forests

Supplementary Materials: Tradeoffs in timber, carbon, and cash flow under alternative management systems for Douglas-fir in the Pacific Northwest

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Modifications to FVS growth-and-yield: Cross-validation with yield curves, permanent plots, and FIA data

Ten simulations were conducted for each level of 50-year Site Index ranging from 22.86-39.62 m (75-130 ft) in 1.52 m (5 ft) intervals (i.e., 75, 80, 85… 130 ft), covering Site Classes II - IV. Simulations used default settings for the FVS Pacific Northwest Coast (PN) Variant [1], and were iteratively adjusted through trial-and-error, resulting in the modifications below. Stochastic variability was introduced into the FVS model using the RANNSEED keyword. Stands were established with 1,075 trees per hectare (435 trees per acre (TPA)) of Douglas-fir with 85% survival rate.

Growth and mortality adjustments

Basal area increment was adjusted to a fraction of default rates using the BAIMULT keyword, and Maximum Stand Density Index, which governs density-driven mortality in FVS-PN was set at:

Table S1. FVS keyword modifications

Site Class	IV	III	II
SDIMAX	450	450	550
BAIMULT	0.3	0.5	0.5

For all stands, background mortality of large trees was modified to 5% of default mortality rates until the age of 30 using the MORTMULT keyword. At age 30, background mortality rates are restored to 100% of FVS-PN defaults. MORTMULT modifications do not affect density-related mortality, which is governed by the SDIMAX keywords described above.

Timber volume adjustments

By default, FVS calculates cubic and boardfoot volumes using equations from the National Volume Estimator Library (NVEL), which is documented by Wang [2]. The NVEL boardfoot volume were modified using the BFDEFECT keyword in FVS to provide timber volume estimates more consistent with field experiences and inventory census such as the US Forest Service Forest Inventory Analysis (FIA), which place a greater emphasis on quantifying merchantable timber volume using regional equations. Adjustment factors to NVEL volumes were determined by computing Scribner boardfoot volume for all trees >= 15″ DBH of common merchantable species from FIA plots in western Oregon and western Washington using two separate methods: the NVEL equations, and the equations utilized by the FIA program [3]. In general, NVEL overestimated Scribner boardfoot volume compared to FIA equations, ranging from 5% in 15-20″ red alder trees up to 49% in western redcedar. The correction factors used are shown in **Table S2**.

Based on comparisons to yields of Douglas-fir using the Stand Management Cooperative's (SMC) Yield Calculator [4], we capped the Scribner volume adjustment factor at 25% for 25.4 cm (10 in) DBH trees. This allowed for standing boardfoot volumes to follow rapid plantation development consistent with SMC reference plantation network, while allowing volume corrections in larger trees that bring the yield curves down into the range of the 75th percentile of FIA observations as the stands reach 60-80 years old, and near the median value of FIA observations around 100 years old. This approach to boardfoot volume adjustments implies that the advanced volume growth observed in

young plantations does not persist beyond the ages at which these stands are commonly harvested in contemporary production forestry in western Oregon and Washington. This is intended to be a conservative assumption and may underestimate the boardfoot volume that might be achieved if contemporary plantations were retained through longer rotations.

Table S2. Mean percent defect incorporated into FVS for each species diameter at breast height

	25.4 cm (10″)		**38.1 cm (15″)**		**50.8 cm (20″)**		**63.5cm (25″)**	
Species	Defect	*Count*	Defect	*Count*	Defect	*Count*	Defect	*Count*
Pseudotsuga menziesii (Douglas-fir)	50%	*23,575*	33%	*10,838*	28%	*5,443*	33%	*31,043*
Tsuga heterophylla (western hemlock)	42%	*9,554*	22%	*4,135*	18%	*1,905*	28%	*7,075*
Abies amabilis (Pacific silver fir)	44%	*4,241*	22%	*1,778*	16%	*861*	15%	*2,900*
Alnus rubra (red alder)	37%	*3,497*	5%	*1,169*	11%	*264*	22%	*112*
Thuja plicata (western redcedar)	56%	*1,673*	45%	*912*	44%	*489*	49%	*3,413*
Abies procera (noble fir)	47%	*706*	24%	*334*	18%	*192*	14%	*765*
Abies grandis (grand fir)	39%	*562*	18%	*271*	14%	*131*	14%	*255*
Picea sitchensis (Sitka spruce)	54%	*324*	37%	*182*	34%	*107*	31%	*600*
Callitropsis nootkatensis (yellow cedar)	57%	*226*	46%	*93*	48%	*45*	52%	*203*

General notes about the following graphs and yield tables

In all graphs shown below, the FVS simulations are displayed as gray lines. Blue lines show data from permanent plots in fully-stocked Douglas-fir stands [5,6]. Black lines show published yield curves of Douglas-fir from California to British Columbia [4,7–11]. The red line in each graph represents the median value observed among "conditions" observed in the US Forest Service's Forest Inventory and Analysis (FIA) network of plots from western Oregon and Washington that contained more than 80% of their basal area in Douglas-fir. Site Indices recorded in the FIA data were translated directly into Site Classes for each "condition" (rather than using the cubic volume productivity classes employed by USFS). The red shaded areas around the FIA median line correspond to observations in the 25th – 75th percentile range (darker red) and the 10th – 90th percentile range (lighter red). Data from the PNW FIA Database were analyzed using a site index base age of 50 (assuming the majority of base ages actually recorded in the database listing a base age of 100 were incorrect (personal communication, Andy Gray, Washington state coordinator for the FIA program).

Boardfoot volumes are Scribner 32-foot log scale. Each data source uses different specifications for minimum top diameter inside bark. FVS, FIA, and SMC volumes are up to a 15.24 cm (6″) minimum top diameter with a 0.30 m (1′) stump. FVS, FIA, and SMC cubic volumes are shown for trees to a 10.16 cm (4″) minimum top diameter inside bark with a 0.30 m (1′) stump, while cubic volumes from other yield table publications are showing total cubic volume including top and stump.

The Yield Tables are direct outputs from the simulations conducted using the modified version of FVS-PN. The values in each cell represent the mean value for the metric being among the 10 simulations of each Site Index.

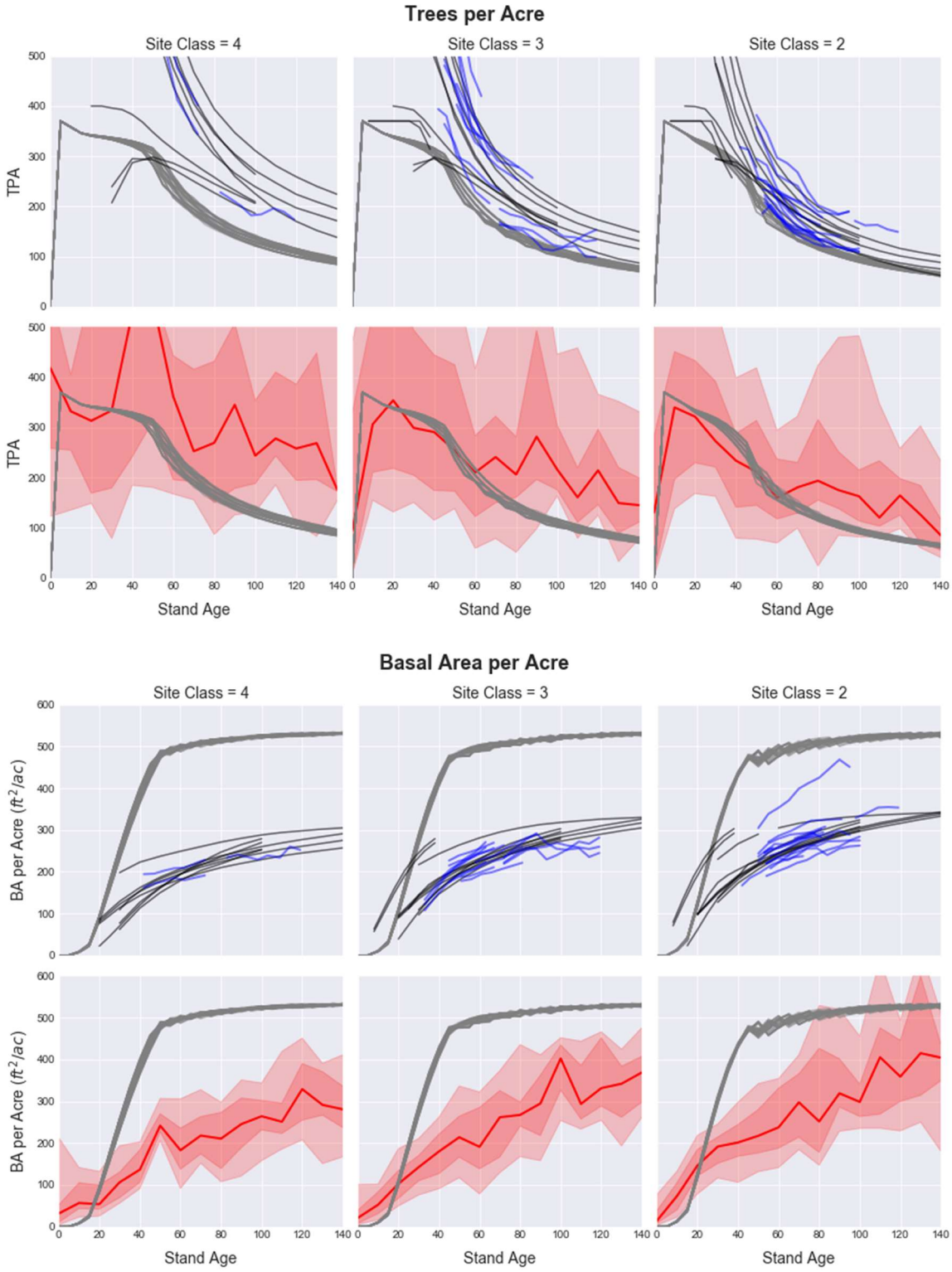

Figure S1. Default FVS Parameterization comparing PN variant output to measured stands (Part 1 of 3): Trees Per Acre (TPA, top 6 graphs) and Basal Area (BA) per Acre (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

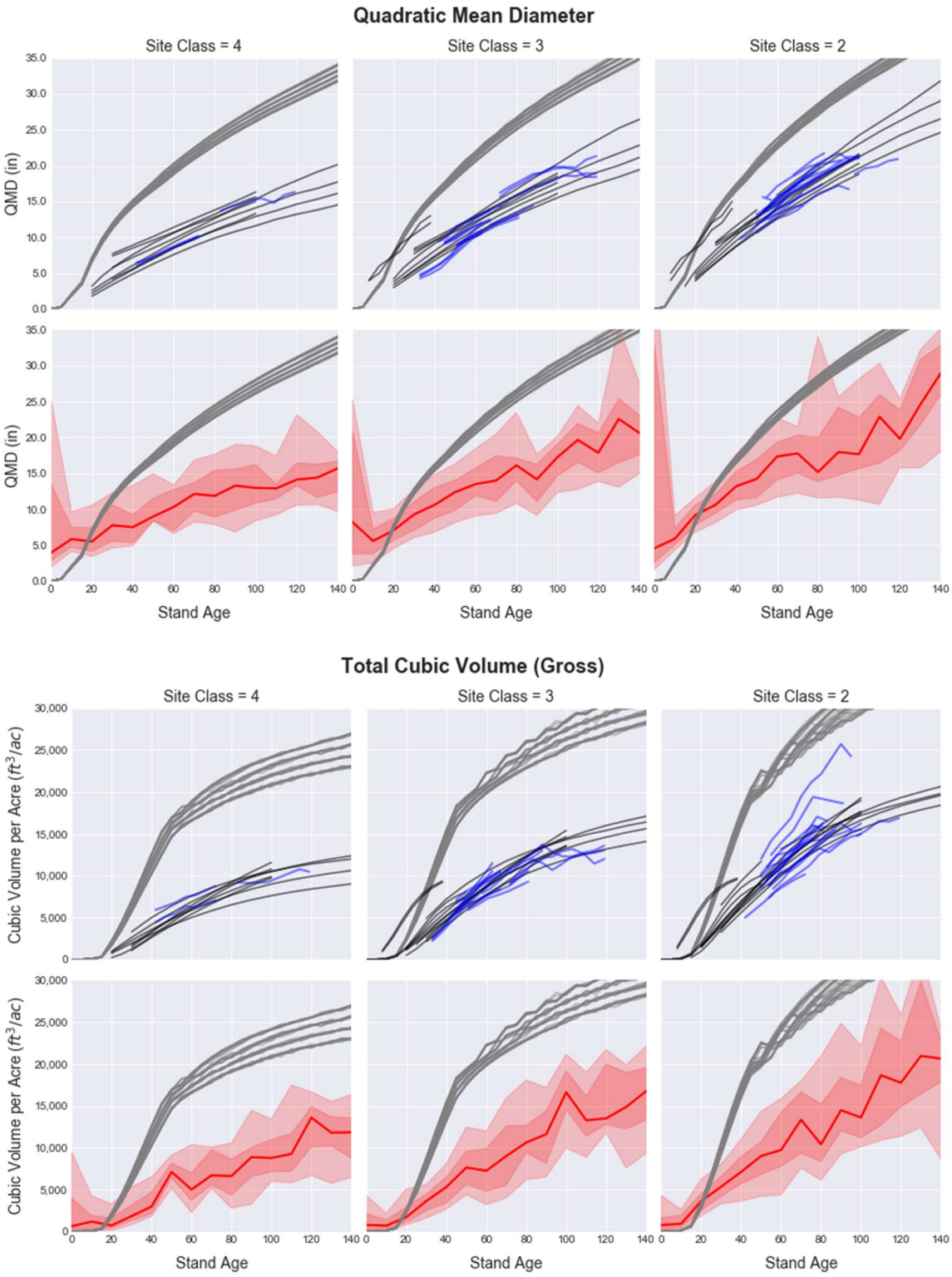

Figure S2. Default FVS Parameterization (Part 2 of 3): Quadratic Mean Diameter (QMD, top 6 graphs) and Total Cubic Volume (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

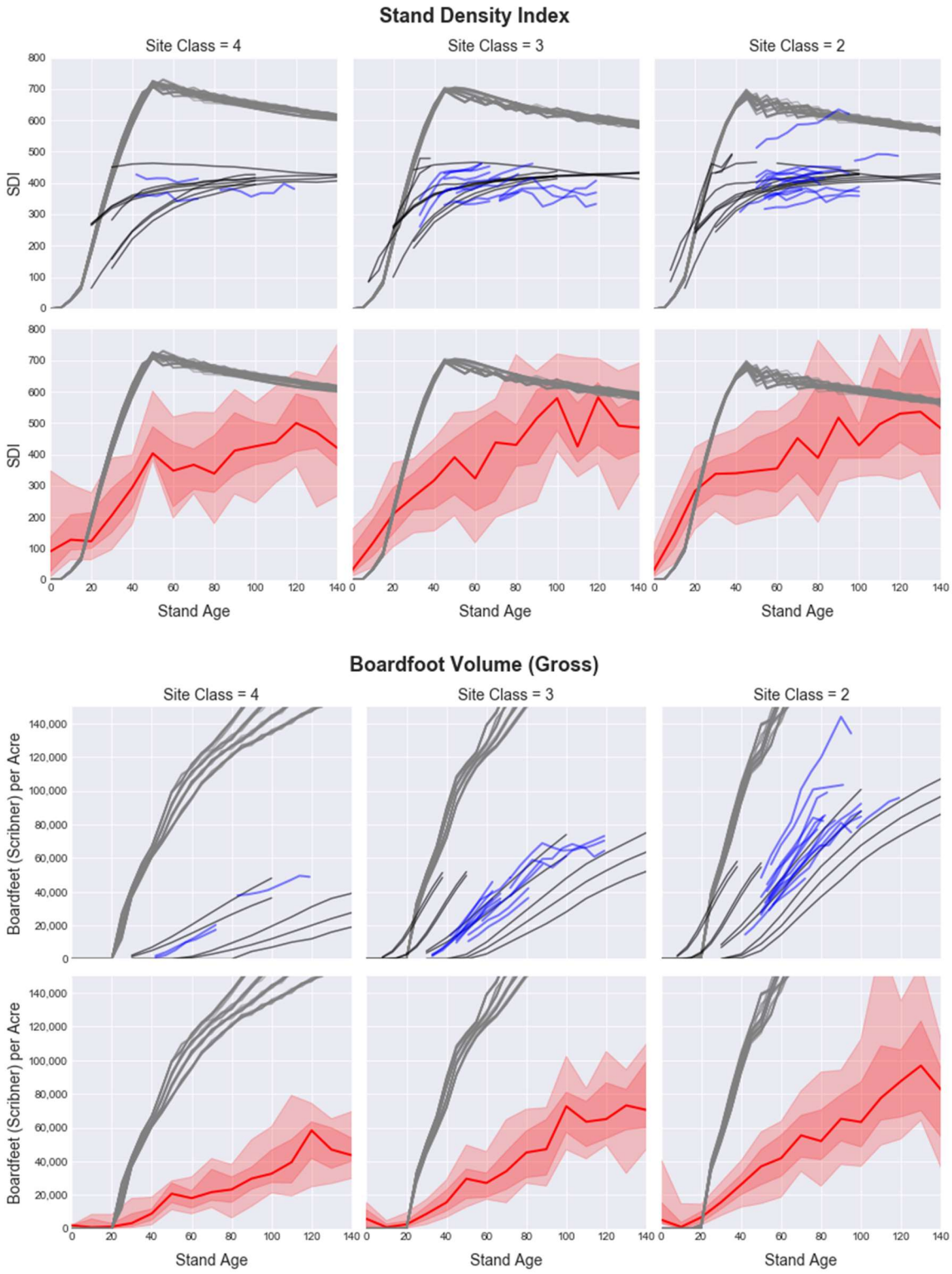

Figure S3. Default FVS Parameterization (Part 3 of 3): Stand Density Index (SDI, top 6 graphs) and Gross Boardfoot Volume (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

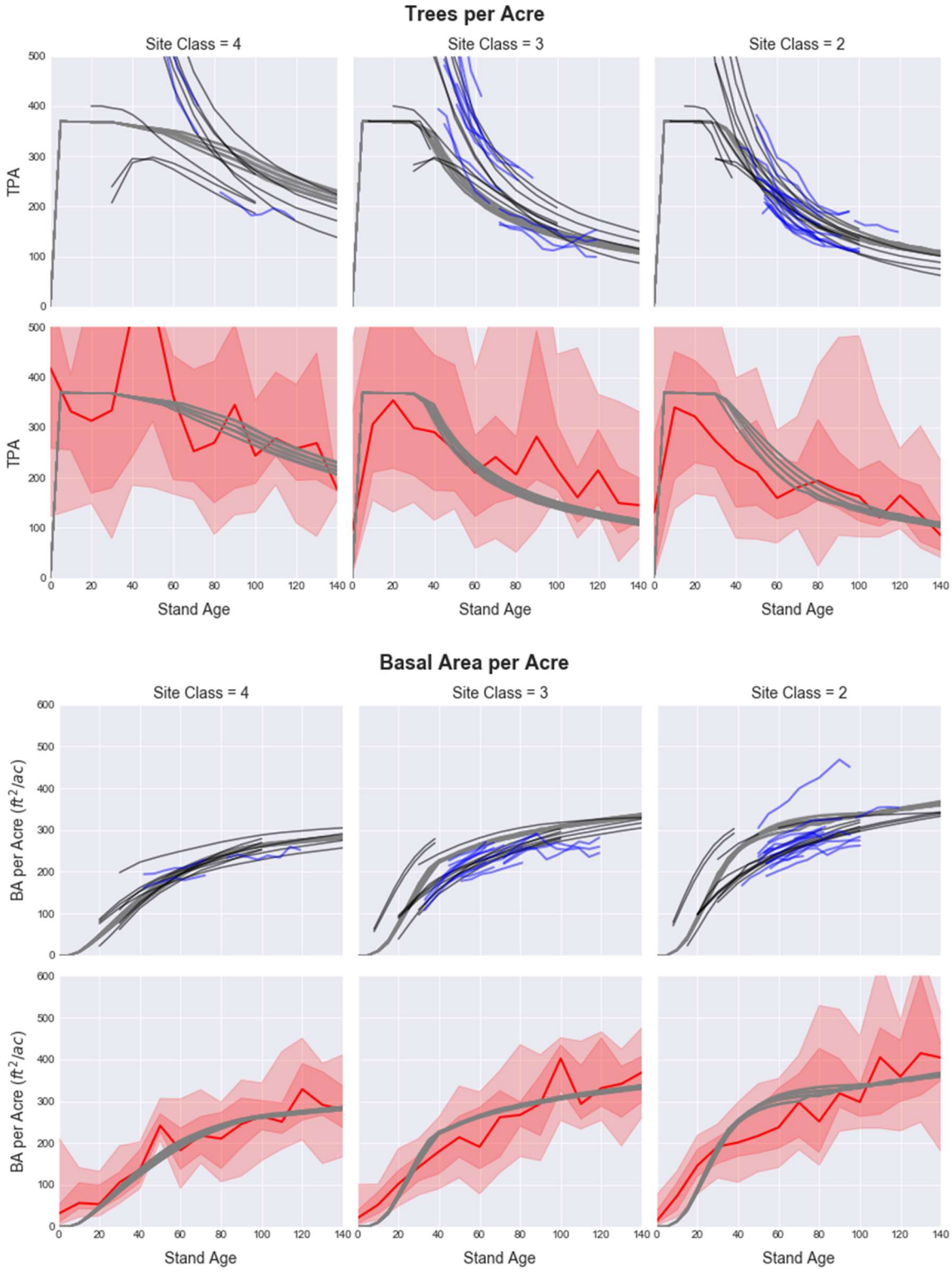

Figure S4. Modified FVS Parameterization (Part 1 of 3): Trees Per Acre (TPA, top 6 graphs) and Basal Area (BA) per Acre (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

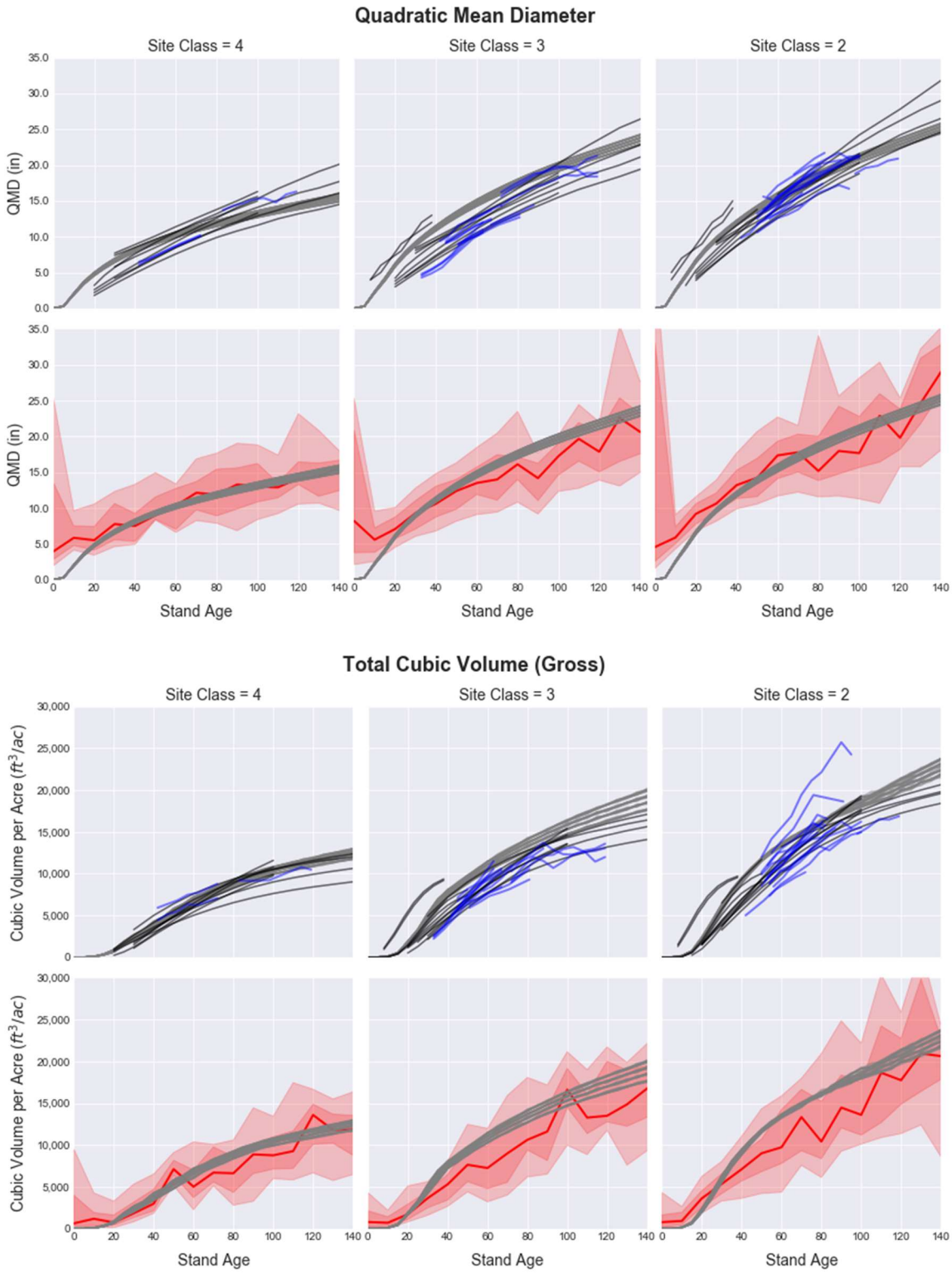

Figure S5. Modified FVS Parameterization (Part 2 of 3): Quadratic Mean Diameter (QMD, top 6 graphs) and Total Cubic Volume (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

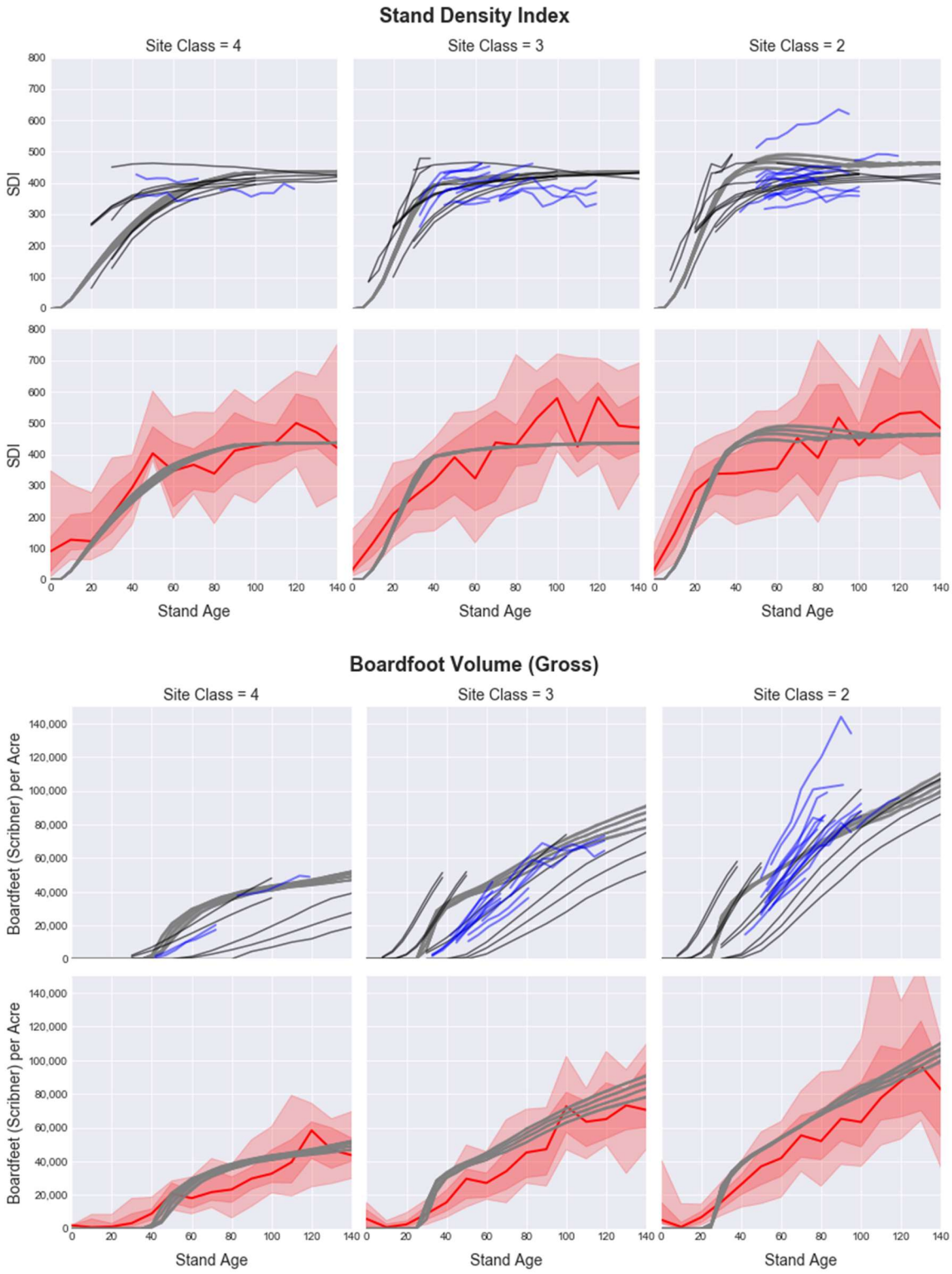

Figure S6. Modified FVS Parameterization (Part 3 of 3): Stand Density Index (SDI, top 6 graphs) and Gross Boardfoot Volume (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

Table S3. Yield Table: Dominant Height (feet), 40 tallest trees per acre.

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	37	38	40	42	44	46	48	49	51	53	55	57
25	44	46	49	51	54	56	59	61	63	65	68	70
30	51	54	57	60	63	66	68	71	74	77	80	82
35	58	61	64	67	71	74	78	81	84	88	91	93
40	63	67	71	74	78	82	86	90	93	97	100	103
45	68	73	77	80	85	89	94	98	102	106	109	112
50	73	78	82	85	91	96	100	105	109	114	117	120
55	78	82	86	89	97	102	107	112	116	121	124	127
60	82	87	91	93	102	108	113	118	123	127	131	134
65	85	91	95	97	107	113	118	124	128	133	137	140
70	89	94	98	100	112	117	123	129	134	138	142	145
75	92	97	101	103	116	122	128	134	139	144	147	150
80	95	100	104	106	120	126	132	138	144	148	152	155
85	97	103	107	109	123	129	136	142	148	153	157	160
90	100	106	110	112	126	133	140	146	152	157	161	164
95	102	108	112	114	129	136	143	150	155	161	165	168
100	104	110	115	116	132	139	146	153	159	164	169	172

Table S4. Yield Table: Trees per Acre

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	368	368	368	368	368	368	368	368	368	368	368	368
25	368	368	368	368	368	368	368	368	367	367	367	367
30	368	368	368	368	368	368	367	367	367	367	367	366
35	365	365	364	363	357	355	353	350	357	355	353	337
40	362	361	360	359	345	334	323	314	335	330	323	306
45	359	358	356	355	306	296	288	276	313	305	295	277
50	356	355	353	350	277	268	258	251	292	281	269	251
55	354	351	349	345	254	245	238	229	271	259	246	228
60	351	348	343	336	235	226	220	213	252	238	225	208
65	347	340	335	327	218	211	204	198	234	220	207	191
70	341	333	327	317	204	198	192	186	217	204	191	176
75	334	326	318	308	192	186	180	175	203	190	177	170
80	328	318	310	299	182	176	171	166	190	177	165	158
85	321	311	302	290	173	168	162	158	178	166	155	151
90	314	304	293	281	165	160	155	150	168	156	149	146
95	306	293	283	273	158	153	148	144	159	147	144	140
100	294	283	273	264	152	147	142	138	150	142	137	134

Table S5. Yield Table: Basal Area (sq. ft. per acre)

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	42	45	47	50	68	71	75	79	82	86	90	93
25	62	66	70	73	110	115	120	125	130	135	140	145
30	83	88	92	96	152	159	165	171	177	184	190	196
35	103	108	113	118	189	196	202	208	219	225	231	228
40	122	128	133	138	222	223	225	227	248	252	256	250
45	140	146	152	158	233	235	237	237	272	274	274	267
50	157	164	170	176	244	246	246	248	290	290	288	279
55	174	181	187	193	253	255	257	257	304	301	297	288
60	189	196	202	206	261	262	265	267	314	309	304	294
65	203	209	214	217	268	270	271	274	321	315	308	297
70	214	220	225	227	275	277	279	281	326	319	312	300
75	225	230	234	236	280	283	284	286	330	322	314	312
80	235	239	243	244	286	288	290	293	334	325	316	314
85	244	247	250	251	291	293	295	297	336	327	319	321
90	252	255	257	257	296	299	300	302	337	328	326	329
95	257	259	261	262	300	303	305	306	338	329	332	334
100	260	262	264	266	305	307	309	311	339	333	334	339

Table S6. Yield Table: Quadratic Mean Diameter (inches)

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	4.6	4.7	4.9	5.0	5.8	6.0	6.1	6.3	6.4	6.5	6.7	6.8
25	5.6	5.7	5.9	6.0	7.4	7.6	7.7	7.9	8.0	8.2	8.4	8.5
30	6.4	6.6	6.8	6.9	8.7	8.9	9.1	9.3	9.4	9.6	9.8	9.9
35	7.2	7.4	7.5	7.7	9.9	10.1	10.2	10.4	10.6	10.8	11.0	11.1
40	7.9	8.0	8.2	8.4	10.9	11.1	11.3	11.5	11.6	11.9	12.0	12.3
45	8.5	8.7	8.9	9.0	11.8	12.0	12.3	12.5	12.6	12.8	13.1	13.3
50	9.0	9.2	9.4	9.6	12.7	13.0	13.2	13.5	13.5	13.7	14.0	14.3
55	9.5	9.7	9.9	10.1	13.5	13.8	14.1	14.3	14.3	14.6	14.9	15.2
60	9.9	10.2	10.4	10.6	14.3	14.6	14.9	15.2	15.1	15.4	15.7	16.1
65	10.4	10.6	10.8	11.0	15.0	15.3	15.6	15.9	15.9	16.2	16.5	16.9
70	10.7	11.0	11.2	11.5	15.7	16.0	16.3	16.6	16.6	16.9	17.3	17.7
75	11.1	11.4	11.6	11.9	16.4	16.7	17.0	17.3	17.3	17.6	18.0	18.4
80	11.5	11.7	12.0	12.2	17.0	17.3	17.6	18.0	17.9	18.3	18.7	19.1
85	11.8	12.1	12.3	12.6	17.6	17.9	18.3	18.6	18.6	19.0	19.4	19.7
90	12.1	12.4	12.7	12.9	18.1	18.5	18.8	19.2	19.2	19.6	20.0	20.3
95	12.4	12.7	13.0	13.3	18.7	19.0	19.4	19.8	19.8	20.2	20.6	20.9
100	12.7	13.0	13.3	13.6	19.2	19.6	19.9	20.3	20.4	20.8	21.2	21.5

Table S7. Yield Table: Cubic volume including top and stump (hundreds of cubic feet per acre)

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	6.3	7.0	7.9	8.9	16.8	17.7	18.3	18.9	19.6	20.3	21.5	23.7
25	14.3	16.1	17.5	18.6	28.3	29.8	31.2	33.1	36.2	38.8	40.9	42.8
30	20.3	21.3	23.5	26.5	42.5	45.2	48.4	52.3	55.7	58.2	60.6	62.9
35	27.3	29.7	31.3	32.5	57.1	60.7	64.8	68.9	74.3	77.3	79.7	79.7
40	33.9	37.3	40.8	42.3	72.2	74.4	77.2	80.2	89.0	92.0	94.1	93.7
45	41.3	43.9	45.6	48.2	80.4	83.7	86.7	88.6	103.1	105.4	106.7	105.8
50	48.1	52.2	55.8	57.8	88.6	91.8	94.5	97.5	115.4	116.8	118.0	116.5
55	55.5	58.7	61.0	63.7	96.2	99.9	103.5	105.5	125.9	127.1	127.5	125.0
60	60.8	65.3	68.8	71.6	102.9	106.6	110.6	114.3	135.2	135.7	135.3	133.0
65	68.6	72.2	74.8	76.2	109.9	114.2	117.6	121.2	142.8	143.1	142.5	139.8
70	73.9	76.8	80.4	82.7	115.6	120.5	124.7	128.2	149.9	149.6	148.7	146.0
75	78.8	82.6	85.5	87.4	121.8	126.5	130.7	134.5	156.5	155.6	154.3	155.6
80	84.2	87.8	90.4	92.0	127.2	132.5	136.9	141.3	162.0	161.3	159.8	161.3
85	88.7	92.3	95.3	96.9	133.0	137.9	142.3	147.0	167.6	166.7	165.7	169.6
90	93.4	96.7	99.3	100.7	137.9	143.5	148.4	152.4	172.3	170.8	173.1	177.3
95	97.2	99.6	103.2	104.6	142.4	148.8	153.3	158.3	176.3	175.3	180.3	184.3
100	99.6	102.8	105.7	107.8	147.2	153.2	158.6	163.4	180.3	181.3	185.1	190.4

Table S8. Yield Table: Boardfoot Volume, Scribner Rule (thousands of boardfeet per acre) *

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	1.3	1.9	2.9
30	0.0	0.0	0.0	0.0	5.4	9.5	12.8	16.0	18.1	20.7	23.2	25.7
35	0.0	0.0	0.0	0.0	22.6	24.9	27.1	28.7	30.8	32.2	33.5	33.2
40	0.9	1.8	2.0	2.4	29.9	30.4	32.1	33.1	37.3	38.5	39.4	39.1
45	3.7	5.1	8.8	13.0	33.5	34.6	36.3	37.1	42.7	43.3	43.9	43.0
50	11.5	15.2	18.8	21.2	36.9	37.8	38.5	39.8	46.9	47.0	47.2	46.3
55	18.4	21.0	23.8	25.6	39.1	40.2	41.3	42.0	50.3	50.4	50.6	49.8
60	23.2	25.7	28.2	29.8	40.8	42.5	43.7	45.0	54.0	54.1	54.3	53.6
65	28.0	29.7	31.3	32.0	43.5	45.0	46.5	48.4	57.5	57.6	57.9	57.1
70	30.6	32.3	33.6	34.7	46.0	48.0	50.2	51.8	61.1	61.4	61.2	60.8
75	33.2	34.7	35.9	37.0	48.6	51.0	53.1	55.5	64.8	64.8	64.8	66.1
80	35.5	36.6	38.1	38.6	51.3	54.3	56.6	59.2	67.8	67.9	68.0	69.4
85	37.3	38.5	39.6	40.1	54.3	57.2	59.9	62.2	71.0	71.1	71.7	73.6
90	38.9	40.0	41.1	41.3	57.3	60.7	63.2	65.3	73.8	74.1	75.5	78.2
95	40.0	41.2	41.9	42.7	60.2	63.6	65.6	68.5	76.6	76.6	79.2	81.4
100	40.8	42.1	42.8	43.6	63.0	66.1	68.6	71.3	79.0	80.1	82.3	84.0

*** Scribner volume calculated for all trees >= 9″ DBH to a minimum 6″ top diameter inside bark, with a 1′ stump.**

Table S9. Yield Table: Stand Density Index

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	105	110	116	121	154	160	167	173	179	186	192	198
25	144	151	158	164	227	235	243	252	259	267	276	283
30	181	189	197	204	295	305	314	324	333	343	352	361
35	215	224	232	240	349	358	367	374	392	400	408	400
40	246	255	264	272	394	393	393	394	428	433	436	424
45	274	284	293	301	400	400	401	397	455	455	452	438
50	301	311	320	328	406	406	404	404	472	468	462	444
55	325	335	344	352	411	411	411	409	483	475	466	447
60	347	357	365	369	416	414	415	416	489	478	466	446
65	367	374	380	383	418	418	417	418	490	478	463	443
70	382	388	394	395	422	421	421	421	490	475	460	440
75	396	401	405	405	423	424	422	423	488	472	456	450
80	408	412	415	413	425	426	425	426	485	469	452	446
85	418	421	423	420	428	427	426	427	482	465	450	450
90	427	429	429	426	429	430	428	428	478	461	455	456
95	433	431	432	430	430	431	430	429	474	456	458	457
100	433	433	433	433	432	432	431	432	470	458	455	459

Table S10. Yield Table: Curtis Relative Density

	Douglas-fir 50-year Site Index (King's)											
Age	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**
20	19.8	20.7	21.5	22.4	28.2	29.2	30.4	31.4	32.4	33.5	34.7	35.7
25	26.5	27.6	28.7	29.7	40.5	41.7	43.1	44.5	45.7	47.1	48.4	49.6
30	32.7	34.1	35.4	36.6	51.6	53.2	54.8	56.3	57.8	59.4	60.9	62.3
35	38.4	39.8	41.1	42.4	60.2	61.7	63.1	64.3	67.2	68.5	69.8	68.3
40	43.5	45.0	46.4	47.8	67.3	67.1	66.8	66.9	72.7	73.3	73.7	71.5
45	48.2	49.7	51.2	52.5	67.8	67.6	67.6	66.8	76.6	76.4	75.9	73.2
50	52.5	54.1	55.5	56.8	68.3	68.3	67.7	67.6	78.9	78.1	76.9	73.8
55	56.4	58.0	59.4	60.6	68.8	68.6	68.4	67.9	80.2	78.7	77.1	73.8
60	59.9	61.5	62.6	63.2	69.1	68.7	68.7	68.6	80.7	78.7	76.6	73.2
65	63.1	64.1	65.1	65.3	69.2	69.1	68.6	68.6	80.6	78.3	75.8	72.4
70	65.4	66.3	67.1	67.2	69.4	69.1	69.0	68.9	80.1	77.6	74.9	71.4
75	67.5	68.2	68.7	68.6	69.3	69.3	68.9	68.8	79.4	76.7	73.9	72.8
80	69.3	69.8	70.2	69.8	69.4	69.3	69.0	69.0	78.8	75.9	72.9	71.9
85	70.9	71.2	71.3	70.7	69.5	69.3	69.1	68.9	77.9	75.0	72.4	72.3
90	72.3	72.3	72.2	71.4	69.6	69.5	69.1	68.9	77.0	74.0	72.9	73.0
95	73.0	72.5	72.5	72.0	69.5	69.5	69.2	68.9	76.1	73.1	73.3	73.0
100	72.9	72.5	72.5	72.2	69.6	69.5	69.2	69.1	75.2	73.1	72.6	73.1

Mapping Riparian Management Zone Buffers in Oregon and Washington

Constraints on harvest activities near streams are handled differently for each State's forest practice regulations [12,13], as well as under the FSC-US Standard for the Pacific Coast [14]. The width of RMZs are displayed in **Table S11**.

Table S11. Buffer widths for Riparian Management Zones under FPA and FSC Rules (in feet)

		Oregon			Washington [1]			FSC-US
		Stream Size			*Site Class* [2]			Pacific Coast [3]
Stream Type	**Buffer Type**	*SM*	*MED*	*LRG*	II	III	IV	
Type F (fish-bearing)	core	20	20	20	50	50	50	50
	inner	30	50	80	78	55	33	150
	outer	--	--	--	42	35	27	--
Type SSBT (salmon, steelhead, bull trout)	core	20	20	--	--	--	--	50
	inner	20	30	--	--	--	--	150
	outer	20	30	--	--	--	--	--
Type N/Np (non-fish, perennial)	core	0	20	20	50[4]	50	50	25
	inner	0	30	50	0	0	0	75
	outer	--	--	--	0	0	0	--
Type Ns (non-fish, seasonal)	core	--	--	--	--	--	--	--
	inner	--	--	--	--	--	--	75
	outer	--	--	--	--	--	--	--

[1] Washington RMZ widths also differ whether stream bank-full width is above or below 10 feet. All buffers shown here, and all RMZs modeled in this study assume a > 10-foot bank-full width.

[2] Site Class categorizes forest growth potential using Douglas-fir 50-year Site Index (height of dominant trees at 50 years of age): II = 35.1-41.1 m (115-135 ft); III = 29.0-35.1 m (95-115 ft); IV = 22.9-29.0 m (75-95 ft)

[3] FSC rules for the Pacific Coast do not identify a 'core' no-touch buffer zone, but rather distinguish inner and outer buffer zones for Category A (fish-bearing) and Category B (perennial non-fish-bearing) streams. FSC limits harvests to single-tree selection in inner buffers, and to single-tree or group selection in outer buffers [14]. Because neither of these harvest systems are implemented in this study, all FSC buffer areas are modeled as no-touch (comparable to the core buffers of OR and WA ~FPA scenarios).

[4] In Washington, Type Np (non-fish perennial) stream buffers are defined with additional criteria described below.

Geospatial layers identifying stream locations, stream types and site class were obtained from the Washington Department of Natural Resources, and a similar data layer for including stream locations, stream type and size was also obtained from the Oregon Department of Forestry. Buffers on streams were created using a Geographic Information System (GIS).

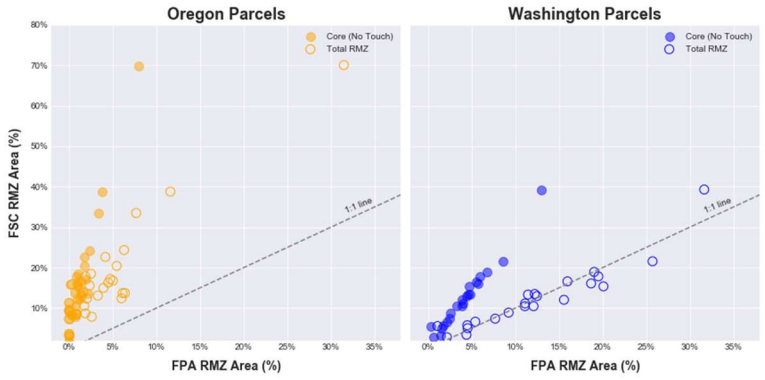

Figure S7. Comparisons of the area encumbered by FSC and FPA RMZs for Oregon and Washington.

In Washington State, non-fish perennial stream (Type Np) RMZs are designated based on the location of sensitive sites and the stream's intersection with other streams. A 56-foot-radius buffer was assigned surrounding sensitive sites defined as a headwater spring or an intersection of two or more Type Np streams. Additionally, the length of 50 foot no-touch buffers applied to Np streams in cases where they intersect with a Type S (shorelines) or Type F (fish-bearing) stream are described in

Table S12. The total area encumbered by no-touch and lighter-touch RMZ areas for FPA and FSC rules are visualized in **Figure S7**.

Silvicultural Prescriptions for RMZs in Washington State under FPA Rules

All core RMZ buffer areas in Washington State are modeled as no-touch under the FPA scenarios. Only Type F streams have additional RMZ constraints beyond the core no-touch buffer. The outer RMZ buffer area in Washington requires the retention of at least 20 conifer TPA with DBH ≥ 20". For the inner RMZ buffer area, we used an online tool produced by the Washington Department of Natural Resources [15] to estimate the green-tree retention during a proposed harvest to meet a desired future condition for the stocking of conifer trees of 325 sq. ft. per acre at age 140. With this tool, we identified the minimum retention requirements for a "thin from below" treatment in the Inner RMZ buffer area for Type F streams.

Table S12. RMZ length for 50-foot core (no-touch) buffer area for Type Np streams that intersect with Type S or Type F streams, Washington State.

Length of Type Np stream	Length of 50' Riparian Management Area
> 1,000'	500'
300' - 1,000'	50% of entire length or 300', whichever is greater
≥ 300'	The entire length

Table S13. Minimum Retention for Inner RMZ Buffers on Type F streams, Washington State

Site Class	Harvest Age *(years)*	Green-Tree Retention * *(trees per acre)*
II	35	57
III	40	60
IV	40	66

* Retention is for conifer trees with DBH ≥ 12, and must be at least 57 conifer TPA.

Silvicultural Prescriptions for RMZs in Oregon under FPA Rules

All core RMZ buffer areas in Oregon are modeled as no-touch under the FPA scenarios. Retention requirements in Oregon FPA rules are defined in terms of retention for a pre-defined length of stream (e.g., 1,000 ft). These retention requirements were converted to trees per acre and basal area per acre by dividing the specified retention by the area that would fall within each buffer type for the pre-defined length of stream.

In practice, these retention requirements are enforced at the level of the entire RMZ rather than for separate RMZ buffer areas. To simplify growth-and-yield simulations, we model each RMZ buffer area independently and do not count retention in other RMZ buffers towards a total value. This approach does not follow the common practice of "packing" retention into core and inner buffer areas, and thus is likely to represent a higher level of green tree retention than is required by Oregon FPA rules. For example, we model all core RMZ buffers as no-touch, and require all inner RMZ buffers to meet the per-acre retention requirements without consideration of the retention neighboring core buffers.

For Type F and Type N streams, Oregon FPA rules following a branching logic approach. Each stream size in these types has a pre-defined "Standard Target." If, at the time of the proposed harvest, a stand is at or above the Basal Area Standard Target, the retention must meet the levels shown in **Table S14**. If a stand falls between 50-100% of the Basal Area Standard Target, the retention must meet the levels shown in **Table S15**. If the stand does not currently meet or exceed these retention levels, no harvest is permitted. Harvests within RMZ buffers are modeled as a "thin from below," removing the smallest trees from the stand's diameter distribution first, while enforcing the minimum TPA and DBH requirements for retention.

Table S14. Oregon FPA "Standard Targets" for Retention in Inner RMZ Buffers

Retention Type	Type F	Type N	Type SSBT [1]

	SM	*MED*	*LG*	*SM*	*MED*	*LG*	*SM*	*MED*
Basal Area [2] *(sq. ft. per acre)*	35	75	100	-- [4]	44	56	81	100
Trees per Acre [3]	-- [5]	19	18	--	9	19	18	22
Minimum DBH [3] *(inches)*	--	8	11	--	8	11	8	8

[1] Type SSBT Streams have only one set of retention targets, they do not another retention option as is the case with Type F and Type N streams. If a stand does not meet SSBT targets at the time of proposed harvest, no harvest is permitted.

[2] FPA rules for Type F and Type N streams count basal area in live conifer trees with DBH ≥ 6″. For Type SSBT streams, the basal area target may include any species of trees with DBH ≥ 6″

[3] The requirements for the minimum number (TPA) and size (DBH) of retained trees refers to live conifers only. Although exceptions exist in Oregon FPA rules for different stream types and sizes, snags and hardwood trees are not counted toward retention requirements as modeled in this study.

[4] Small Type N streams do not have specific retention requirements for inner RMZ buffers. These zones are modeled the same way as non-riparian areas.

[5] Small Type F streams have no specific tree size or count requirements for inner RMZ buffers.

Table S15. Oregon FPA "Alternative Targets" for Retention in Inner RMZ Buffers

Retention Type	**Type F**			**Type N**		
	SM	*MED*	*LG*	*SM*	*MED*	*LG*
Trees per Acre [1]	61	63	66	-- [2]	61	63
Minimum DBH [1] *(inches)*	6	6	6	--	6	6

[1] The requirements for the minimum number (TPA) and size (DBH) of retained trees refers to live conifers only.

[2] Small Type N streams do not have any specific retention requirements for inner RMZ buffers. These zones are modeled the same way as non-riparian areas.

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