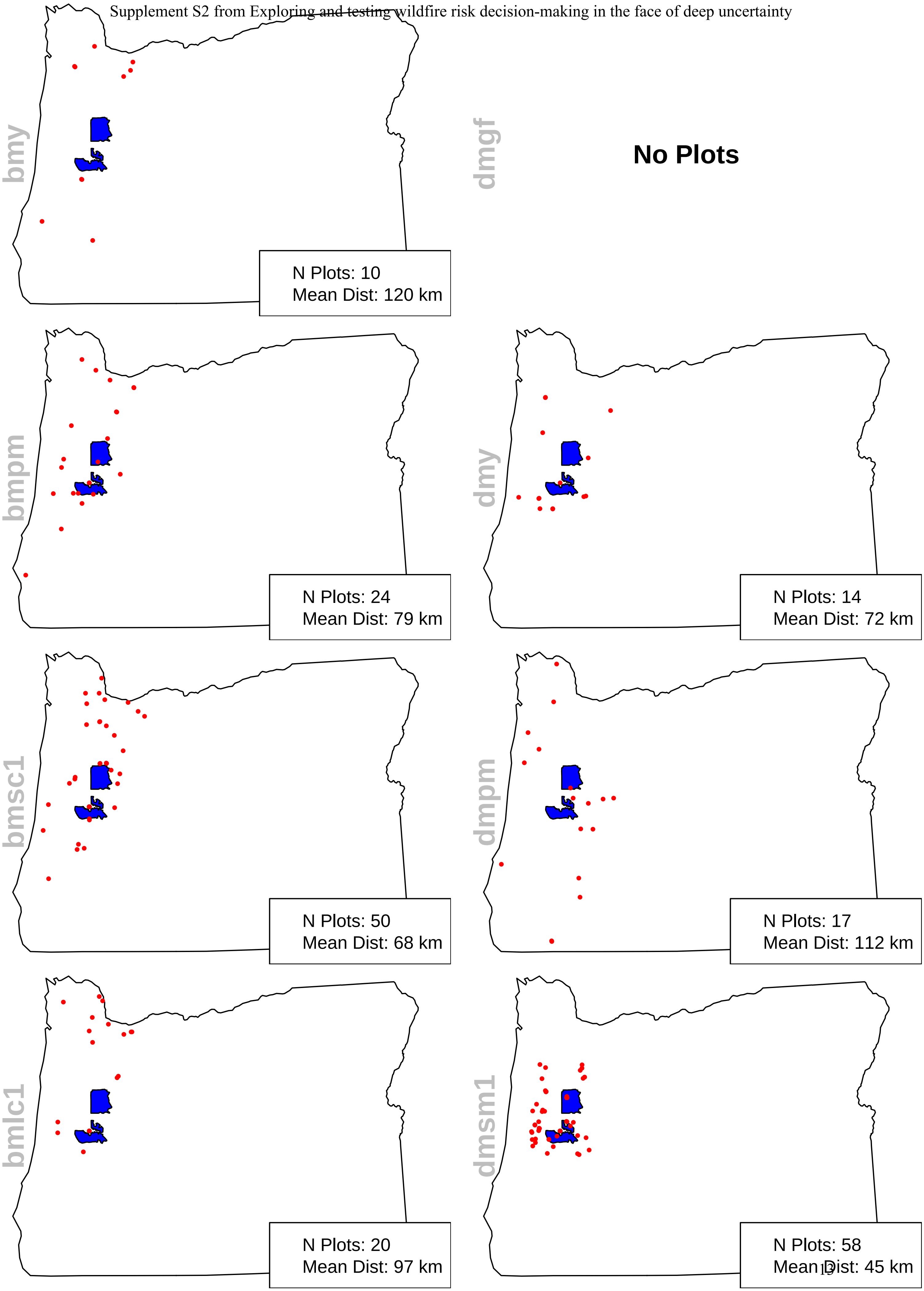
Table 1. Selected plots.

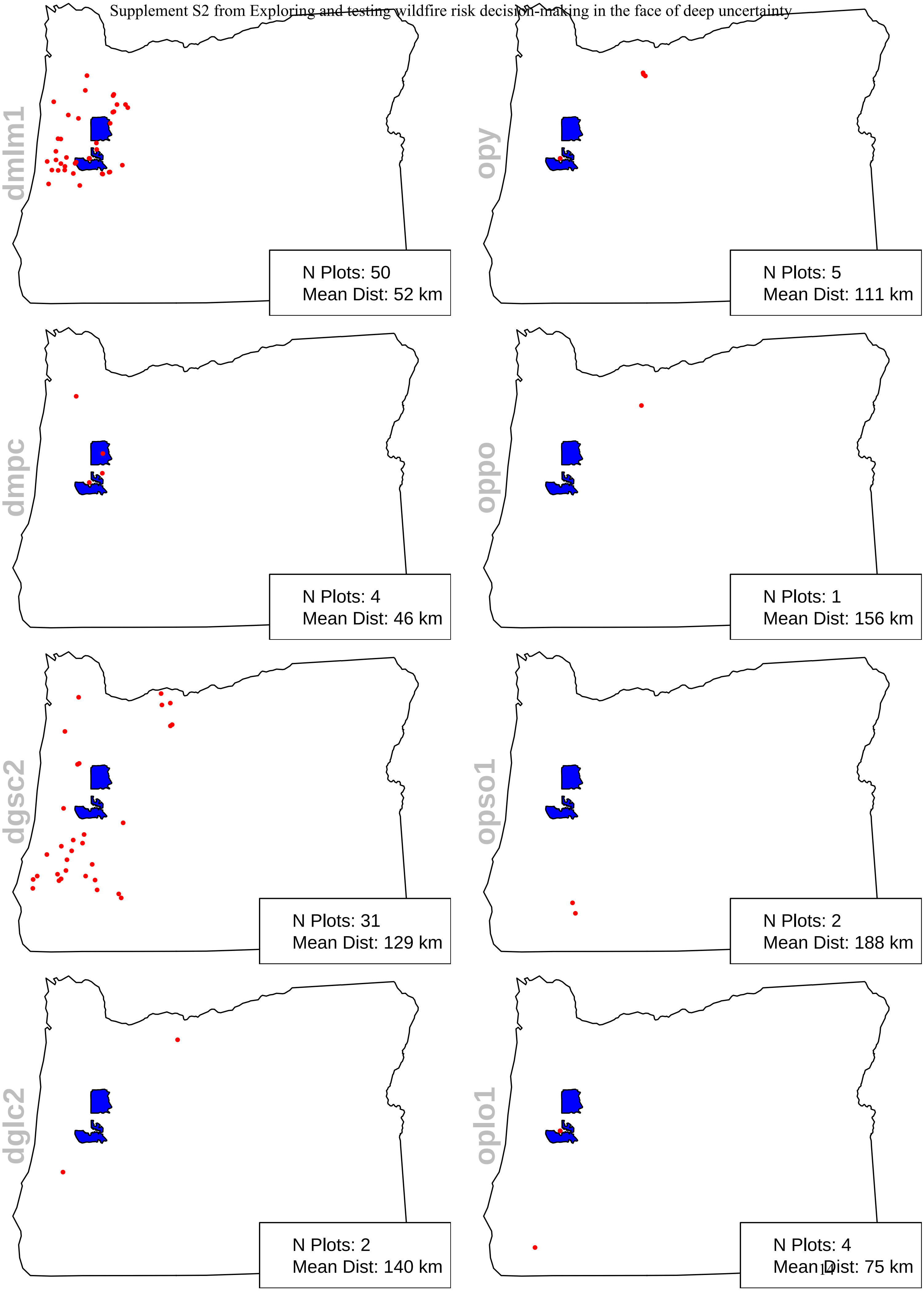
Source	Number of Plots
GAP	342
Joint Fire Science	446
PNW Annual FIA	377
PNW-IDB	927

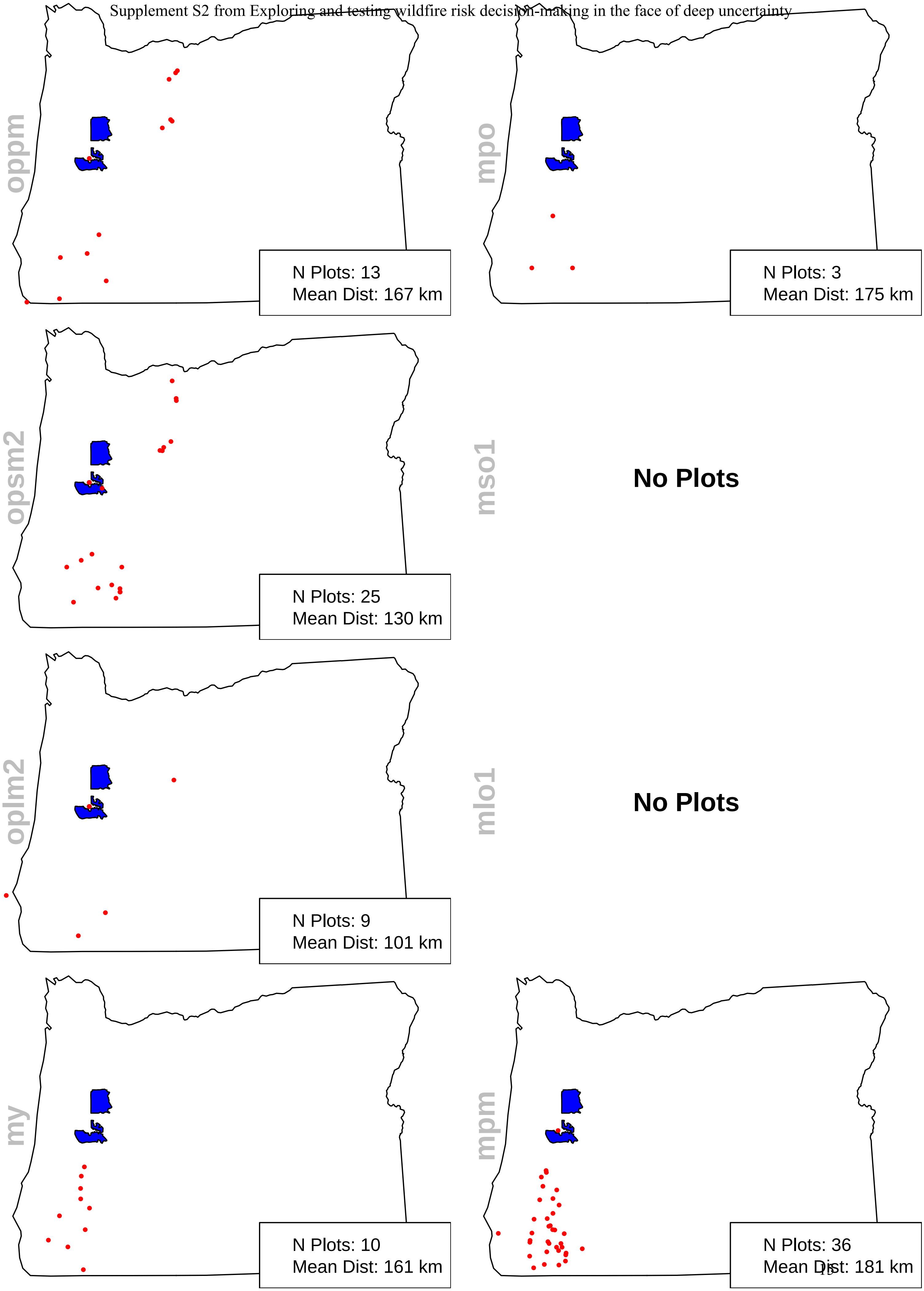

oagf
No Plots
oalo1
N Plots: 5
Mean Dist: 35 km
oay
N Plots: 18
Mean Dist: 65 km
owpm
N Plots: 50
Mean Dist: 70 km
oapo
N Plots: 25
Mean Dist: 89 km
owsm1
N Plots: 66
Mean Dist: 33 km
oaso1
N Plots: 21
Mean Dist: 88 km
owlm1
N Plots: 20
Mean Dist: 45 km


odsm2
N Plots: 46
Mean Dist: 50 km
dopm
N Plots: 17
Mean Dist: 97 km
odlm2
N Plots: 6
Mean Dist: 48 km
dosm2
N Plots: 62
Mean Dist: 37 km
dogf
No Plots
dolm2
N Plots: 18
Mean Dist: 40 km
doy
N Plots: 1
Mean Dist: 205 km
ddgf
No Plots

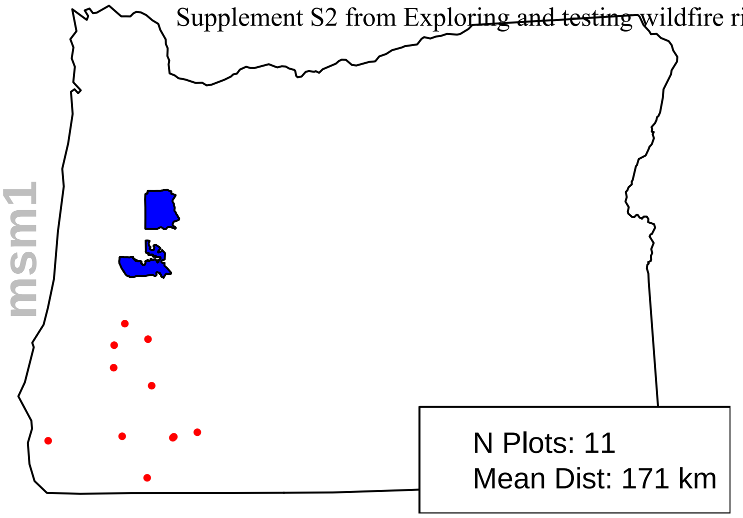

ddy
N Plots: 73
Mean Dist: 55 km
ddpm
N Plots: 50
Mean Dist: 81 km
ddpo
N Plots: 87
Mean Dist: 55 km
ddsm2
N Plots: 218
Mean Dist: 49 km
ddso1
N Plots: 216
Mean Dist: 54 km
ddlm2
N Plots: 234
Mean Dist: 49 km
ddlo1
N Plots: 103
Mean Dist: 52 km
bmgf
No Plots


bmy
N Plots: 10
Mean Dist: 120 km
dmgf
No Plots
bmpm
N Plots: 24
Mean Dist: 79 km
dmy
N Plots: 14
Mean Dist: 72 km
bmsc1
N Plots: 50
Mean Dist: 68 km
dmpm
N Plots: 17
Mean Dist: 112 km
bmlc1
N Plots: 20
Mean Dist: 97 km
dmsm1
N Plots: 58
Mean Dist: 45 km


dmlm1
N Plots: 50
Mean Dist: 52 km
opy
N Plots: 5
Mean Dist: 111 km
dmpc
N Plots: 4
Mean Dist: 46 km
oppo
N Plots: 1
Mean Dist: 156 km
dgsc2
N Plots: 31
Mean Dist: 129 km
opso1
N Plots: 2
Mean Dist: 188 km
dglc2
N Plots: 2
Mean Dist: 140 km
oplo1
N Plots: 4
Mean Dist: 75 km


oppm
N Plots: 13
Mean Dist: 167 km
mpo
N Plots: 3
Mean Dist: 175 km
opsm2
N Plots: 25
Mean Dist: 130 km
mso1
No Plots
oplm2
N Plots: 9
Mean Dist: 101 km
mlo1
No Plots
my
N Plots: 10
Mean Dist: 161 km
mpm
N Plots: 36
Mean Dist: 181 km

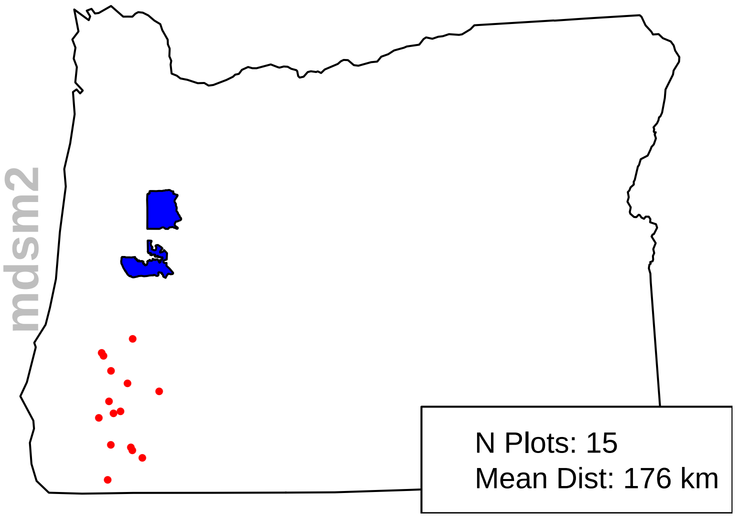
msm1



mlm1

No Plots

mdsm2



mdlm2

No Plots

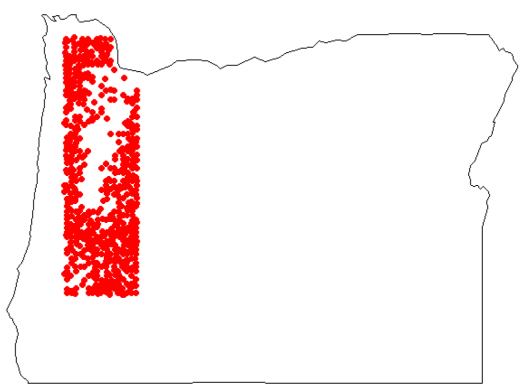
4. Tree Regeneration for States in the NSF CNH Project

Peter Gould and Connie Harrington
Pacific Northwest Research Station
August 31, 2010

The objective of this part of the project is to use existing data sources to evaluate regeneration for each forest state in the state-and-transition model. FVS does not add regeneration during projections unless a regeneration list is provided by the user. The regeneration list describes the species, size, and density of regeneration.

The annual FIA inventory system, which started in 2001, includes seedling plots that can be used to estimate regeneration densities. Seedlings are counted by species on four 1/300th acre plots on each FIA plot. Conifer seedlings are counted if they are > 0.5 ft tall and < 1.0 in DBH. Hardwood seedlings are counted if they are > 1.0 ft tall and < 1.0 DBH. The most recent FIA database covers the period from 2001 to 2008. The annual inventory system is designed to measure 10 percent of plots each year, so the database includes about 80 percent of all FIA plots.

FIA plots were selected so that they fell within a rectangular area centered on the Willamette Valley. The selection yielded 628 plots (shown below).



Plots were classified into states by summarizing the tree data and using the state definition table to assign states. The states were then merged with the seedling data so that seedling densities could be calculated by state. The summary of seedling densities in each state is attached.

The seedling summary can be used as one piece of information for determining regeneration composition. There was little or no data for most states other than those dominated by Douglas-fir (i.e., states beginning with “dd”). Regeneration for these states can be determined by combining similar states into more general categories. Additionally, the seedling data may need to be modified to estimate regeneration of larger trees. FVS does not do a good job projecting the growth of small trees (< 3.0 in DBH). More realistic projection may be made by adding larger regeneration. If this approach is taken, some assumptions will need to be made regarding growth and survival of seedlings into larger size classes.

Table 1. Seedling densities by species and state that were calculated from FIA data.

State	Species	Trees / Acre	N Plots
bmlc1	PSME	100	3
bmlc1	CONU4	100	3
bmlc1	FRLA	50	3
bmpm	PSME	37	6
bmpm	THPL	12	6
bmpm	ACMA3	12	6
bmsc1	ACMA3	64	7
bmsc1	ALRU2	11	7
ddlm2	PSME	273	84
ddlm2	TSHE	194	84
ddlm2	CHCHC4	46	84
ddlm2	ALRU2	36	84
ddlm2	CADE27	33	84
ddlm2	ABGR	25	84
ddlm2	TABR2	19	84
ddlm2	THPL	19	84
ddlm2	ABCO	16	84
ddlm2	ACMA3	15	84
ddlm2	ABAM	9	84
ddlm2	PILA	5	84
ddlm2	ABPR	3	84
ddlm2	ACGL	3	84
ddlm2	TSME	2	84
ddlm2	CONU4	1	84
ddlo1	PSME	163	76
ddlo1	TSHE	38	76
ddlo1	CHCHC4	26	76
ddlo1	PREM	15	76
ddlo1	THPL	14	76
ddlo1	ABGR	13	76
ddlo1	LIDE3	12	76
ddlo1	ABCO	10	76
ddlo1	CADE27	6	76
ddlo1	ACMA3	5	76

ddlo1	ALRU2	5	76
ddlo1	PIPO	3	76
ddlo1	TABR2	3	76
ddlo1	ARME	3	76
ddlo1	PILA	2	76
ddpm	ABGR	75	1
ddpo	PSME	225	51
ddpo	TSHE	60	51
ddpo	QUGA4	59	51
ddpo	ARME	35	51
ddpo	CHCHC4	25	51
ddpo	TABR2	22	51
ddpo	ACMA3	15	51
ddpo	ABGR	10	51
ddpo	PREM	7	51
ddpo	THPL	6	51
ddpo	ALRU2	6	51
ddpo	CADE27	4	51
ddpo	PILA	1	51
ddpo	CONU4	1	51
ddpo	PRUNU	1	51
ddsm2	PSME	106	27
ddsm2	ACMA3	67	27
ddsm2	ABGR	56	27
ddsm2	THPL	47	27
ddsm2	TABR2	25	27
ddsm2	TSHE	22	27
ddsm2	CADE27	11	27
ddsm2	TSME	6	27
ddsm2	ALRU2	6	27
ddsm2	ABCO	3	27
ddsm2	PILA	3	27
ddsm2	CHCHC4	3	27
ddso1	PSME	109	158
ddso1	TSHE	103	158
ddso1	THPL	49	158
ddso1	CHCHC4	23	158
ddso1	CADE27	13	158
ddso1	ABGR	10	158
ddso1	ABCO	9	158
ddso1	ACMA3	9	158
ddso1	ALRU2	9	158
ddso1	PREM	8	158

ddso1	ARME	7	158
ddso1	TABR2	6	158
ddso1	PRVI	3	158
ddso1	ABAM	2	158
ddso1	TSME	1	158
ddso1	FRLA	1	158
ddso1	PILA	0	158
ddso1	PIPO	0	158
ddso1	PRUNU	0	158
ddy	PSME	120	30
ddy	TSHE	27	30
ddy	ACMA3	20	30
ddy	THPL	15	30
ddy	PISI	7	30
ddy	ALRU2	5	30
ddy	PREM	5	30
ddy	ABGR	2	30
ddy	CADE27	2	30
ddy	CHCHC4	2	30
ddy	QUGA4	2	30
dgsc2	ABGR	400	3
dgsc2	PSME	200	3
dgsc2	TSHE	25	3
dmlm1	PREM	54	7
dmlm1	QUGA4	54	7
dmlm1	PSME	21	7
dmlm1	ACMA3	21	7
dmlm1	TSHE	11	7
dmlm1	MAFU	11	7
dmpm	THPL	37	2
dmpm	ACMA3	37	2
dmsm1	THPL	80	14
dmsm1	TSHE	43	14
dmsm1	PSME	37	14
dmsm1	ALRU2	11	14
dmsm1	PREM	11	14
dmsm1	CADE27	5	14
dmsm1	TABR2	5	14
dmsm1	ACMA3	5	14
dmy	NONE	0	1
dolm2	PSME	75	1
dopm	FRLA	25	3
dosm2	PSME	125	3

dosm2	ARME	75	3
dosm2	QUGA4	50	3
oalo1	NONE	0	1
oapo	QUGA4	337	2
oapo	PSME	150	2
oapo	ACMA3	37	2
oaso1	PIPO	45	5
oaso1	PSME	45	5
oaso1	FRLA	45	5
oaso1	CADE27	15	5
oaso1	ACMA3	15	5
oay	QUGA4	450	1
odlm2	NONE	0	1
odsm2	FRLA	75	1
owlm1	NONE	0	2
owpm	QUGA4	75	1
owsm1	PREM	289	7
owsm1	QUGA4	54	7
owsm1	PIPO	32	7
owsm1	PSME	32	7
owsm1	FRLA	21	7
owsm1	ARME	11	7

5. Calculation of Current and Future Site Index for the Willamette Valley NSF-CNH Project

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August 14, 2009

Introduction

The Willamette Valley NSF-CHN project is a coupled human-natural systems modeling project that seeks to incorporate vegetation dynamics, human decision making, and climate change into a model to project future landscape conditions for two study areas in the Willamette Valley, Oregon (the Eugene and Lebanon study areas). Current and future site productivity needs to be estimated at a fairly fine spatial scale within the study areas for vegetation modeling. The productivity metric is site index (*SI*) for Douglas-fir using King's (1966) curve with a base age of 50 years. *SI* will be used to project vegetation development using the Forest Vegetation Simulator (FVS) and for other purposes such as determining initial vegetation composition and changes in composition owing to climate change. The purpose of this report is to document how initial *SI* was estimated throughout the study areas based on soil and climate information.

Estimating Initial Site Index

Methods

Our approach was to 1) retrieve *SI* estimates where available for map units in the Natural Resources Conservation Service (NRCS) soil surveys; 2) predict *SI* for map units where it was missing using soil and climate variables as predictors; and 3) modify the *SI* values for soil conditions that were not reflected in the original estimates (for example we would lower the *SI* value for poorly drained soils). Digitized county soil survey maps were downloaded for 13 counties in western Oregon: Benton, Clackamas, Coos, Curry, Douglas, Hood River, Jackson, Josephine, Lane, Linn, Polk, Yamhill, and Washington (http://soildatamart.nrcs.usda.gov). The study areas are in Lane and Linn counties but the larger area was used to better understand the relationships between *SI* and the predictor variables. The smallest spatial unit in the soil surveys is the map unit. The combined counties included 2511 map units. Map units contain either a single soil, a soil association containing two or more components, or a non-soil feature (e.g., water, rock outcrop). Douglas-fir *SI* estimates were given in the soil databases for 1259 map units (Figure 1). The *SI* estimates were based on field data collected as part of the soil surveys; therefore we considered them to be the most reliable estimates of *SI* that were available.

We focused on soil variables that described depth, texture, and water holding capacity. Climate data were derived from PRISM GIS layers (Daly et al. 1994) and spatially joined with the soil data. Several climate variables were evaluated including mean annual precipitation, precipitation in the summer months (May – September), mean temperature in the summer months, and mean temperature in the winter months (January – March). Individual climate variables and combinations were evaluated for their predictive power. Data from the 1259 map units where Douglas-fir *SI* was estimated from measured tree heights and ages were used for the modeling dataset.

Different combinations of variables and model forms were tested. McCune's (2002) heat load was calculated and tested for its ability to predict *SI* using a secondary dataset derived from data collected on Forest Inventory and Analysis plots. It was not correlated with *SI* and therefore was not considered for the final model. The final model was selected based on parsimony (models with relatively few predictor variables were deemed superior), biological interpretability, and the amount of variation in *SI* that the model explained (measured by r^2).

Results

A modified logistic function was used to predict *SI* for the map units where it was not included in the NRCS database:

$$SI = \frac{133 - \exp(\alpha_1 \cdot JUNEDRY)}{1 + \exp(\alpha_2 + \alpha_3 \cdot \ln(2.71 + SWC))} \qquad [1]$$

Where:

JUNEDRY = Dryness index in June, calculated as mean temperature (°C) divided by 1 + precipitation (cm) for the month of June.

SWC = Soil water capacity (volume of water per volume of soil).

The model form has an upper asymptote that was set to the 95^{th} percentile of the modeling dataset (133 ft) (Figure 2). The asymptote is modified by *JUNEDRY* so that soils in drier climates have a lower maximum *SI* than those in wetter cimates. *SI* is predicted in relation to the climatic maximum by *SWC.* The model explained 53 percent of the variation in *SI.*

SI was predicted using Equation 1 for map units where it was missing (Figure 3). Predicted *SI* values tended to be lower in the parts of the study areas where it was missing compared with those areas where it was given (Figure 1). In addition, the given values were generally lower in the study areas than in the surrounding areas, especially to the east. The values predicted by Equation 1 reinforce the pattern of low *SI* within the study areas. This is a favorable result since it shows that Equation 1 was able to extend the trend in the given data to the areas where *SI* was missing.

We modified *SI* values based on soil phase, depth to restrictions, and soil drainage class (Figure 4). NRCS soil types are divided into phases which are designed to represent differences in productivity. Phases can be based on many factors such as soil texture or presence of gravel or cobbles or frequency of flooding, but in western Oregon phases are commonly based on slope and aspect. Despite the differences in productivity, *SI* values did not differ among phases in the NRCS database. For example, the phase Nekia silty clay loam, 2 to 12 percent slopes had the same *SI* value as Nekia silty clay loam, 30 to 50 percent slopes. We changed *SI* by up to 20 ft based on our assessment of how slope, aspect, and soil texture interact to affect site productivity. In the example above, *SI* was reduced by 10 ft for the steeper phase. Changes in *SI* were applied both to the original NRCS values and the predicted values since phase differences were not already accounted for in either set of values.

We found that Equation 1 using *SWC* and *JUNEDRY* tended to overpredict *SI* for map units that had a relatively impermeable "cemented" restriction within 1.5 m of the surface (Figure 5). The information that was used to make the modifications (e.g., whether or not a soil had a restricted layer) was taken from the NRCS databases. Therefore, we reduced *SI* by 7 ft for such map units. *SI* was reduced by 20 ft in map units that were described as soil complexes which included rock outcrops. *SI* was reduced by 5 ft for map units with somewhat poorly drained soil and 10 ft for poorly drained soil. Very poorly drained soils would be unsuitable for Douglas-fir; only one map unit was assigned to this drainage class.

Updated *SI* values were calculated for the two study areas (Figure 6). The exceptions were areas that were covered by water or structures (e.g., concrete dam). The changed for phase, drainage, depth to restrictions, and rock outcrops were applied to 34 percent, 27 percent, 3 percent, and 0.2 percent of the study areas, respectively. *SI* ranged between 100 and 120 ft for about 70 percent of the Eugene study area and 80 percent of the Lebanon study area (Figure 7). Most of the low values of SI (< 90 ft) were predicted and most of the high values were from the NRCS database, suggesting *SI* tended to be measured on more productive soils.

The final product from this project is a table with the following columns:

MUKEY: unique code linking spatial polygons to the tabulated information
MUNAME: name of the soil unit
SI_PRED: *SI* value predicted by Equation 1
NRCS_SI: *SI* value from the NRCS database where available
SI_FINAL: final adjusted *SI* value
PHASE_CHANGE: the adjustment for phase differences
REASON: the reason for making the phase change
RESTR_CHANGE: adjustment for soil restrictions
ROCK_CHANGE: adjustment for rock outcrops
DRAIN_CHANGE: adjustment for soil drainage class
COMMENT: comments

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McCune, B., D. Keon, and R. H. Marrs. 2002. Equations for potential annual direct incident radiation and heat load. Journal of Vegetation Science 13:603-606.

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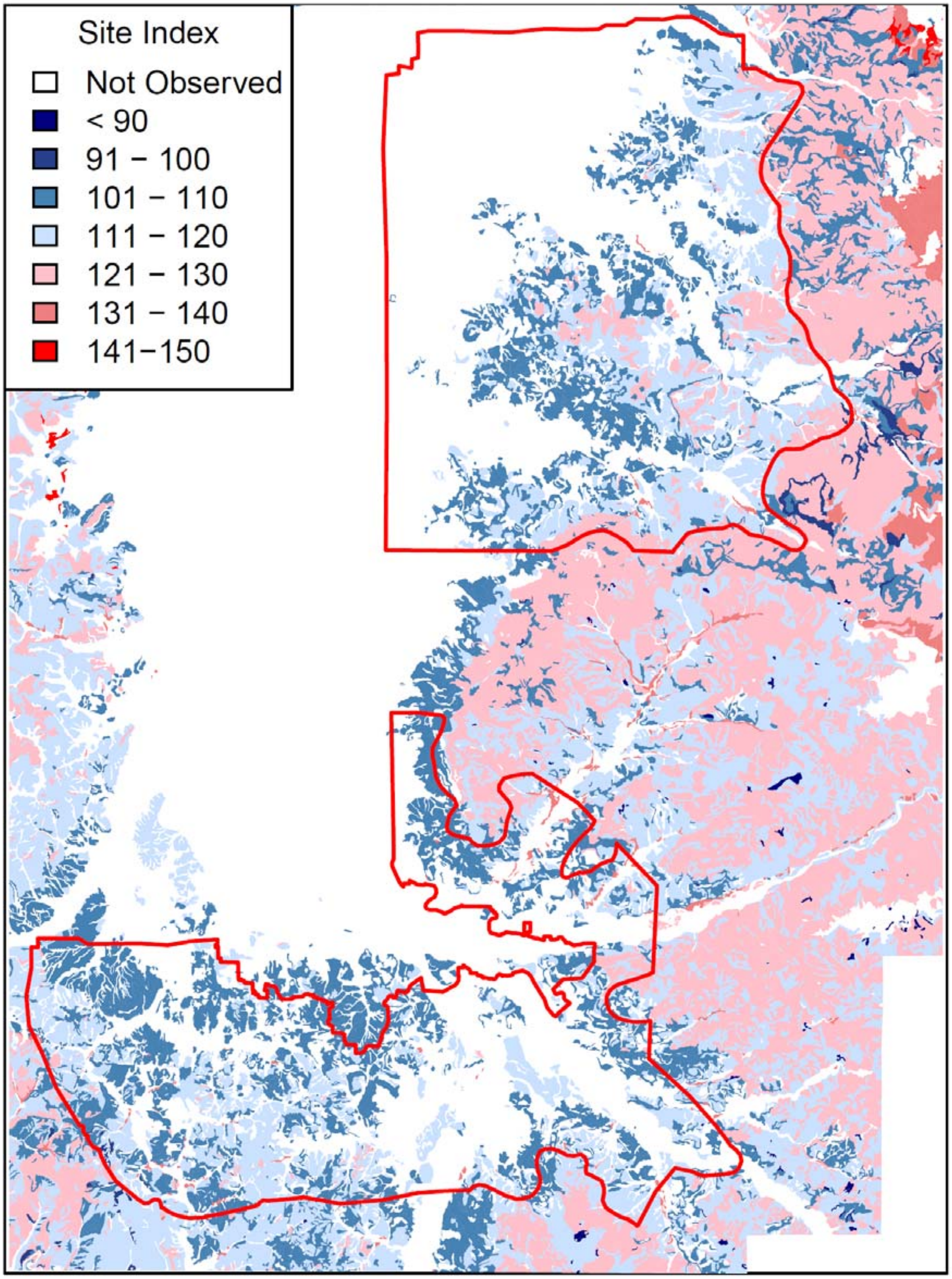

Figure 1. Douglas-fir site index values taken from the NRCS soil survey databases. The Lebanon (upper right) and Eugene (lower left) study areas are outlined in red. Site index values are associated with soil series or phases and were not necessarily measured within the study areas.

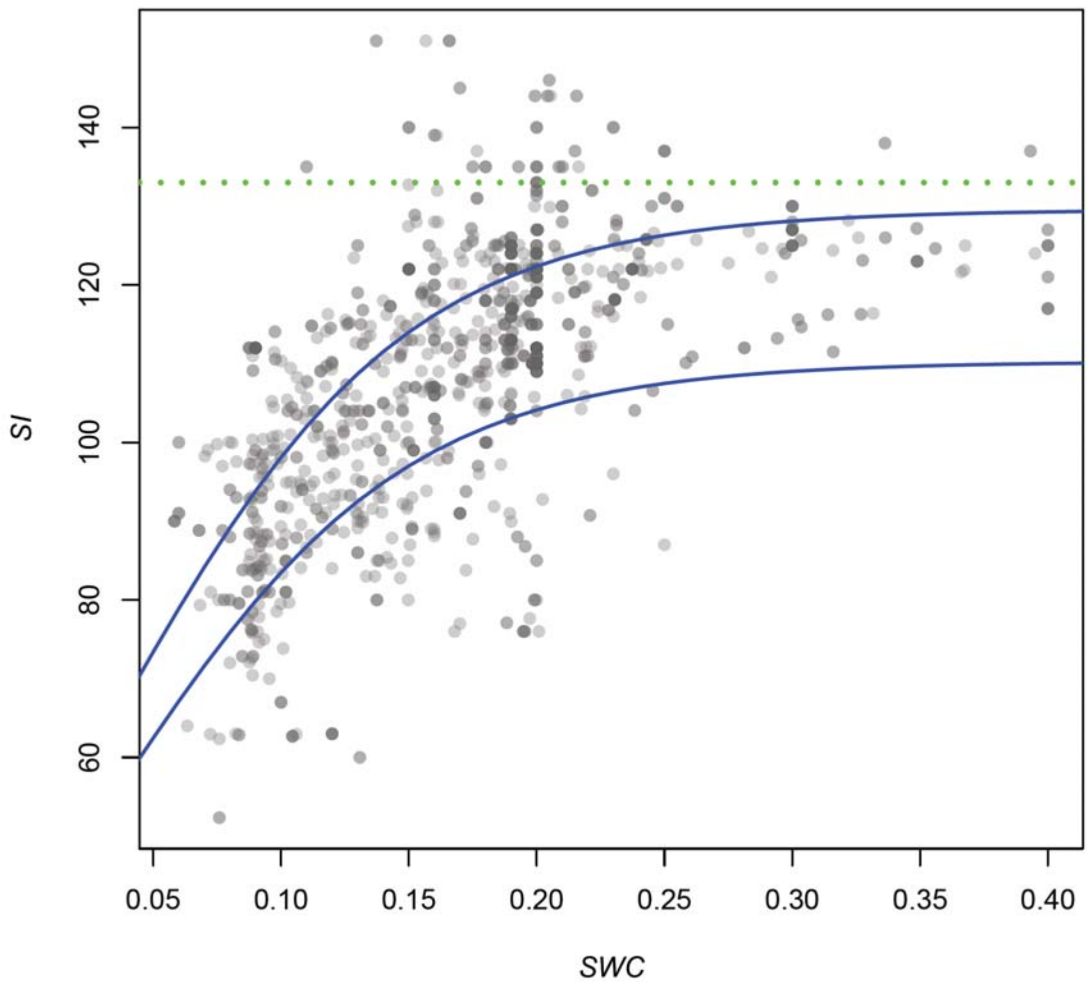

Figure 2. The fit of the model to predict site index. The points show the observed values of site index (*SI*) and soil-water capacity (*SWC*). The solid blue lines show predicted site index for the 5th and 95th percentiles of *JUNEDRY*; thus 90 percent of the predicted *SI* values fall between the blue lines. The upper dotted line shows the overall maximum value that can be predicted by the model (133 ft).

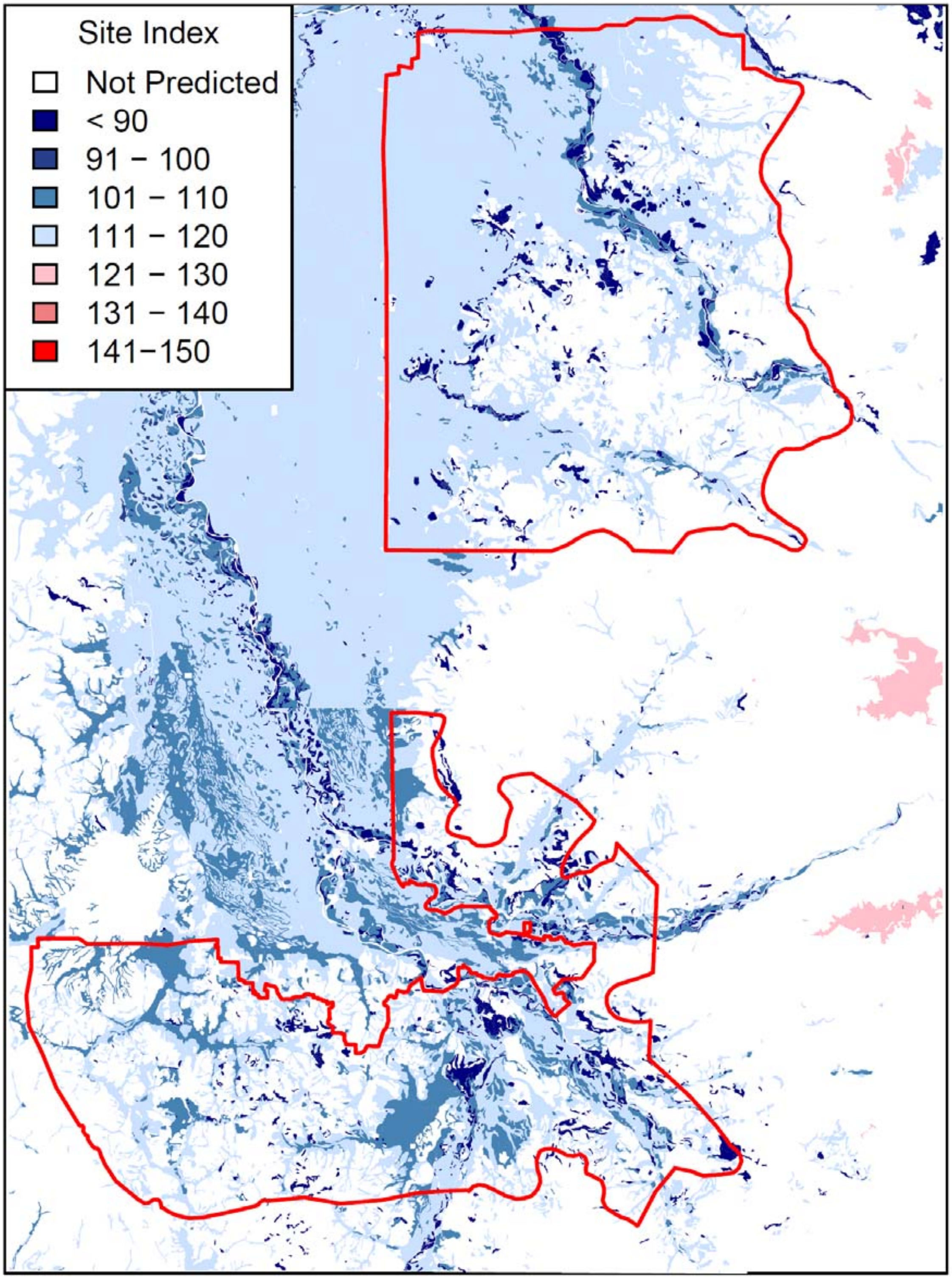

Figure 3. Douglas-fir site index values predicted by soil water-holding capacity and June temperature and precipitation.

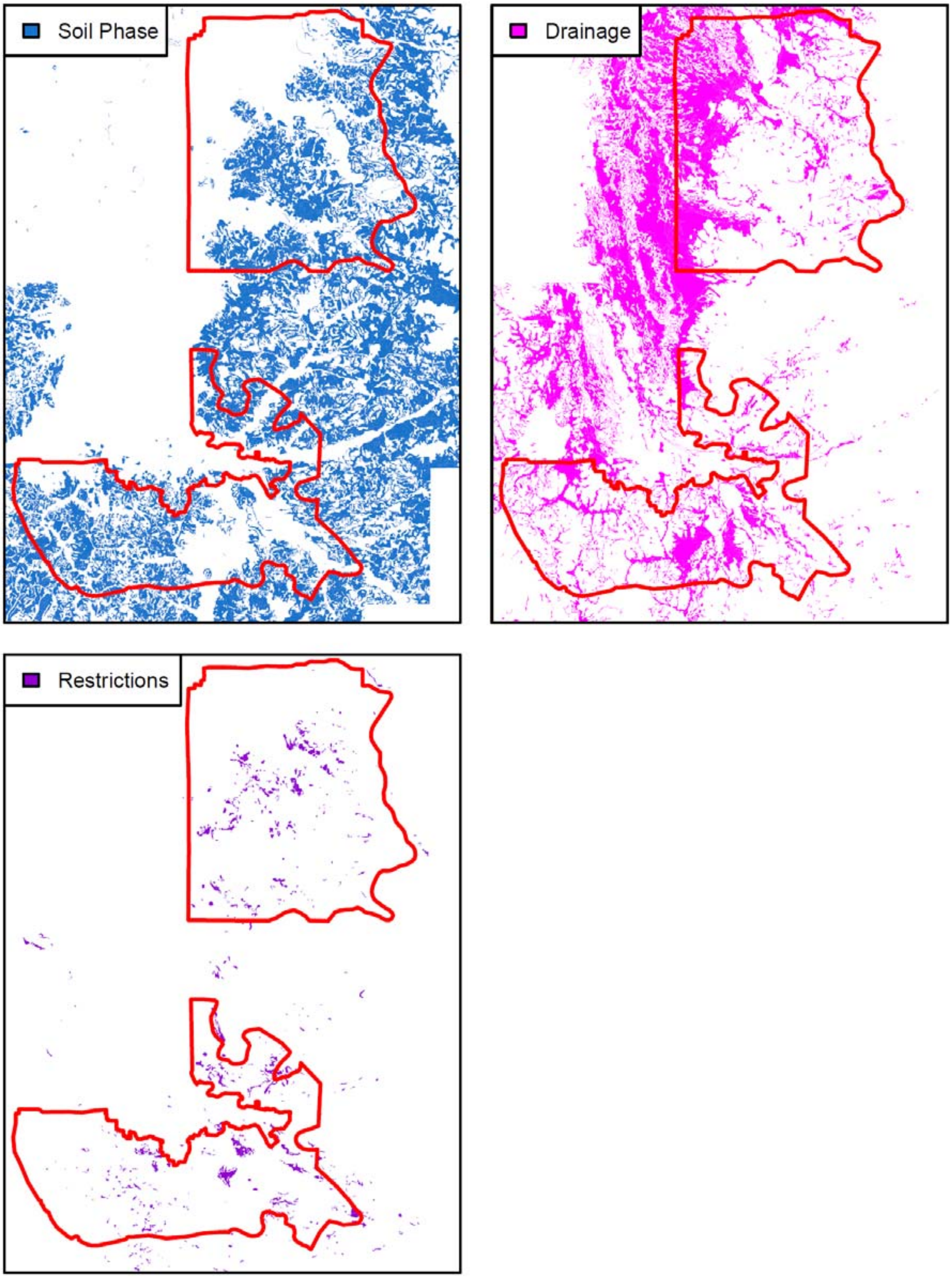

Figure 4. Areas where site index values were modified to reflect differences among soil phases (top left), concreted soil restrictions within 150 cm of the surface (bottom left), and poor soil drainage (top right).

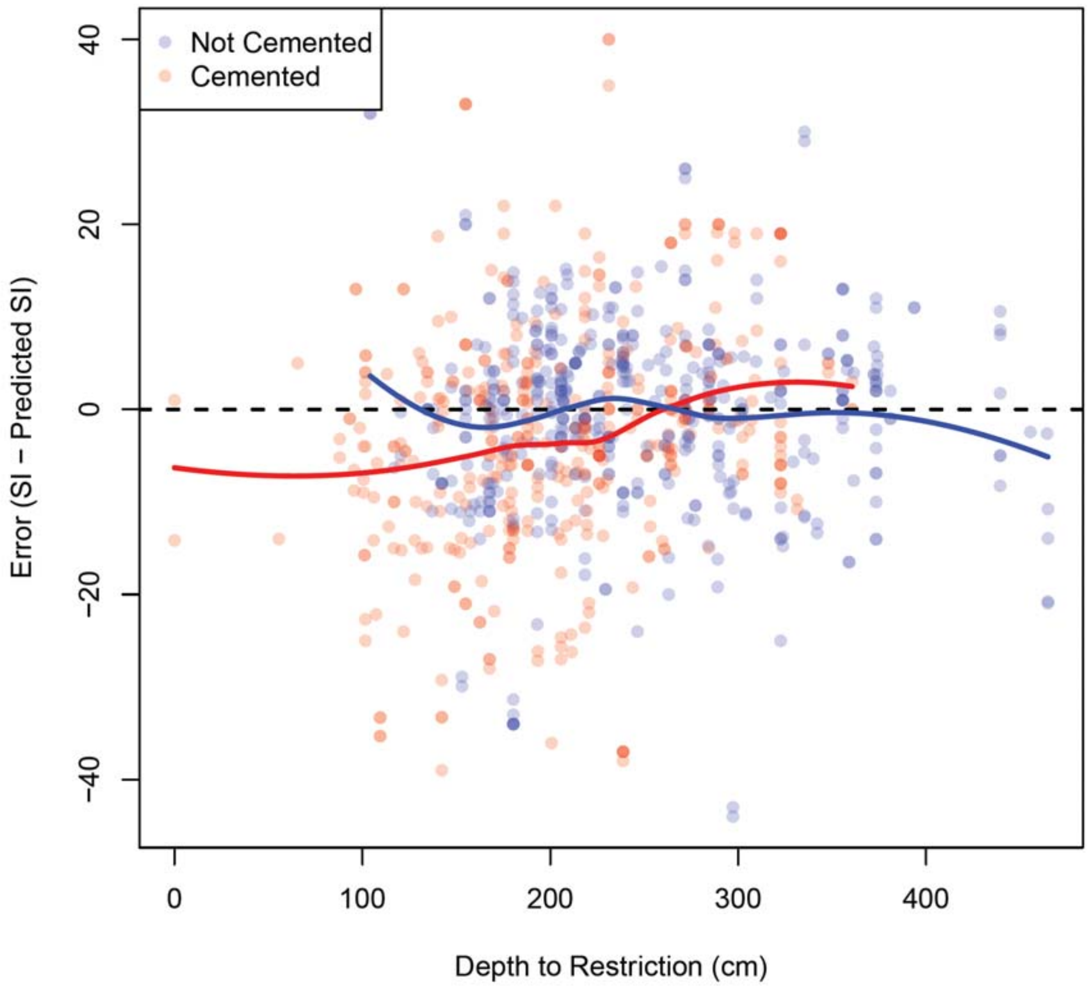

Figure 5. Error in predicted site index (*SI*) compared with depth to restriction for map units with concreted (red) and non-concreted (blue) restrictions. The solid lines are moving averages of the error values. *SI* tended to be overpredicted for map units with cemented restrictions within 1.5 m of the soil surface.

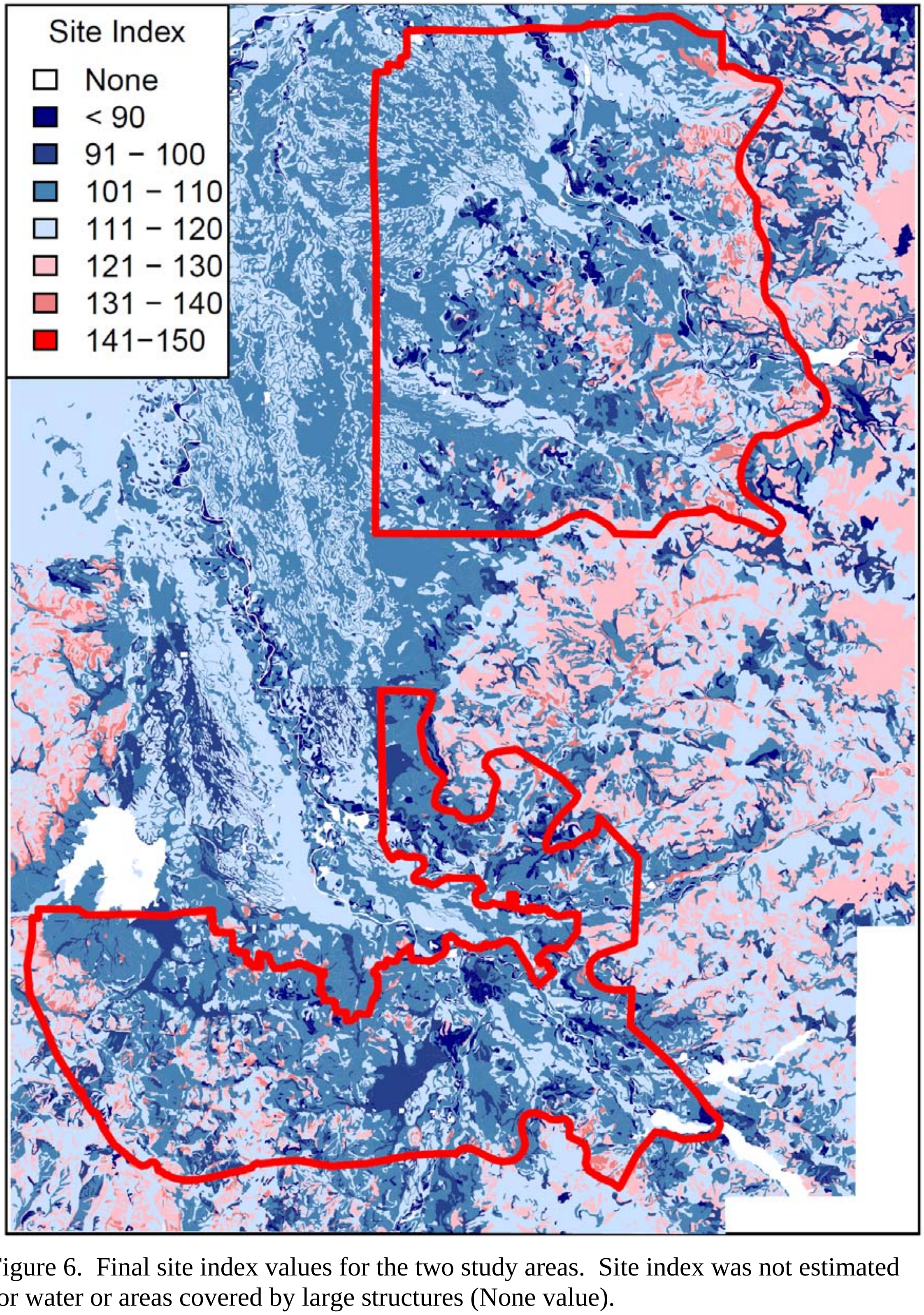

Figure 6. Final site index values for the two study areas. Site index was not estimated for water or areas covered by large structures (None value).

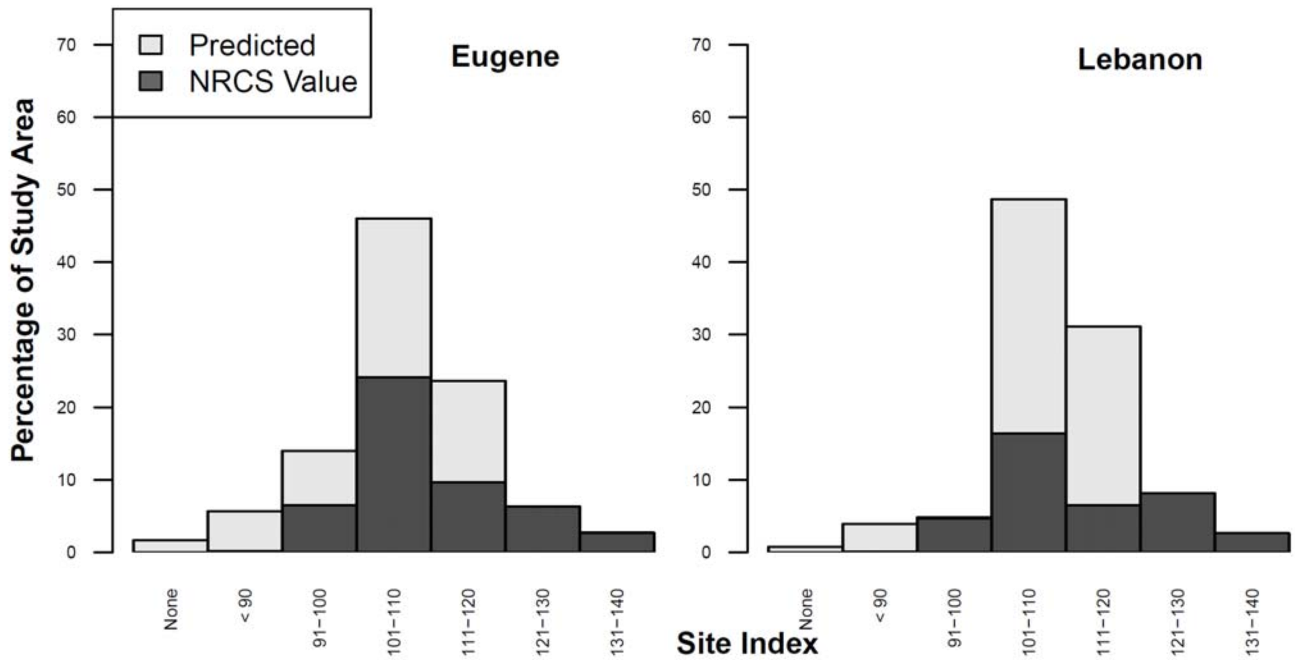

Figure 7. Percentages of the two study areas that were assigned to each range of *SI* values.

6. Notes on Estimation of Future Site Index for Douglas-Fir
Peter Gould 08/26/2009

June temperature and precipitation are among the best predictors of site index under the current climate. This makes sense biologically since site index measures the rate of height growth and most height growth occurs in May and June. June may be a critical month because the depletion of soil moisture causes height growth to cease; the longer soil moisture is available, the greater the period of height growth.

June temperature is predicted to increase from about 16.5°C to around 20°C in the Lebanon and Eugene study areas under the A2 Scenario (Figure 1). Precipitation is not predicted to change directionally.

One approach to estimating future site index is to use relationships found under the current climate. For example, SI increases with increasing temperature given the available data (Figure 2). But how does Douglas-fir grow with June temperature > 20°C? It turns out that very little Douglas-fir grows under that climate (Figure 3). The area where June temperature is > 20°C does a good job of delineating the southern boundary of Douglas-fir's range in California.

Not only is the future climate largely outside the range of Douglas-fir, such a climate occurs almost nowhere in the western United States (Figure 4). The combination of June temperature around 20°C and precipitation > 2 cm is a novel climate and there are not any good contemporary analogs on which we can base projections of site index. Most areas with warm June temperatures are drier than the future climate. Extrapolation of relationships found under the current climate is still possible, but it must be done carefully.

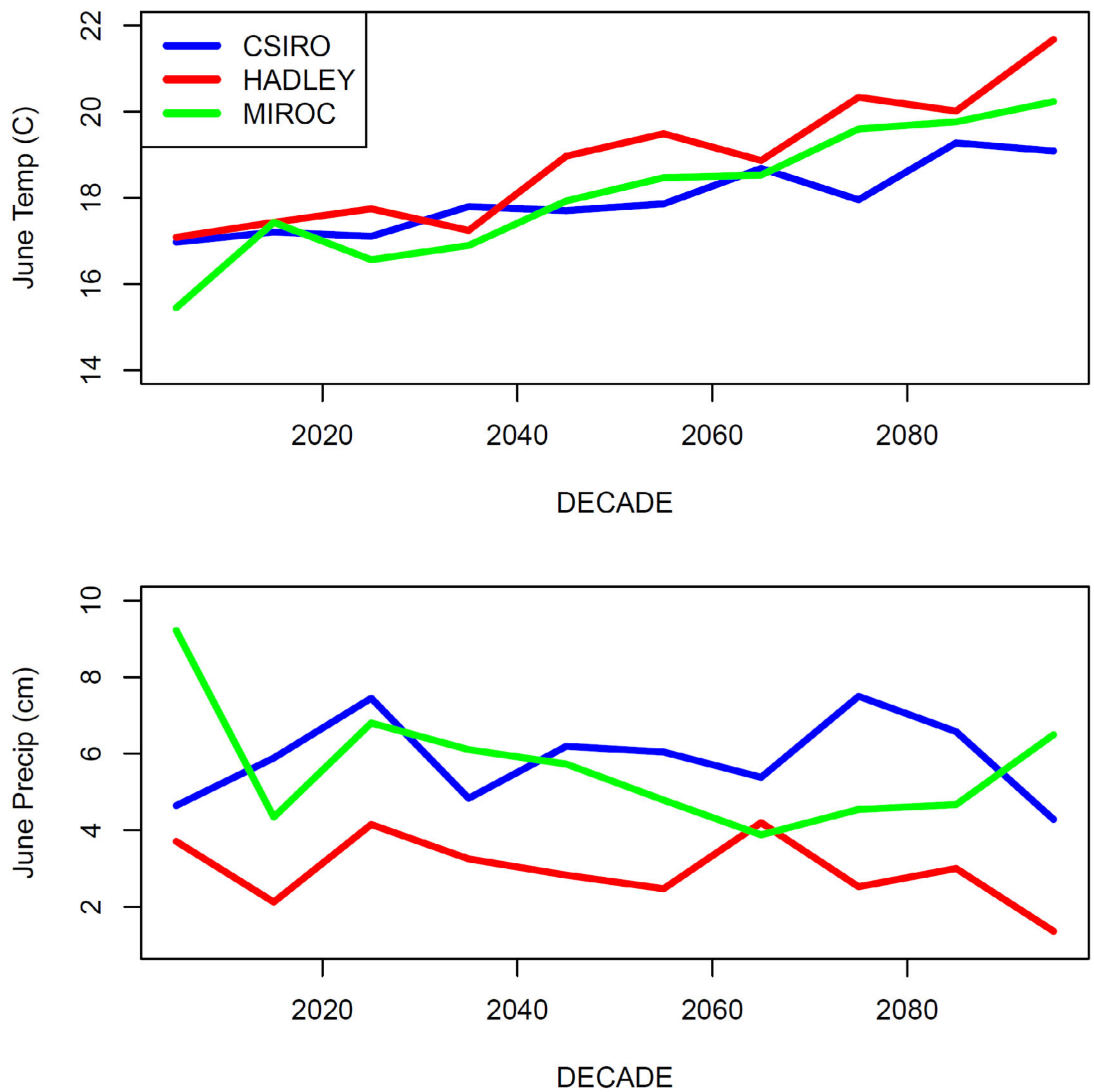

Figure 1. Decadal mean June temperature (top) and precipitation (bottom) in the Lebanon and Eugene study areas projected by three GCMs under the A2 Scenario.

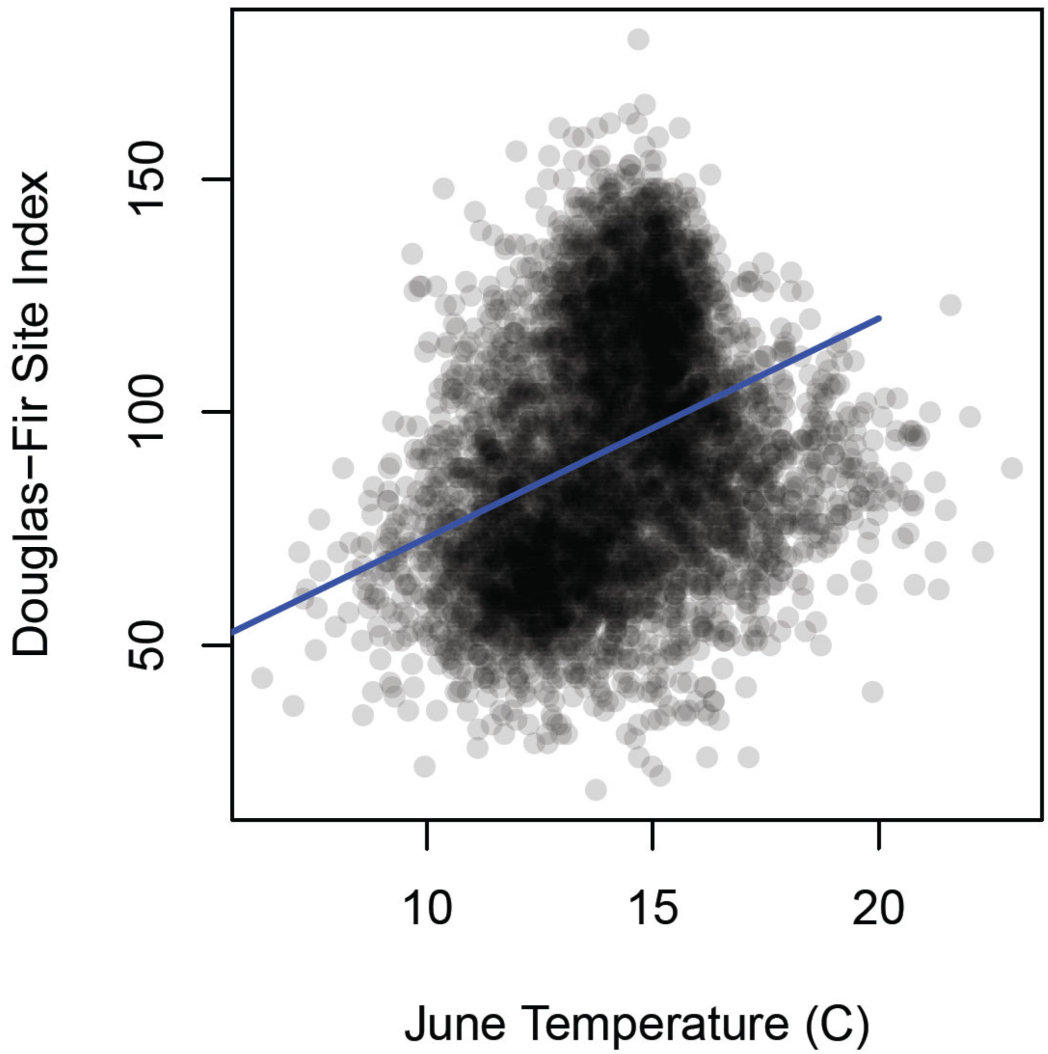

Figure 2. Relationship between June temperature and site index under the contemporary climate.

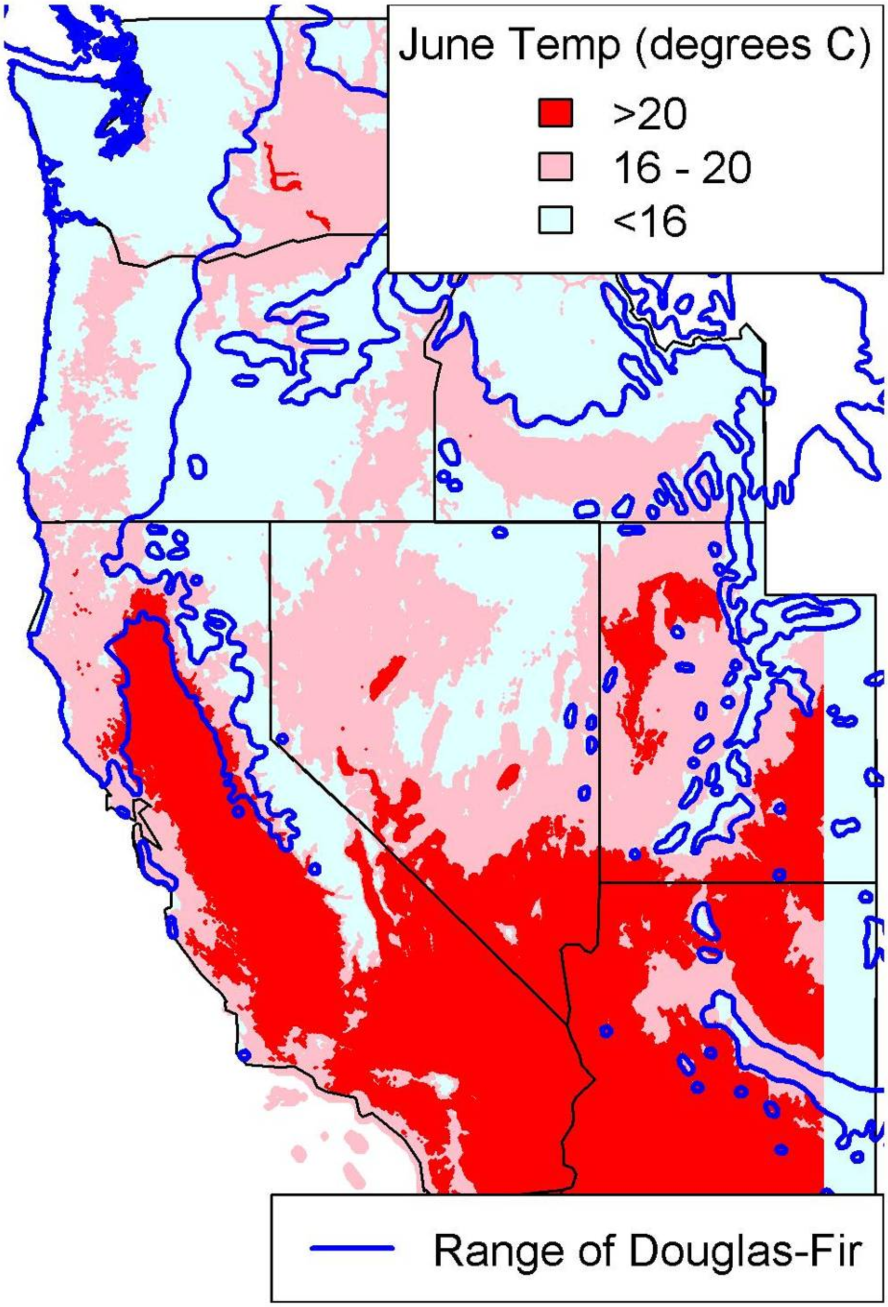

Figure 3. Contemporary mean June temperature and the range of Douglas-fir. Temperature estimates are from PRISM.

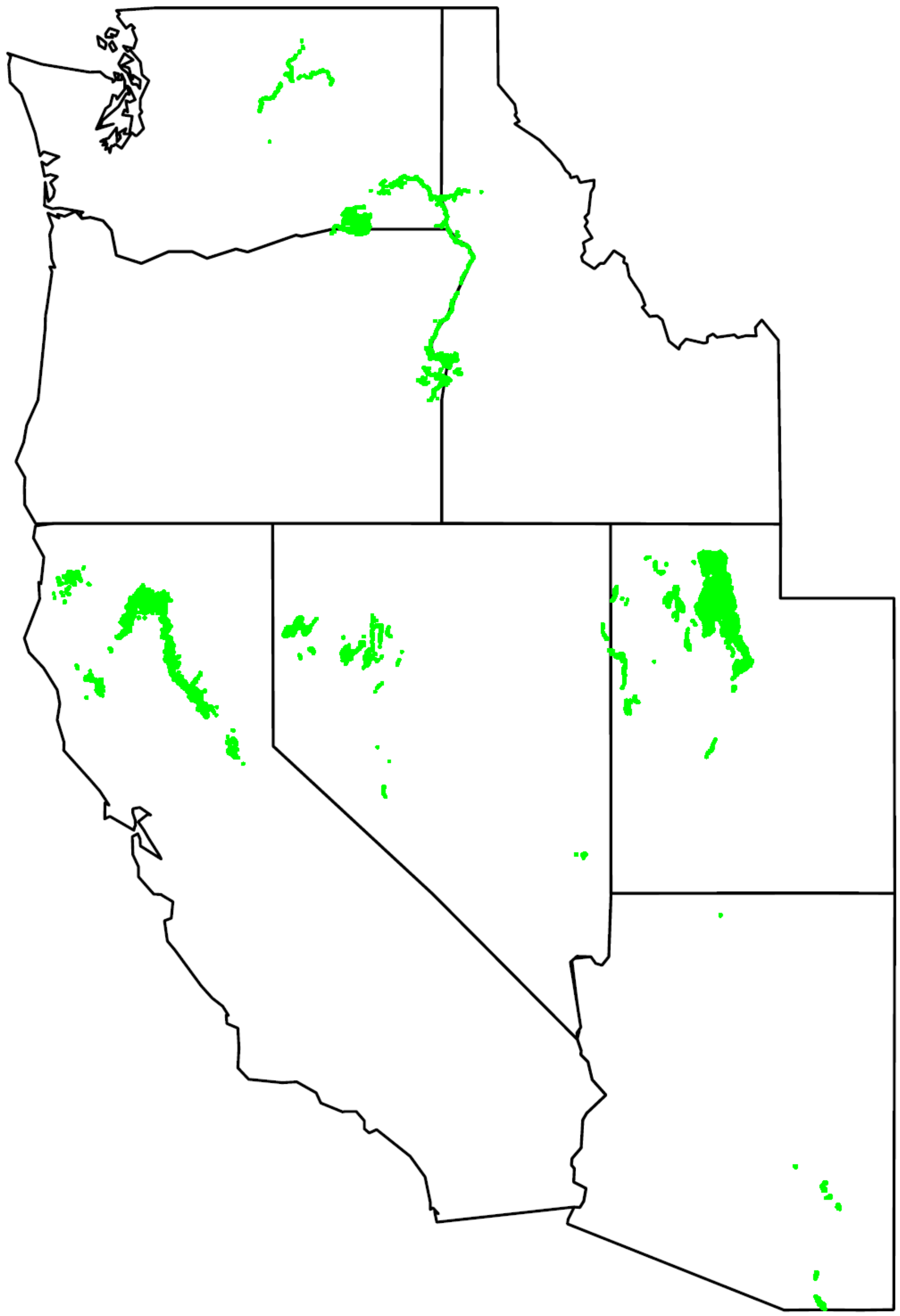

Figure 4. Areas (green) with a current June mean temperature between 19 and 21 degrees and precipitation > 2cm.