Growth Model Runoff II

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Introduction

GROWTH MODEL RUNOFF II is a follow-up to our first Runoff conducted in 2002. We are interested in looking at the performance of commonly available Pacific Northwest Douglas-fir growth models in projecting stands with thinning and fertilization treatments. We are not looking for "truth" (although that would be great) – just to understand how each model simulates treatment effects.

Introduction

In **GMRO I** [Johnson (2002)] users were asked to run three stands through the growth model they used and report the results. The hypothesis under test was that there would be no significant user effects, but potentially large model effects.

We found that there were both **user** and **model** effects. The same model and version produced different results depending on the user. Model effects were sometimes large.

Introduction

GMRO II extends the experiment to examine how Douglas-fir growth models handle thinning and fertilization. In this experiment, user effects were minimized by asking each model's author to make the projections. The thought was to limit potentially misleading user effects from the main effect of the model.

Models Examined

The models examined are:

- DFSIM v1.4 (Marshall)
- FPS v6.44 (Arney)
- FVS (Smith-Mateja)
- SMC-ORGANON v8.0 (Hann)
- SPS 4.1h, circa 1999 (Hamlin)
- TASS vII (Goudie)

Models Examined
DFSIM

- **Model: D**ouglas-**F**ir **SIM**ulator [Curtis, et. al. (1981)]
- **Version:** 1.4
- **Type** [Munro (1974)]: Whole Stand
- **Settings:**
  - Specified residual stand rather than specifiying the residual basal area per acre (BA) and trees per acre (TPA).
  - Starting conditions specified the total age, TPA and BA.
  - The maximum Curtis relative density (RD) was allowed to increase above the default value of 70 up to 100.

Models Examined
FPS

- **Model:** **F**orest **P**rojection **S**ystem [Arney (2005)]
- **Version:** 6.44
- **Type:** Individual tree - distance dependent.
- **Settings:**
  - Region 12 - Western Washington.
  - Used composite tree list – did not assume each tree record was an individual tree.
  - Assumed a residual thinning clumpiness of 0.92
  - Site prep setting: 8Y75

Models Examined
FVS

- **Model:** **F**orest **V**egetation **S**imulator [Donnelly (1997)]
- **Version:** Pacific Northwest Coast (PN) Variant
- **Type:** Individual tree - distance independent.
- **Settings:**
  - Location Run: Olympia
  - SDI_{max} of 520
  - BA_{max} of 300
  - This variant does not have keywords applicable to fertilizer in Oregon. Used keywords to increase basal area growth by 30% for 10 years and decreased mortality by 10% for 10 years. After 10 years growth and mortality defaulted to unmodified growth equations.

Models Examined
SMC-ORGANON

- **Model: S**tand **M**anagement **C**ooperative - ORGANON [Hann (2003)]
- **Version:** 8.0
- **Type:** Individual tree - distance independent.
- **Settings:**
    - No special settings reported.

Models Examined
SPS

- **Model:** **S**tand **P**rojection **S**ystem [Arney (1985)]
- **Version:** 4.1h
- **Type:** Individual tree - distance independent.
- **Settings:**
  - No special settings reported.

Models Examined
TASS

- **Model:** **T**ree **A**nd **S**tand **S**imulator [Mitchell (1975)]
- **Version:** II
- **Type:** Individual tree - distance dependent.
- **Settings:**
  - Expanded tree records to create a pseudo-fixed area plot (TASS requires a fixed-area plot).
  - Randomly thinned out a proportion of the replicated trees based on the probability of thinning shown in the "after" tree list.
  - Randomly added or removed a few trees from the expanded after-thinning tree list to ensure a target of 180 trees/ac (445/ha) was achieved.
  - Since TASS is spatially explicit, we established the unthinned trees to ensure they were well spaced, and then randomly added the thinned trees in between.
  - Created a unique dominant height growth curve that starts at the establishment height and passes through the assigned height at breast height age 50.
  - The fertilizer response model was developed using our large fertilizer-thinning experiment in coastal BC. The data and models indicate little or no response for sites above 35m (114') at BH age 50. Thus, the fertilization runs for Sites 1 and 2 were not done because TASS shows no response for these high sites.

The Problem

Three stands were provided spanning a range of site qualities; young and high enough stocking to be thinned. The initial conditions were:

Stand	Site	TPA	BA	Dq	HT	HTLC	RD	Age_{bh}	Age_{total}
1	120	608	146.9	6.7	58.2	31.6	56.9	22	29
2	100	732	138.4	5.9	50.1	20.4	57.0	17	25
3	140	384	151.5	8.5	59.7	27.1	51.9	17	19

Stands were sub-sampled for height and crown ratio. For trees without field-measured heights and crowns, regressions specific to each stand were used to impute missing values.

The Problem

After Thinning

The thinnings were all to 180 trees per acre with a $\frac{d}{D}$ less than 1.0. The after thinning stand statistics were:

Stand	Site	TPA	BA	Dq	HT	HTLC	RD
1	120	180	63.1	8.0	64.1	32.8	22.3
2	100	180	47.8	7.0	54.3	21.2	18.1
3	140	180	86.3	9.4	62.5	27.5	28.2

The Problem

The Treatments

Each stand was projected 20 years using the following treatment matrix. Treatments were applied at the start of the projection.

Scenario	Thinning	Fertilization
Base Case	–	–
Thin Only	180 TPA	–
Fertilize Only	–	200lbs N
Combined	180 TPA	200lbs N

Thinning was performed by adjusting tree expansion factors in the tree list to simulate a thinning (in contrast to assuming the tree list was a sample from a fixed-area plot where discrete trees were removed).

The Theory

Both thinning and fertilization have a long history of use in Pacific Northwest Douglas-fir silviculture. There is a rich resource of designed experiments and response-surface studies devoted to quantifying the effects of these treatments. Given this background, we would expect a clear understanding of these treatments.

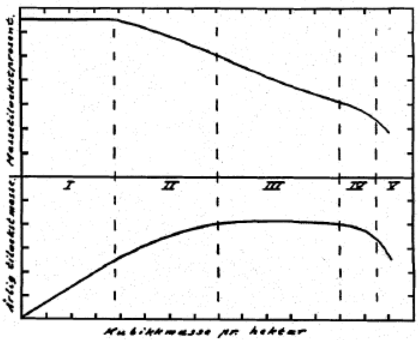
The Theory
Thinning

Conventionally thinning is thought to concentrate growth on fewer stems per acre. Thus, while possibly not increasing total volume production, stem size is enhanced with treatment. Existing research is equivocal on how height growth is affected:

- A study at Wind River [Harrington and Reukema (1983)] found that pre-commercial thinning had a shock effect on height growth resulting in substantial height growth reductions.
- The Levels of Growing Stock Study (LOGS) [Marshall and Curtis (2002)] found stable height growth trends, with thinning treatments resulting in higher exhibited site index over time (possibly due to the chain-saw effect).

The Theory
Thinning

A few studies have shown an increase in total volume production with thinning. Some of the LOGS [Marshall and Curtis (2002)] light thinning treatments have now exceeded total volume production on the controls. Generally, the reduction in growing stock from thinning reduces total volume growth. This is equivalent to moving left along the Langsaeter curve [Langsaeter (1944)] prior to the plateau (regions I and II).



The Theory
Fertilization

Nitrogen fertilization of Douglas-fir has been studied for several decades, primarily through the Regional Forest Nutrition Research Program (RFNRP). The RFNRP found that Douglas-fir generally responded to additions of Nitrogen as urea. Many soils in the Pacific Northwest have sufficiently low available N for economic responses to be obtained. In a summary of RFNRP and other research [Miller, et. al. (1986)] documented the type and duration of response. Of the findings, several are important:

- Response duration was limited – the effect of N additions was not permanent.
- Response is inversely proportional to site quality as measured by site index (at least in unthinned stands).
- Absolute and relative response was greater in thinned stands.
- No mention of height growth response.

The Theory
Fertilization

Another RFNRP report [Stegemoeller and Chappell (1988)] documented 16 year results on fertilization of unthinned and thinned stands. Installations ranged between site index 114 and 118, and averaged 200 $\frac{ft^2}{acre}$ basal area unthinned and 120 $\frac{ft^2}{acre}$ thinned. Conclusions from the report:

- Response duration was limited, ranging from 8 years in thinned stands to 14 years in unthinned conditions.
- Basal area response averaged 10.8 $\frac{ft^2}{acre}$ in unthinned stands and 7.4 $\frac{ft^2}{acre}$ in thinned stands over a 16 year period.
- Volume response averaged 455 $\frac{ft^3}{acre}$ in unthinned stands and 406 $\frac{ft^3}{acre}$ in thinned stands over a 16 year period.
- No mention of height growth response.

Results

Definitions:

- Growth:

  $$Growth_t = (X_t - X_0)$$

- Cumulative Fertilized Response:

  $$Response_t = (Treated_{t,i} - Control_{t,i})$$
  where t = time period, i = thinning treatment

- Cumulative Thinned Response:

  $$Response_t = (Treated_t - Control_t) + (Control_0 - Treated_0)$$

Cubic Volume Growth after 20 Years

Site	Model	NN	TN	NF	TF
100	DFSIM	5398	4448	6244	5301
100	FPS v6.44 Western Washington	4364	2104	6858	3355
100	FVS PN OLY	4502	3157	4978	3558
100	ORGANON—SMC	4603	3285	4798	3495
100	SPS 4.1h	5104	3087	5229	3459
100	TASS	4859	3687	5959	4316
120	DFSIM	5520	4830	6026	5310
120	FPS v6.44 Western Washington	5084	2983	6950	4158
120	FVS PN OLY	3817	3277	4372	3739
120	ORGANON—SMC	5066	4126	5186	4268
120	SPS 4.1h	6164	3897	6738	4481
120	TASS	5959	5116		
140	DFSIM	10168	10237	10904	11084
140	FPS v6.44 Western Washington	9651	6729	11533	8246
140	FVS PN OLY	4904	4392	5523	4964
140	ORGANON—SMC	6793	5803	6878	5905
140	SPS 4.1h	8713	6919	9111	7761
140	TASS	8675	7931		

where: NN = No Treatments, TN = Thinned, NF = Fertilized, TF = Thinned and Fertilized.

Basal Area Growth after 20 Years

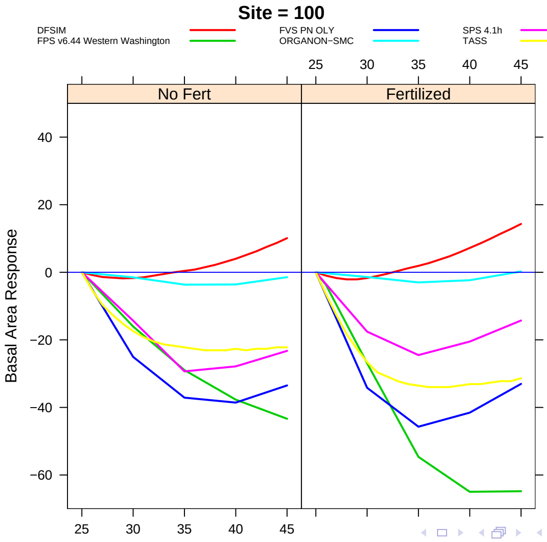
Site	Model	NN	TN	NF	TF
100	DFSIM	117	127	136	150
100	FPS v6.44 Western Washington	91	47	135	70
100	FVS PN OLY	126	92	138	105
100	ORGANON—SMC	90	88	94	94
100	SPS 4.1h	97	73	99	85
100	TASS	122	100	146	115
120	DFSIM	87	99	96	108
120	FPS v6.44 Western Washington	84	55	115	75
120	FVS PN OLY	99	83	111	94
120	ORGANON—SMC	77	88	79	91
120	SPS 4.1h	107	78	117	93
120	TASS	139	127		
140	DFSIM	187	229	202	249
140	FPS v6.44 Western Washington	172	125	200	149
140	FVS PN OLY	97	92	109	104
140	ORGANON—SMC	95	106	97	108
140	SPS 4.1h	147	136	156	159
140	TASS	195	185		

where: NN = No Treatments, TN = Thinned, NF = Fertilized, TF = Thinned and Fertilized.

Dominant Height Growth after 20 Years

Site	Model	NN	TN	NF	TF
100	DFSIM	38.0	38.0	40.6	40.6
100	FPS v6.44 Western Washington	30.1	30.6	42.3	42.7
100	FVS PN OLY	31.6	31.7	31.1	31.6
100	ORGANON—SMC	31.2	29.4	31.7	29.5
100	SPS 4.1h	33.9	34.9	32.9	35.6
100	TASS	35.1	34.8	38.7	38.4
120	DFSIM	41.7	41.7	43.6	43.6
120	FPS v6.44 Western Washington	33.3	34.6	43.7	45.1
120	FVS PN OLY	33.6	38.2	35.9	38.7
120	ORGANON—SMC	37.3	34.2	37.7	34.6
120	SPS 4.1h	38.6	39.7	39.4	40.7
120	TASS	37.1	38.1		
140	DFSIM	58.3	58.3	59.8	59.8
140	FPS v6.44 Western Washington	49.5	51.2	58.3	60.0
140	FVS PN OLY	46.8	49.0	48.7	49.8
140	ORGANON—SMC	48.1	45.8	48.1	45.9
140	SPS 4.1h	50.2	51.1	50.0	51.0
140	TASS	53.5	52.8		

where: NN = No Treatments, TN = Thinned, NF = Fertilized, TF = Thinned and Fertilized.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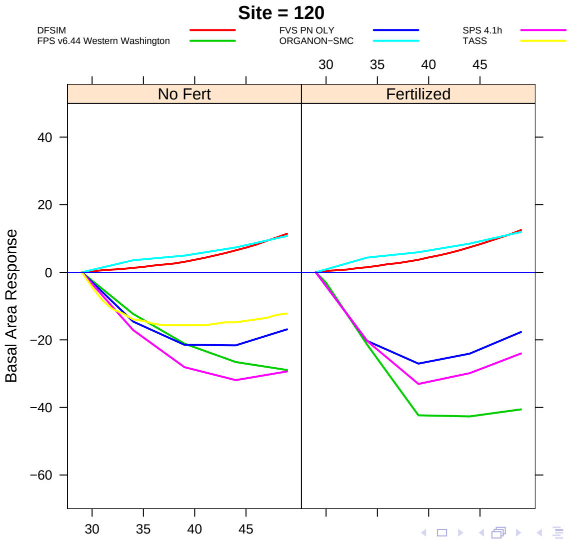
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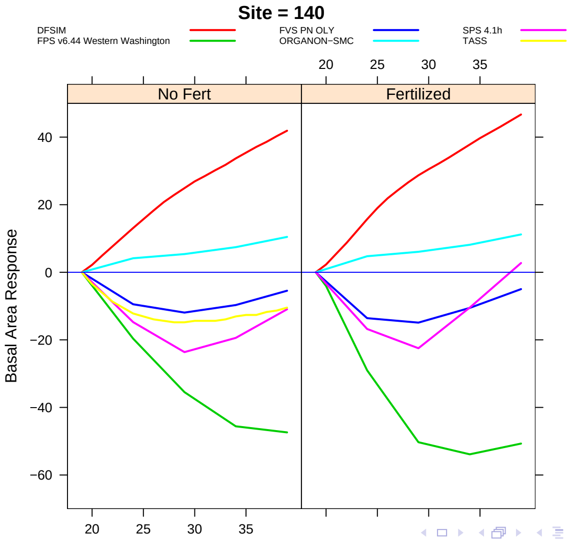
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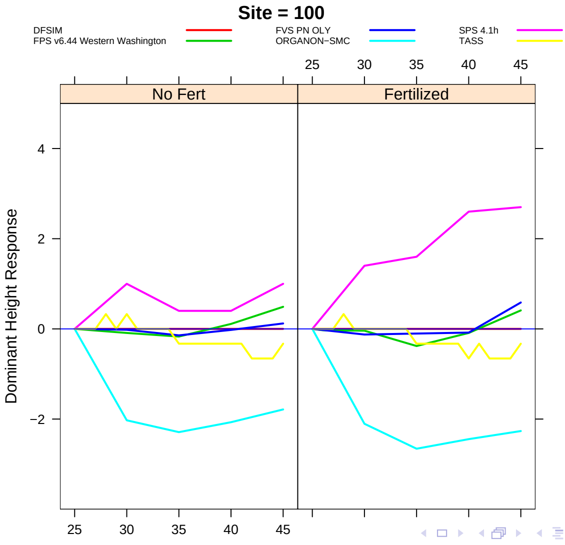
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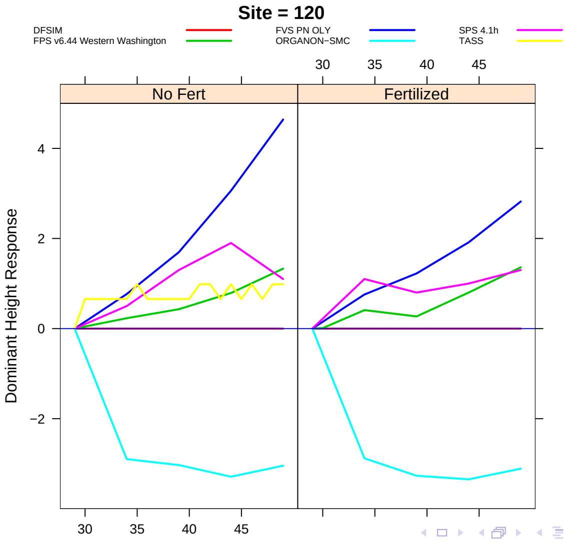
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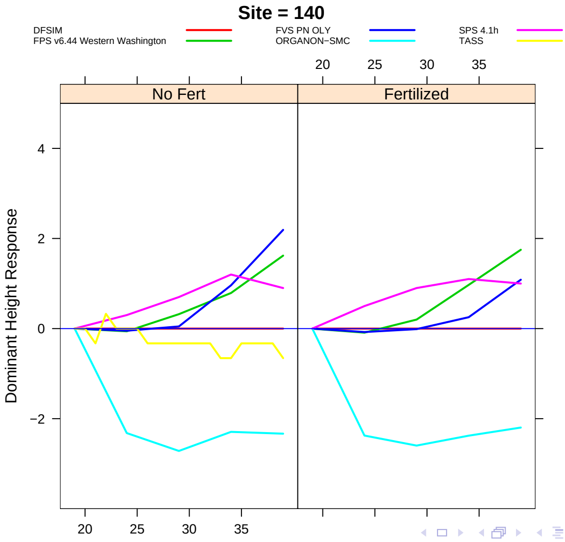
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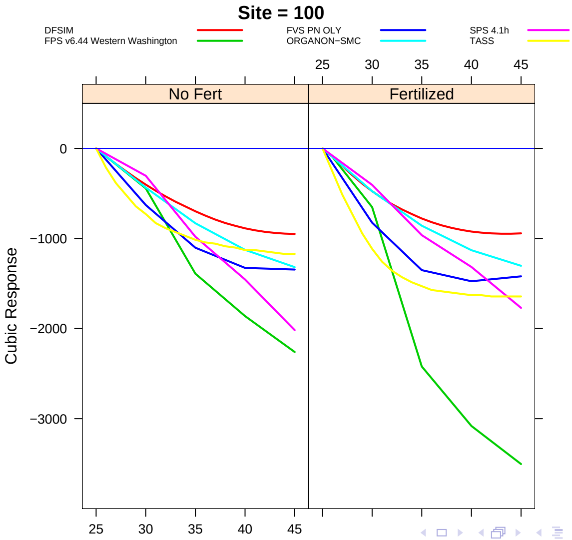
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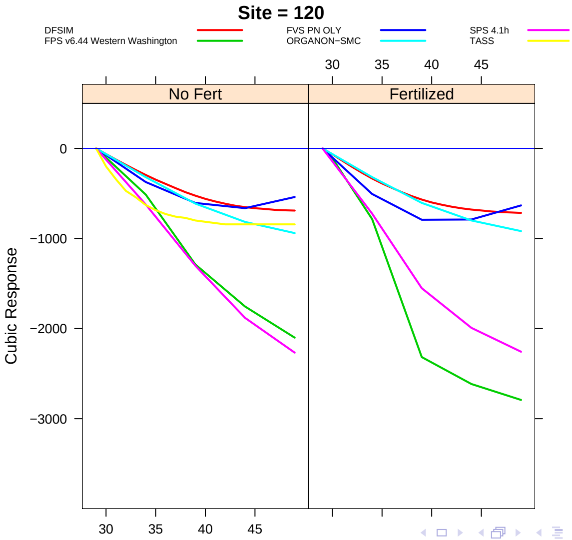
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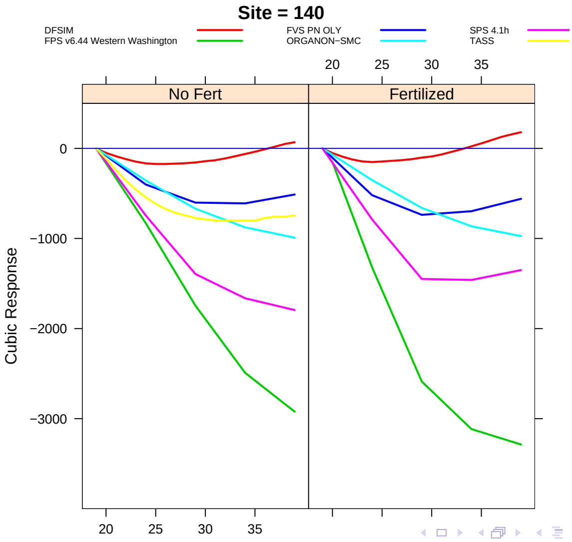
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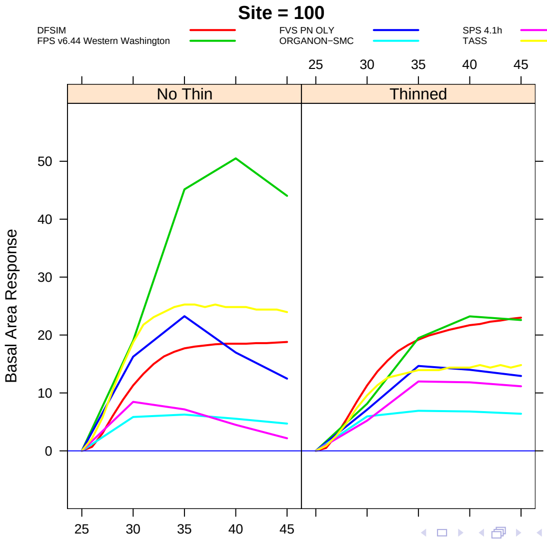
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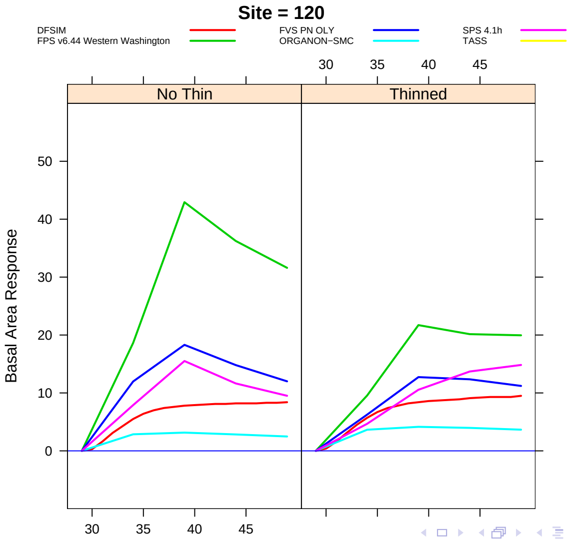
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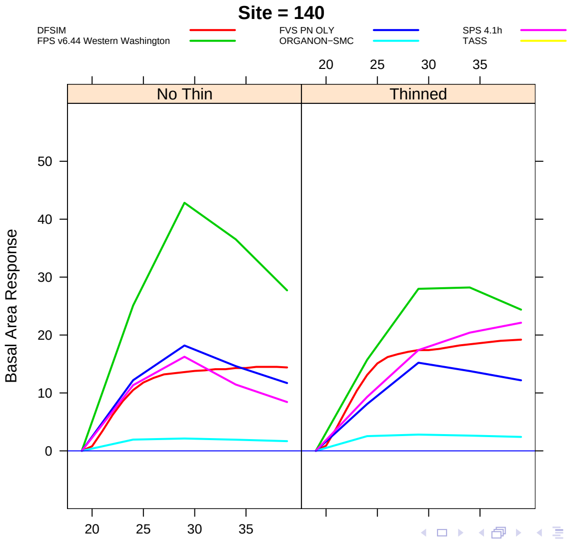
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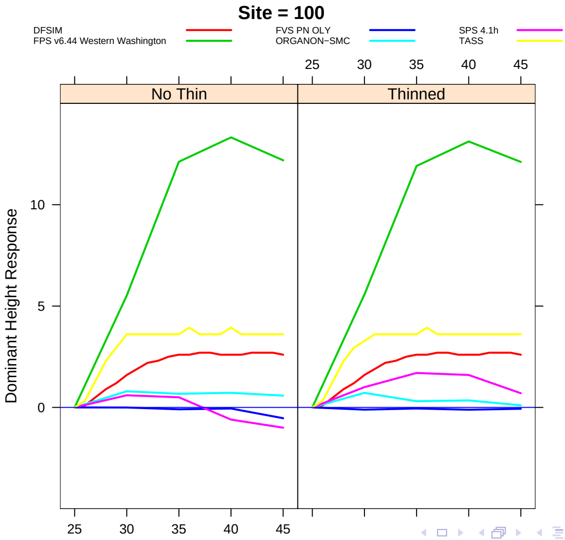
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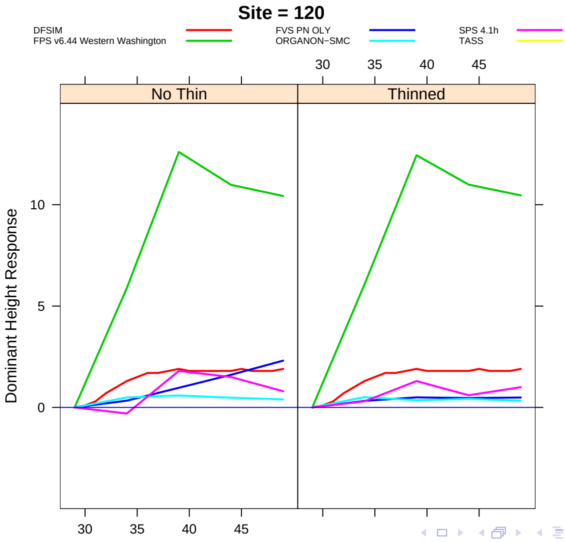
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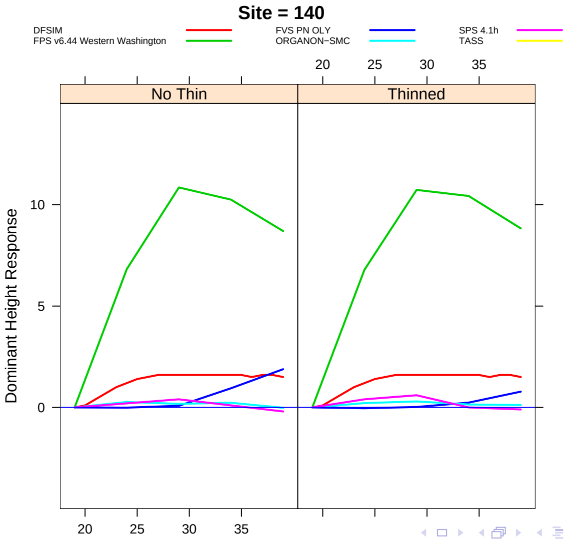
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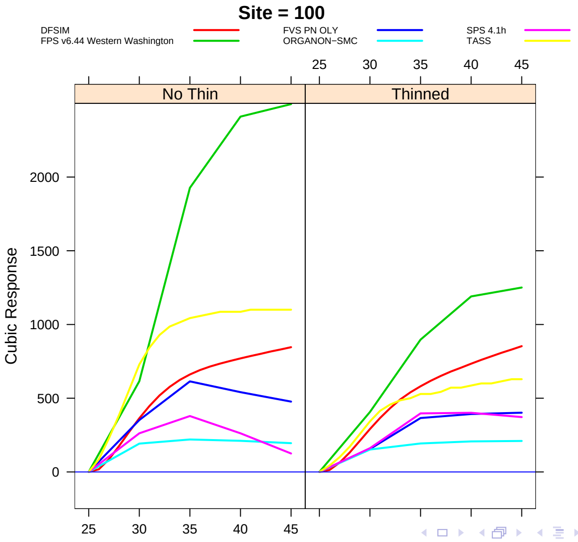
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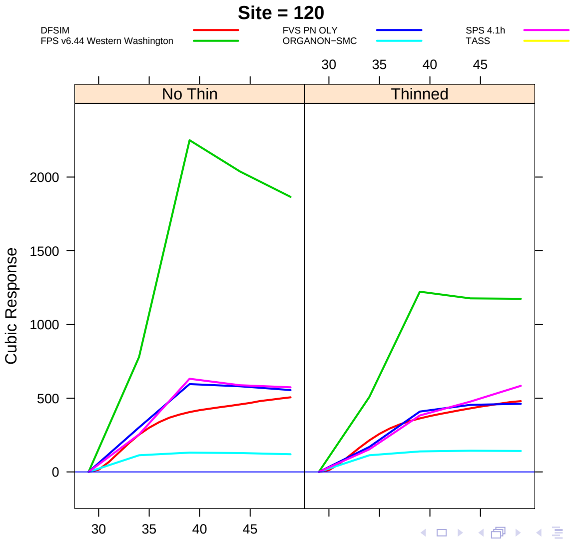
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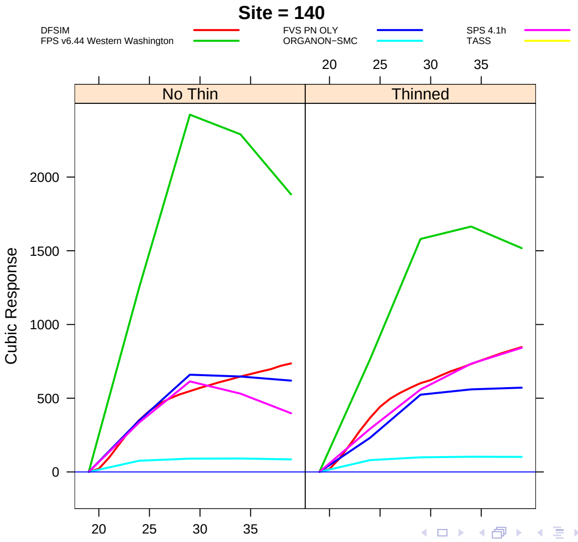
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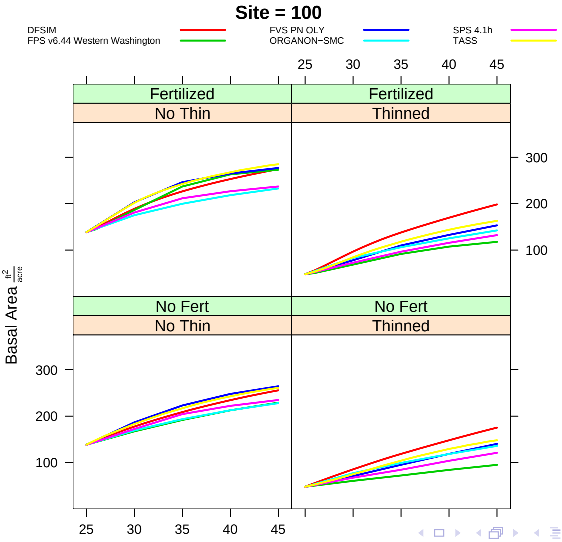
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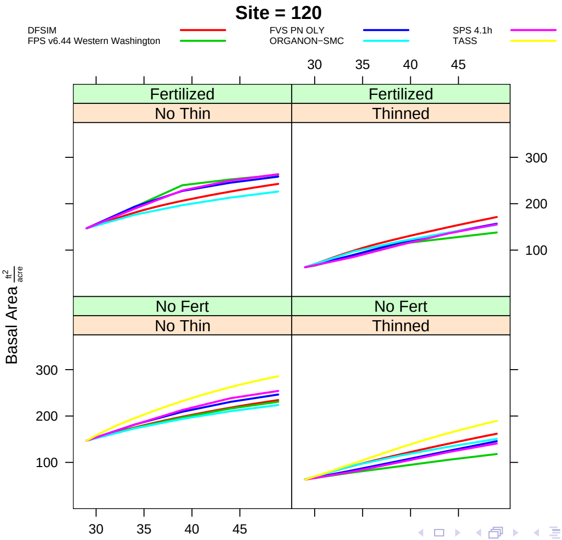
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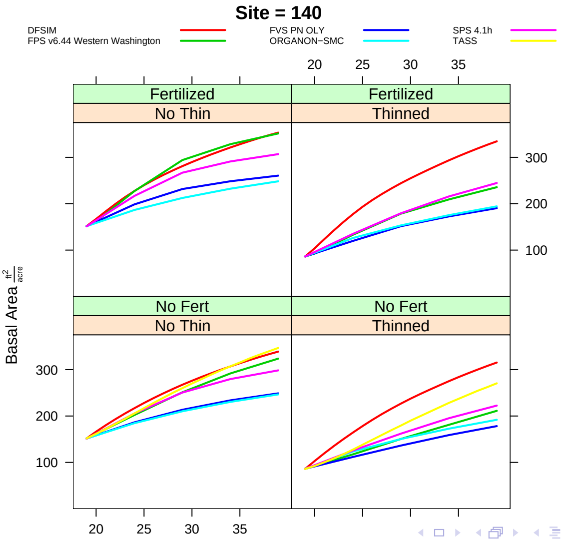
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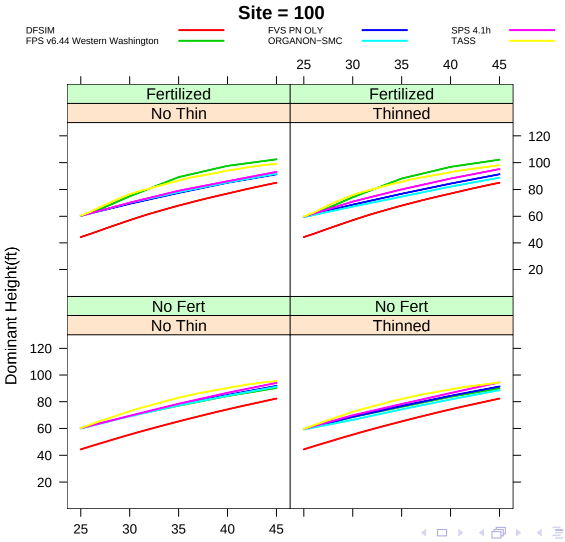
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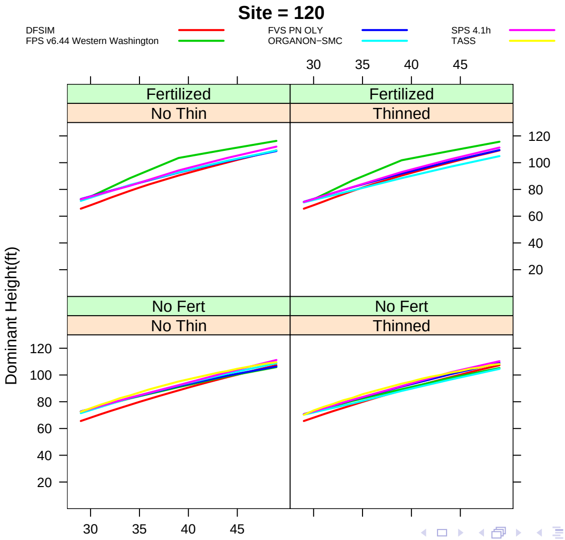
FVS PN OLY
ORGANON−SMC
SPS 4.1h
TASS
Fertilized
No Thin
Fertilized
Thinned
No Fert
No Thin
No Fert
Thinned
Dominant Height(ft)
25 30 35 40 45
20 40 60 80 100 120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ORGANON−SMC
SPS 4.1h
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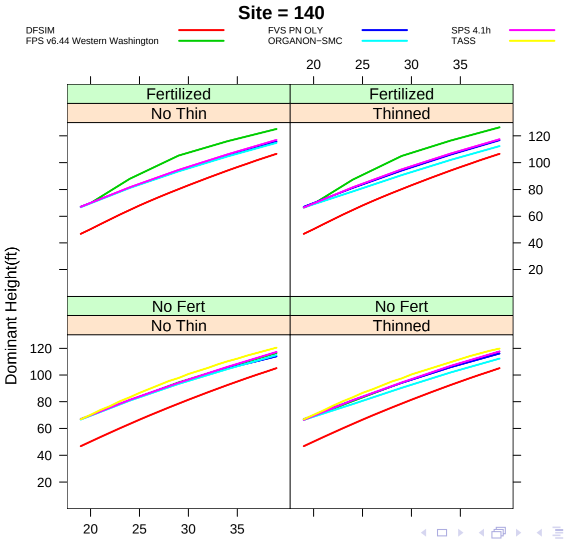
Fertilized
Thinned
No Fert
No Thin
No Fert
Thinned
Dominant Height(ft)
30
35
40
45
20
40
60
80
100
120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Fertilized
Thinned
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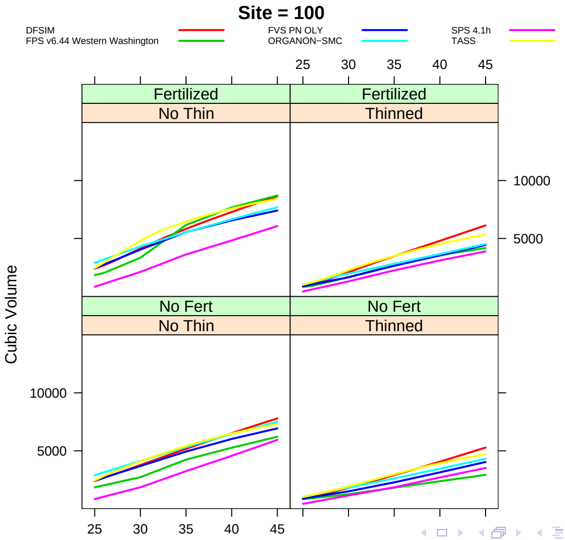
No Thin
No Fert
Thinned
Dominant Height(ft)
20
25
30
35
120
100
80
60
40
20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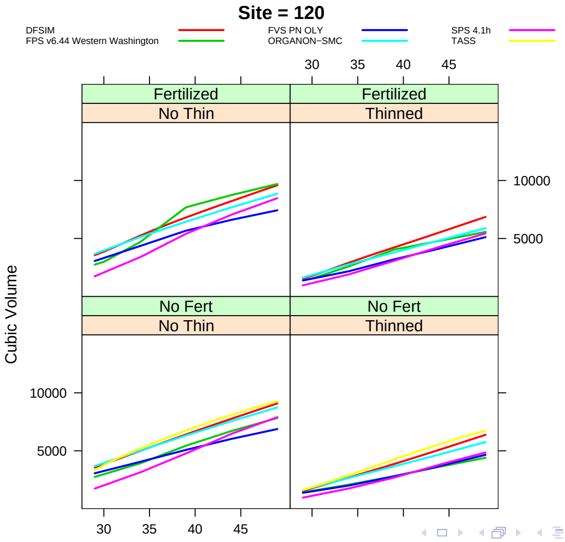
Thinned
No Fert
No Thin
No Fert
Thinned
Cubic Volume
10000
5000
25
30
35
40
45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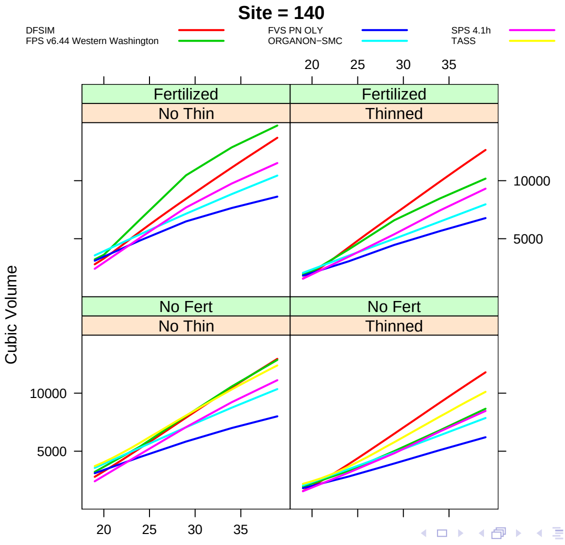
No Fert
Thinned
Cubic Volume
10000
5000
30
35
40
45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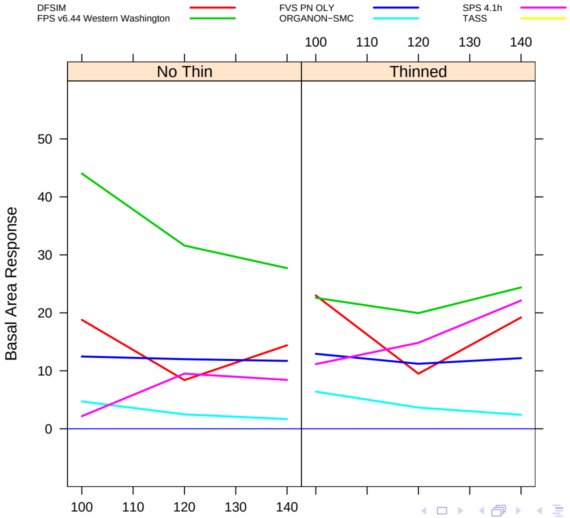
No Fert
No Thin
No Fert
Thinned
Cubic Volume
20
25
30
35
10000
5000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Basal Area Response
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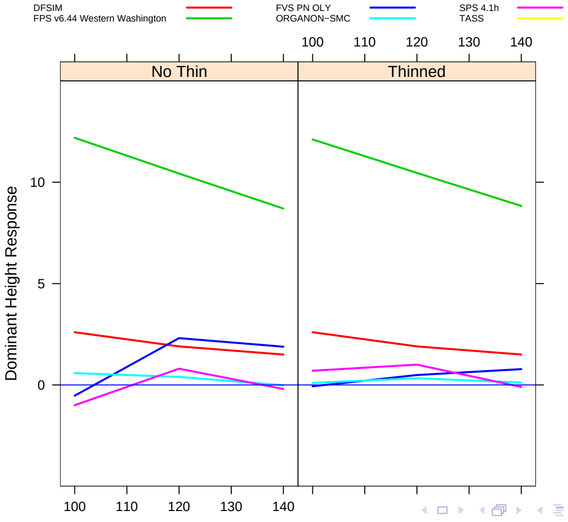
30
40
50
100
110
120
130
140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Thinned
Dominant Height Response
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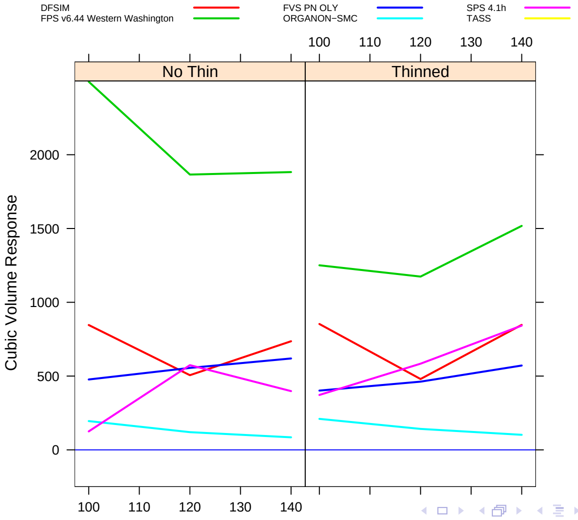
100
110
120
130
140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SPS 4.1h
TASS
No Thin
Thinned
Cubic Volume Response
0
500
1000
1500
2000
100
110
120
130
140

Conclusions

The six models tested here show a wide range of responses to thinning, fertilization, and the combination of those treatments. No one model adhered to all of general research findings on these treatments. Users need to be careful when applying these models to silviculture investment analyses.

Of the models tested, TASS is the closest to a process-level model. It was well behaved, however, because of its base dataset, it was unable to estimate fertilization on medium to high PNW Douglas-fir sites.

Observations about Thinning

- Two models predict basal area response incremental to the control.
- One model predicts reductions in height growth with thinning.
- One model predicts "bonus wood" – total volume growth with thinning exceeds the control.
- Half the models have begun to accrete volume relative to the controls by the end of the 20 years.

Observations about Fertilization

- One model predicts very large increases in basal area and dominant height with fertilization.
- Most models show a peak response at 10 years from application.
- Three models are in the cubic volume ballpark suggested by the RFNRP report for sites between 100 and 120 but appear to have a high basal area growth response. Is height growth response being underestimated?
- Almost all models show decreased response with thinning.
- Several models show increased response to fertilization as site index increases.


CAVEAT EMPTOR

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- Jim Arney – FPS
- Jim Goudie – TASS
- Dave Hamlin – SPS
- David Hann – ORGANON
- David Marshall – DFSIM
- Erin Smith-Mateja – FVS

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