Addendum's

A: Agenda (pg.2), B: Budget (pg.4), C:Technical Reports (pg.11)

SMC 2016 Spring Meeting

4-19-2016

Eric Turnblom, Interim Director

Stand Management Cooperative

School of Environmental and Forest Sciences

UNIVERSITY *of* WASHINGTON

College of the Environment

STAND MANAGEMENT COOPERATIVE SPRING MEETING
April 19, 2016
World Forestry Center, 4033 SW Canyon Rd, Portland, OR 97221

AGENDA

8:00 Light Refreshments

8:15 Welcome & Introductions: Candace Cahill, Policy Committee Chair; Eric Turnblom, Acting Director

8:30 Accomplishments

1. October 2015 – April 2016
   - Budget carryover: $200,000
   - Database
   - Field measurements
   - Research highlights

8:40 New Business 2016-2017

1. 9-Points of contact
2. Welcome new members
3. New Policy Committee Vice Chair
4. Budget
   - 2016 Dues, $617,237
   - 2017 Dues, $542,000
   - SMC hires
5. External funding
   - $327,936 from the following sources: NSF-CAFS Phase III, 5-years funding; NSF-I/UCRC FRP: Collaborative Project; NCASI, USDA Biofuels; McIntire-Stennis; B. Bruce Bare Endowed Chair of Forest Resources
6. Research
   - Type IV Genetic Gain trials measurements
   - Funding ongoing RFP's
   - Collaborative
7. Meetings 2016
   - Joint Technical Advisory Committee, January 12, 2016
   - Policy Advisory, March 3, 2016
   - CAFS Annual Meeting, Pensacola Beach, Florida, April 26-28, 2016
   - 2016 Annual Fall Meeting and possible field tour: September 22, 2016
   - Set Dates:
     - Installation Review (IRC) Committee (July)
     - Nutrition and Silviculture TAC (first week in June)
8. Student Updates
   - 4-PhD and 3-MS

Addendum A: Agenda

STAND MANAGEMENT COOPERATIVE SPRING MEETING
April 19, 2016
World Forestry Center, 4033 SW Canyon Rd, Portland, OR 97221

Technical Reports

9:35	Western Hemlock Slash Yield	Jason Cross, SMC Database Manager
10:00	**Break**	
10:20	PCT Analysis	Eric Turnblom, Silviculture TAC
10:45	Yield Performance of SMC Type I, II, and III Inst. $(SMC)^2$ Analysis	Maureen Kennedy, UW Tacoma
11:10	SMC Type I Installation 722-Sunsetting Results to Date	Eini Lowell, Wood Quality TAC
11:35	Fertilizer Response using Relative Growth Response	Rob Harrison, Nutrition TAC/Kim Littke
12:00	**Lunch**	
1:00	Soil Nutrition: Effects of Nitrogen Fertilization & Thinning	Cole Gross (Harrison's MS student)
1:20	BH & Upper-Stem Diameter Response in Pruned DF	John Kirby (Turnblom's MS student)
1:40	Late Stand Fertilization Response Study Design	Scott Holub, Weyerhaeuser

Database Hands-On Workshop

2:00 *Bring a laptop loaded with SMC's database*

Jason Cross, SMC Database Manager will demonstrate to cooperators how to: retrieve installation, plot, and tree data for specified age ranges; along with specifications for project (e.g. Type I, II, III…), density, and treatment regime. These basic queries will be combined for more complex queries, such as retrieving Type I fertilized and un-fertilized plots, Type V paired-tree records, and tree data formatted for export to growth and yield models.

3:00 **Break**

3:20 Database Workshop cont.

4:20 Closing Remarks

4:30 Adjourn

Addendum B: Budget

Budget 2016 – 2017

- Welcome Green Crow
- Introduce New Policy Committee Chair
- Budget (8% overhead rate)
  - 2016 Dues: $617,237
  - 2017 Dues: $542,024
  - SMC Hires

New Business: External Funding

- Total External Funding:
  - $327,936 from the following sources: NSF-CAFS Phase III, 5-years funding; NSF-I/UCRC FRP: Collaborative Project; NCASI, USDA Biofuels; McIntire-Stennis; B. Bruce Bare Endowed Chair of Forest ResourceS

New Business: Meetings 2016

- Joint TACs meeting January 12, 2016
  - Silver Creek Mainline (722) sunset update
- Policy Advisory meeting March 3, 2016
- CAFS Annual Meeting April 26 – 28, 2016, Pensacola, FL
  - **Final**: Understanding Site-Specific Factors Affecting the Nutrient Demands and Response to Fertilizer by Douglas-fir: Harrison et al
  - **Continue**: Appraising Rotation-age Tree and Stand Characteristics in a 1970's Decadal Cohort of Douglas-fir Plantations in the PNW: Turnblom et al.
  - **New Project Proposal**: Stand and Tree Responses to Late-Rotation Fertilization: Turnblom, Cross, Littke, Harrison

Budget Preamble

- We carried over $200,000 into 2015
- We have lost West Fork (but acreage under SPI)
- We had a loss of 139,635 acres from Campbell Global
  - But adding Lewis and Clark Tree Farm who bought the acreage
- We approved 3 research projects at the Spring Meeting
  - Sunsetting of Type I Installation 722 has begun ($121,650 committed)
  - 2nd Generation western hemlock Trials approved (y1: $3750, y2: $17,515, y3: $17,400, y4: $13,000--$51,665 committed)
  - Late rotation fertilization project approved: budget evolving ($26,685 over two years is committed)
- We will not be taking contract measurements as Bob has agreed to train a new crew next year

2015 Budget Projection

Category	Amount
2015 Formula Dues	$628,624
Carried into 2015	$200,000
Total Available Revenue	$828,942
Salaries	$304,648
Benefits	$83,124
Travel	$58,700
Equipment , Supplies, Tuition, Contracts	$57,955
Subtotal expenses	$504,427
Indirect (8% rate while CAFS funded)	$80,210
Total Direct & Indirect expenses	$584,637
Project Costs*	$200,000
Projected Carryover	$123,659

*These project cost are considered committed funds. These funds will be held for project commitments.

2016 Dues Projected

American Forest Mgt.	$	8,700
Bureau of Land Management	$	83,000
Campbell Global	$	24,746
Cascade Timber Consulting	$	19,152
Green Crow/New	$	8,659
Green Diamond Resource	$	25,156
Hampton Affiliates	$	10,322
Hancock Forest Management	$	36,862
Lewis & Clark Tree Farms	$	18,981
Lone Rock Timber	$	18,563
ORM Inc	$	20,813
Oregon Dept. Forestry	$	41,099
Pacific Denkman	$	7,340
Plum Creek	$	27,057
Port Blakely Tree Farms	$	19,084
Quinault DNR	$	9,331
Rayonier Forest Resources	$	27,628
Roseburg Res.	$	25,493
Stimson Lumber	$	20,525
TimberWest-Coast Timberlands	$	40,974
Washington DNR	$	54,077
Weyerhaeuser NR	$	79,515
Total	$	**627,077**

If acres > 100,000, dues = $13,501
If acres< 100,000, dues = $ 6,751+ $0.039242 ac
Dues cap = $80,000

SMC-Related Contributions

Organization	Funds Contributed 2015
BC Ministry of Forestry	$ 68,000
UW faculty salaries (state support tied to mentoring SMC-based student research)	$100,000
UW Teaching and Research Assistantships ($33,630/student)	$157,052
Total	$325,052

2016 Budget Projection

Category	Amount
2016 Formula Dues	$627,077
Carried into 2016 (minimum)	$123,659
Total Available Revenue	$767,379
Salaries	$380,275
Benefits	$103,820
Travel	$65,925
Equipment & Supplies	$22,215
Subtotal expenses	$572,235
Indirect (8% rate while CAFS funded)	$51,497
Total Direct & Indirect expenses	$623,732
Projected Carryover	$143,646

Addendum C: Technical Reports

SMC 2016 Spring Meeting

School of Environmental
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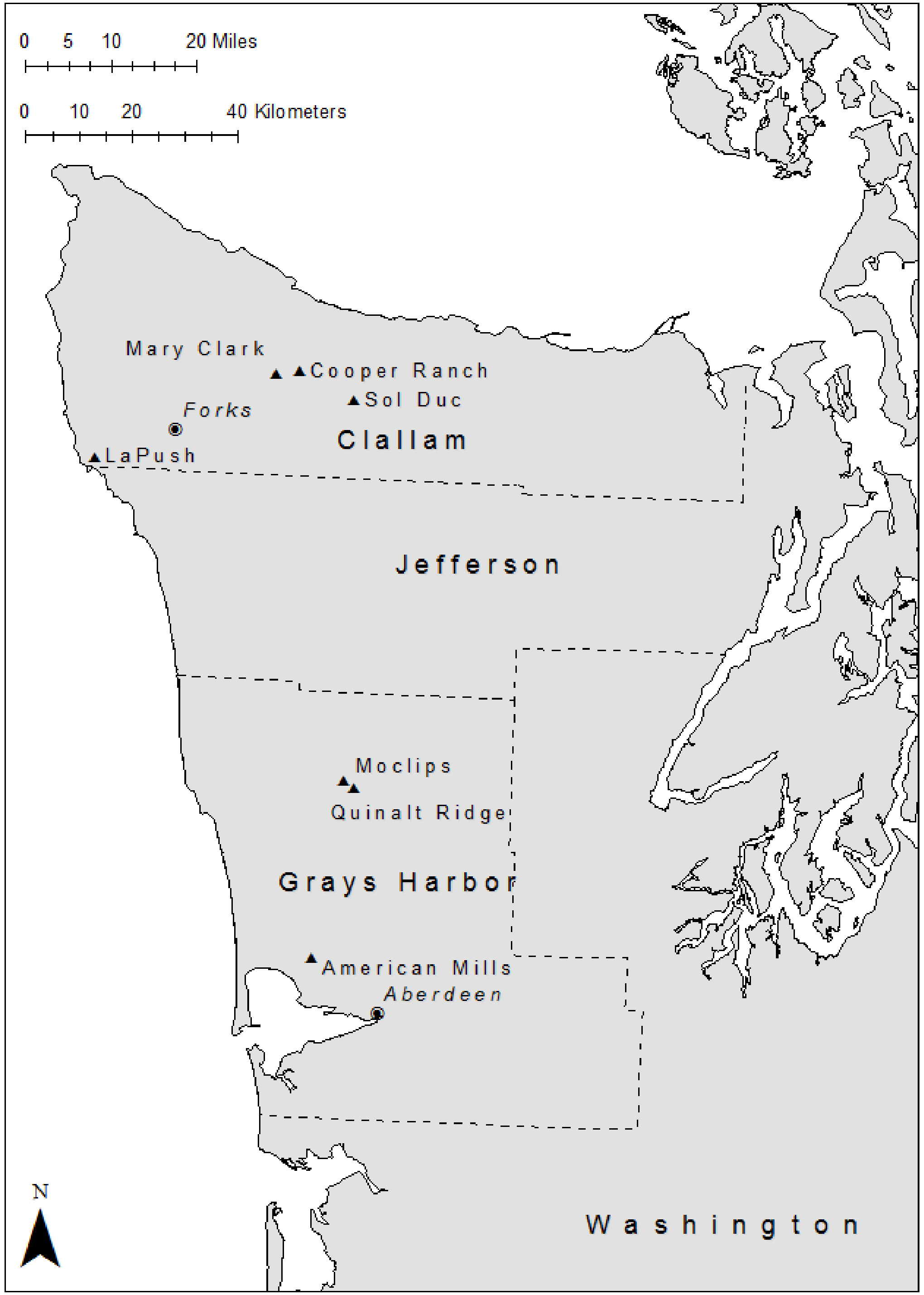
Slash yield of Tsuga heterophylla in forests on the Olympic Peninsula, Washington

Jason Cross
Eric Turnblom
Jeffrey Comnick
University of Washington

Study area and descriptors



Site Name	Location	Age Class	Density
American Mills	South	Young	Dense
American Mills	South	Young	Sparse
La Push	North	Young	Dense
La Push	North	Young	Sparse
Moclips	South	Old	Sparse
Moclips	South	Old	Sparse
Quinault	South	Old	Dense
Quinault	South	Old	Dense
Cooper Ranch	North	Old	Sparse
Mary Clark	North	Old	Sparse
Sol Duc	North	Old	Dense
Sol Duc	North	Old	Dense

ID	Site	DBH	Ht	Crown Class	Crown Base Ht
01	01	11.4"	70.2	Dominant	70.2
02	01	6.4"	57.3	Intermediate	74.5
03	02	12.0"	81.7	Dominant	66.0
04	02	9.3	76.9	Intermediate	93.1
05	03	15.5	80.0	Dominant	85.0
06	03	6.0	57.5	Intermediate	77.3
07	04	13.2	71.5	Dominant	63.0
08	04	9.6	76.8	Intermediate	76.6
09	01	15.6	72.6	Dominant	82.0
10	01	6.9	64.0	Intermediate	32.2
11	02	13.6	91.6	Dominant	34.8
12	02	6.9	75.9	Intermediate	42.8
13	03	7.9	77.3	Intermediate	44.2
14	03	15.1	71.2	Dominant	39.5
15	04	11.5	73.4	Dominant	35.9
16	04	8.3	77.8	Intermediate	52.0
22	07	21.6	131.7	Dominant	46.0
23	05	17.6	132.0	Intermediate	30.0
24	06	18.2	122.0	Intermediate	22.7
25	06	25.6	145.0	Dominant	53.0
26	05	24.3	140.6	Dominant	52.3
27	12	16.4	143.8	Intermediate	43.0
28	07	11.8	118.4	Intermediate	44.5
29	08	11.1	121.7	Intermediate	36.5
30	08	15.9	121.8	Dominant	50.0
31	09	19.3	140.2	Intermediate	72.5
32	11	20.0	137.4	Dominant	70.0
33	10	14.0	121.0	Intermediate	81.6
34	10	22.4	134.7	Dominant	84.0
35	11	14.7	129.0	Intermediate	88.0
36	12	24.9	131.4	Dominant	90.0
37	09	34.9	158.5	Dominant	91.0

Factor Analysis


```
Anova Table (Type II tests)

Response: logTreeSlashDryWt
                  Sum Sq Df F value    Pr(>F)
LatClass          1.2480  1  5.9864   0.02149 *
CrownClass        7.9609  1 38.1878 1.552e-06 ***
AgeClass          6.3857  1 30.6317 8.246e-06 ***
AgeClass:TpaClass 2.0800  2  4.9889   0.01466 *
Residuals         5.4202 26
---
Signif. codes: '***' .001
                 '*' 0.05
```

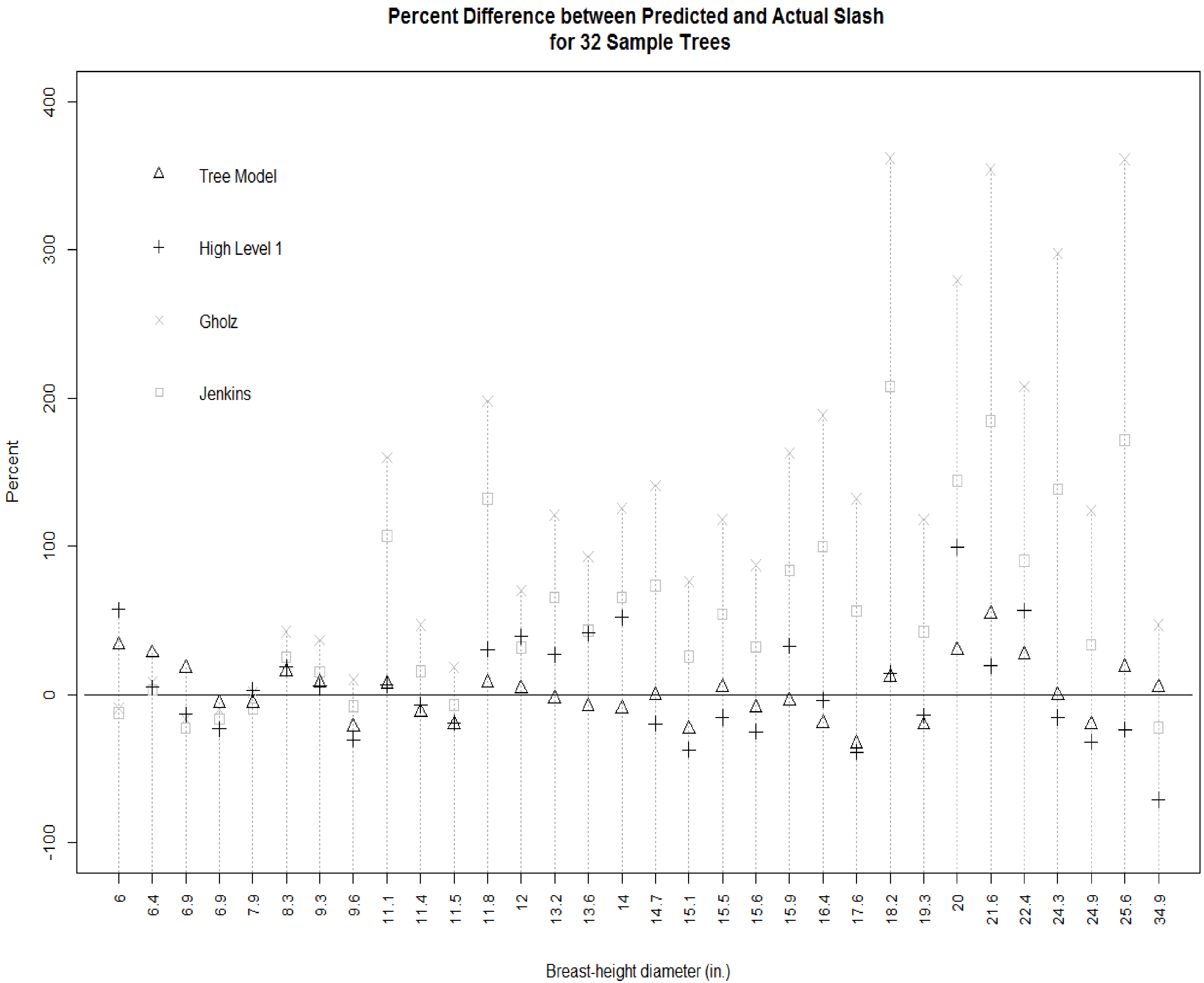
Model Objectives

High Level (Stand):

- In-office model
- No field work required

Low Level (Tree):

- Use after cruise completed



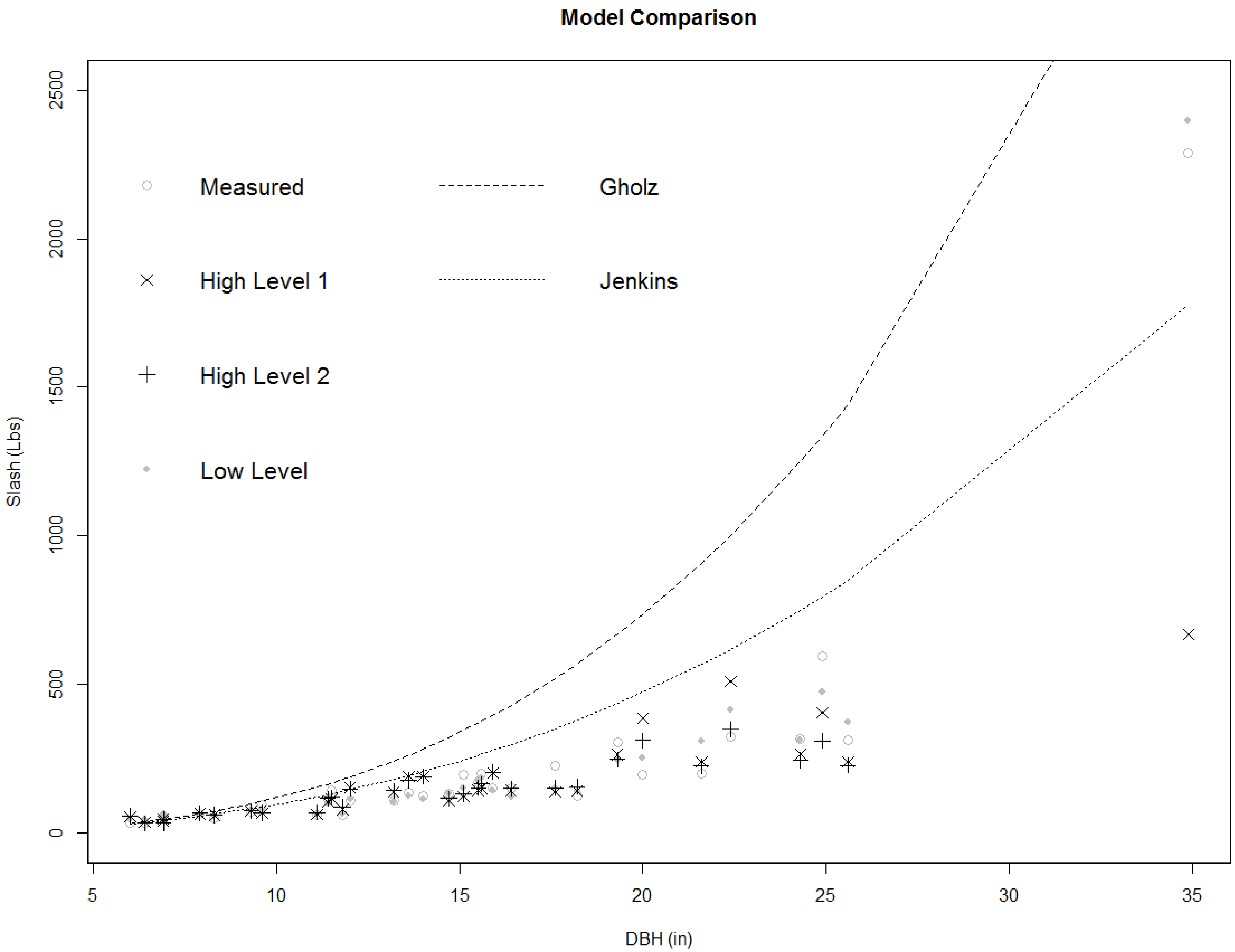
High Level 1

$\sqrt[3]{S}$ ~ Age +
TPA +
Latitude +
DBHpercentile +
Age : Latitude +
TPA : DBHpercentile

Adj R^2 = 0.524

RMSE = 87.52

MAE = 64.62



High Level 2

ln(*S*) ~ Age + TPA + Latitude + DBHpercentile + Age : Latitude + TPA : DBHpercentile

Adj. R^2= 0.60

RMSE = 46.81 MAE = 35.15

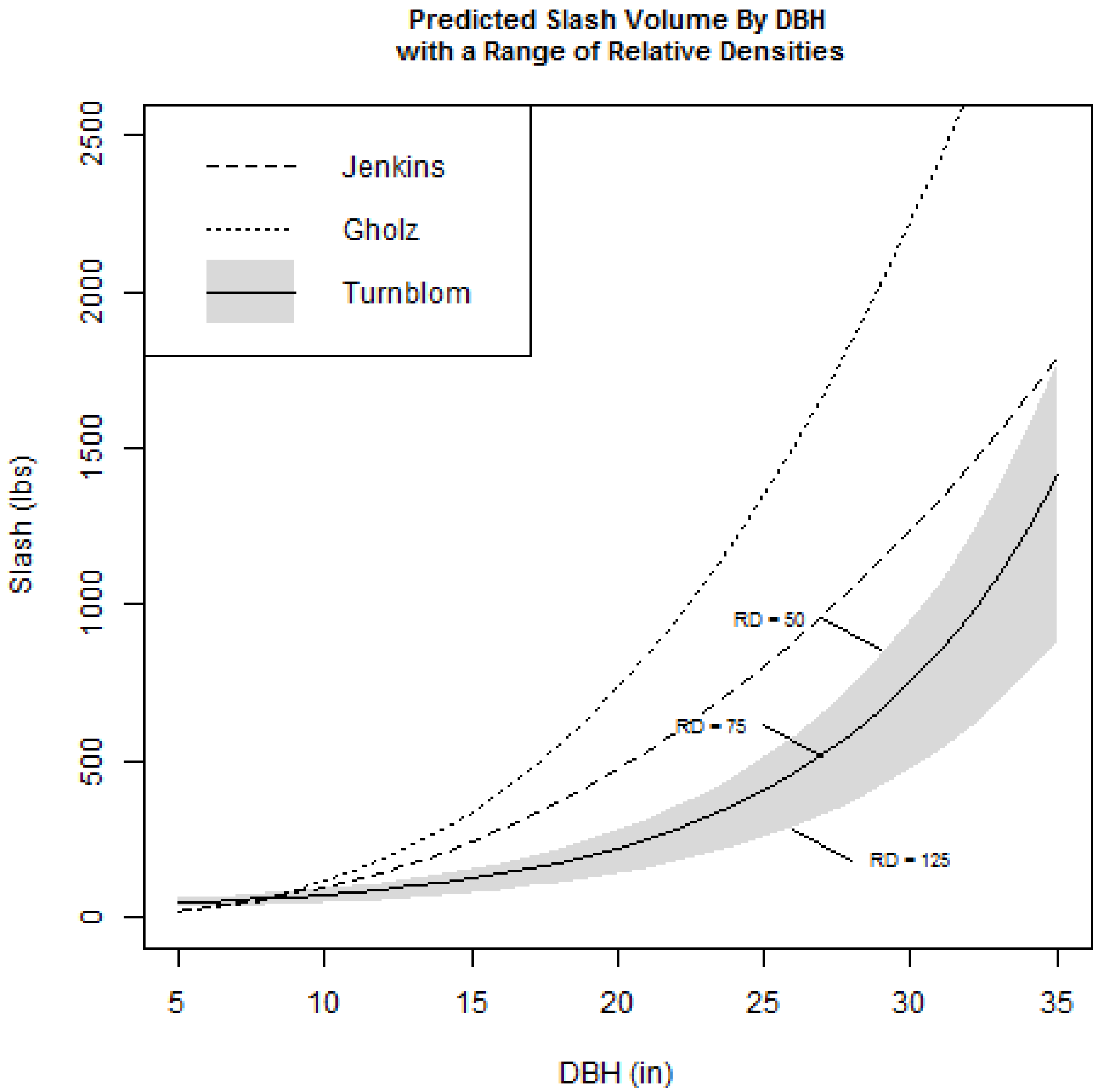
Tree Model

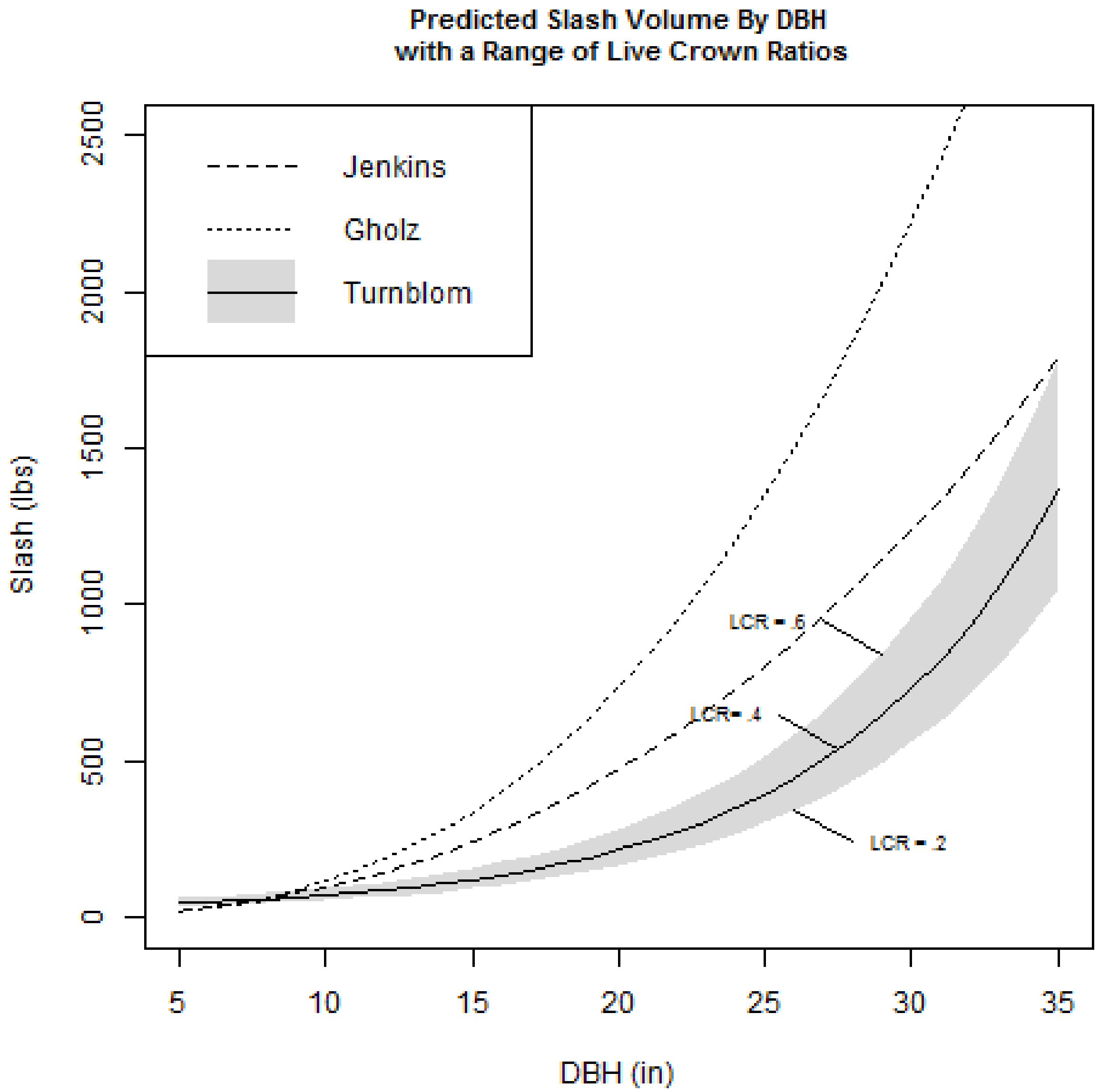
ln(*S*) ~ DBH + TreeHt + LCR + Elevation + RelativeDensity

Adj. R^2 = 0.986

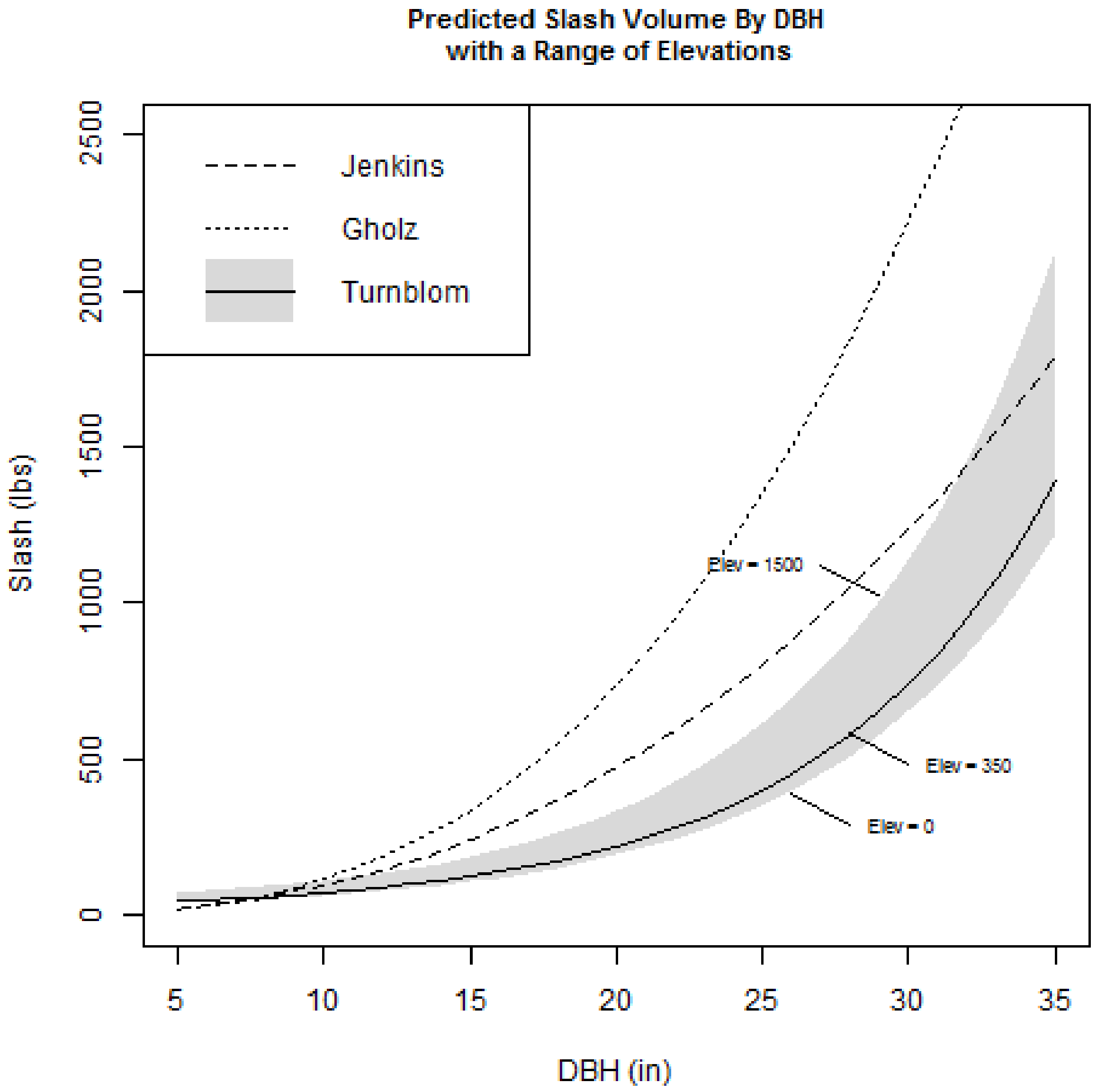
RMSE = 46.31 MAE = 33.25

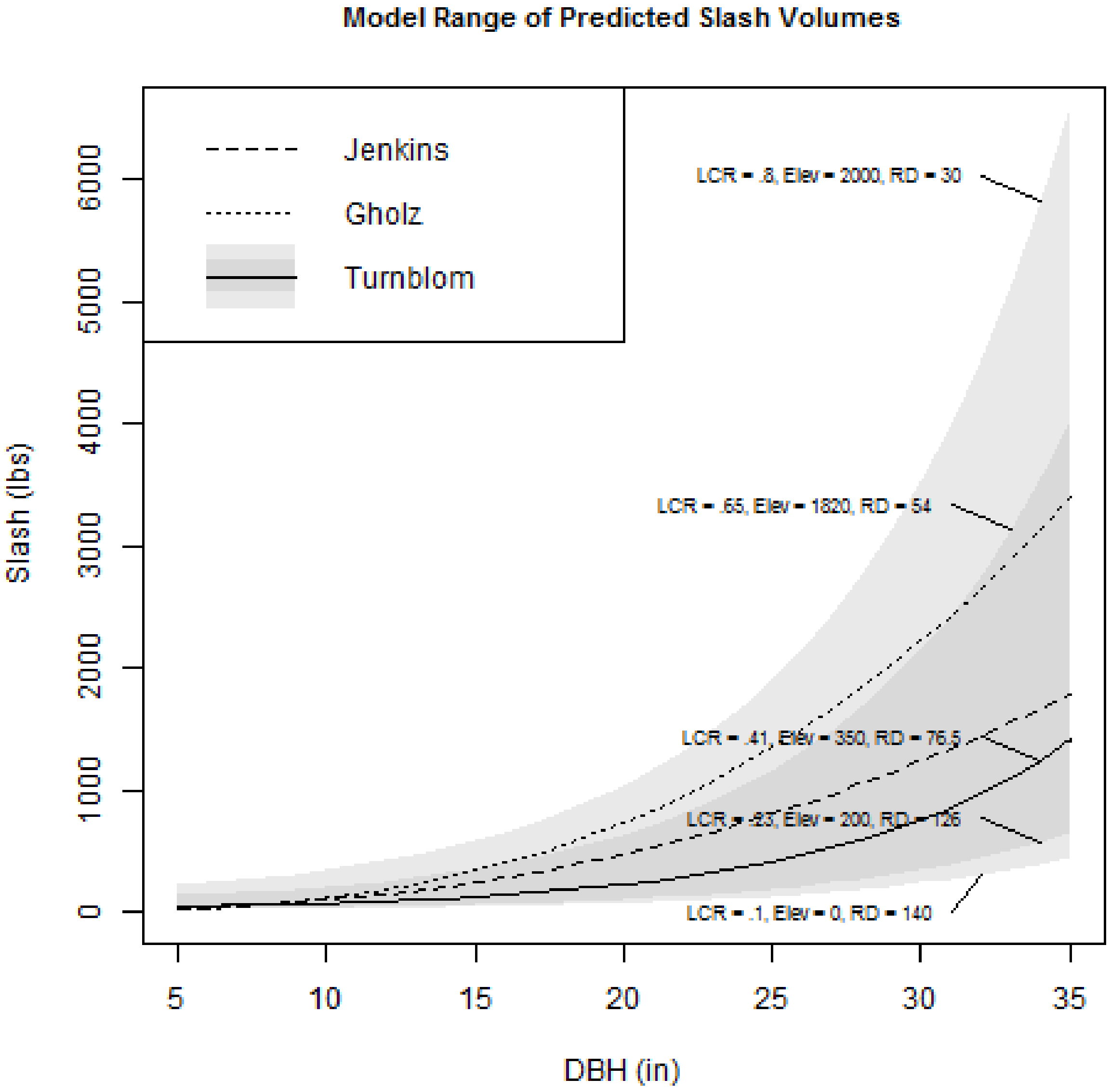
Tree model sensitivity





Tree model sensitivity and performance envelope





PCT Analysis

Eric Turnblom

PCT Analysis

- Rationale
- Objectives
- Experimental Plan
- Results
- Final Steps

Rationale

- SMC members seek to maximize timber volume & value, but also place some degree of priority on less conventional stand attributes such as:
  - Live Crown Length
  - Branch / Knot Size
  - Other habitat values
- The impacts of timing / intensity of PCT on these attributes are not well understood / publicized

Member Benefits

- Better understanding of how stands with given characteristics could be most profitably managed for the mix of materials that might be produced
- Resulting whole stand models will provide independent corroboration of growth modeling work

Experimental Plan

- Use existing SMC data –
  - Type I data
    - Two levels of spacing (ISPA/2, /4)
    - Two types of spacing (systematic, select best trees)
    - Applied at different ages
    - Twenty-nine (29) Type I installations were available for analysis, 12 contained auxiliary "Best Tree Selection" (BST) plots
    - ISPA ranged from 250 to 700; age at PCT from 5 to 17 yr; 30-yr SI ranged from 40 to 90 ft

Experimental Plan

- Use existing SMC data –
  – Type III data
    - PCT is combination of two factors
      – Timing: early / late
      – Intensity: light / heavy

Experimental Plan

- Objective 1: Describe Stand yield
  - Multiple linear or nonlinear response surface
  - Experimentally controlled factors are fixed effects
  - Other factors are random effects

- Objective 2: Provide stand / stock tables (stand structure) expected under different PCT regimes
  - Implementing Treelist Generation Database (TGDB)

Experimental Plan

- Objective 3: Illuminate how different stand structures may meet different stand goals, such as for wood quality

- Objective 4: Provide a comparison between how well the assumptions made in setting up Type I installations are supported by Type III results

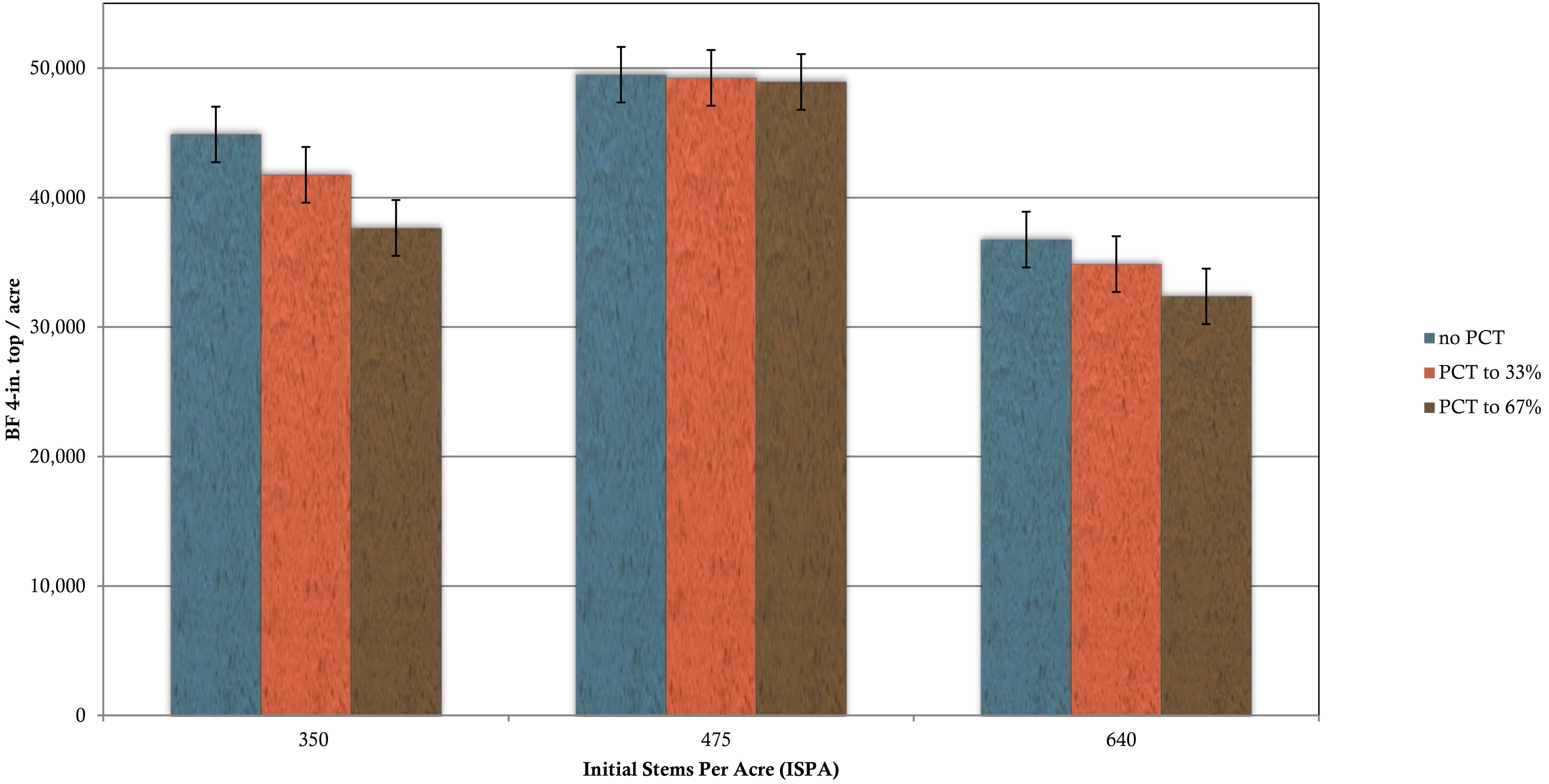
Expected Deliverables

- Models describing yields in stands with & w/o PCT across sites, densities, timings in SMC Working Paper
- Mechanism to deliver tree lists corresponding to defined reporting ages and useful combinations of input variables

Results

- Yield Responses in Type I installations
- A multiple linear regression approach was used to analyze yield responses to PCT
  - Used “late rotation” data, i.e., total stand ages greater than 30 yr from seed
  - Independent variables used:-
    - ISPA, percent stems removed (PRM), SI30, Elev, Tot. Age, Age at PCT, PCT type, Latitude, Longitude – their interactions

Age 45 Yield, varying density & PCT intensity



Stand Table Characterization

- Tested DBH distributions through time
  - Compared DBH distributions in non-PCT’d stands with PCT’d stands in the database through time
    - Differences increase with time since PCT
    - TGDB software schema allows stands to be classified by pct_stems_removed – a parameter indicating % stems thinned
- Rebuilt TGDB using new schema
  - Queried TGDB for stands w/ and w/out PCT at 0y, 10y, 20y, and 30y post treatment
    - Compared DBH distributions in non-PCT’d stands with PCT’d
    - Same result as actual stands in terms of mean and CV

Final Steps

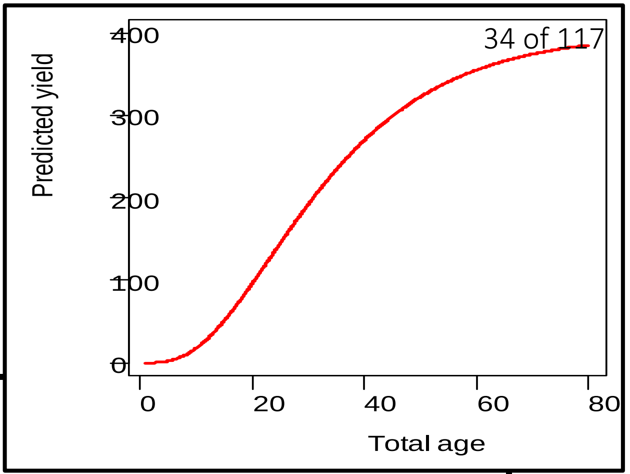
- Write up Type I yield results in Working Paper
- Finish testing TGDB as mechanism for delivering Stand Tables
- Add Type III installations
- Link to PYC

(SMC)2

Silviculture Manipulation Consequences in Stand Management Cooperative Installations

Maureen C. Kennedy, University of Tacoma
Eric Turnblom, Jason Cross, University of Washington

Performance report: Analysis goals



- Predict yield using Chapman-Richards
  - BA, QMD, [TPA], CVT, CV4, CV6, BF4, BF6
- Test differences in yield curves with site characteristics
  - Initial TPA, SI30, species (DF, WH, or Mixed), elevation, latitude, longitude
- Estimate models separately for Type III and for Type I/II combined

From fall meeting and soon after

1. Odd behavior with asymptotic yield and increasing initial stems per acre (ISPA)
2. Suggestion to use top height as a predictor rather than age
3. Concern that model dependencies create overfitting and identifiability issues in coefficient estimation
4. Use geographic zones instead of Lat/Long

Final procedure: divide into geographic zones

Zone 1: Vancouver Island and Strait of Juan de Fuca

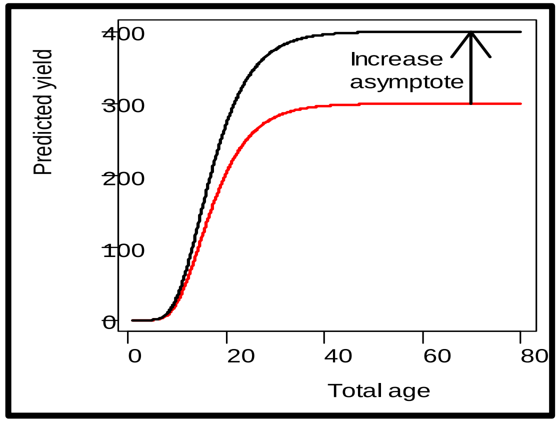
Zone 2: Mainland SW BC, Whatcom and Skagit Counties

Zone 3: "Puget Trough"
E Jefferson, Kitsap, Snohomish, King, Thurston, Pierce, Lewis and E Clallam Counties

Zone 4: "Inland"
Cowlitz, Skamania, Clark Counties, Clackamas, Linn, Marion, E Lane, E Douglas, Jackson counties

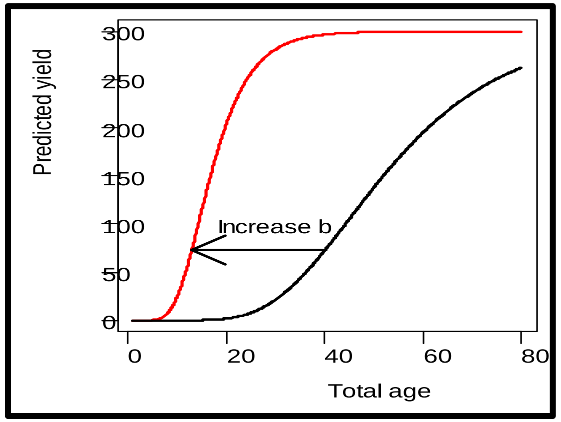
Zone 5: "Coastal"
W Clallam, W Jefferson, Grays Harbor, Pacific, Wahkiakum, Clatsop, Tillamook, Yamhill, Polk, Lincoln, Benton, Columbia, W Lane, W Douglas, Coos, Curry, Josephine

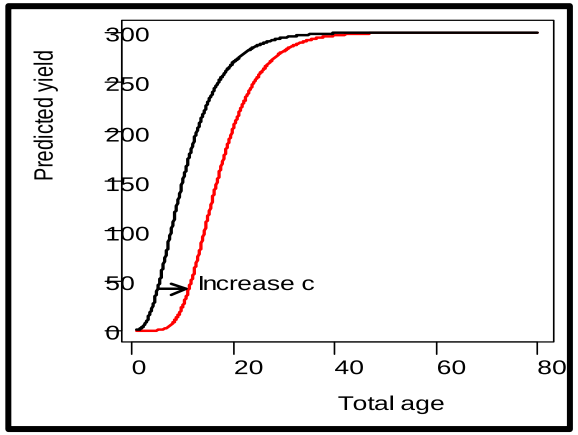
Final procedure: choose variables to test a priori



Asymptote (a) ~ (SI30,species,elevation,zone)

Rate parameter (b) ~ (SI30,species,elevation,zone,ISPA,$ISPA^2$)





Shape parameter (c) ~ (species)

Bootstrap to eliminate non-significant predictors

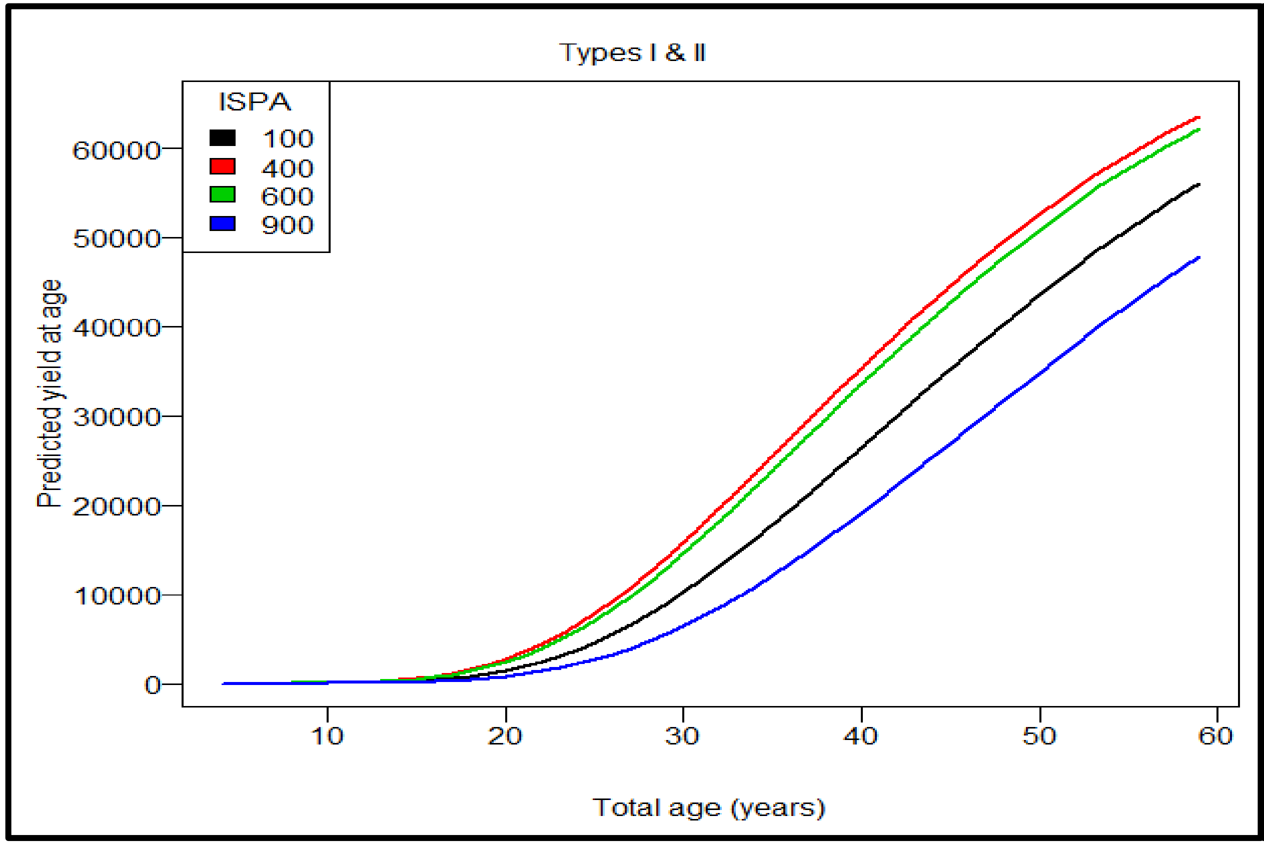
BA and QMD fitted simultaneously with TPA

- Still working on improved/refined model
  - Computational and statistical difficulties in fitting these together
- There is a version in the current calculator ready for prediction, but that will be fine-tuned in the coming months
- Here we present current models for cubic foot volume (top) and board foot to a 6 in top

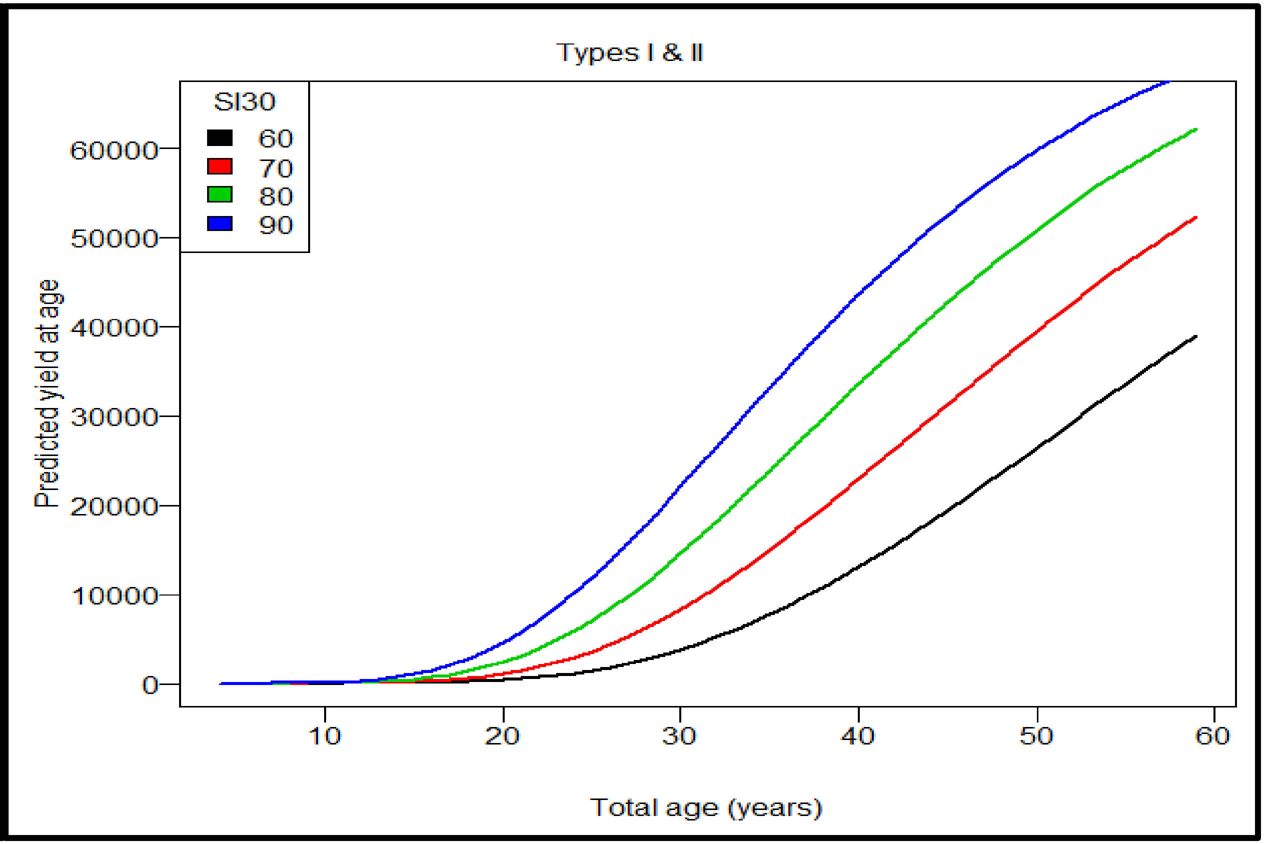
Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough

Board Foot 6 in top
Predicted yield Types I & II: $R^2 = 0.92$

Varying initial stems per acre



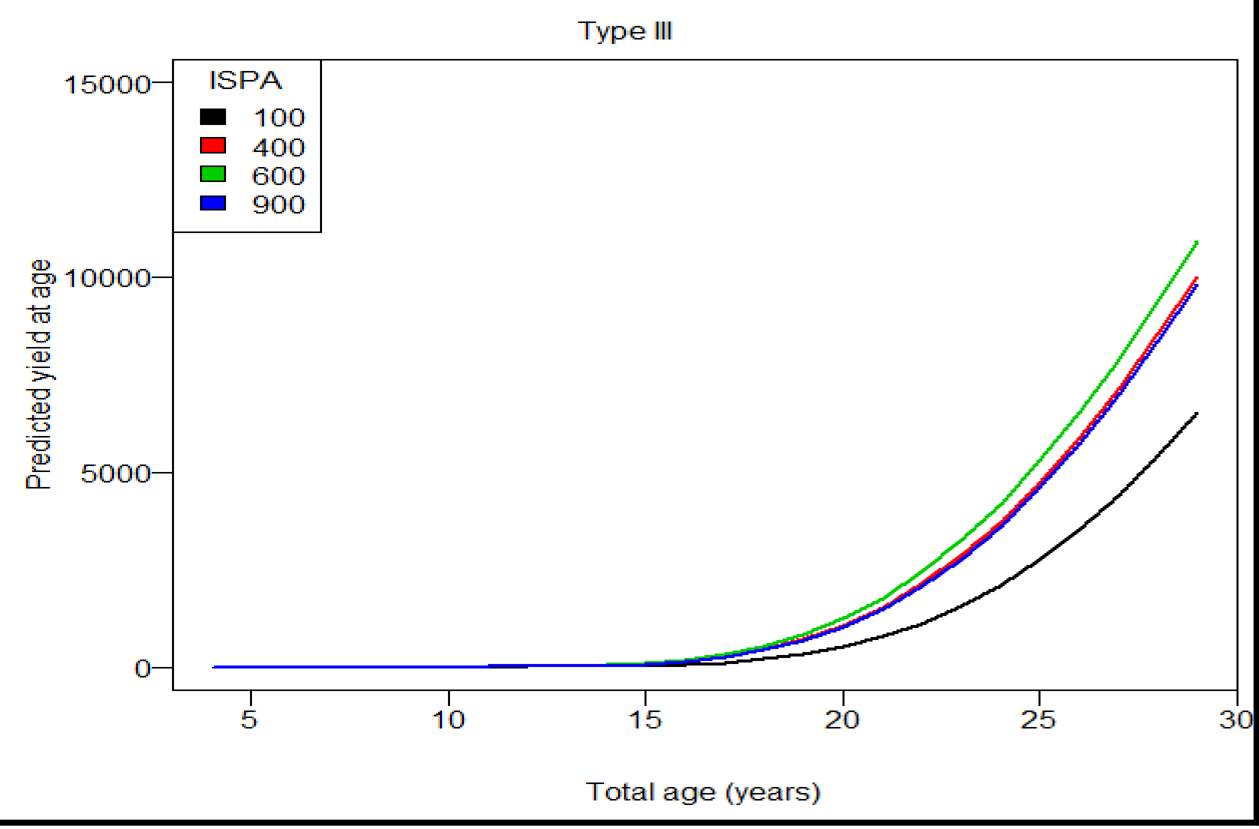
Varying site index



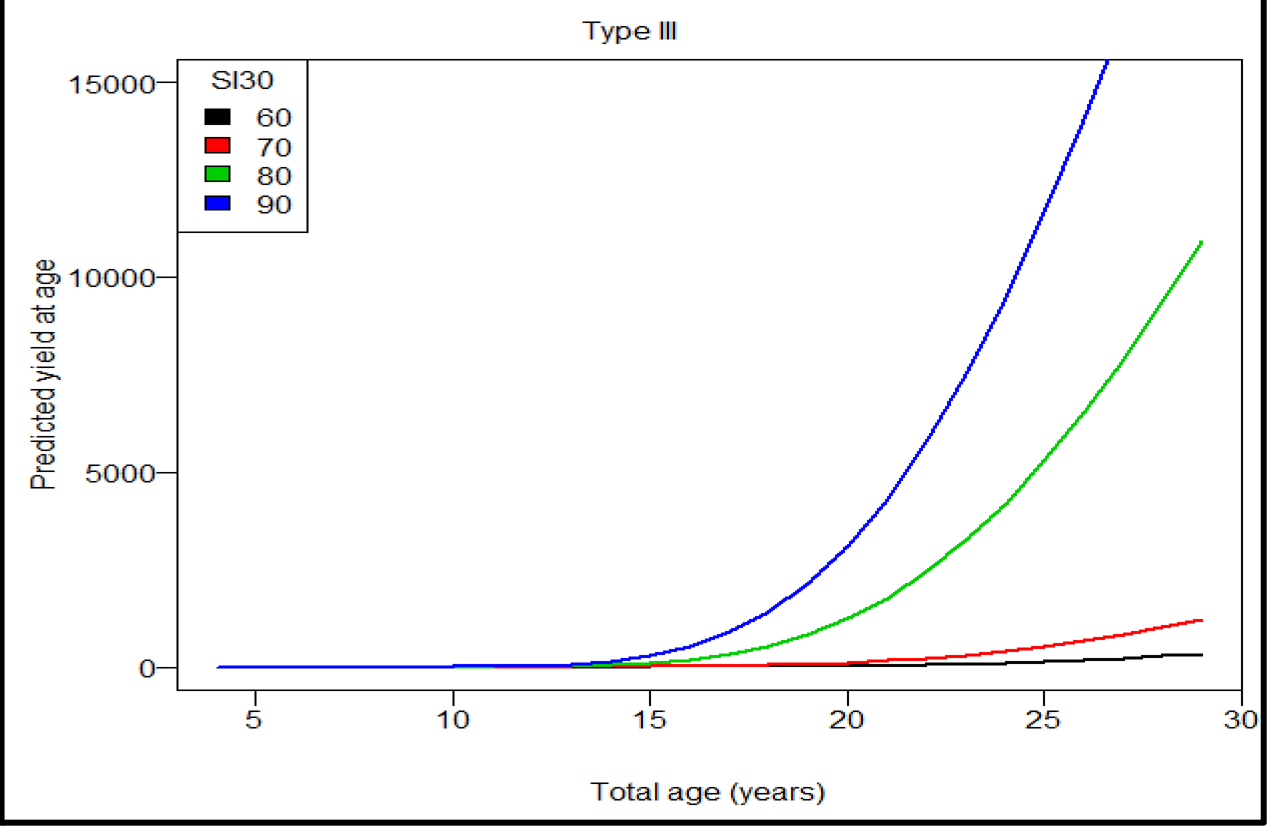
Board Foot 6 in top
Predicted yield Type III: $R^2 = 0.87$

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough

Varying initial stems per acre

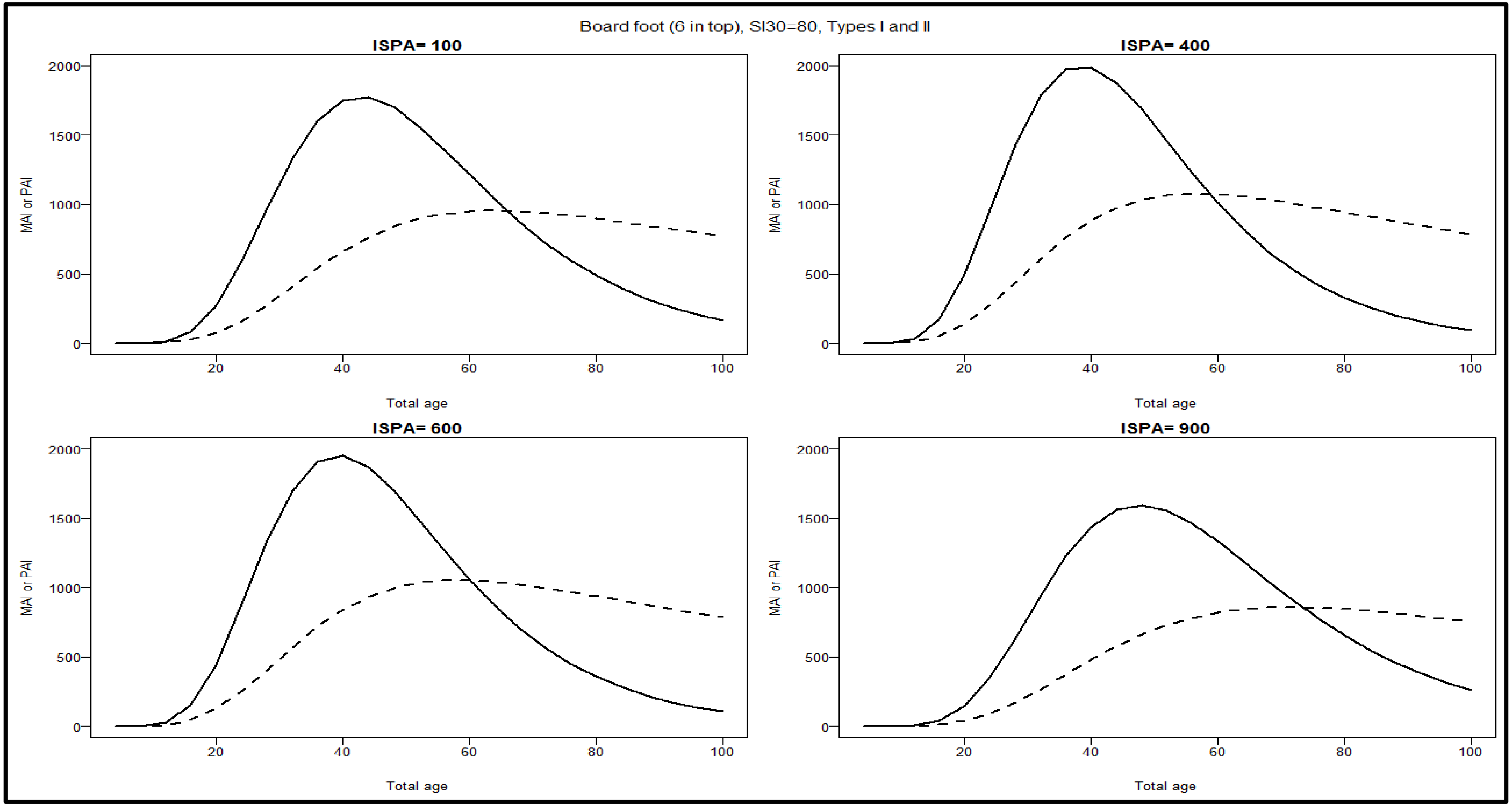


Varying site index



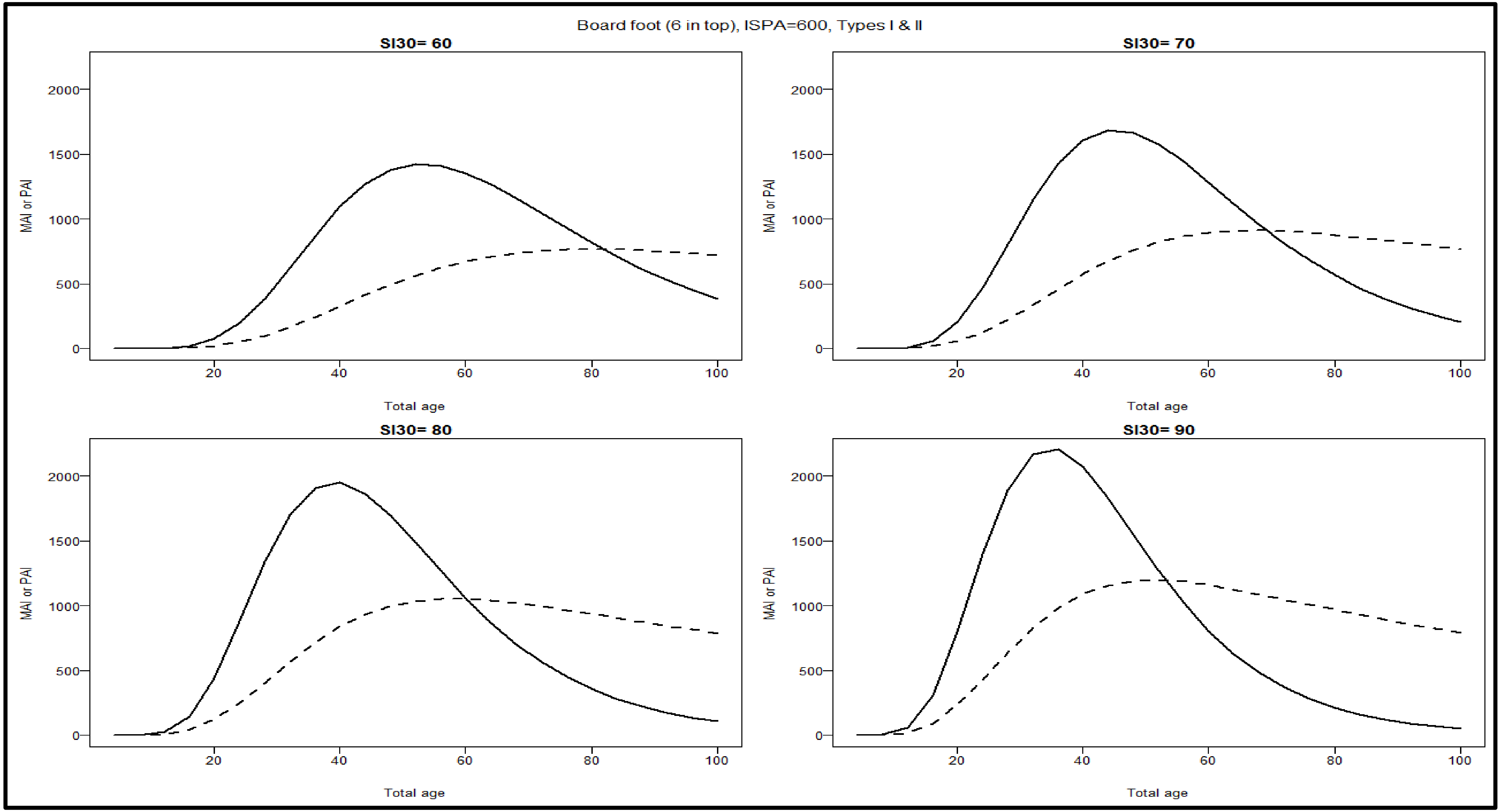
Board Foot 6 in top
Periodic and mean annual increment, Type I/II

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough



Board Foot 6 in top
Periodic and mean annual increment, Type I/II

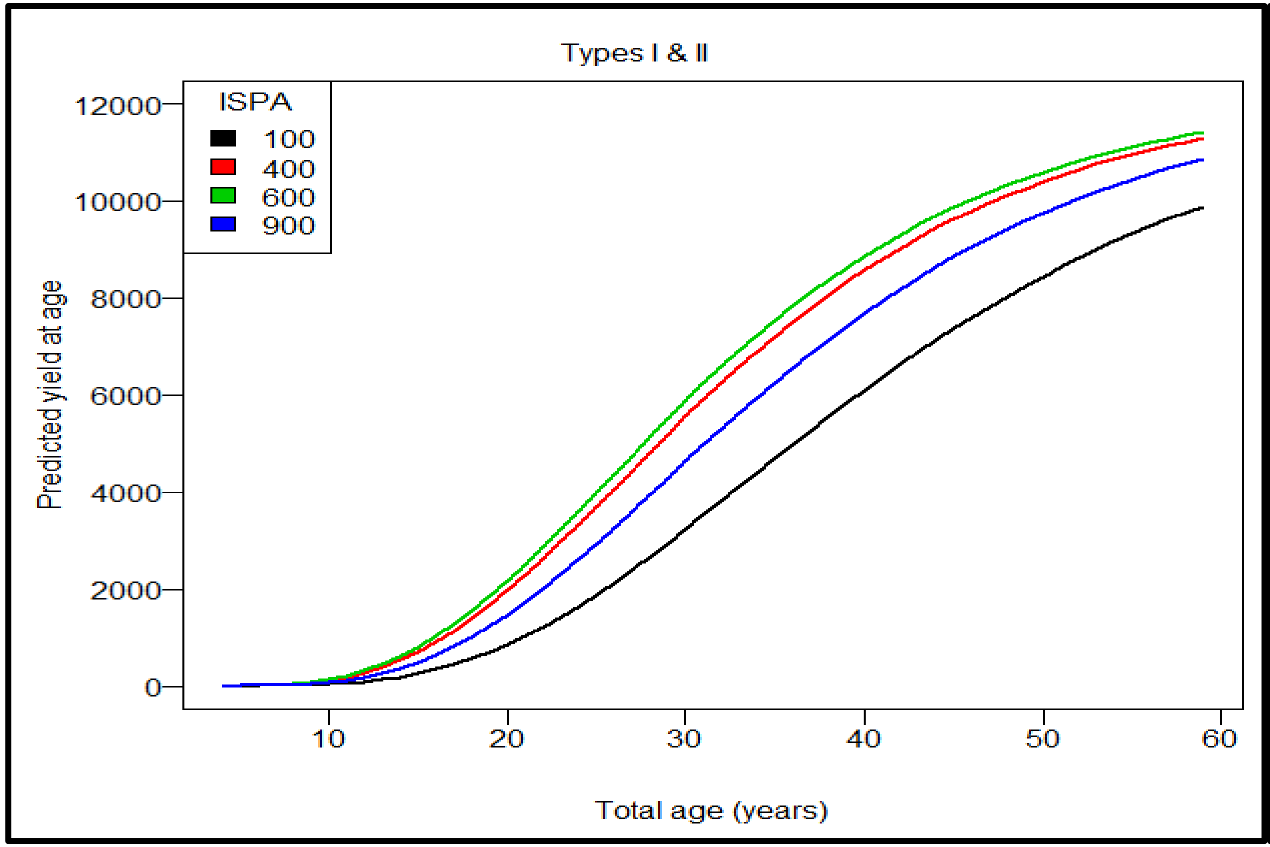
Douglas-fir, ISPA = 600
Elevation = 1000, zone = Puget Trough



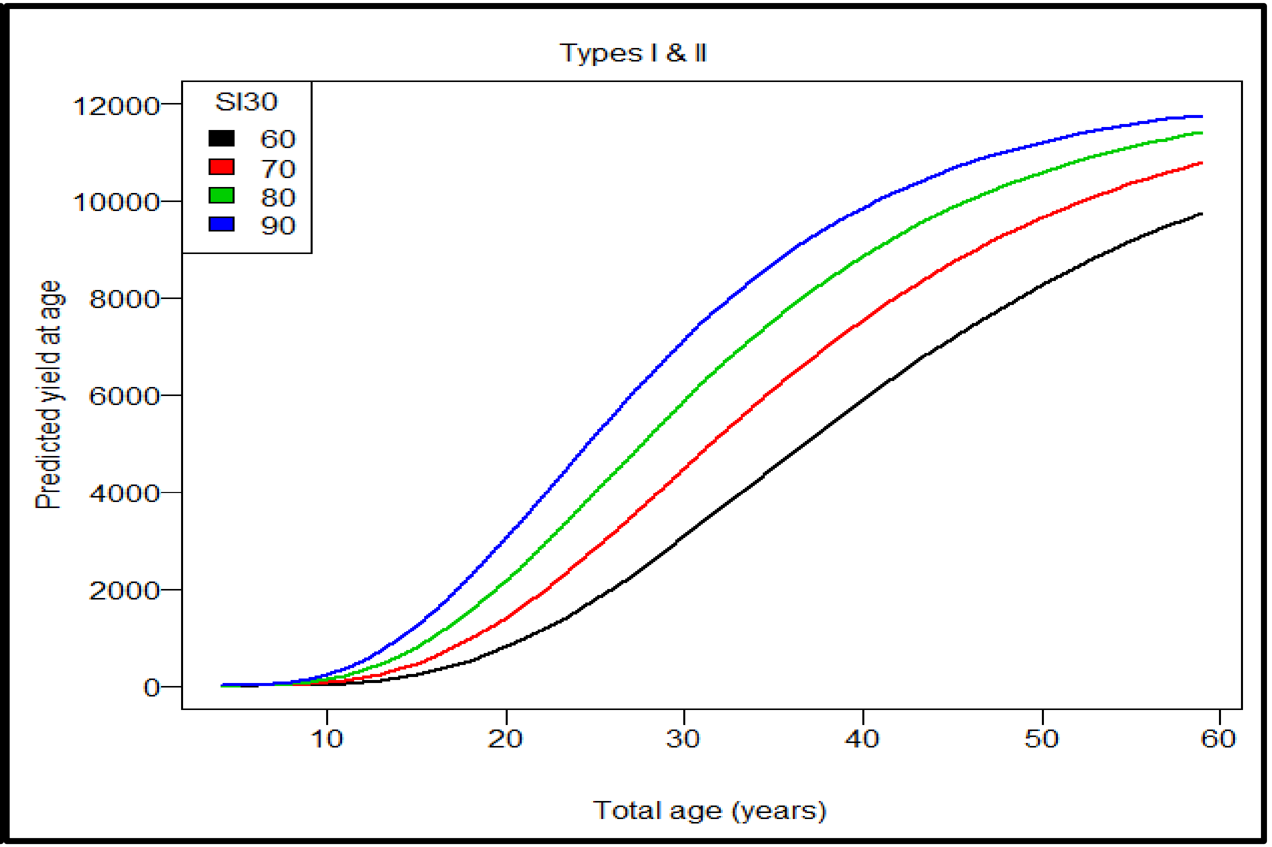
Cubic Foot Volume (including top)
Predicted yield Type I/II $R^2 = 0.94$

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough

Varying initial stems per acre



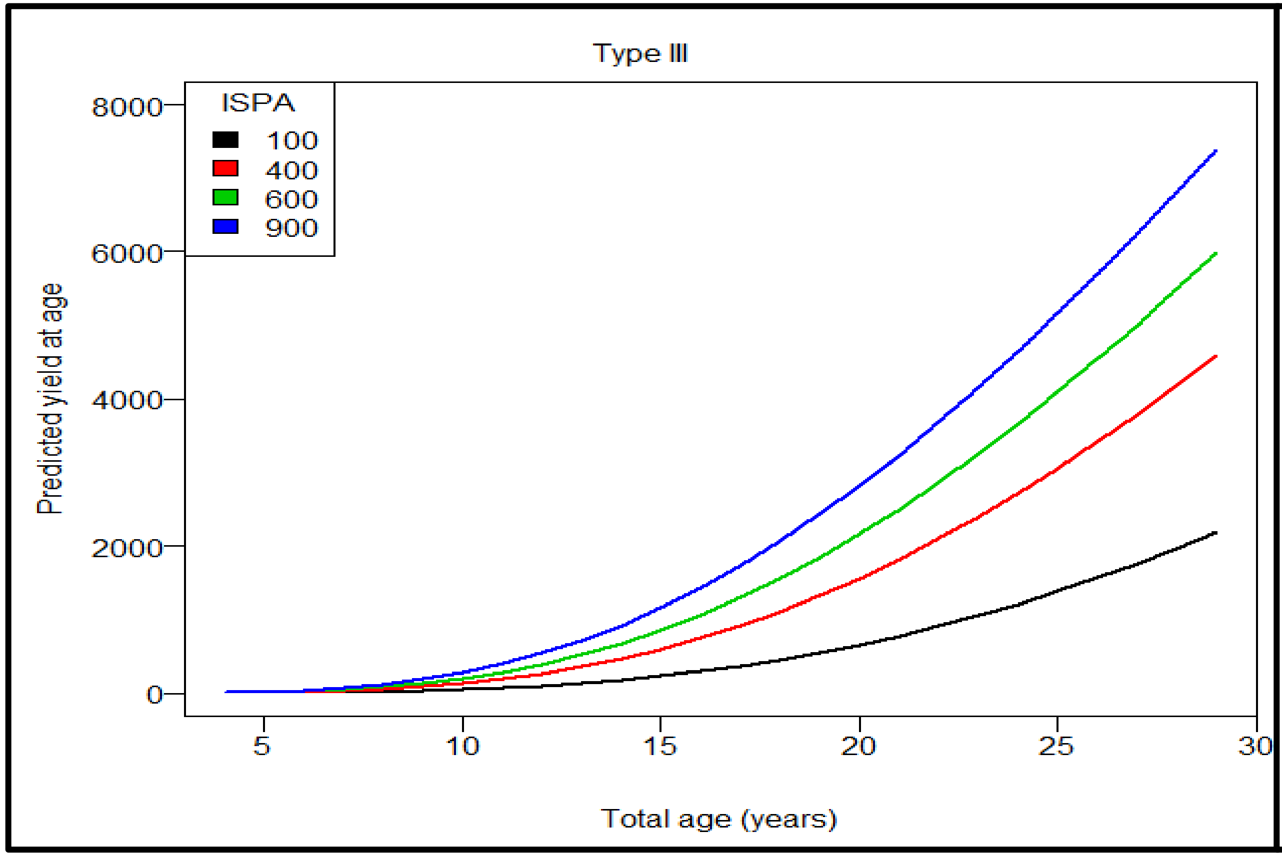
Varying site index



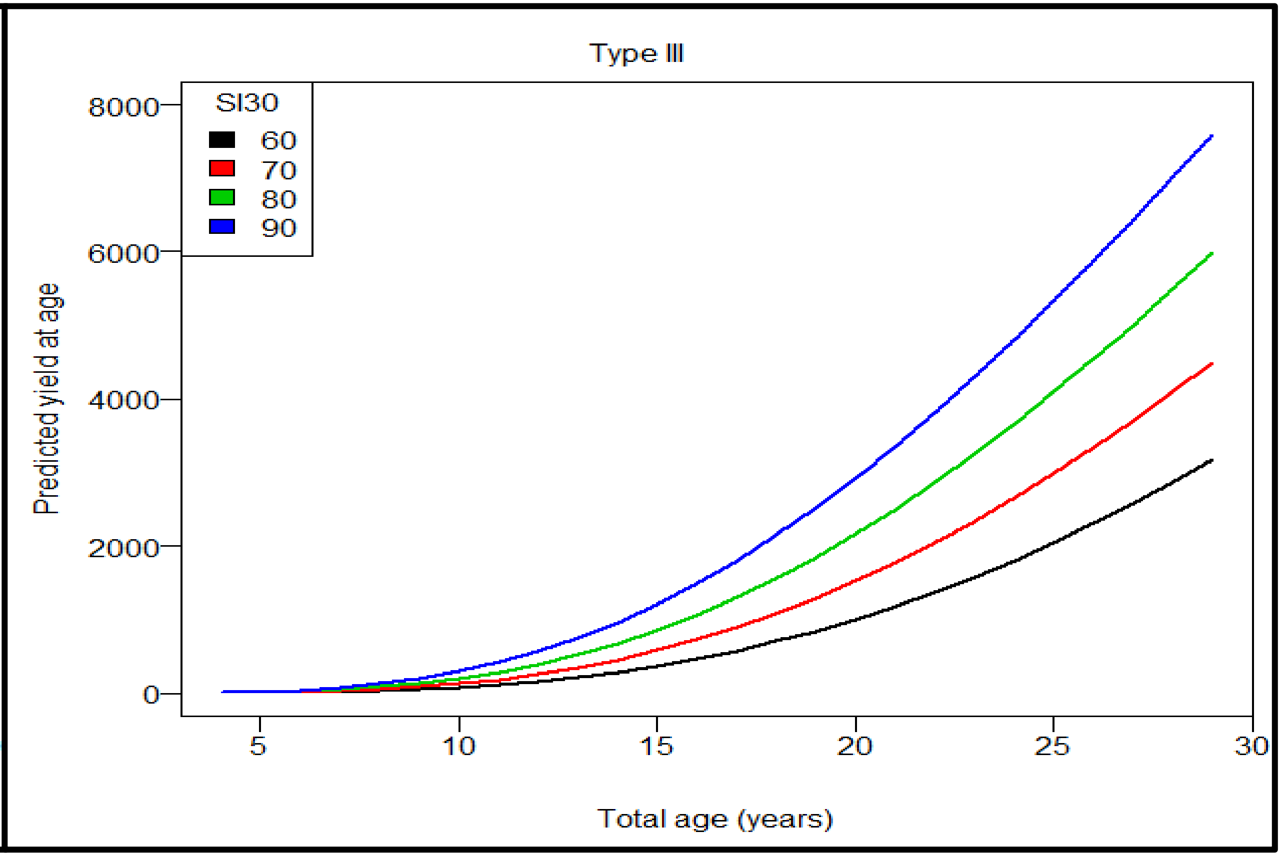
Cubic Foot Volume (including top)
Predicted yield Type III: R^2 = 0.92

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough

Varying initial stems per acre

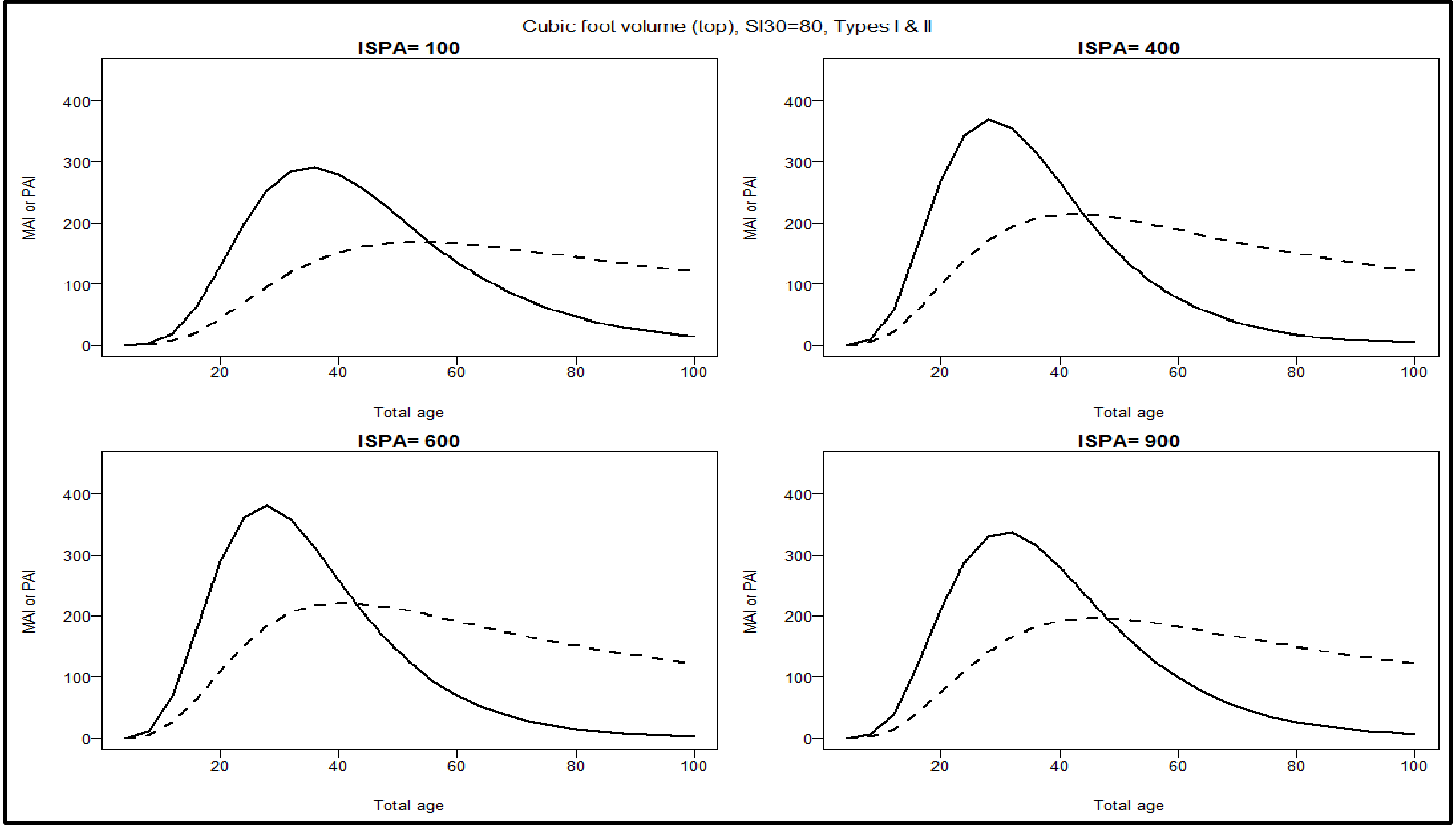


Varying site index



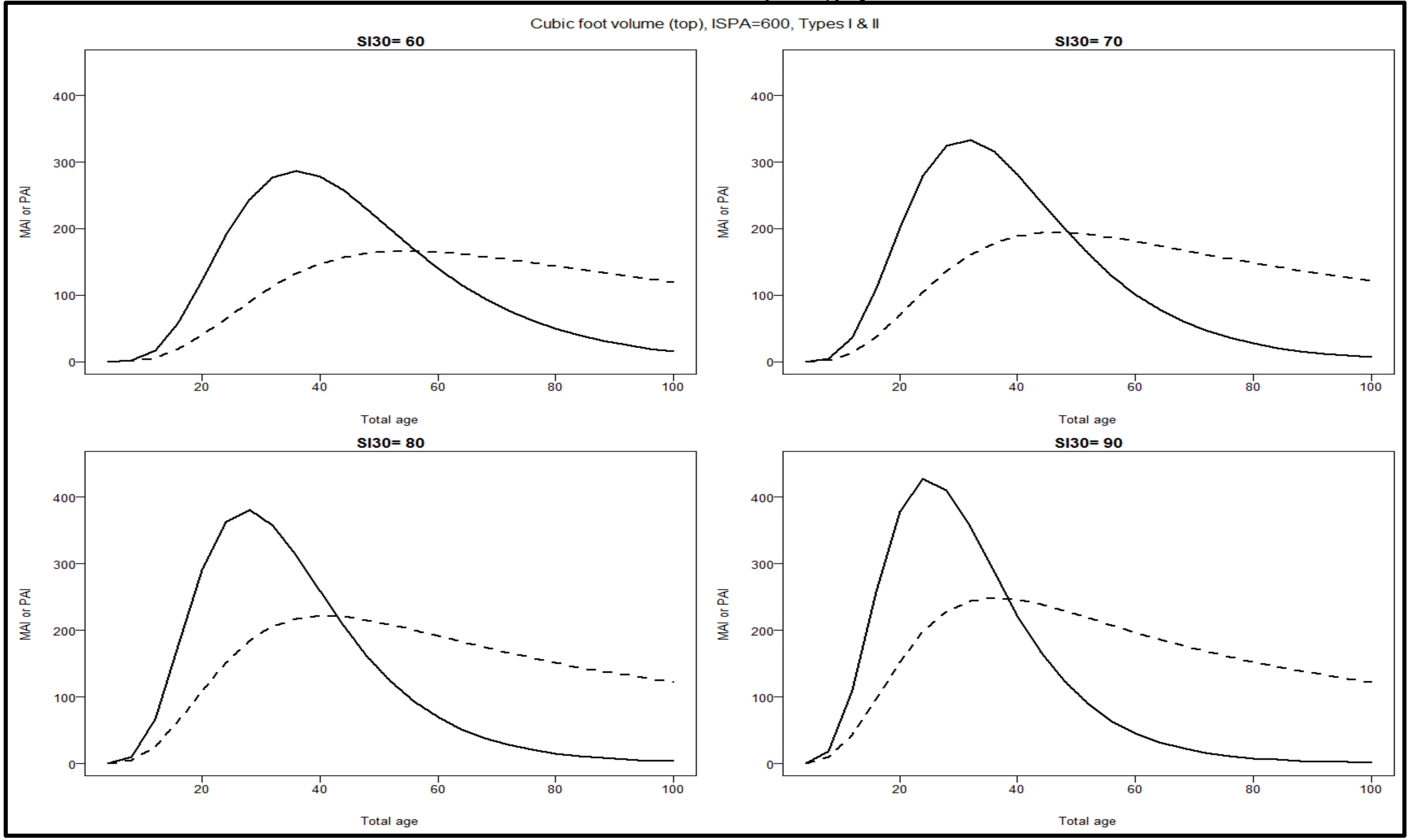
Cubic Foot Volume (including top)
Periodic and mean annual increment . Type I/II

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough



Cubic Foot Volume (including top)
Periodic and mean annual increment , Type I/II

Douglas-fir, Site Index (30) = 80
Elevation = 1000, zone = Puget Trough



Conclusions

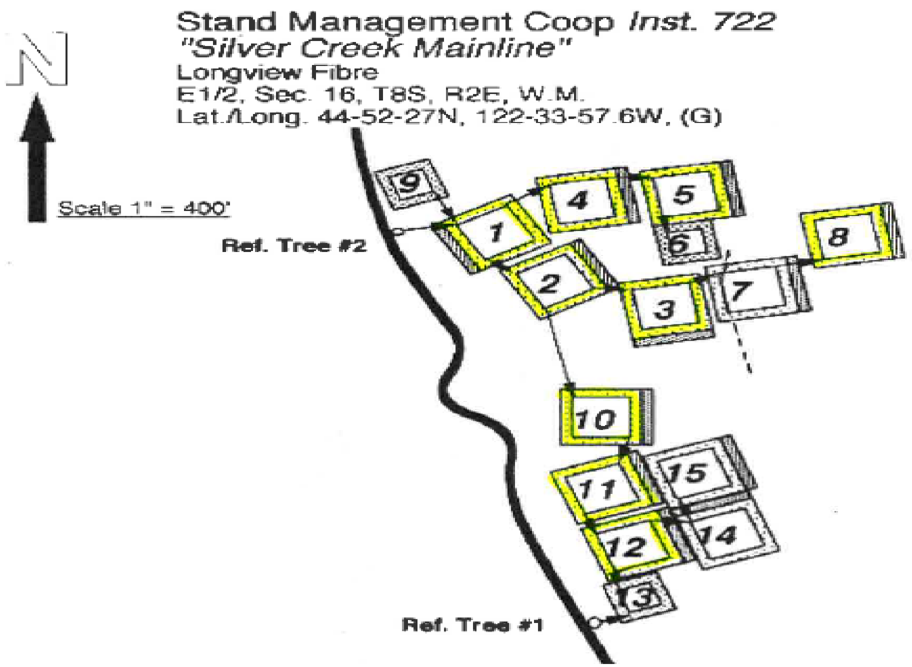
- Finalizing coding of Plantation Yield Calculator
- We recommend limiting predictions to within observed age ranges (<60 years Type I/II, < 30 years Type III's)
- BA and QMD models are included, but will be refined
- Next challenge—add the effect of treatments (pruning, thinning, and fertilization)

SMC Type I Installation 722

Eini Lowell
USFS PNWRS

Treatments 1-6 and 13-15 (9 plots total)

Treatment	Initial Stocking	Regime	Installation 722 Plot No.
1	ISPA/4	No Thinning	2
2	ISPA/2	No Thinning	8
3	ISPA/2	Minimal Thinning: RD55-RD35 once (MT)	3
4	ISPA	No Thinning	5
5	ISPA	Minimal Thinning: RD55-RD35 once (MT)	4
6	ISPA	Repeated Thinning: RD55-35, 55-40 and 60-40 (RT)	1
13	ISPA/4	Fertilization with 200 lbs/acre N as urea 5 times (F)	12
14	ISPA/2	Fertilization and Minimal Thinning (F+MT)	11
15	ISPA	Fertilization and Repeated Thinning (F+RT)	10



Possible Comparisons

- Basic Treatments
  - Ho: ISPA = ISPA/2 = ISPA/4
  - Ho: ISPA = ISPA + MT
  - Ho: ISPA/2 = ISPA/2 + MT
- Supplementary Treatments
  - Ho: ISPA/4 vs. ISPA/4 + F
  - Ho: ISPA/2 vs. ISPA/2 + F + MT
  - Ho: ISPA vs. ISPA + F + RT
- Did not sample felled trees for pruned or selection thinning treatments

Sample sizes and data collection

Vegetation plots

- four, circular vegetation sampling sub-plots (0.01 acres)

Soil Sampling

- Three pits dug per plot to minimum of 1 m

Plot data

- stratified by most recent dbh measurements in database (2013) and divided into quintiles

30-tree sample (standing tree) = 6 trees / quintile

- crown width
- tree sonic
- resistograph
- dbh core (2 / tree)

11-tree sub-sample (felled tree) = 2,2,3,2,2 trees per quintile

- Taper
- Hitman – starting with longest merchantable length and working back to shortest length
- Disks cut at 5 locations
  - At 4-in top
  - Half-way between base of crown and 4-in top
  - base of crown (between 40 & 50 ft)
  - 17-ft
  - stump
- LLAD measurments

3-tree Biomass Sample

- *Trees P10, P50 and P90 only:*
  - crown and stem sampling for biomass estimation
  - remove branches and measured all knots by 16-ft log lengths

- *Trees representing the 10th and 90th percentile only:*
  - identify the foliage chemistry
  - measure and sample dead branches

Status

✓ Winter/Spring 2016

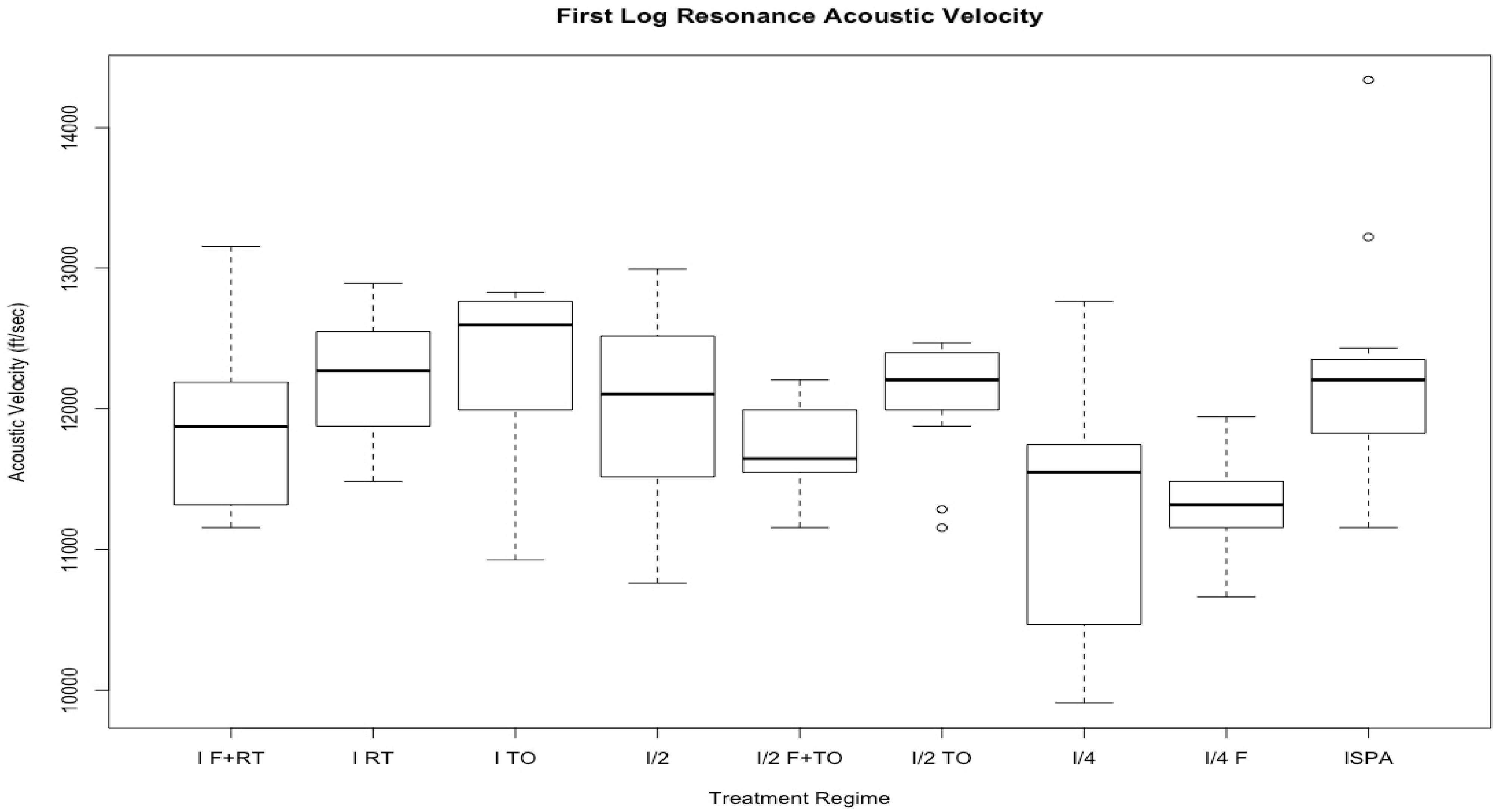
- X-ray densitometry on cores and strips

✓ Spring 2016

✓ Continuing data entry / cleaning of volumetric & weight determinations on disks

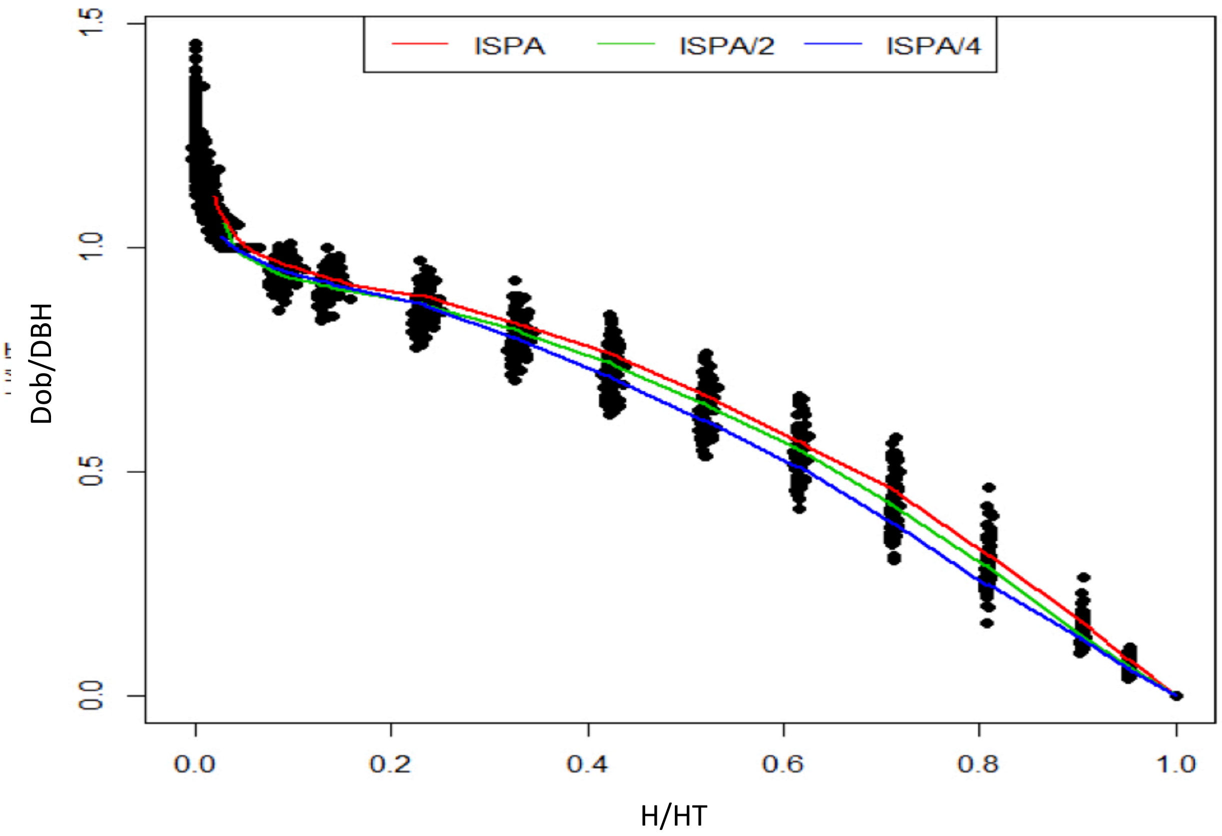
✓ Initiating data extraction / cleaning of resistance value (resistograph drill) data

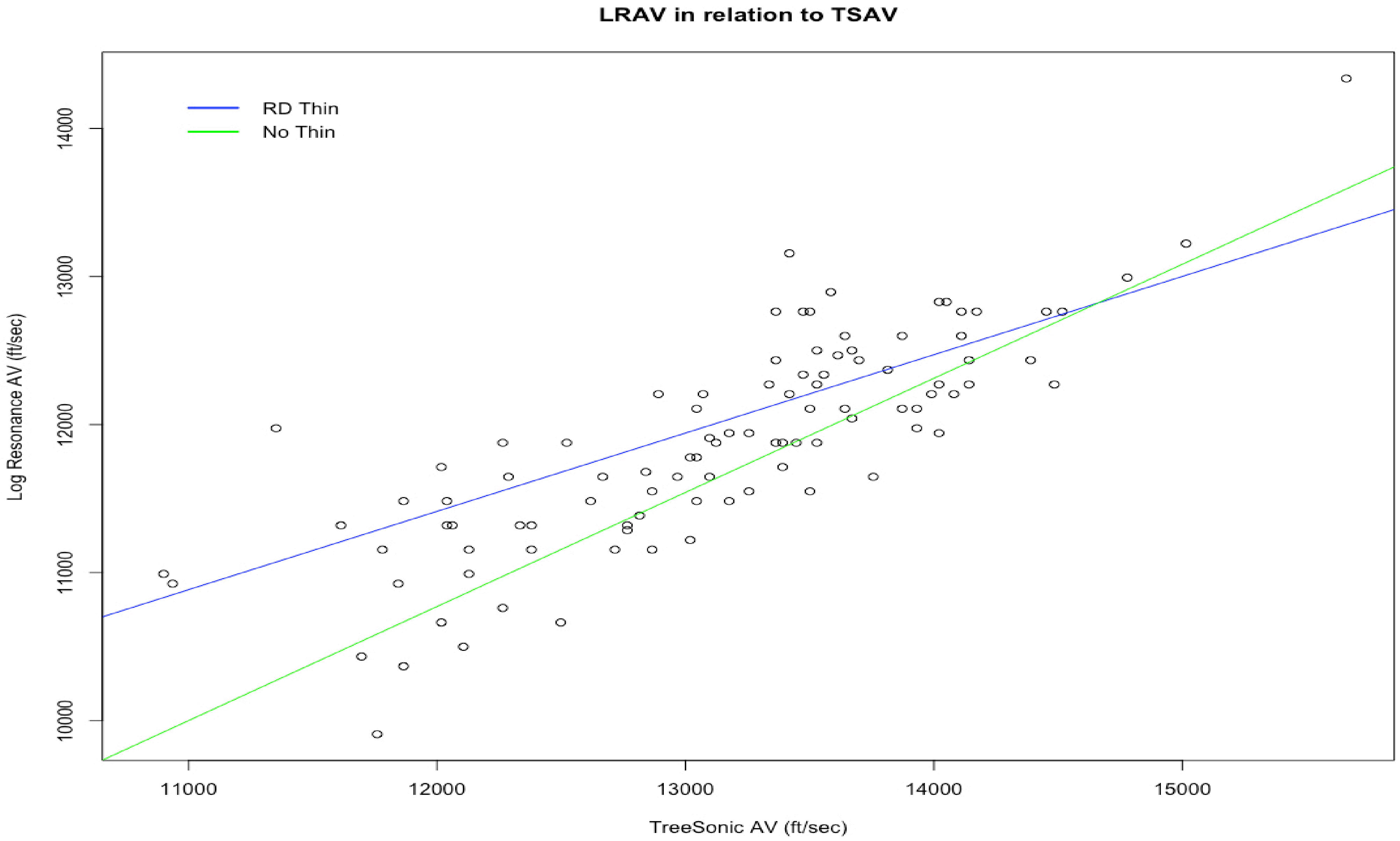
✓ Initiated examination of treatment differences using available variables



First Log Resonance Acoustic Velocity
Acoustic Velocity (ft/sec)
14000
13000
12000
11000
10000
I F+RT
I RT
I TO
I/2
I/2 F+TO
I/2 TO
I/4
I/4 F
ISPA
Treatment Regime

Taper Pattern Among Treatments




LRAV in relation to TSAV
RD Thin
No Thin
Log Resonance AV (ft/sec)
14000
13000
12000
11000
10000
11000
12000
13000
14000
15000
TreeSonic AV (ft/sec)

Next Steps

- Costs total about $20,000 to date
- Further analysis
  - optimize sample sizes
  - develop plans for orderly sunset
  - main plots
  - Buffers
- Choose next installation

SMC Nutrition Report

Rob Harrison

1) SMC Type V – Kim Littke
2) SMC late fertilization study - Kim
3) Student/funding updates

Funding, new initiatives

- NCASI through 2017 $20K/year, $678K total
- Approx $300K/year equiv. TA/Gessel fellowships
- Partial salary buyback by UW Extension for Rob 3 months per year, about $30K/year to spend on SMC work
- CAFS grant for productivity and response modeling and study of role of deep soils in forest productivity $32,500 total
- Bioenergy grant from USDA, $321K total (2011-2016) finishing

People/Graduate Students

- Graduate Students
  - Christiana Dietzgen, PhD start 2014
  - Jason James, PhD start 2015
  - Cole Gross, MS start 2015
  - Amelia Root, MS start 2015
  - Pranjal Dwivedi, MS start Fall 2016

  - Matt Norton (MS) fishished Spring 2015
  - Stephani Michelsen-Correa (PhD) finishing 2016
  - Marcella Menegale (PhD) finishing 2016
  - Kim Littke, Postdoc

  - All salaries currently funded with external funding

Examining Fertilizer Response using Relative Growth Response

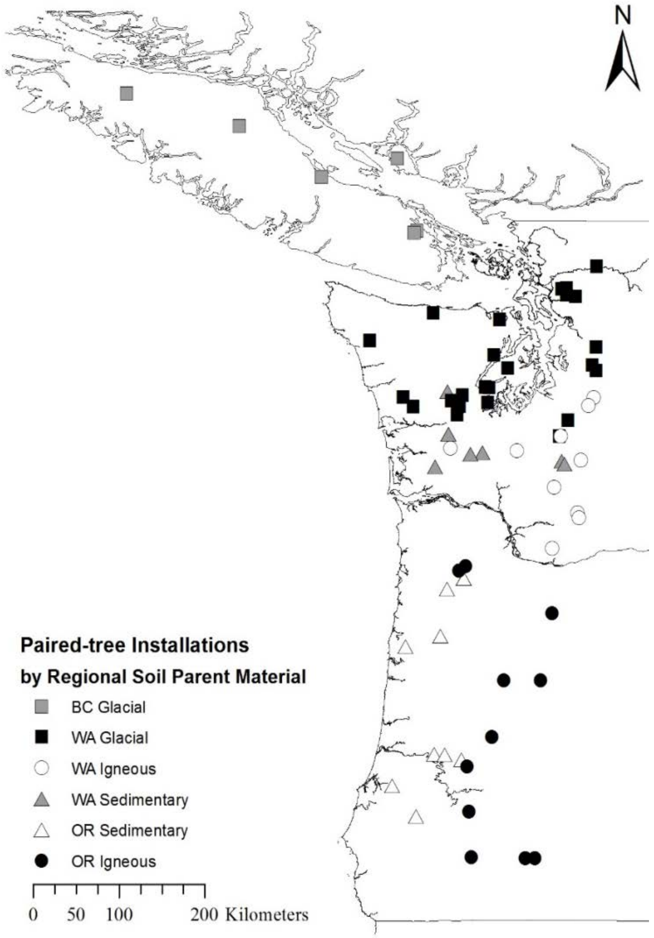
Kim Littke
Jason Cross
Eric Turnblom
Rob Harrison
University of Washington

Objectives

- Compare different ways to describe fertilizer response
- Examine models produced through linear discriminant analysis (LDA)
- Compare with boosted regression tree (BRT) models

Paired-tree Study

- 71 Douglas-fir installations
- At canopy closure
  - 7-28 years old
- Three major soil parent materials
- 12-20 pairs per installation
- One tree per pair fertilized with 224 kg N ha^{-1} as urea



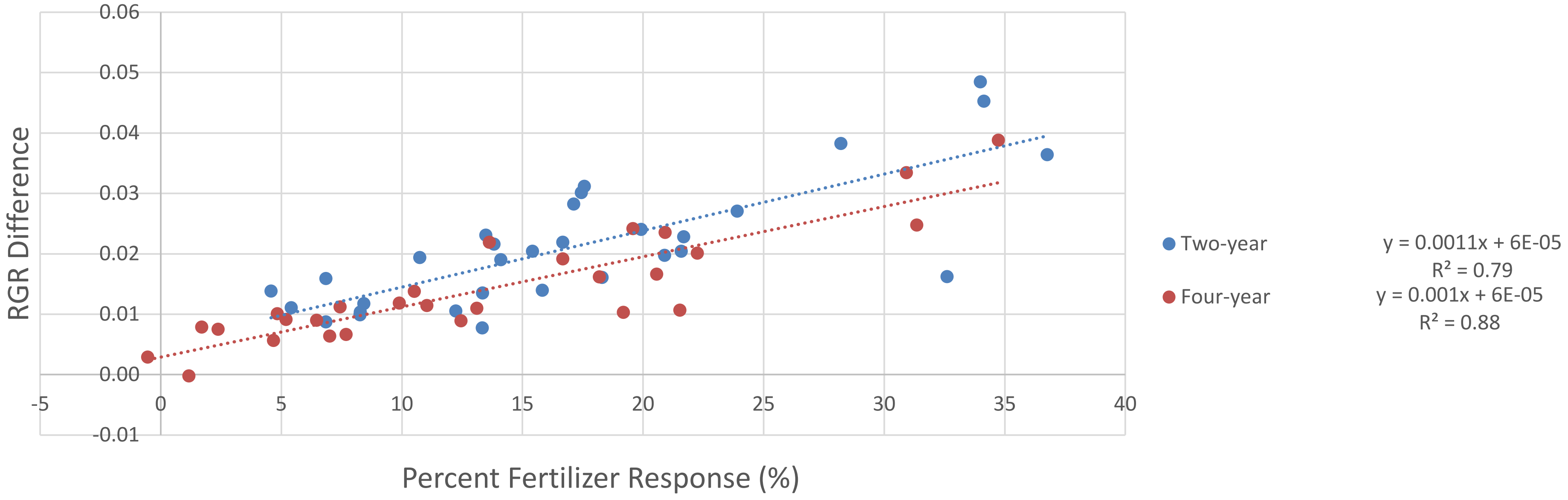
Fertilizer Response

- G=volume growth, V=volume, *f*=fertilized, *c*=control, two and four year response
- Percent fertilizer response (PFR)

$$\frac{Gf(t_{2,4}-t_0)\ -Gc(t_{2,4}-t_0)}{Gc(t_{2,4}-t_0)}$$

- Relative Growth Rate Difference (RGR)

$$\frac{\ln\left[Vf\left(t_{2,4}\right)\right]-\ln[Vf(t_0)]}{\left(t_{2,4}-t_0\right)}-\frac{\ln\left[Vc\left(t_{2,4}\right)\right]-\ln[Vc(t_0)]}{\left(t_{2,4}-t_0\right)}$$



Statistical Methods

- Paired t-test using an alpha < 0.10
- Linear Discriminant Analysis
  - A predictive model to assign classified group membership
  - Linear combination of continuous predictors to discriminate between groups
- Boosted Regression Trees
  - Combination of machine learning and regression trees
  - Regression trees describe the effects of predictor variables on the response variable
- Model RGR at two and four years
  - Mapped and measured variables

RGR Models in LDA

Model	Mapped	All	Model	Mapped	All
	< Site Index	***> Forest Floor C:N***		***> Elevation***	***> Elevation***
	> Summer Temperature	***< Relative Density***		***< Site Index***	***> Forest Floor C:N***
	< Latitude	**< Site Index**		> Precipitation as Snow	***> Surface Soil C:N***
Two-year	***> Elevation***	*> Summer Temperature*	Four-year		***< Relative Density***
		< Latitude			**< Site Index**
		> Surface Soil C:N			> Precipitation as Snow
		> Elevation			

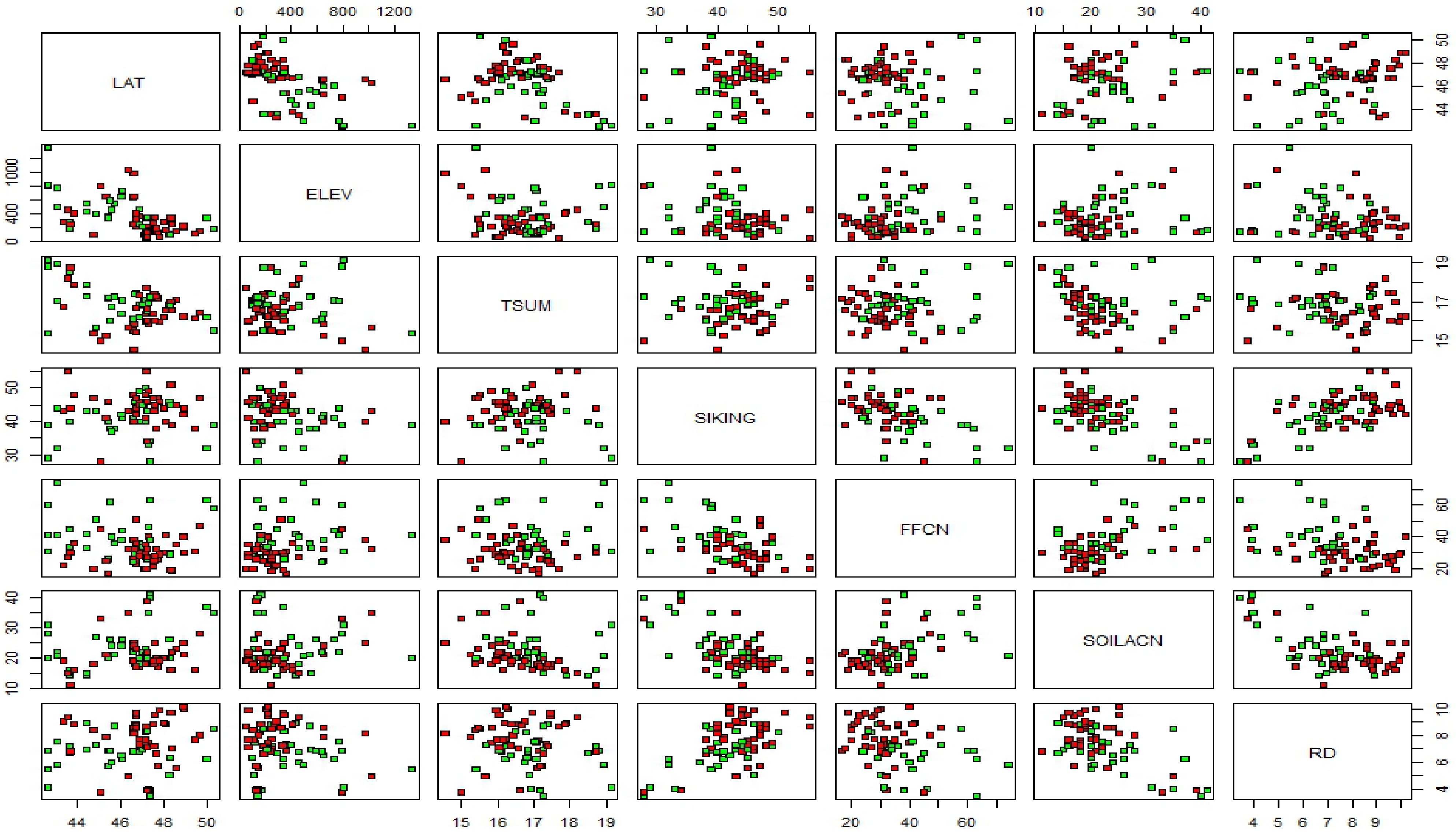
- High elevation sites have colder climates that inhibit N cycling
- Greater response in Oregon (lower latitude and higher summer temp)
- High C:N ratios indicate slow N cycling
- Low site index and RD indicative of response
- < or > shows the direction of the variable;
- **Bold** – Shared variables; *Italic* – BRT variables

RGR Model Prediction from LDA Models

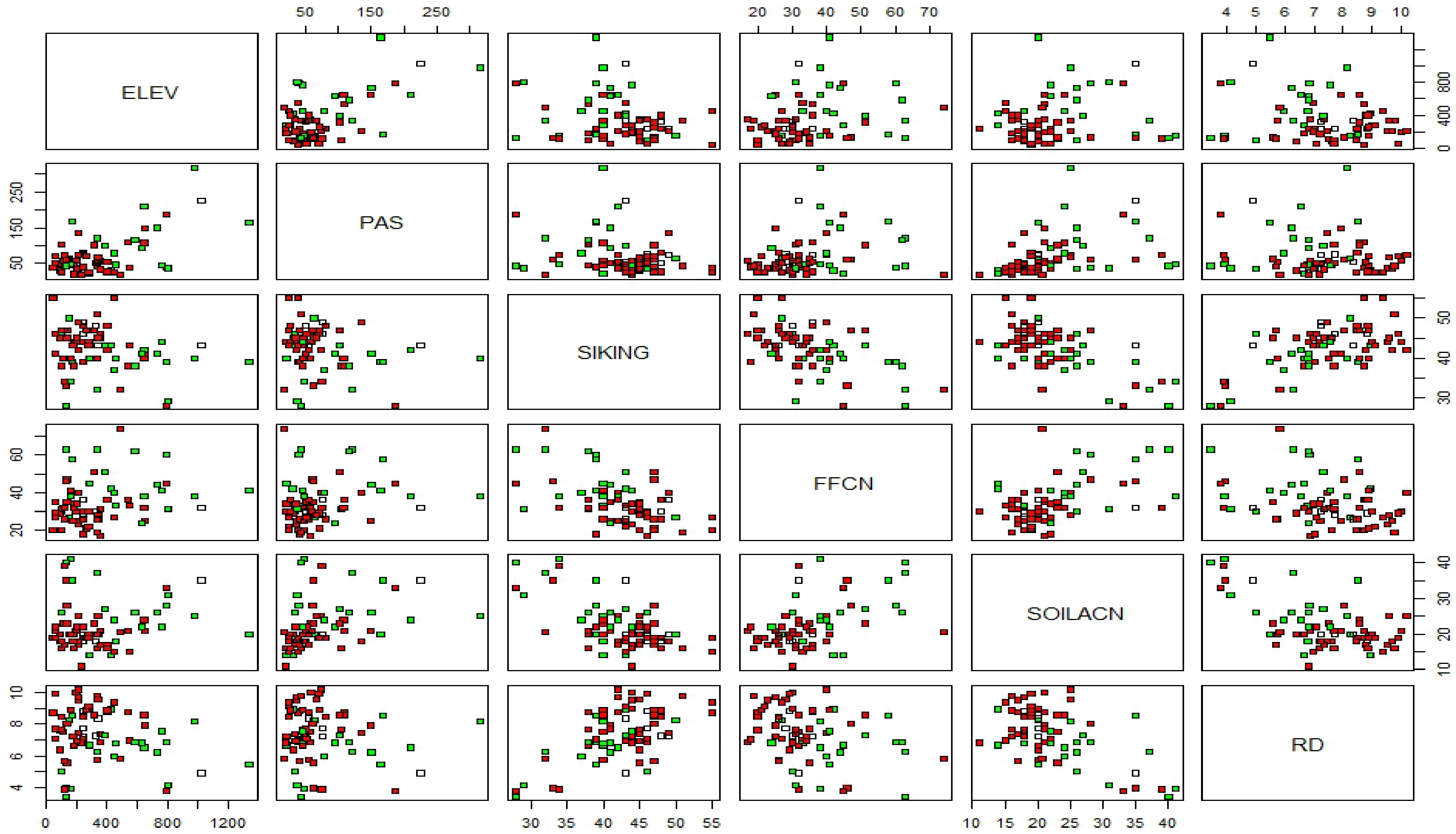
RGR Response	Mapped Predicted	All Predicted
Two-year	**Correct**	**Correct**
No Response	78% *(93%)*	83% *(93%)*
Response	71% *(65%)*	74% *(84%)*
Four-year	**Correct**	**Correct**
No Response	87% *(96%)*	87% *(93%)*
Response	65% *(45%)*	65% *(70%)*

- BRT predictions in *()*
- LDA models predicted responders better in mapped models
- BRT models performed better for predicting non-responders

Two-year LDA Model



Four-year LDA Model



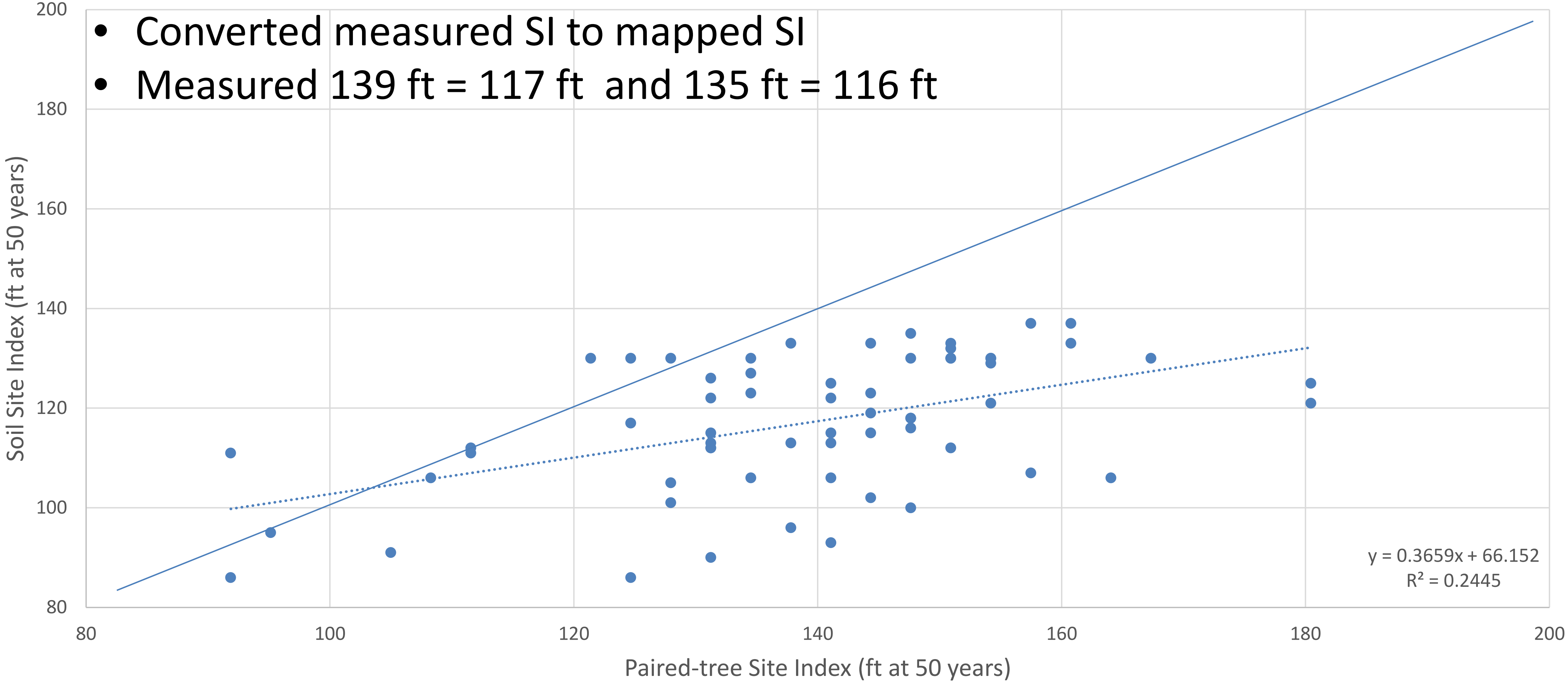
LDA Group Means

Two-year Classification	**Elevation (m)**	**King's Site Index (m at 50 years)**	**Latitude (°)**	**Summer Temp (C)**	Forest Floor C:N Ratio	Surface Soil C:N Ratio	Relative Density
No Response	**294 (1,000 ft)**	**44.1 (145 ft)**	**46.9**	**16.5**	30	21	8
Response	**414 (1,400 ft)**	**40.1 (132 ft)**	**45.9**	**17.0**	41	24	7
Four-year Classification	**Elevation (m)**	**King's Site Index (m at 50 years)**	**Precipitation as Snow (mm)**		Forest Floor C:N Ratio	Surface Soil C:N Ratio	Relative Density
No Response	**263 (860 ft)**	**43.2 (142 ft)**	**59**		31	21	8
Response	**517 (1,700 ft)**	**39.3 (129 ft)**	**97**		43	26	6

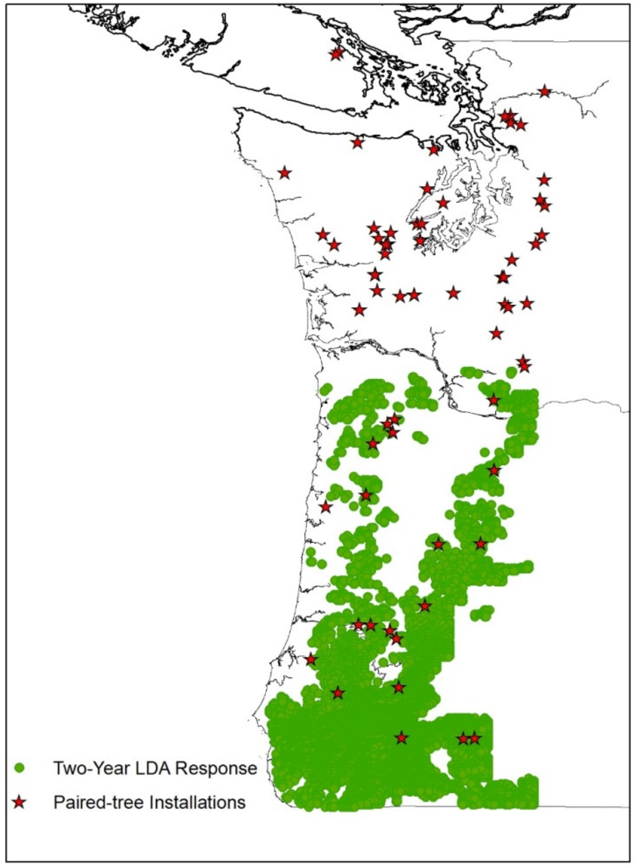
- Bolded values are easily available and included in the mapped models
- Many shared predictors and ranges between the two models
- Variables also included in BRT models

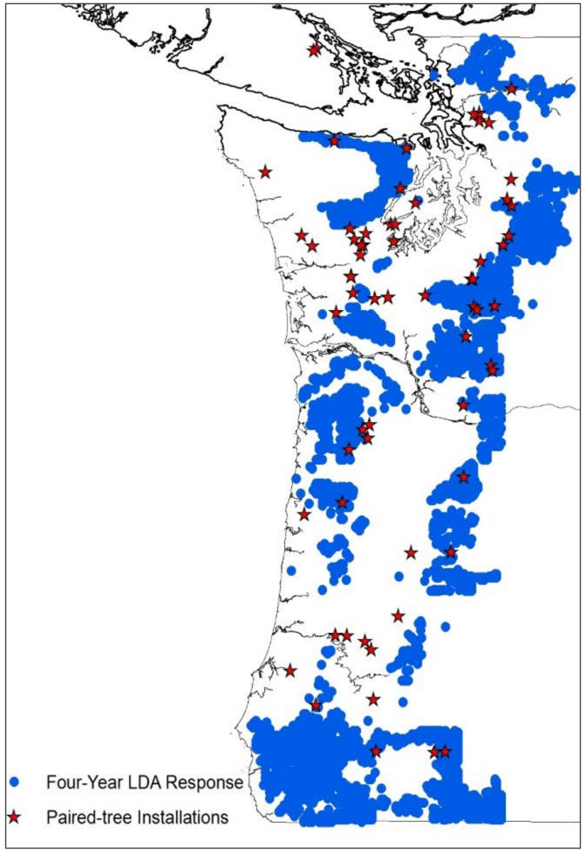
How can we map site index?

- Compared measured site index to NRCS soil site index
- Converted measured SI to mapped SI
- Measured 139 ft = 117 ft and 135 ft = 116 ft



How does this look?





Management Implications

Predictors need to be examined together

Greater response expected at:

- High elevations (>1,000 ft)
- Low and moderate site index
- Soils with high forest floor and soil C:N ratios

Two-year response greater at southern latitudes and warmer summers

Four-year response found on stands with higher precipitation as snow

Next Steps: Measure and model six-year response

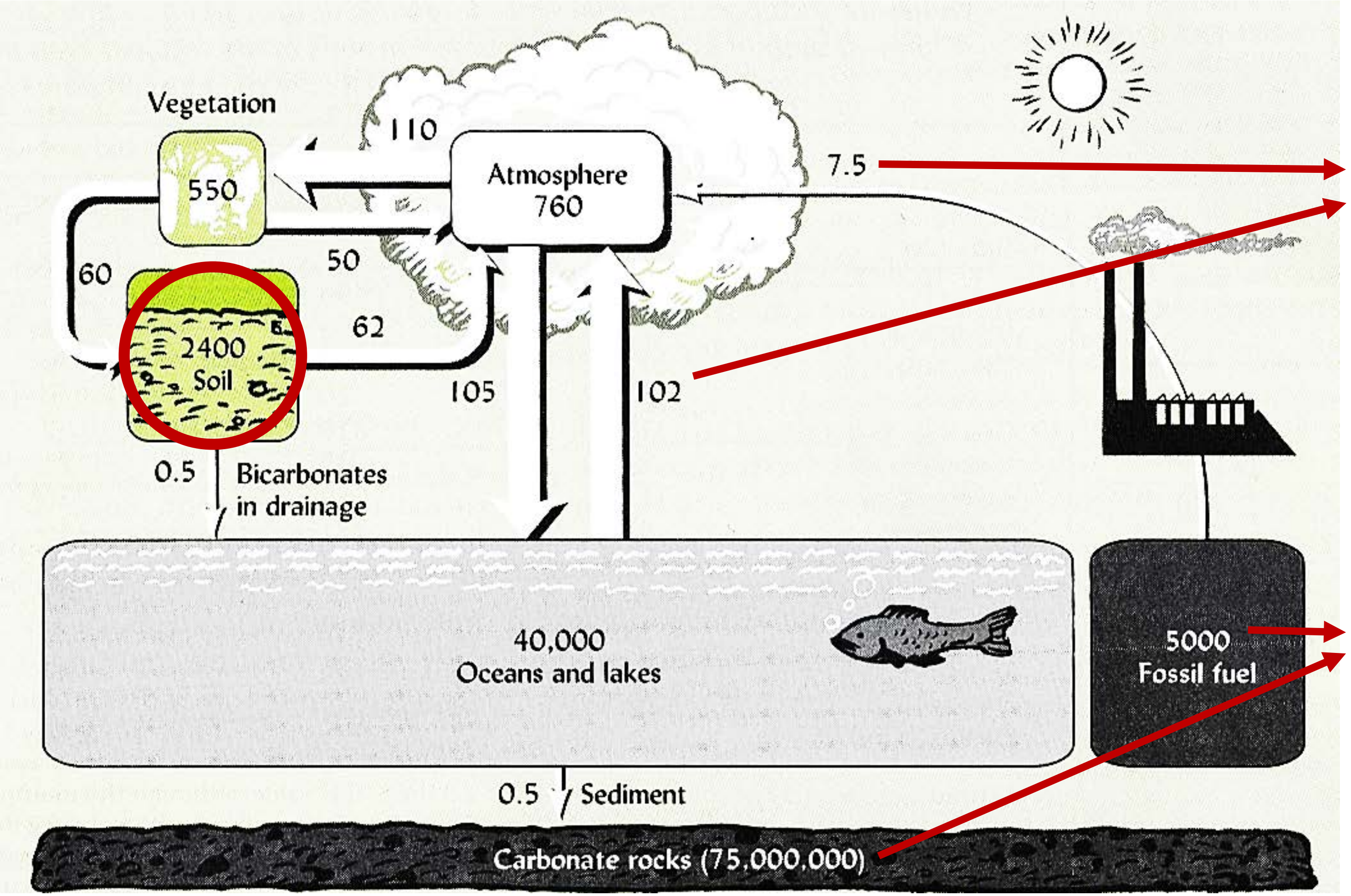
Effects of Nitrogen Fertilization and Thinning Treatments on Subsurface Soil Carbon and Nitrogen

Cole D. Gross
Jason N. James
Robert B. Harrison
University of Washington

Importance of ~~Dirt~~ ~~Mud~~ Soil!

Soil contains almost twice as much carbon as plant biomass and the atmosphere combined.

Carbon Sequestration

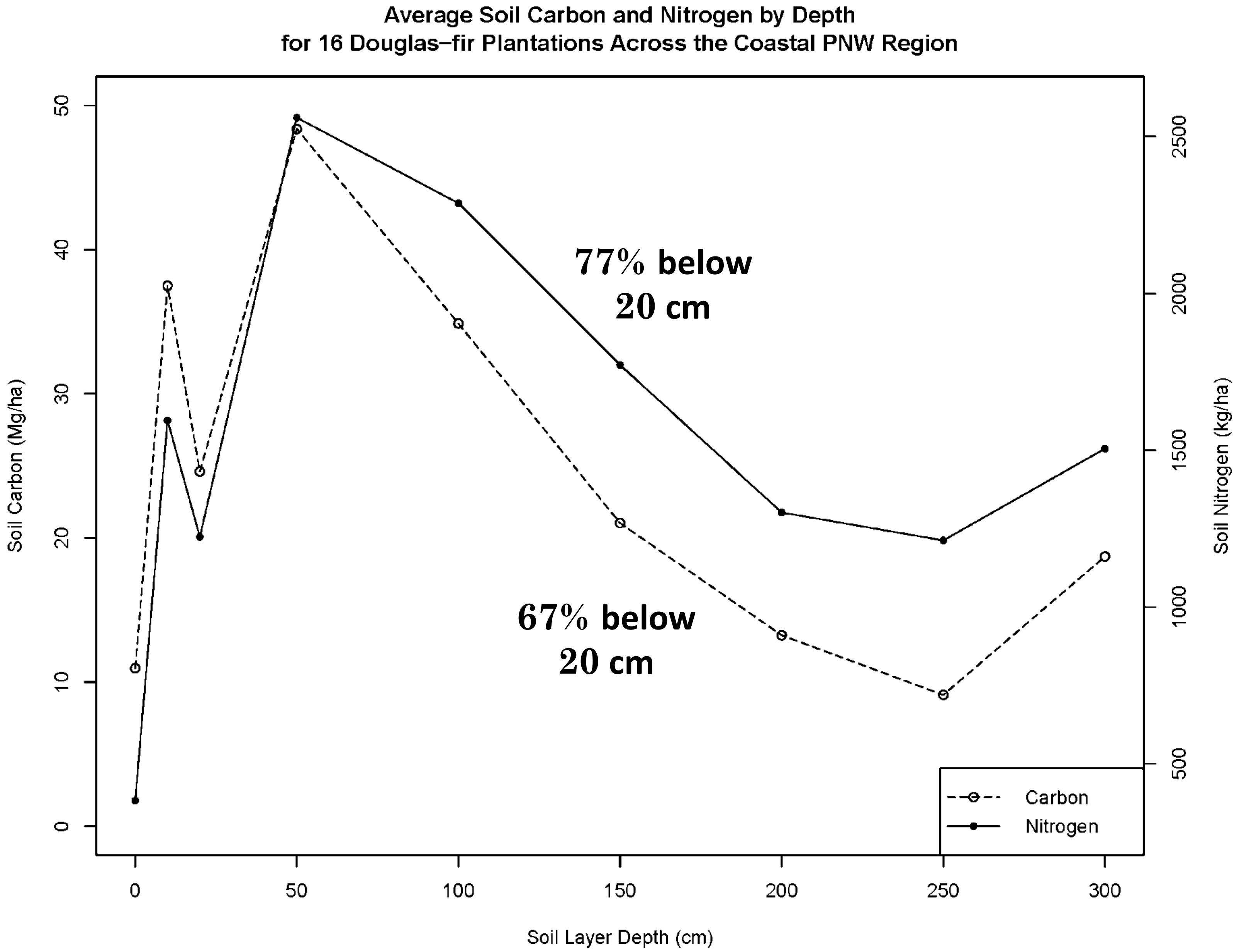


Amount of carbon flowing annually (Pg/yr) between the pools by various processes.

Petagrams (Pg = 10^{15} g) of carbon stored in the major pools.

Brady, N.C. and R.R. Weil. 2008. The Nature and Properties of Soils (pp. 497). 14th Ed. New Jersey: Prentice Education.

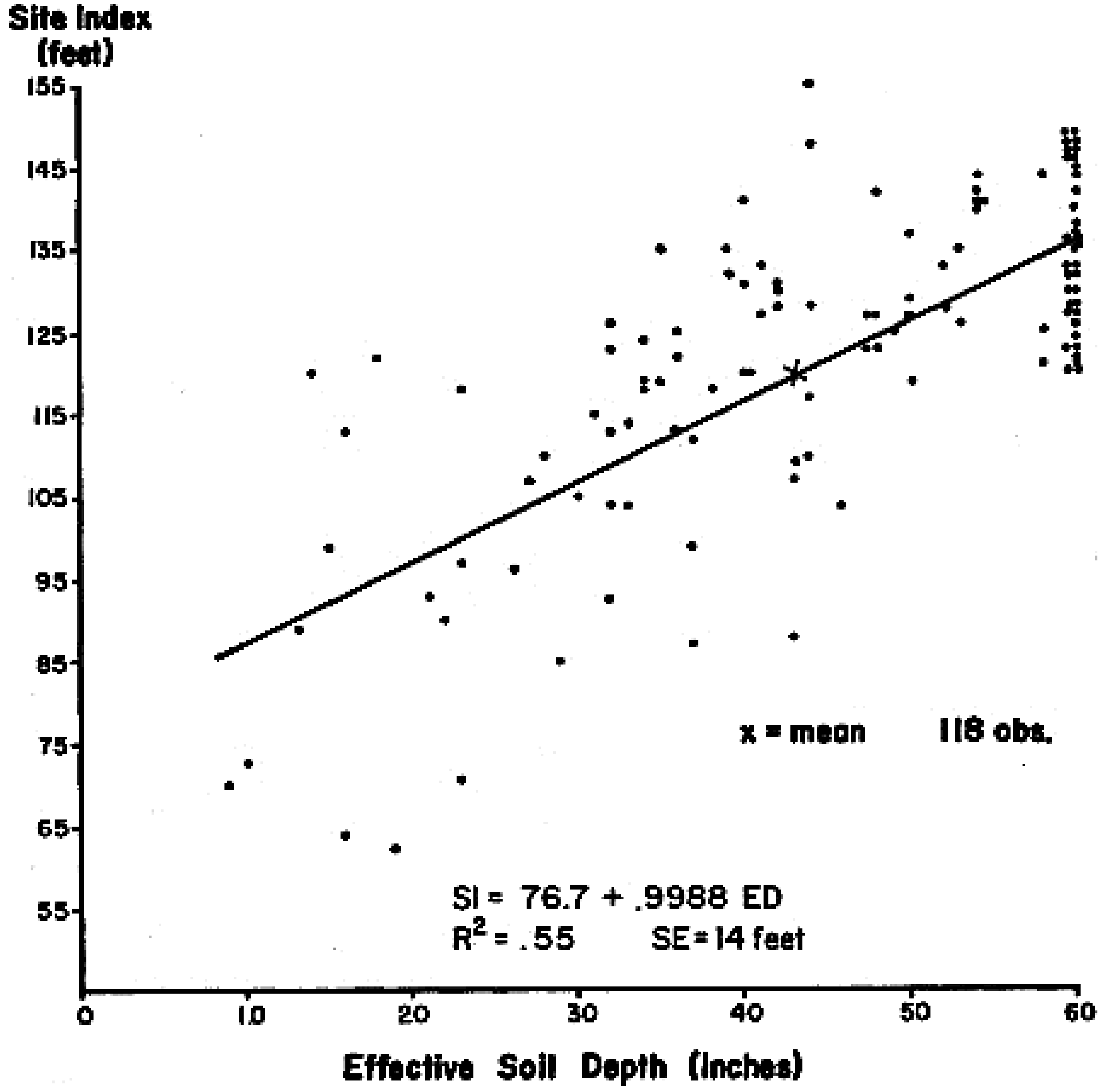
Vertical Distribution of Soil Organic Carbon



- **SMC Type V Long-Term Site Productivity Installations**
- **16 Douglas-fir stands with various treatments**
- **Sites cover a range of soils across the parent materials and climatic conditions of the coastal Pacific Northwest region**

Is Deep Soil Carbon Important?

Site Index vs. Effective Soil Depth



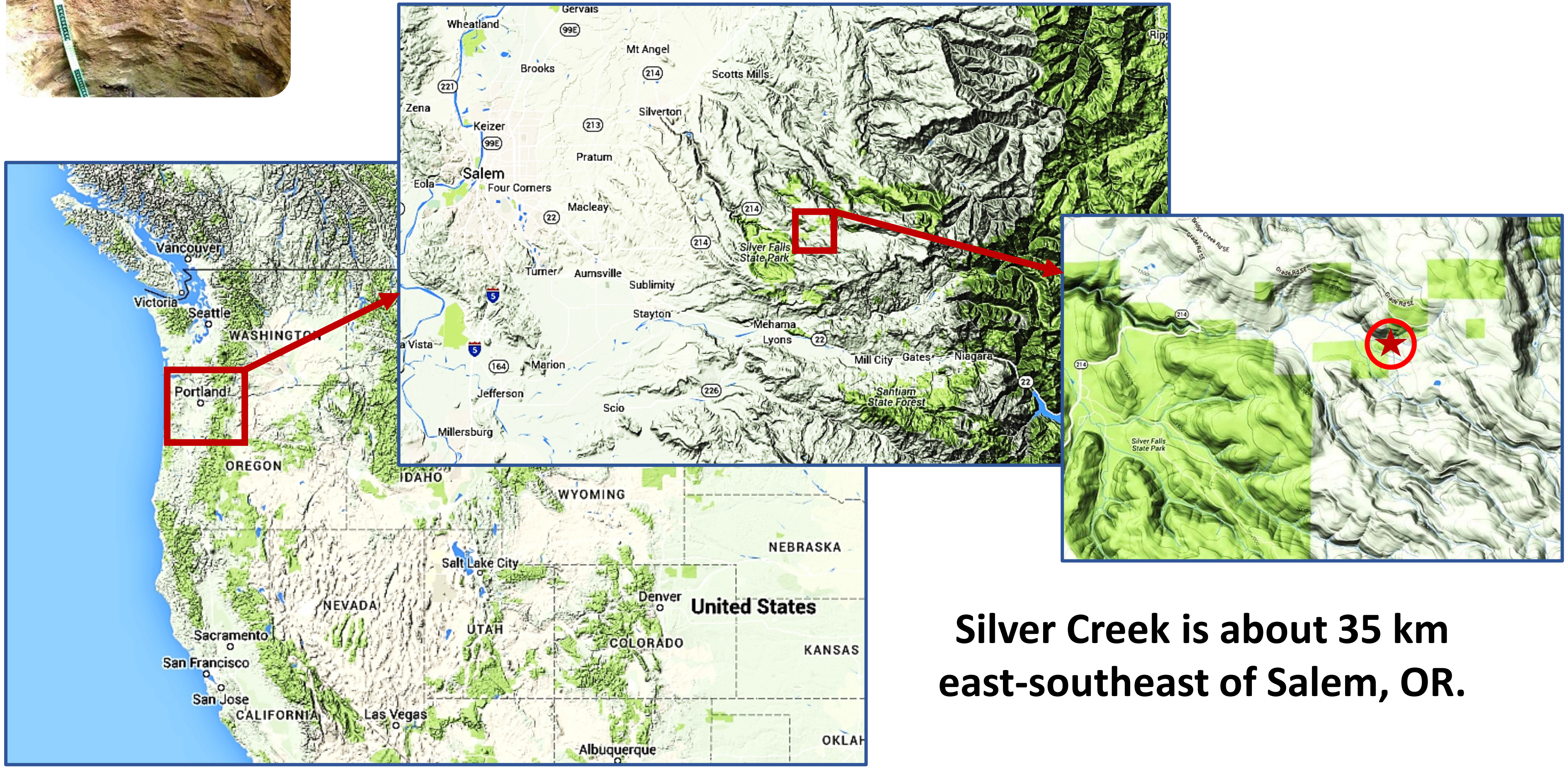
Effective soil depth accounts for 55 percent of the variation in site index for Douglas-fir.

Steinbrenner, E.C. 1979. Forest soil productivity relationships. In Forest Soils of the Douglas-Fir Region (Ch. XII). Washington State University Cooperative Extension.

Purpose

Provide data for regional responses of soil C and N by depth to fertilization and thinning treatments.

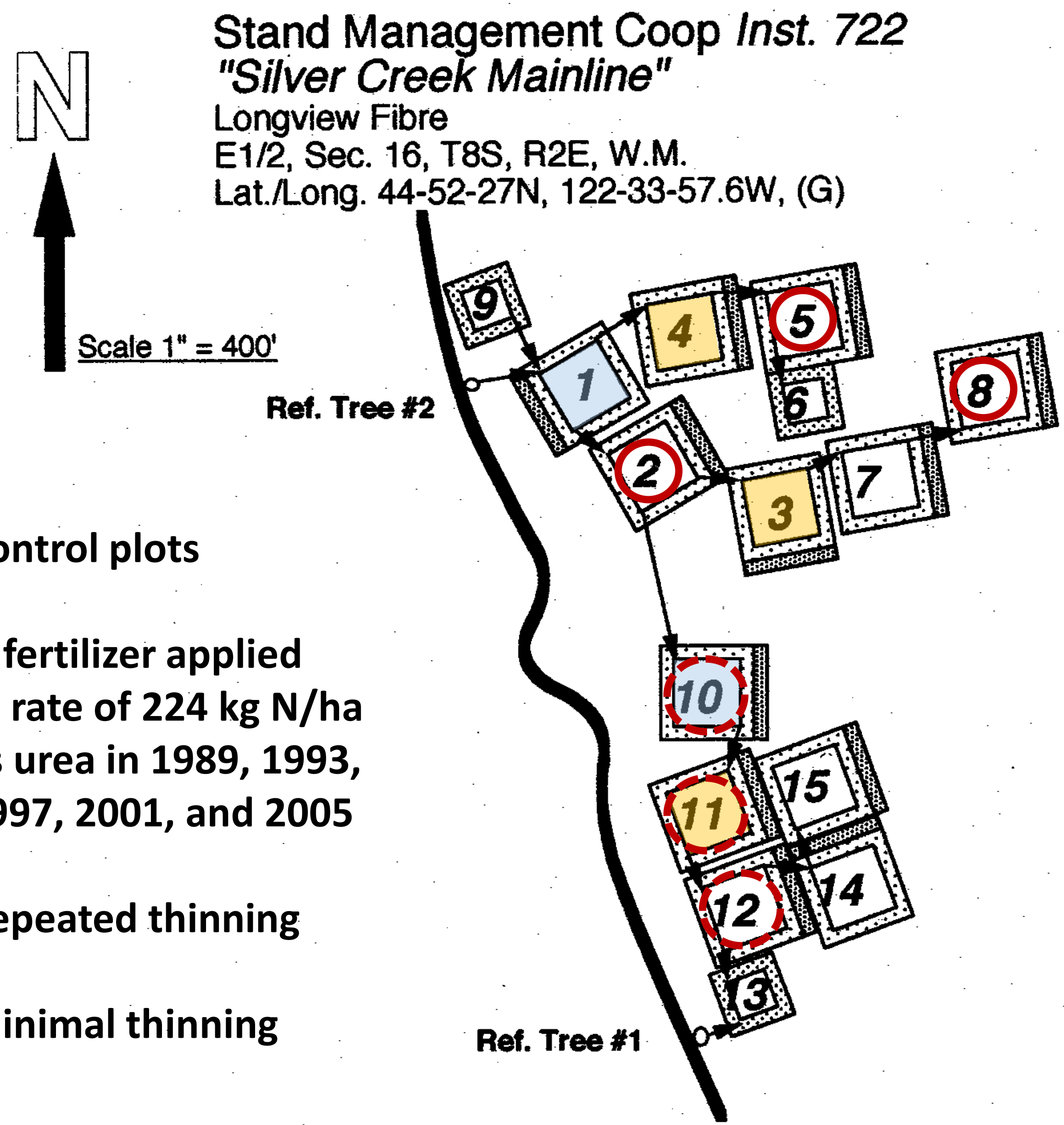
Site



Silver Creek is about 35 km east-southeast of Salem, OR.

Map credit: https://www.google.com/maps/.

Methods



Control plots

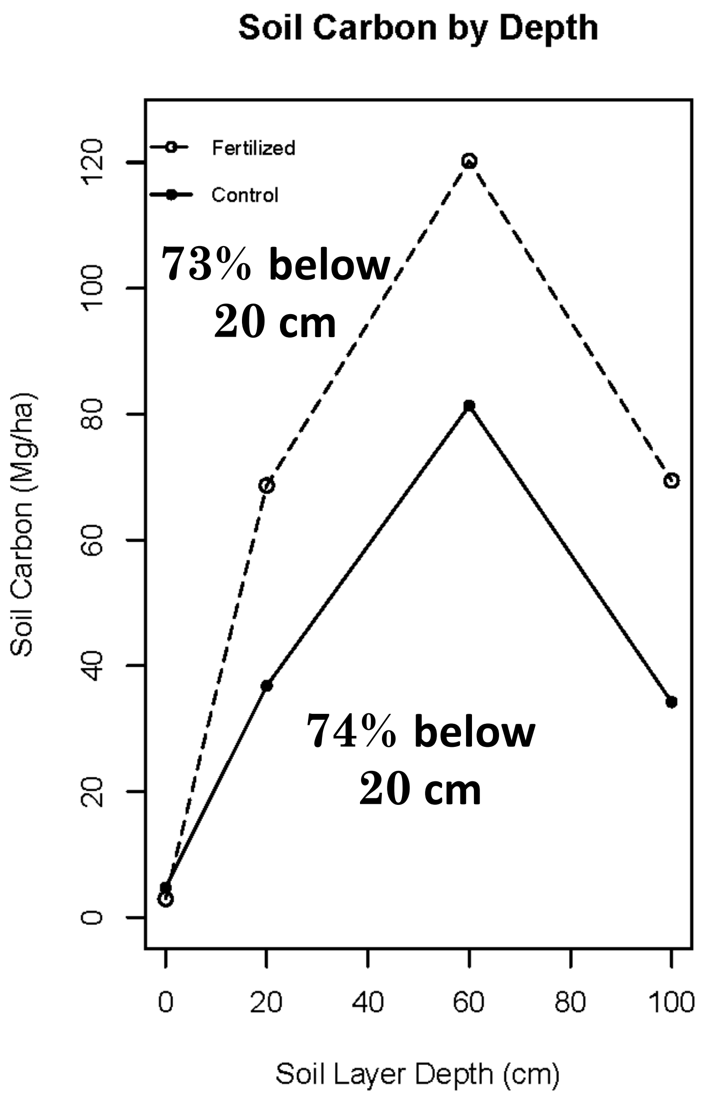
N fertilizer applied at rate of 224 kg N/ha as urea in 1989, 1993, 1997, 2001, and 2005

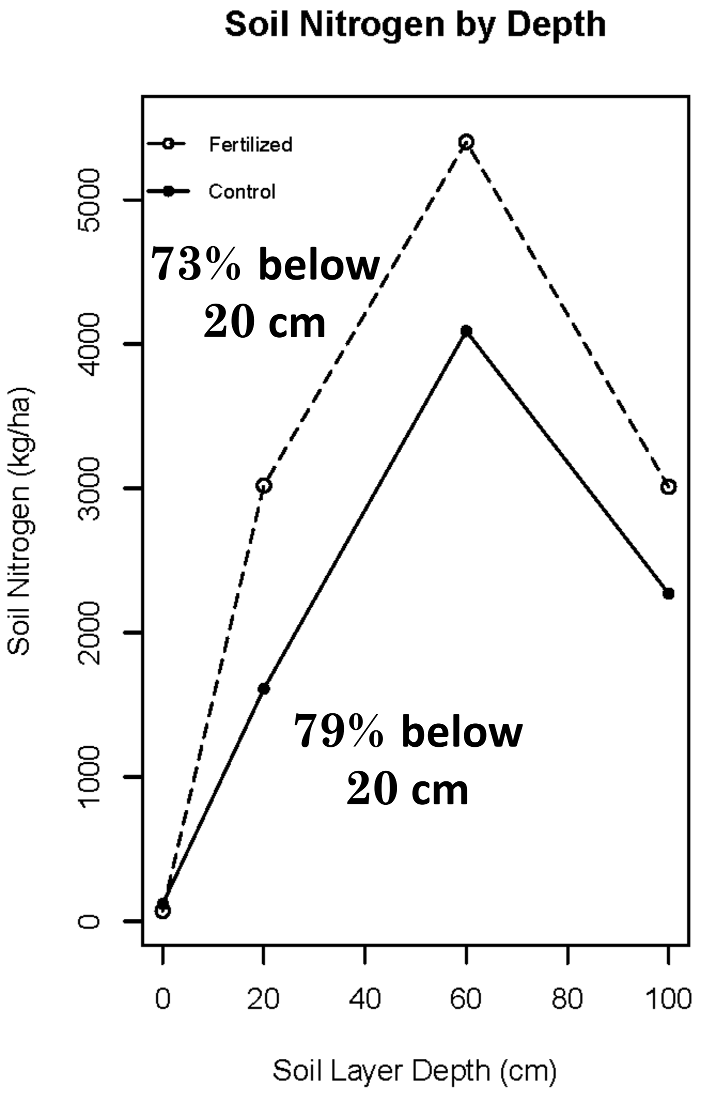
Repeated thinning

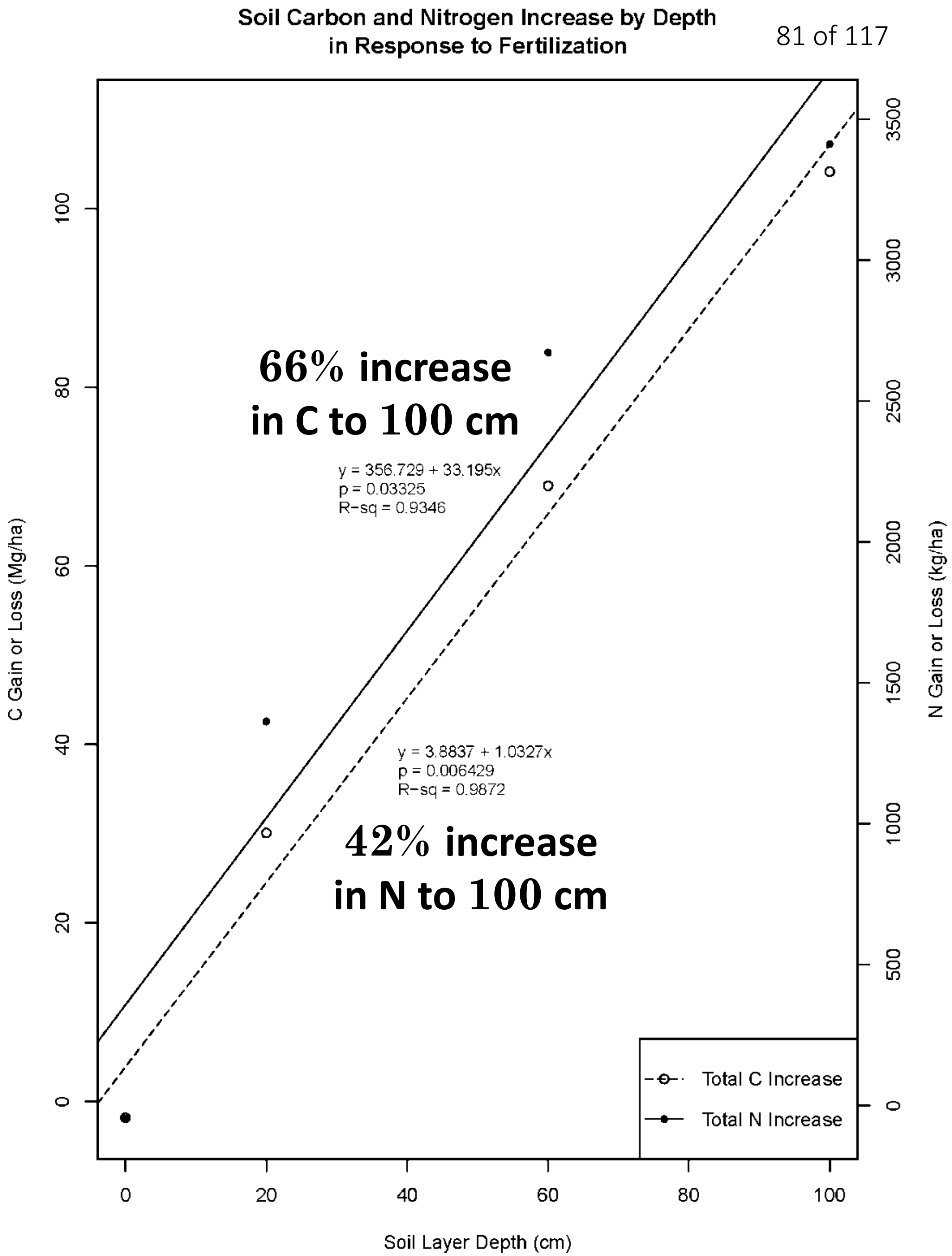
Minimal thinning

- **Douglas-fir plantation**
- **Established in 1989**
- **0.2-ha plots**
- **Three pits/plot**
- **Sampled by depth**
- **At least 1 m depth**
- **Forest floor samples**
- **Methods for bulk density:**
    - **Soil corer**
    - **Volumetric**
    - **Aggregate**

Fertilized Plot vs. Control

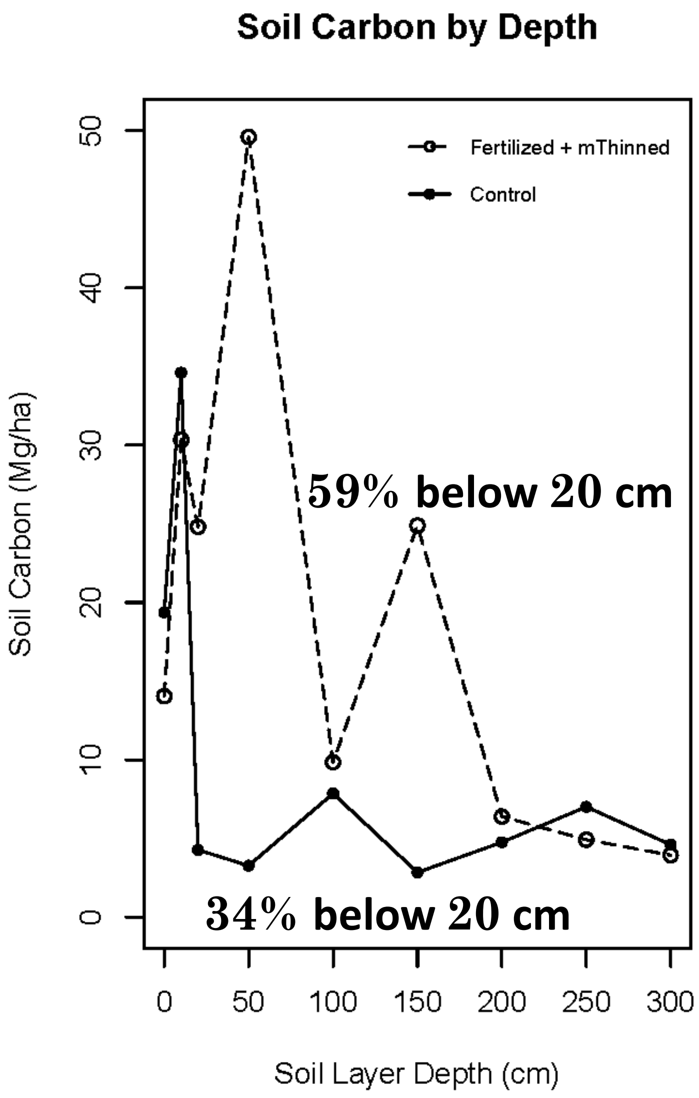


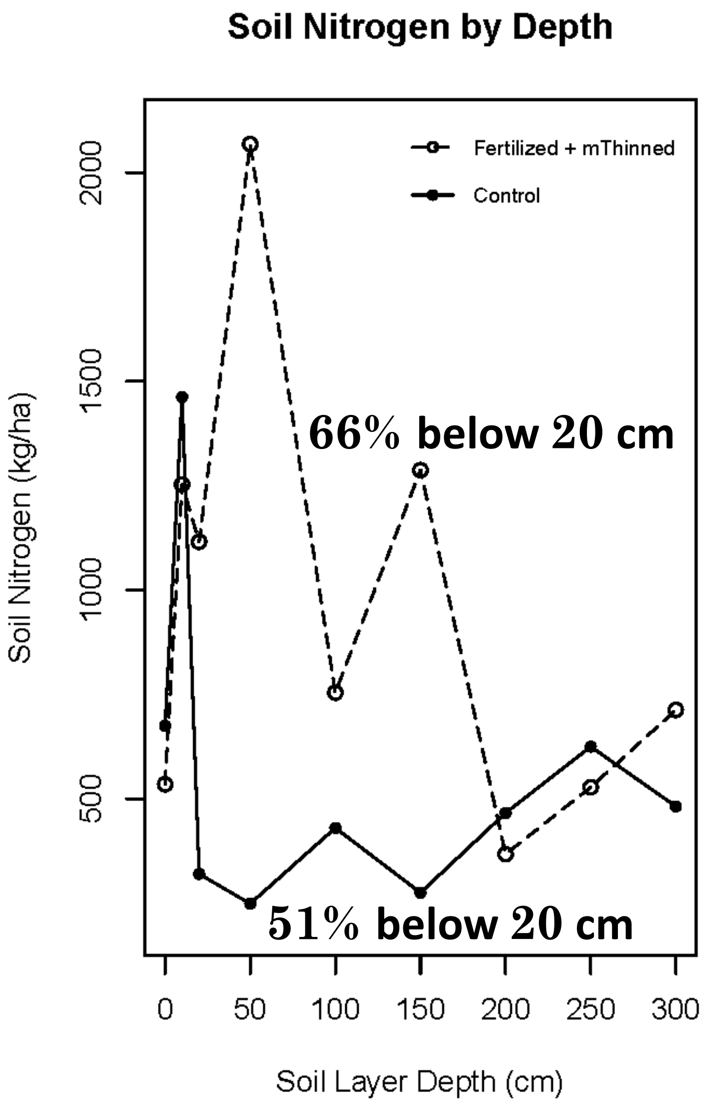


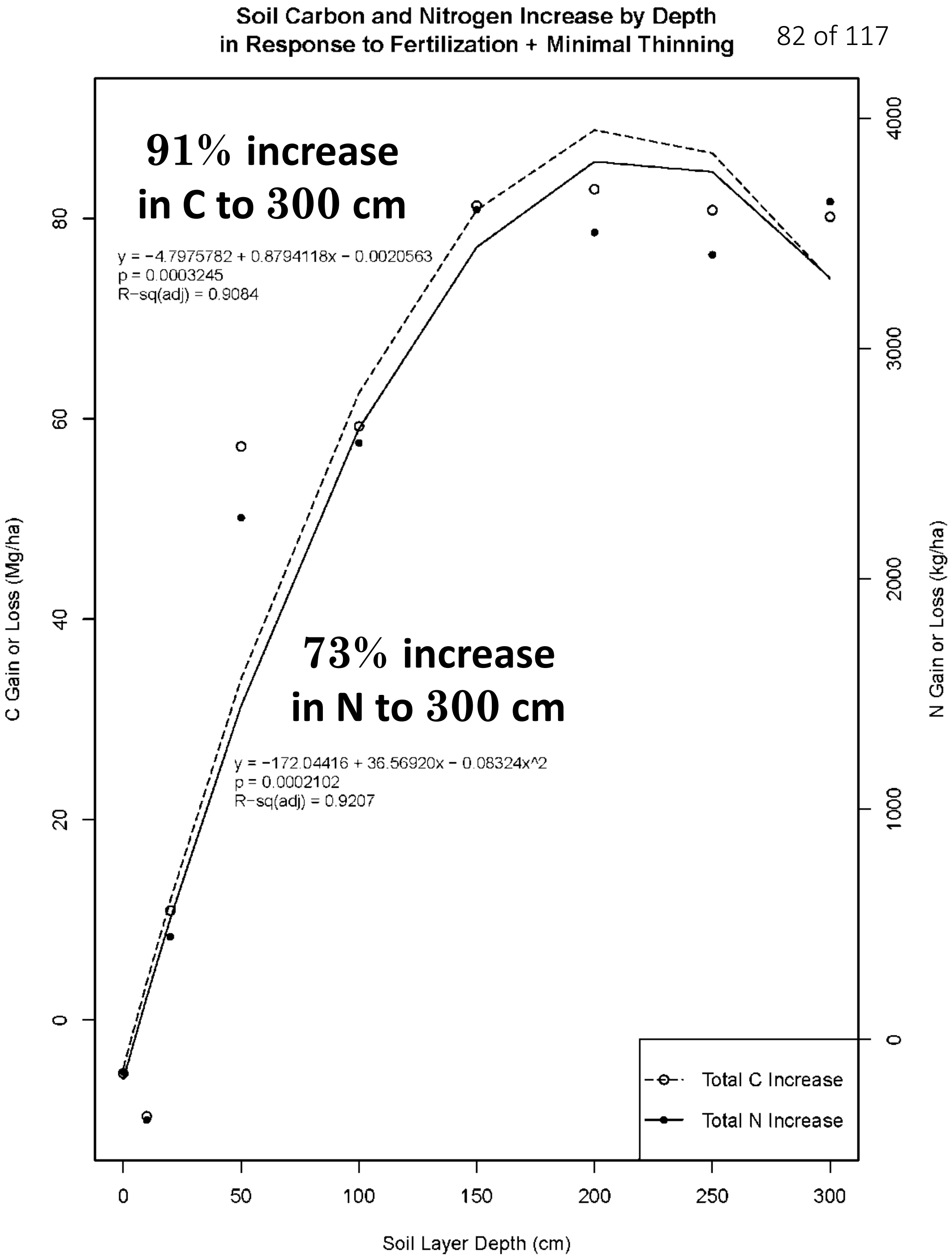


Shryock, B., K. Littke, M. Ciol, D. Briggs and R. Harrison. 2014. The effects of urea fertilization on carbon sequestration in Douglas-fir plantations of the coastal Pacific Northwest. Forest Ecology and Management 318:341-348.

Fertilized + Minimally Thinned Plot vs. Control

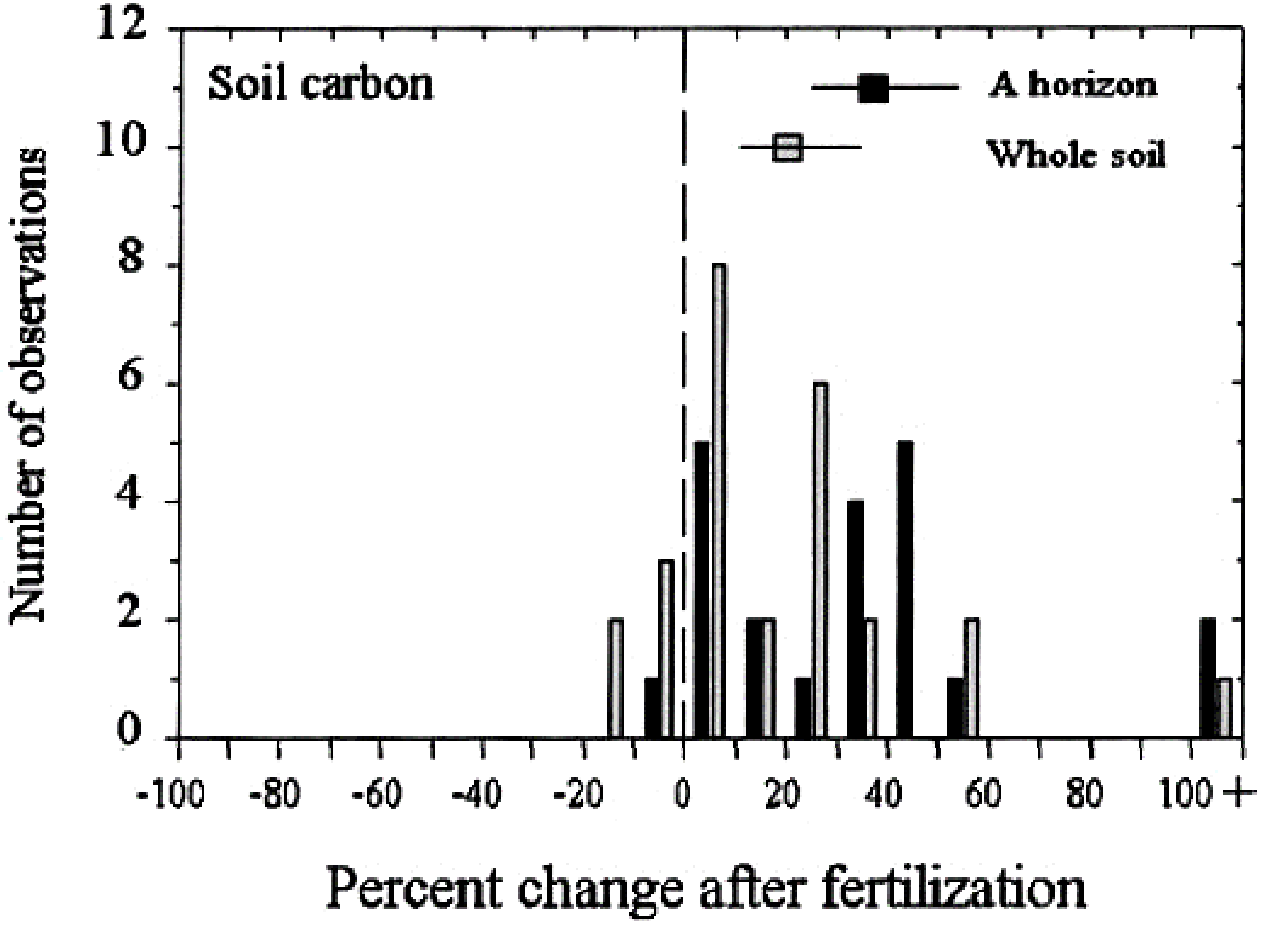






Nitrogen Fertilization and Soil Carbon: Case Studies

Conifers and Hardwoods

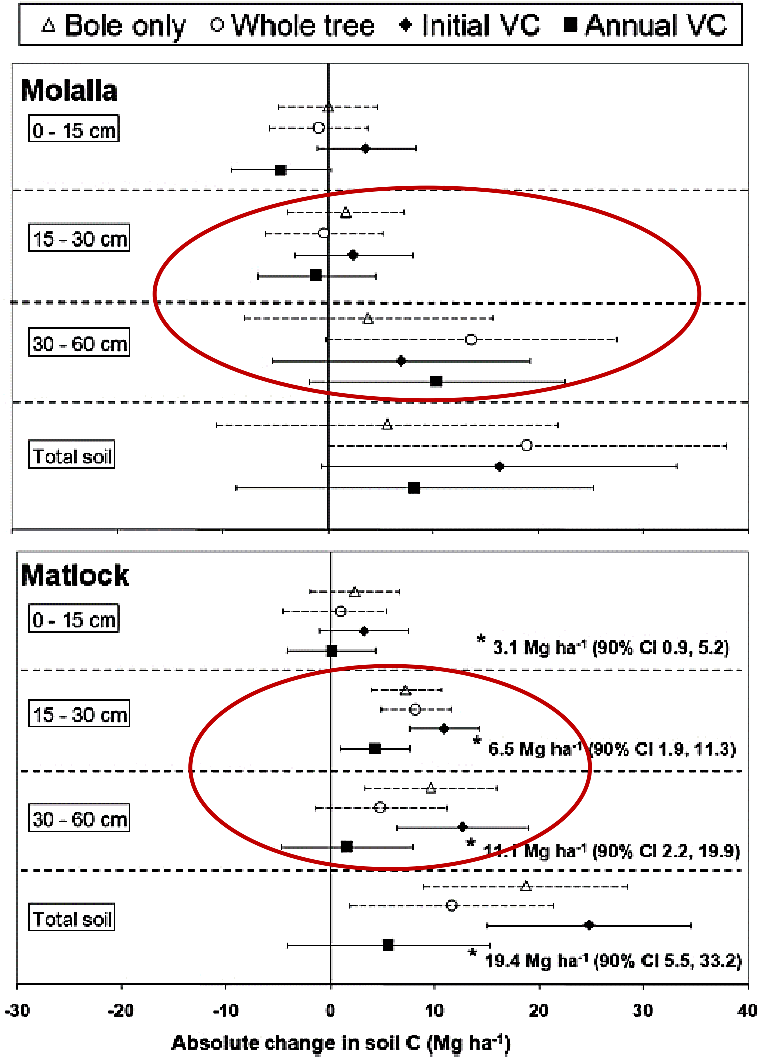


- **Significant increases (+20%) in mineral soil C storage have occurred as a result of N fertilization for conifers and hardwoods**
- **Mineral soil C increases of up to 25% have been found for western conifers**
- **Other studies have found minimal gains (10 to 30 kg C per kg N) or losses (<-1 to -13%) in forest ecosystem mineral soil C pools in response to N fertilization**

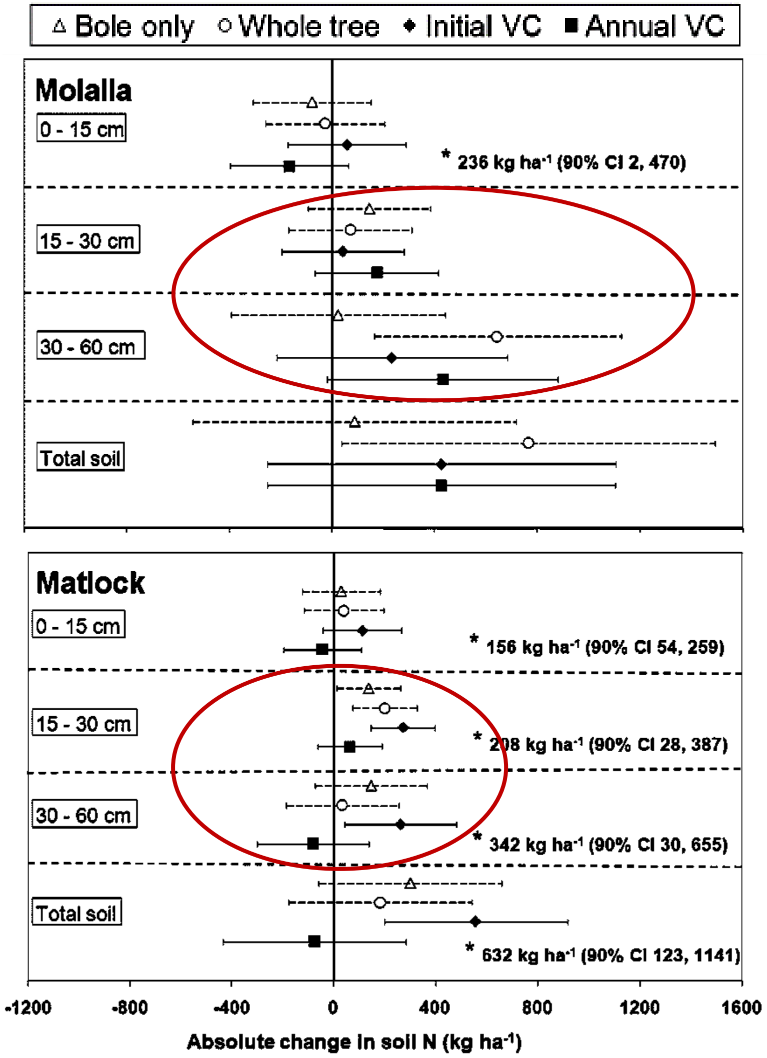
Johnson, D.W. and P.S. Curtis. 2001. Effects of forest management on soil C and N storage: meta analysis. Forest Ecology and Management 140:227-238.
Lu, M., X. Zhou, Y. Luo, Y. Yang, C. Fang, J. Chen and B. Li. 2011. Minor stimulation of soil carbon storage by nitrogen addition: A meta-analysis. Agriculture, Ecosystems and Environment 140:234-244.
Nave, L.E., E.D. Vance, C.W. Swanston and P.S. Curtis. 2009. Impacts of elevated N inputs on north temperate forest soil C storage, C/N, and net N-mineralization. Geoderma 153:231-240.
Shryock, B., K. Littke, M. Ciol, D. Briggs and R. Harrison. 2014. The effects of urea fertilization on carbon sequestration in Douglas-fir plantations of the coastal Pacific Northwest. Forest Ecology and Management 318:341-348.
Vries, W.d., S. Solberg, M. Dobbertin, H. Sterba, D. Laubhahn, G.J. Nabuurs, P. Gundersen and M.A. Sutton. 2008. Ecologically implausible carbon response? Nature 451:E26-E28.

Management Practices and Soil Carbon: Case Studies

Soil Carbon Change by Depth



Soil Nitrogen Change by Depth



C and N increases 2-yrs after harvest were greatest in the deep soil, regardless of the management regime.

Slesak, R.A., S.H. Schoenholtz, T.B. Harrington and N.A. Meehan. 2011. Initial response of soil carbon and nitrogen to harvest intensity and competing vegetation control in Douglas-fir (*Pseudotsuga menziesii*) plantations of the Pacific Northwest. Forest Science 57(1):26-35.

Conclusions

- Forest management regimes can affect both surface and deep soil
- Deep soil contains a large and available pool of nutrients for Douglas-fir
- Carbon sequestration in deep soil can possibly mitigate atmospheric CO_2
- More studies need to sample deeper soil horizons in order to better understand management impacts on soil nutrition and assess long-term forest productivity

Breast Height and Upper-Stem Diameter Response in Pruned Douglas-fir

John Kirby
University of Washington

Study Overview

Hanley et al 1995

- *Why?* Volume, clear-wood, aesthetics, habitat, fire, social benefits
- *Why Not?* Expensive, price premium of clear-wood, uncertainty in tree response
- *Question:* How does pruning Douglas-fir effect diameter *and branch sizes* up the bole of the tree?
- The SMC study uniquely suited to answer this question

Study sites

	Type I	Type III
Stand Age	35.7 yrs.	26 yrs.
Stand Height	84.1’	59.5’
DBH	13.5”	10.4”
Pruning Treatment	20, 40 60% removal	50% removal, up to 22‘ lift
Age at Pruning	11.2 yrs.	9.75 yrs.
Yrs. Treatment	24.5 yrs.	16.2 yrs.
Densities	Mean ISPA=486	100, 200, 300 TPA
Sample Size	204	222

Methods

Ground

Inst:	Plot:	Tree:	Quint:
DBH:	Ht:	Ht -> LCB:	
LrgBHBr:	WhlBrCt:	IntBrCt:	
CW|NE:	CW|SE:	CW|SW:	CW|NW:

Top of first log (17.5')

Dia:			
LBD|NE:	LBD|SE:	LBD|SW:	LBD|NW:

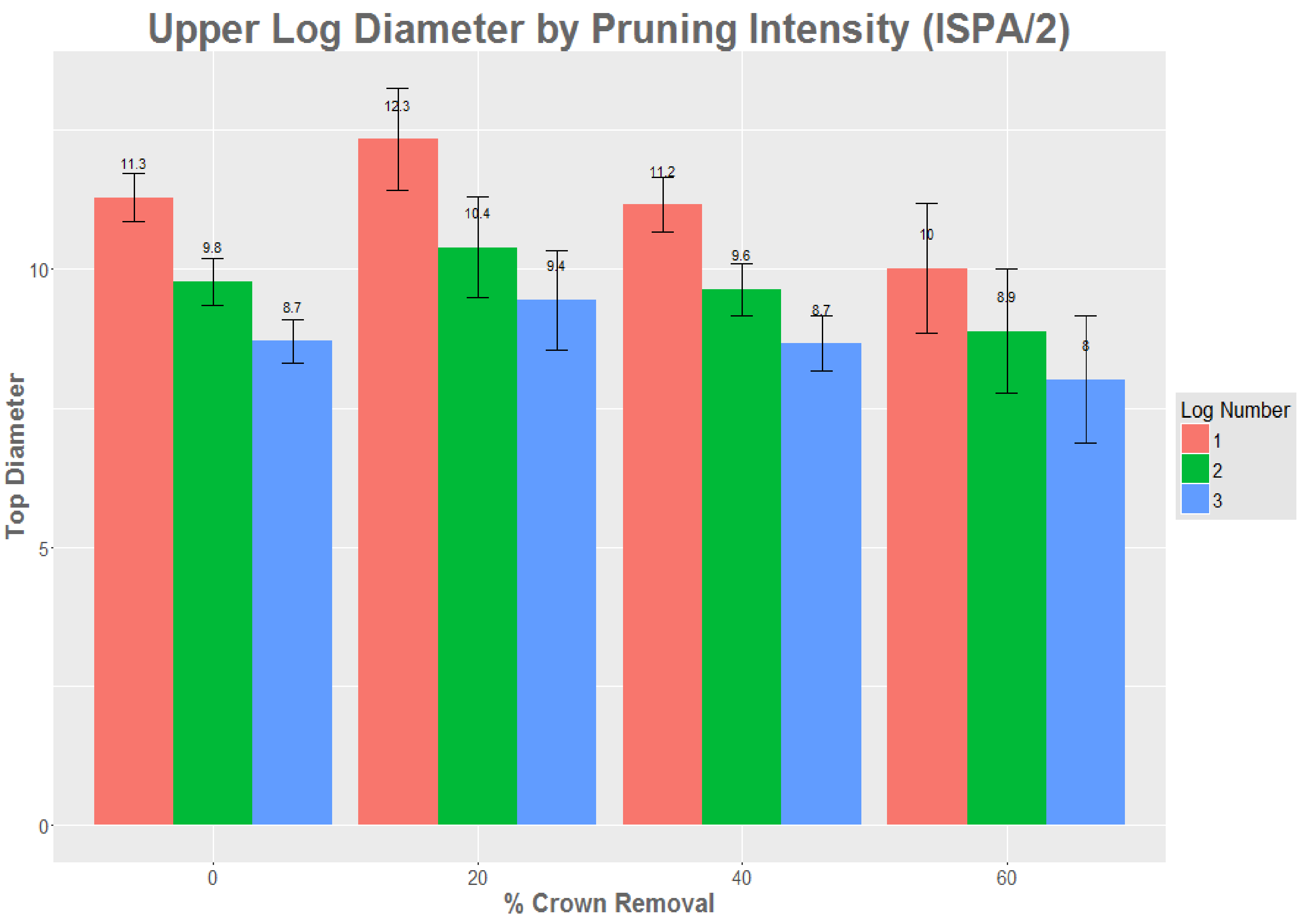
Top of second log (34')

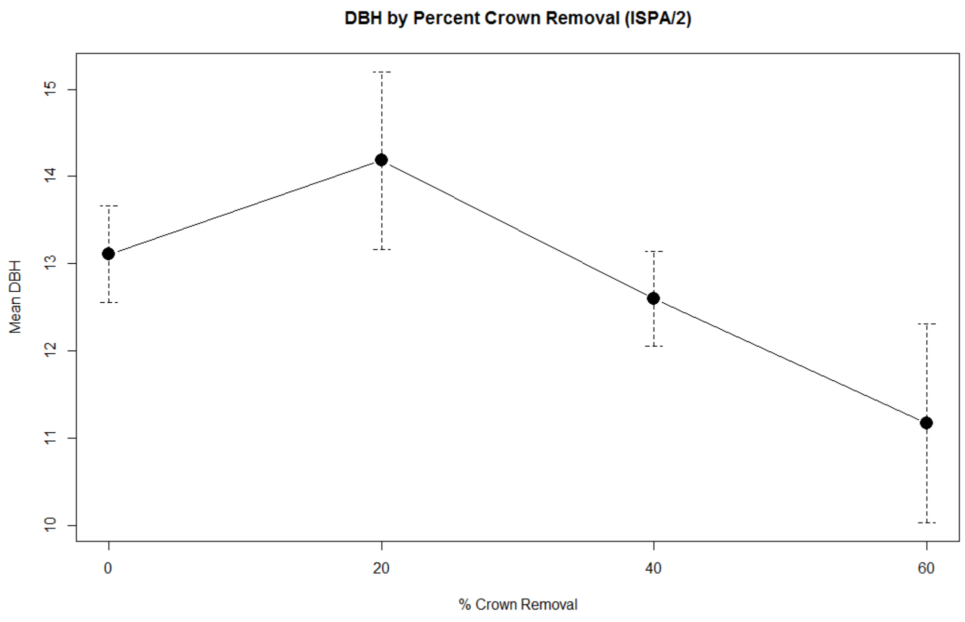
Dia:			
LBD|NE:	LBD|SE:	LBD|SW:	LBD|NW:

Botttom half of third log (-> 42')

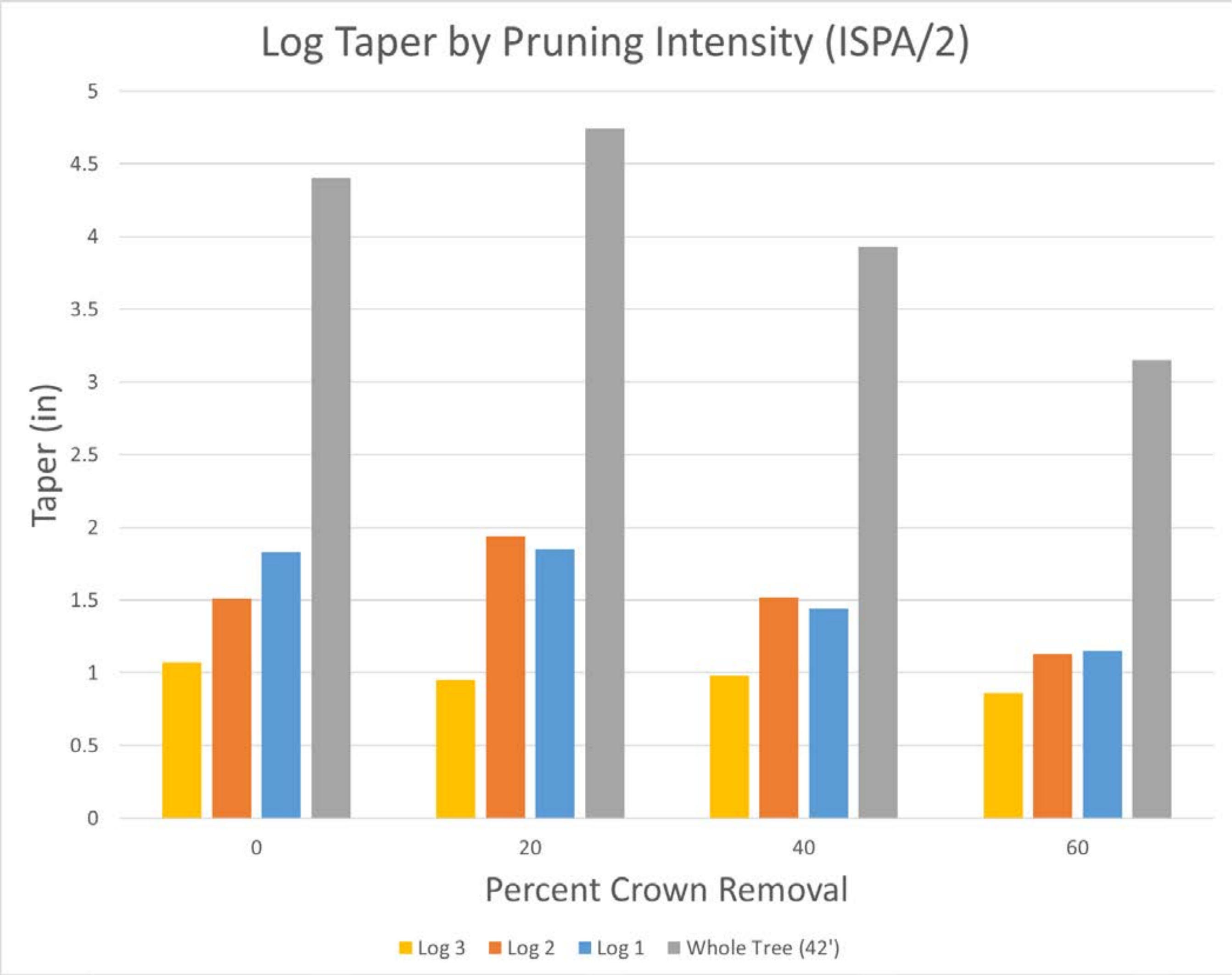
Dia:	Ht -> 4"		
LBD|NE:	LBD|SE:	LBD|SW:	LBD|NW:

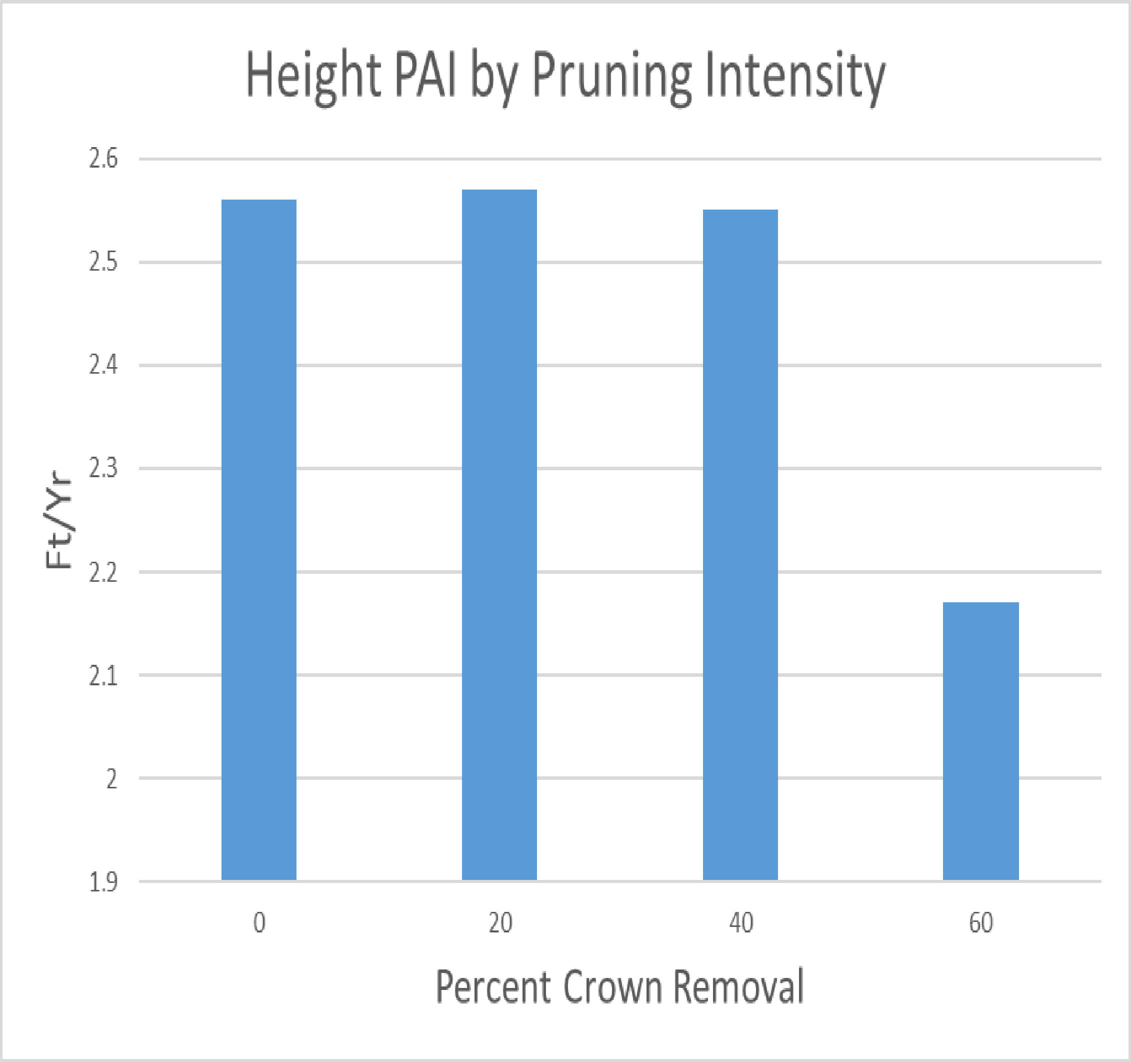
Results (Type 1)



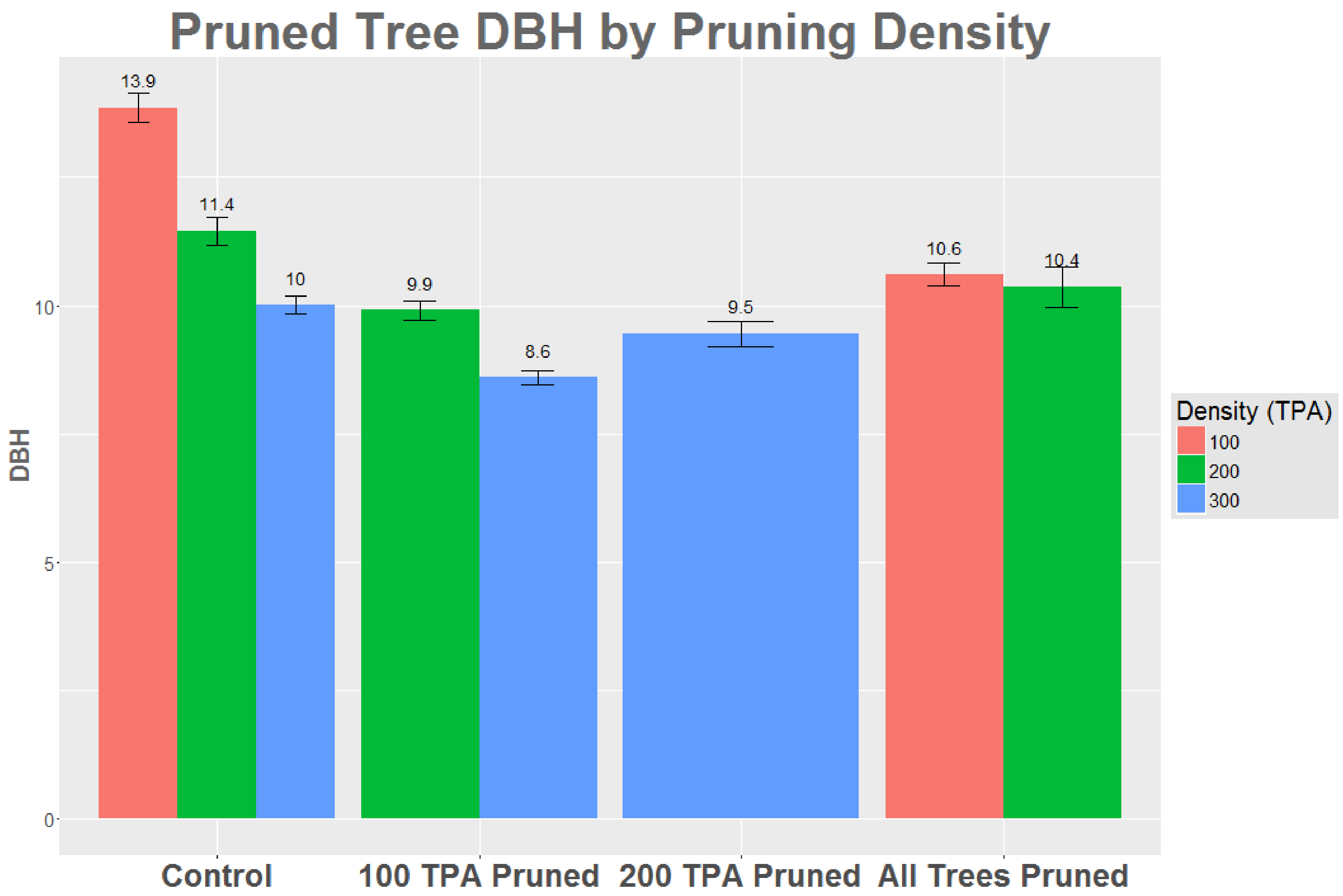


Results (Type 1)

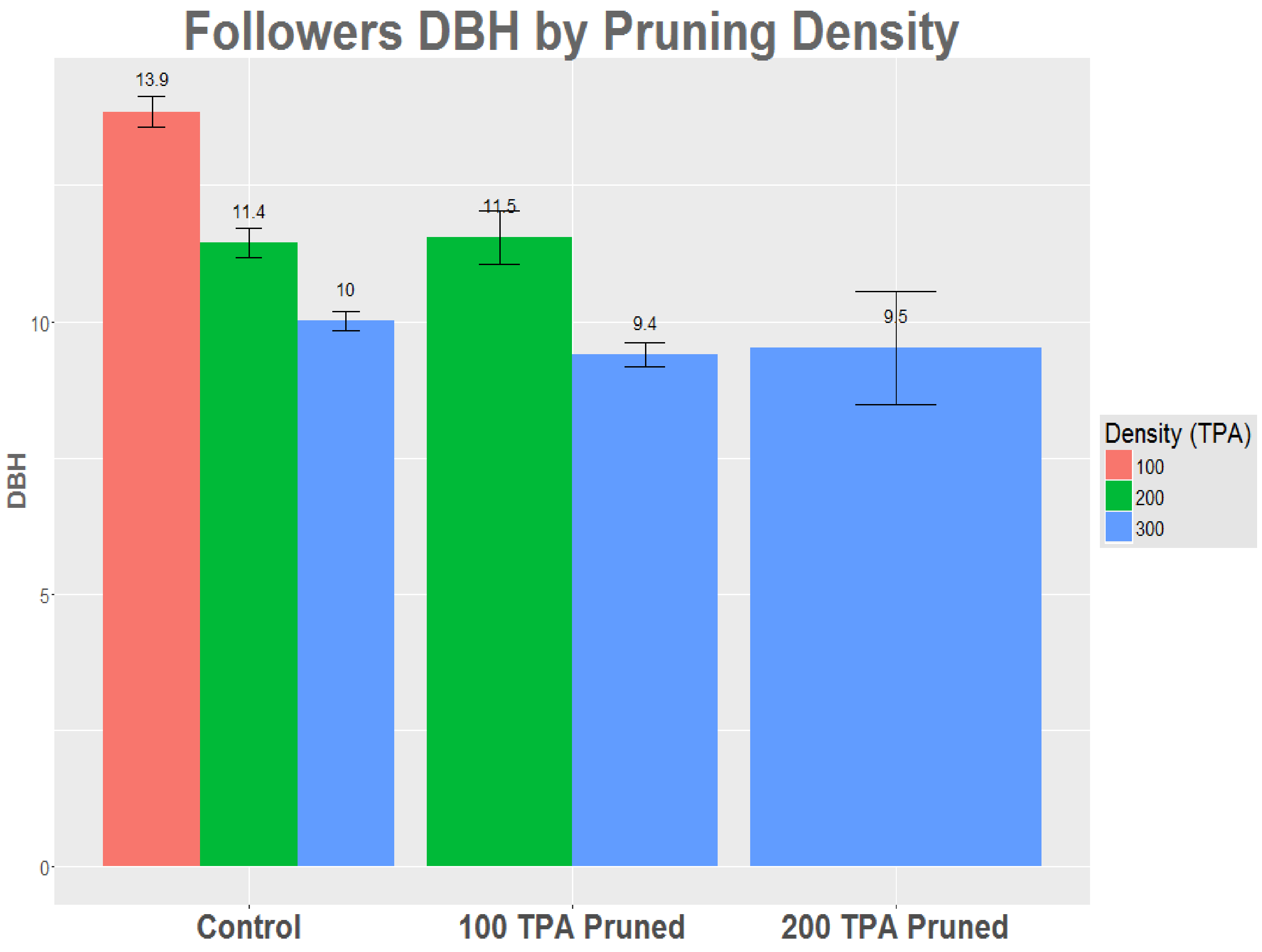


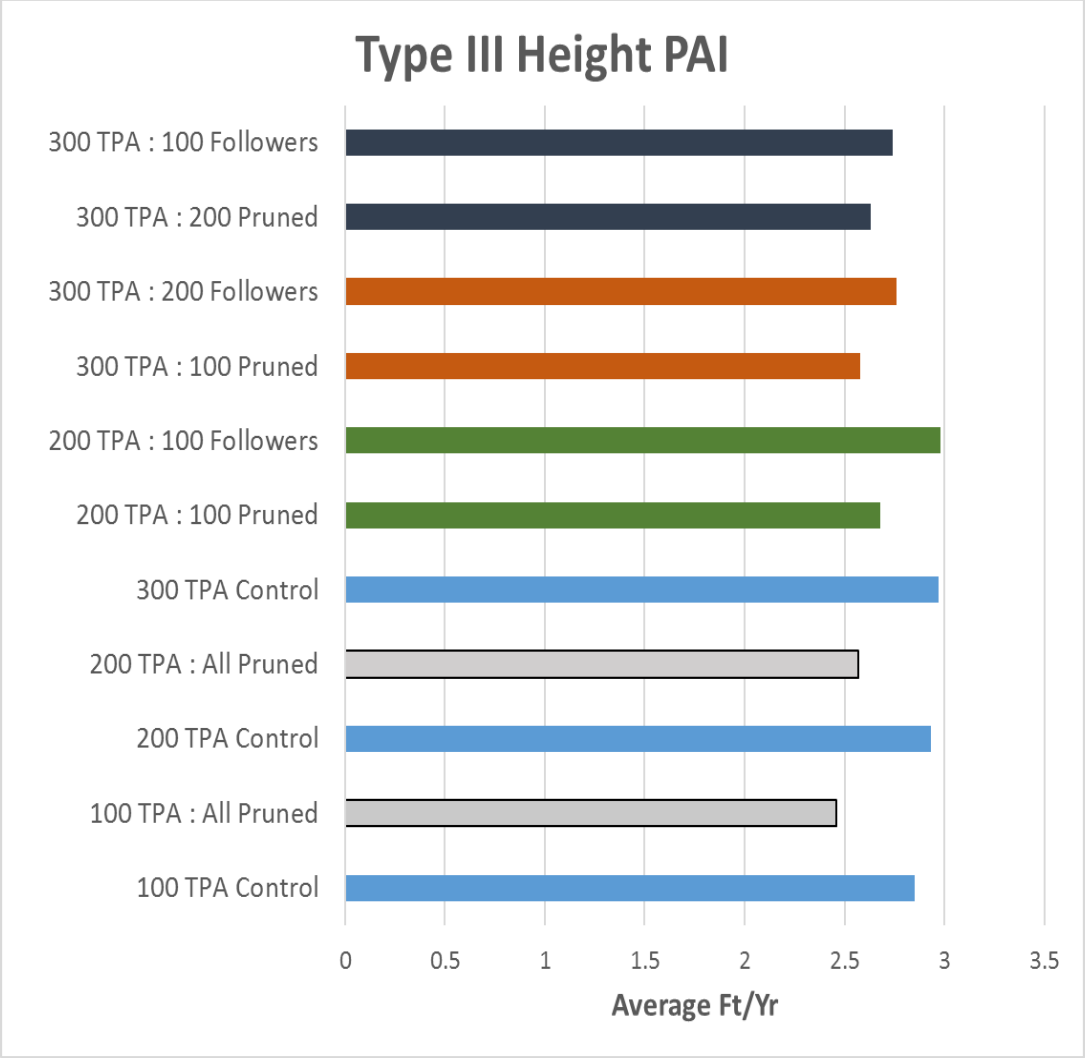


Results (Type III)

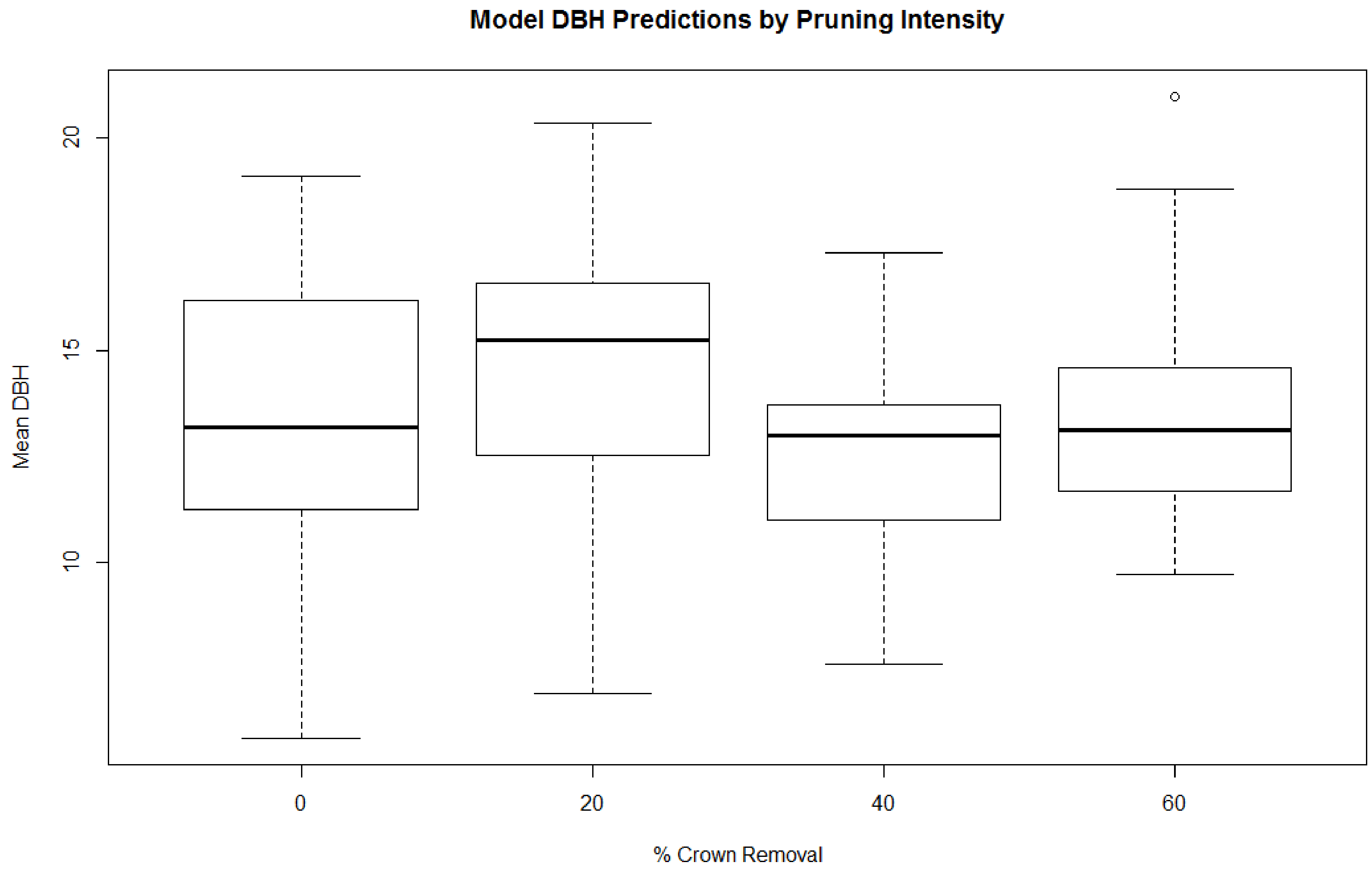


Results (Type III)





Model Results



Tentative Conclusions / *Future Work*

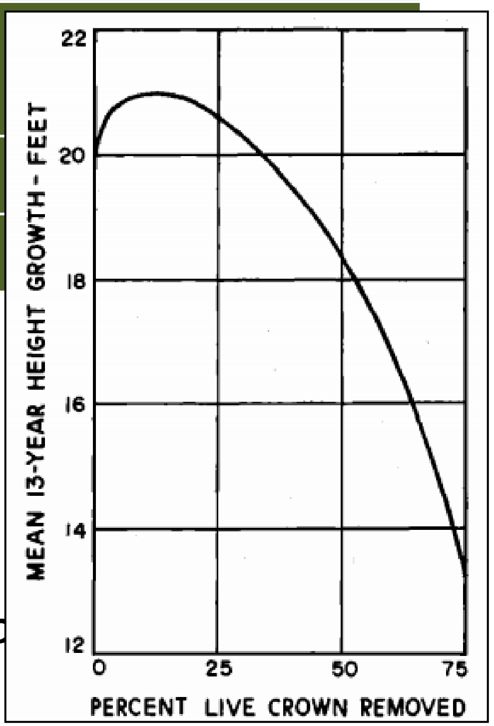
Treatment (I)	Diameter	Height	Taper
20%	Increase	Same	Most
40%	Same	Same	Intermediate
60%	Same/Reduction	Reduction	Least
Treatment (III)	**Diameter (DBH)**	**Height**	
Pruned	Decrease	Decrease	
Followers	Same	Same	

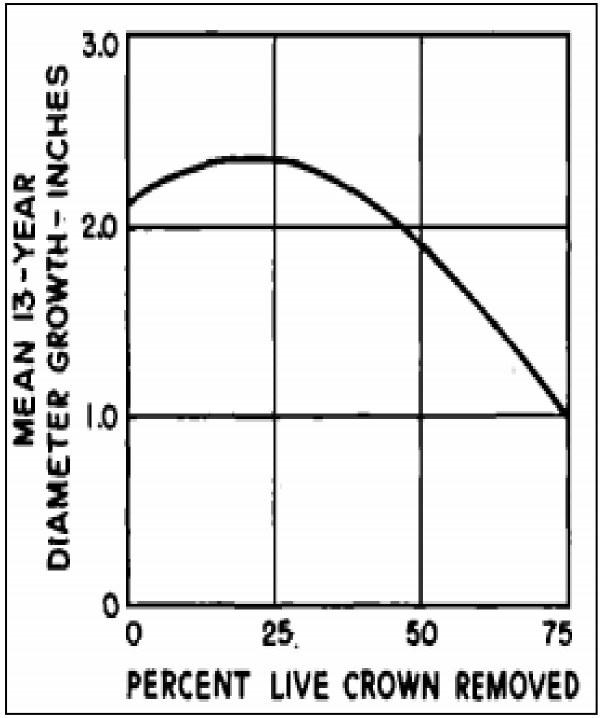
-Branch size response

- *Effects of pruning on branch size up the bole*

-Economic implications?

- *Is the increase in volume worth the expense?*





References

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Stand and Tree Response to Late-Rotation Fertilization – rev. 5

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Background: Late-Rotation Fertilization

- Much research has shown that Douglas-fir plantations on many Pacific Northwest sites are nitrogen deficient and on average will respond to fertilization with urea.
- Inherent risks to fertilization
  - the high cost of fertilizer and amortization of its costs to rotation,
  - the loss of volume from competition-induced mortality, and
  - the potential of stand damage or loss due to fire, insects and diseases
- An alternative strategy that could be economically attractive and may reduce these risks is to apply a single fertilizer application five to ten years before final harvest

Objectives: Late-Rotation Fertilization

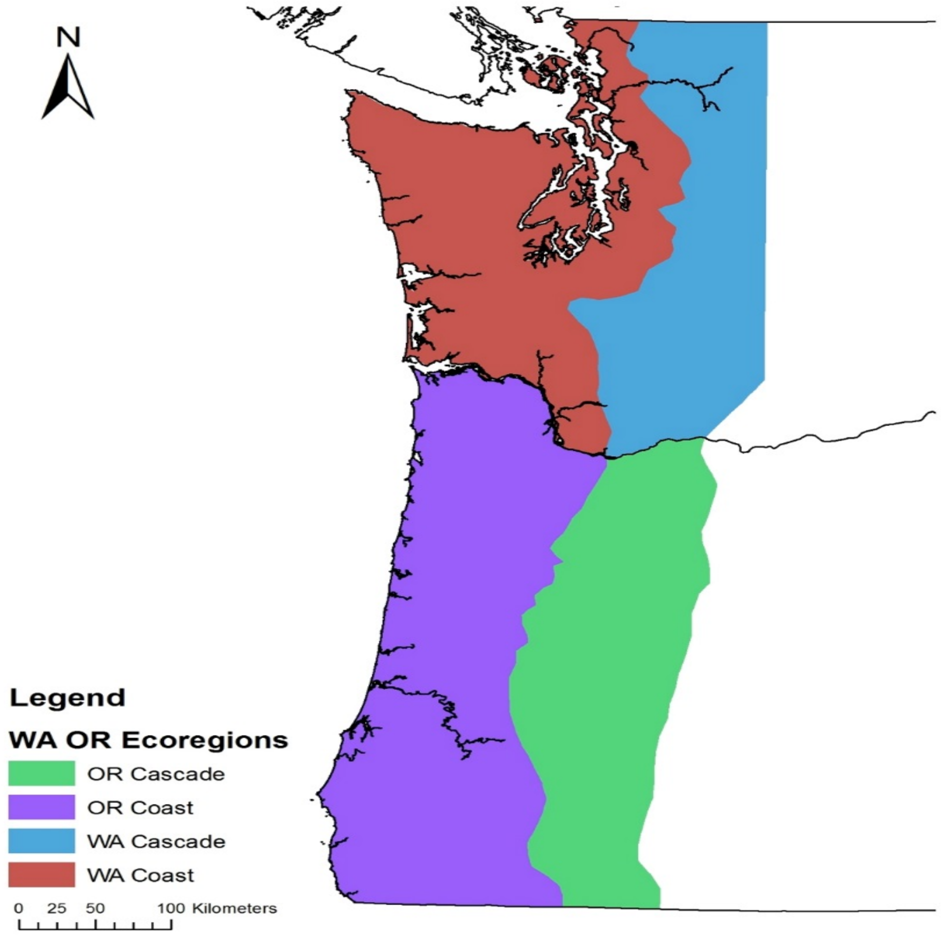
The objectives of this project are:

- Derive a Regional Response Estimate for late-rotation fertilization (the RRE), i.e., an average regional area-based volume response to late-rotation fertilization;
- Provide data for members to determine economic returns of late-rotation fertilization investments;
- if possible w/out compromising goals, to validate site-specific responsiveness predictions of the current model developed from Type V sites

Approach: Stand Criteria (the population)

- a) **Approaching final harvest: 8-10 years before final harvest** with the actual harvest age defined by the land owner. Typically, eligible stands between **approximately 30 and 50 years total age** from planting or ~25 to 45+ years breast height age will be considered. Concomitant with time before harvest, landowners MUST be willing to commit to holding the stand for at least 8 growing seasons after plot establishment and treatment.
- b) **Primarily Douglas-fir**: 75% of the basal area in Douglas-fir with at least 85% of the basal area being conifer,
- c) **Not fertilized** in past 6 years and fertilization history provided to SMC if known.
- d) **PCT'd or commercially thinned OK**
- e) **Uniform Area of 15+ acres**: A stand must have somewhat contiguous portions of area with similar stocking, species mix, and stand conditions, as well as roughly similar soils, aspect (within 120°) and slope, to contain 4 to 5 ~1 acre plots of comparable starting condition. This will likely mean 15-20 ac minimum total area. Use all available GIS and aerial photo information to determine this prior to a field visit.
- f) **Randomly Selected:** Stands shall be chosen by a random selection made from ALL acceptable stands given the above criteria and the selection method described below. The BEST stand in an area should NOT be selected unless by chance

Approach: Regional Strata



- Divided OR and WA into Coastal and Cascade to stratify selection
- Also in BC (not shown)
  - 1) industrial forestland east side of Vancouver Island
  - 2) industrial forestland on the west side of the mainland.

Approach: Stand Selection

- ~20 stands to be selected across OR and WA (more in BC)
  - ~10 in 2016 fall, ~10 in 2017 fall

- Stratified Random Sampling w/ proportional allocation
  - Choose number of stands within geographic zones (strata) proportional to cooperative membership holdings

- Within each strata random points will be generated from coop member land-base.

- Random Lat/Long defines center of a circle equal in area to a township (3.38 miles or 5.44 km diameter)

Approach: Stand Selection

- Coop members within each randomly selected point/circle will be notified and must provide a list of all stands that meet the stand criteria (as described previously).

- Each eligible stand is assigned a random number. Starting with lowest number, stands will receive intense scrutiny in the office re: meeting the stated criteria.

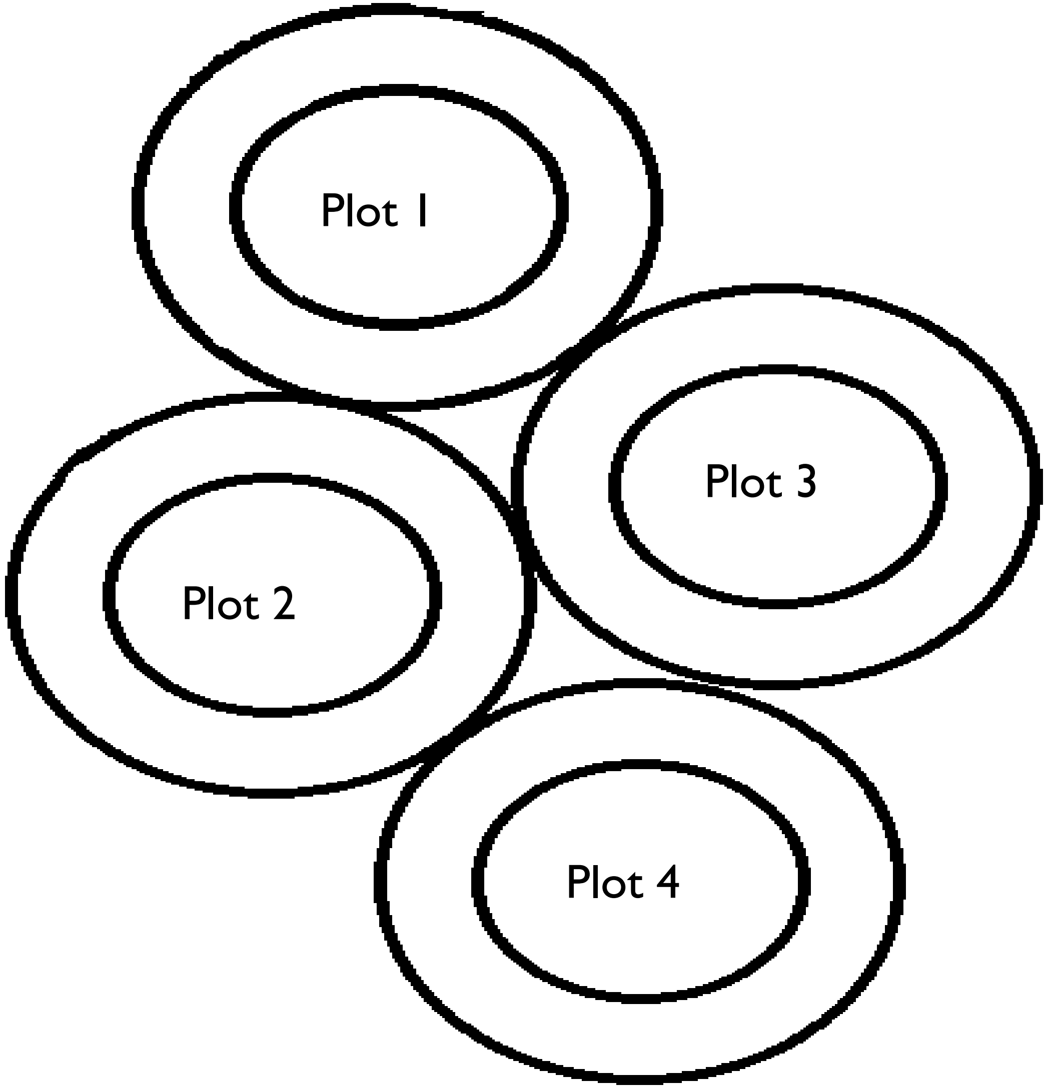
- Field visit will preview stand for eligibility to be included in the study. All adequate stands should be accepted/ attempted, not just the best stands.

Approach: Plot installation – 4 pick 2

- Establish four, initially temporary, circular plots w/ 33 ft. (10 m) buffer.

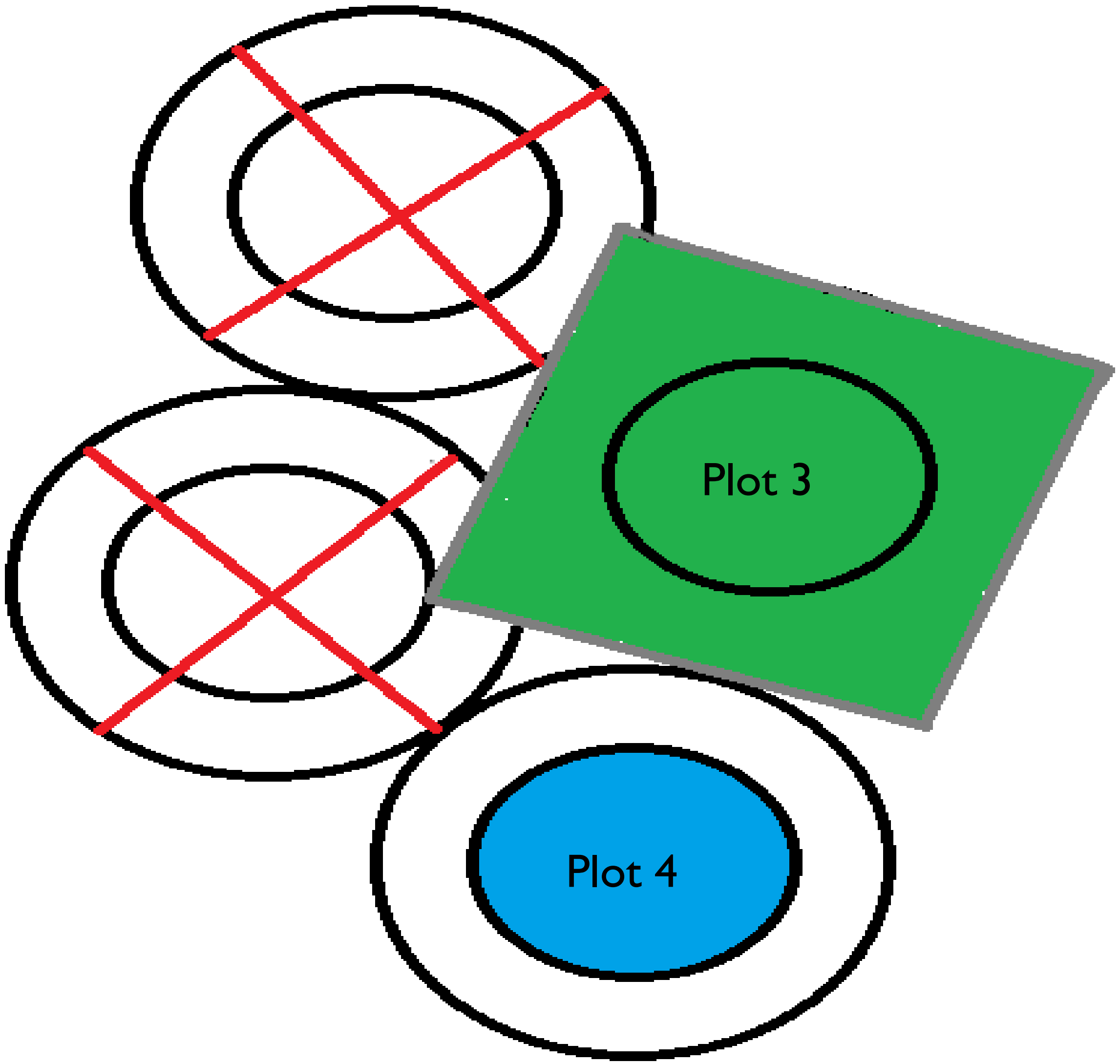
- Choose plot radius to include ~75 to 125 trees per plot.
  - 26m, (0.20ac/0.081ha)
  - 30m, (0.31ac/0.1256ha)
  - 34m, (0.45ac/0.18ha)

- Measure and record:
  - Species,
  - DBH
  - Major damage



Approach: Plot installation – 4 pick 2

- Two most "similar" plots selected for the pair and shall be:
  - ±10% for basal area and
  - ±10% for quadratic mean DBH (QMD)
  - Similar in diameter distribution
  - Similar in species composition and understory
- Install 5th plot if no good matches with 4 plots.
- Drop site if no well matched plots
- Measure and record Heights and Height to live crown on all trees in the selected plots.
- One plot in the pair randomly selected to be fertilized with 200 lb N as urea
  - Square plot for even fertilization



Approach: Soil Sample / Remeasure

- Take 'before and after' soil samples
  - Sample soil down to one meter on all plots, and if not rocky down to 3 or 4 meters

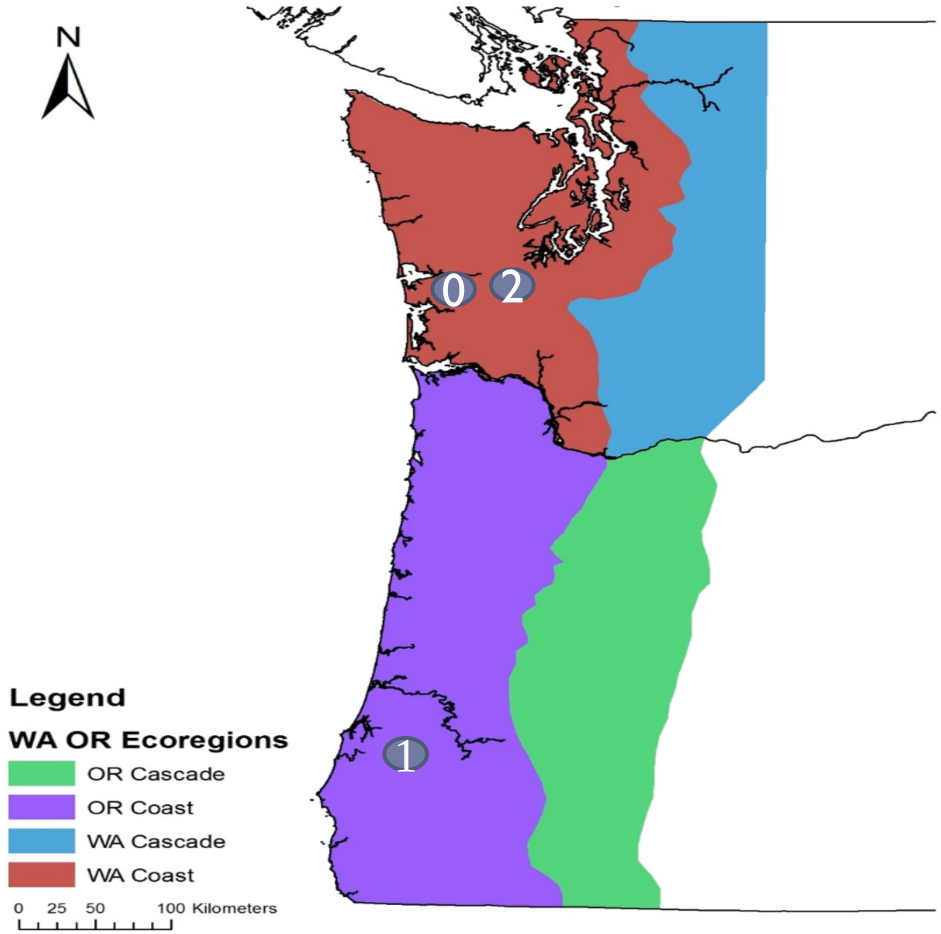
Period	Activity
Winter 2016	Install two "test" installations (Wey.)
Spring 2016	Pick Random points, begin selection
Summer 2016	Establish year 1 plots (8 to 10 sites)
Fall 2016-Winter 2017	Measure and treat year 1 plots
Summer 2017	Establish year 2 plots (10 to 12 sites)
Winter 2017-Spring 2018	Measure and treat year 2 plots
Fall 2018	2-year re-measurement (year 1 plots)
Fall 2019	2-year re-measurement (year 2 plots)
Spring 2020	Interim Report

Continued next page

Timeline: Measurement Schedule

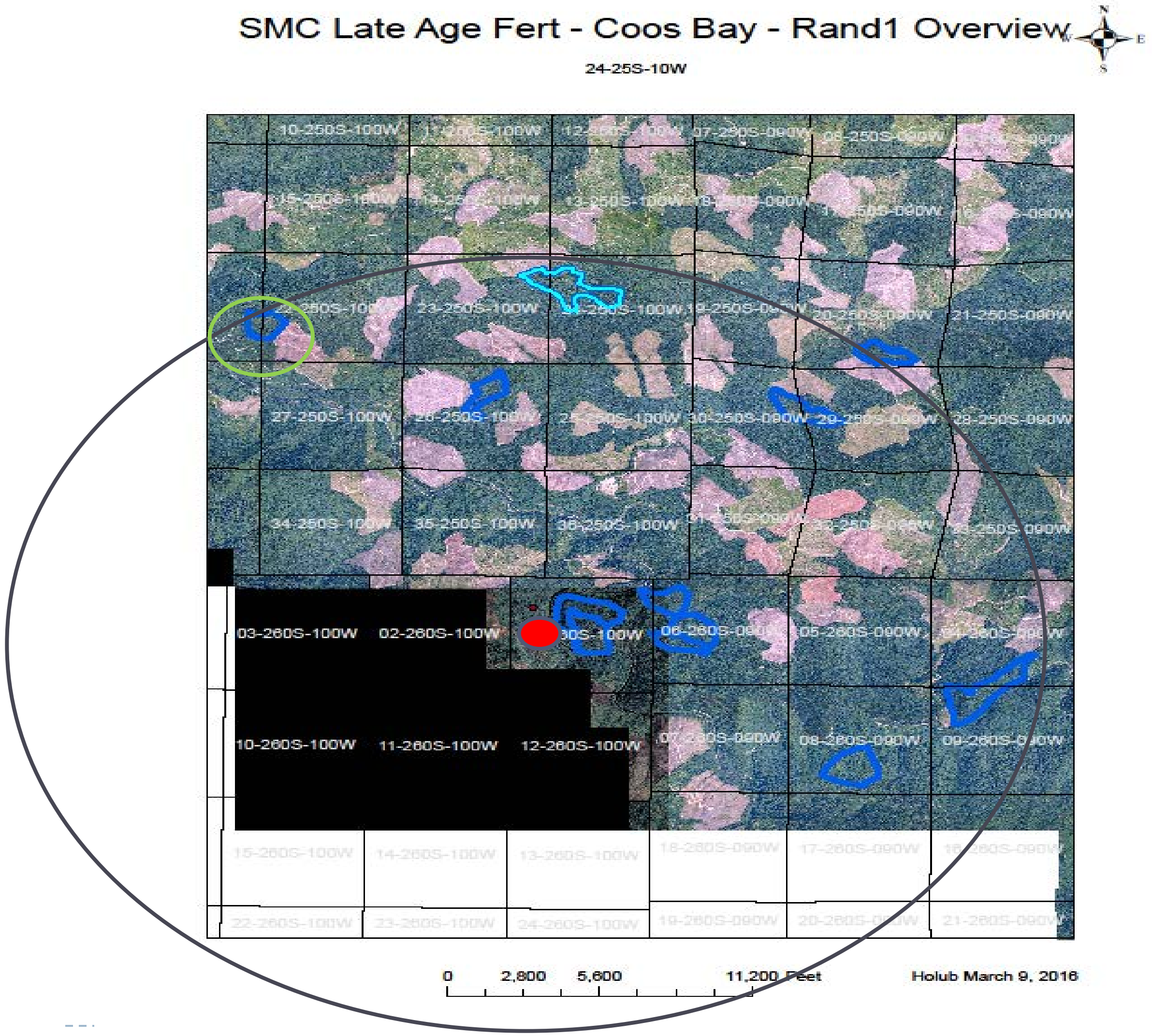
Period	Activity
Fall 2020	4-year re-measurement (year 1 plots)
Fall 2021	4-year re-measurement (year 2 plots)
Spring 2022	Interim Report 2
Fall 2012	6-year re-measurement (year 1 plots)
Fall 2013	6-year re-measurement (year 2 plots)
Spring 2024	Interim Report 3
Fall 2024	8-year re-measurement (year 1 plots)
Fall 2025	8-year re-measurement (year 2 plots)
Spring 2026	Final report

Test installation Summary - Sites

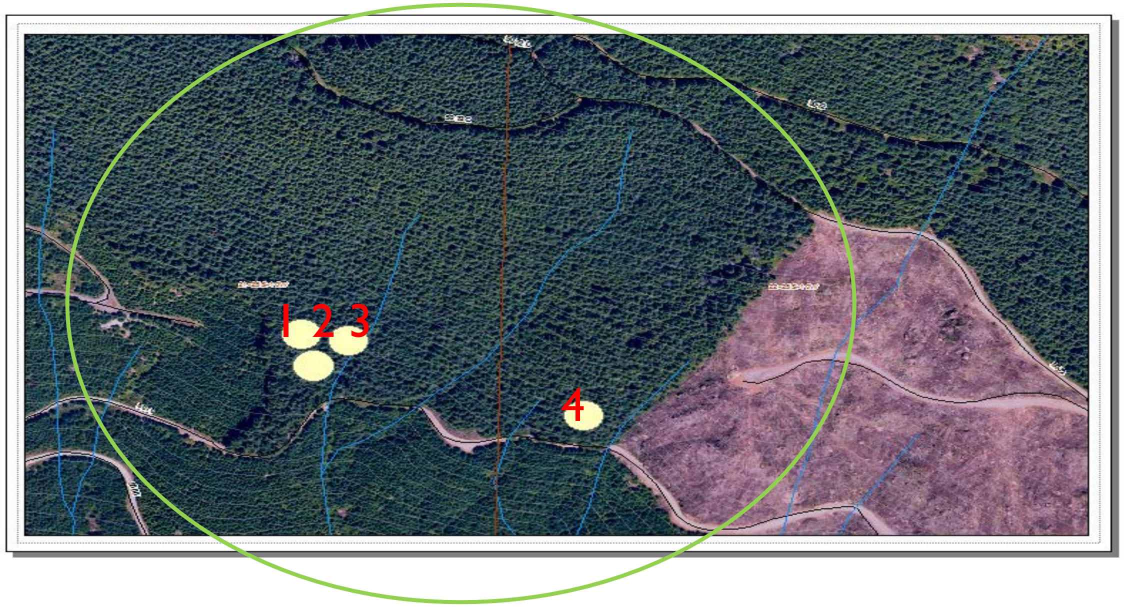


- SMC test installations on Weyerhaeuser ownership
- Random points selected from entire OR/WA ownership of Weyerhaeuser
- Followed described procedure for selected circle, stand criteria, plot installation, etc.
- Random point 0 – dropped
- Random point 1 – Coos Bay, OR
- Random point 2 – Elma, WA

Test installation– Coos Bay



- 7th on the random list of 13 stands that met the criteria.
- 4 plots laid out in uniform area of the unit.
- 30 m radius plots



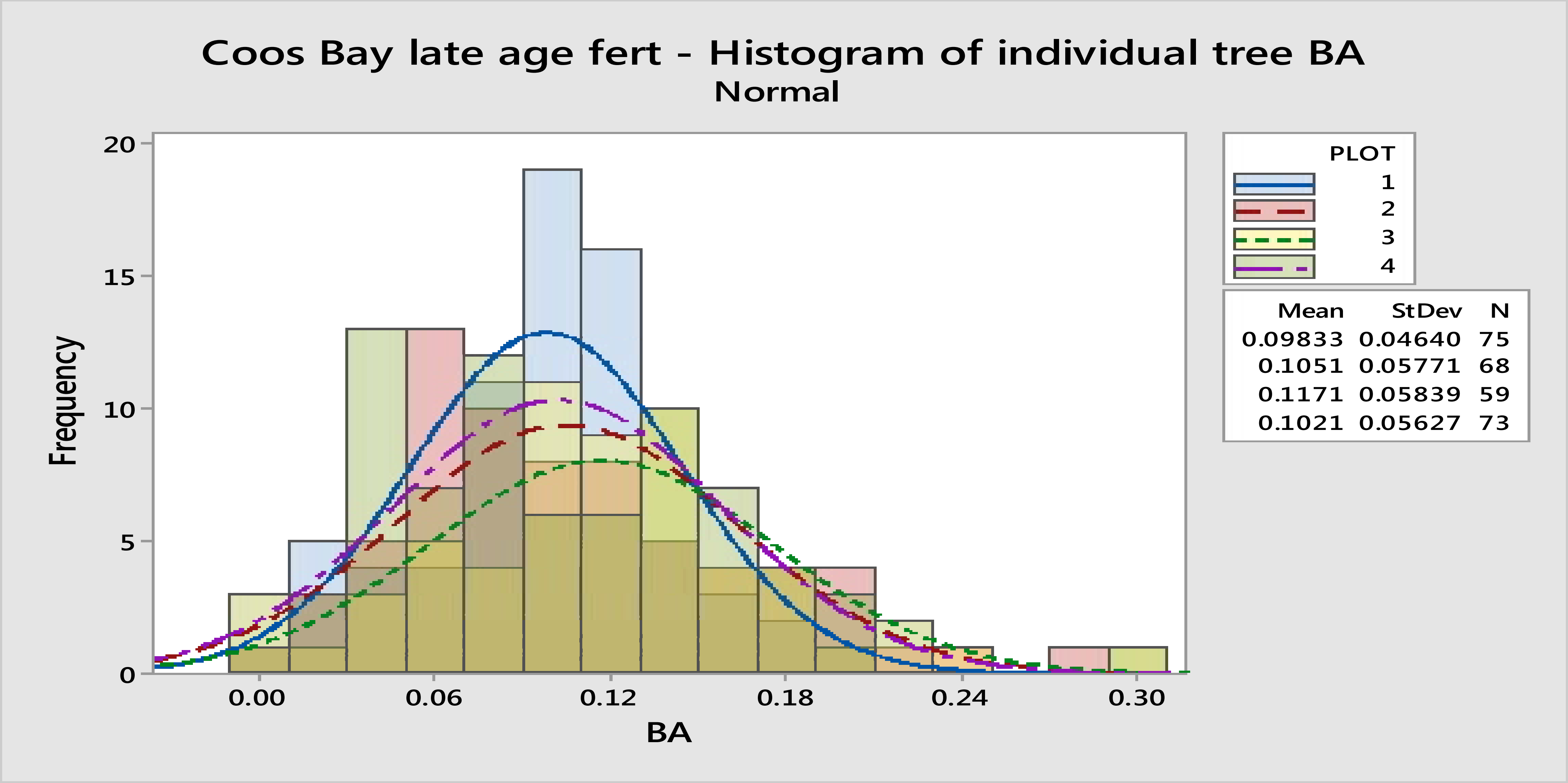
Test installation – Coos Bay

PLOT	Basal Area_DF m2/ha	Basal Area_Total m2/ha	QMD_DF mm	QMD_Total mm	Stems_DF_ha	Stem_Total_ha
1	58	59	367	353	549	629
2	56	57	373	364	510	589
3	50	55	408	372	382	756
4	58	59	374	357	525	701
2vs4%	**3.4**	**4.2**	**0.2**	**-2.0**	**3.0**	**15.9**

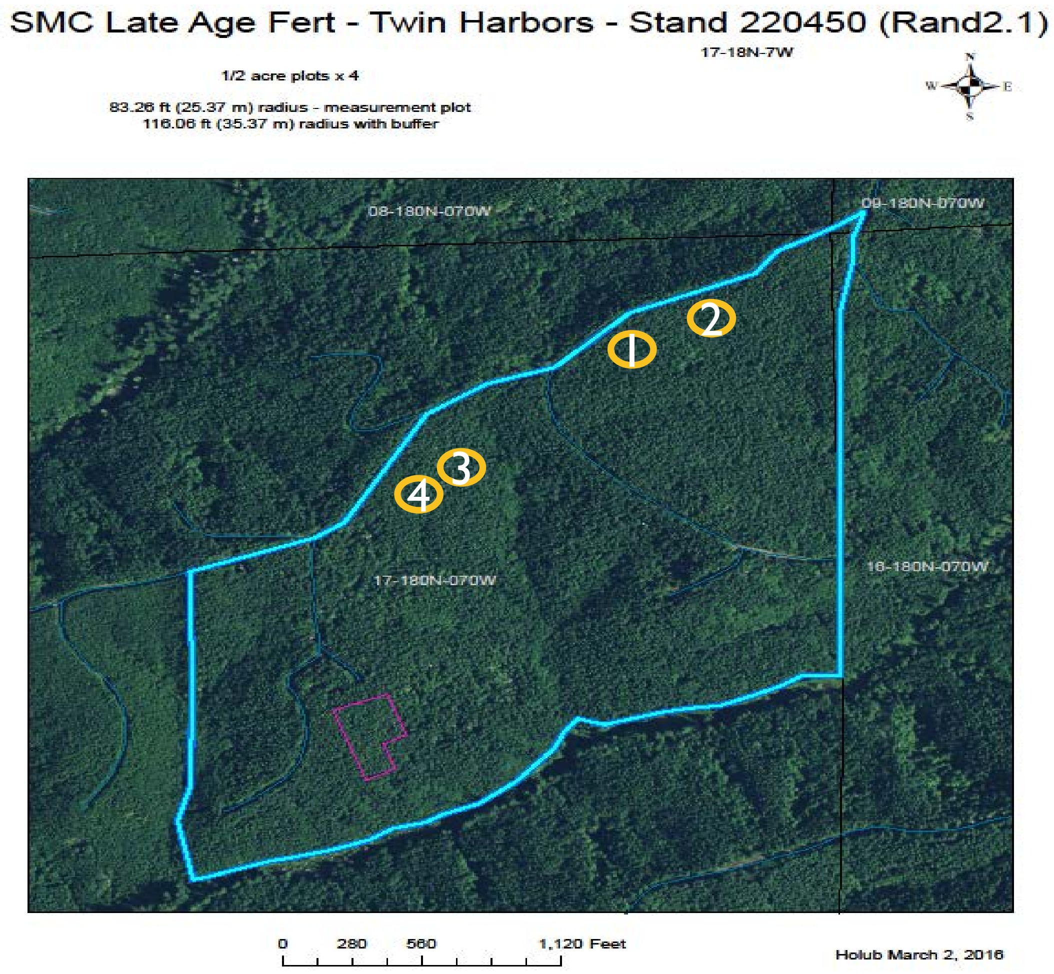
- Stand age: 41
- Douglas fir and Myrtle

- Chose plots 2 and 4 as the most similar
- 1 and 4 were also very close, but stand structure was different, next slide.

Test installation – Coos Bay



Test installation– Elma, WA



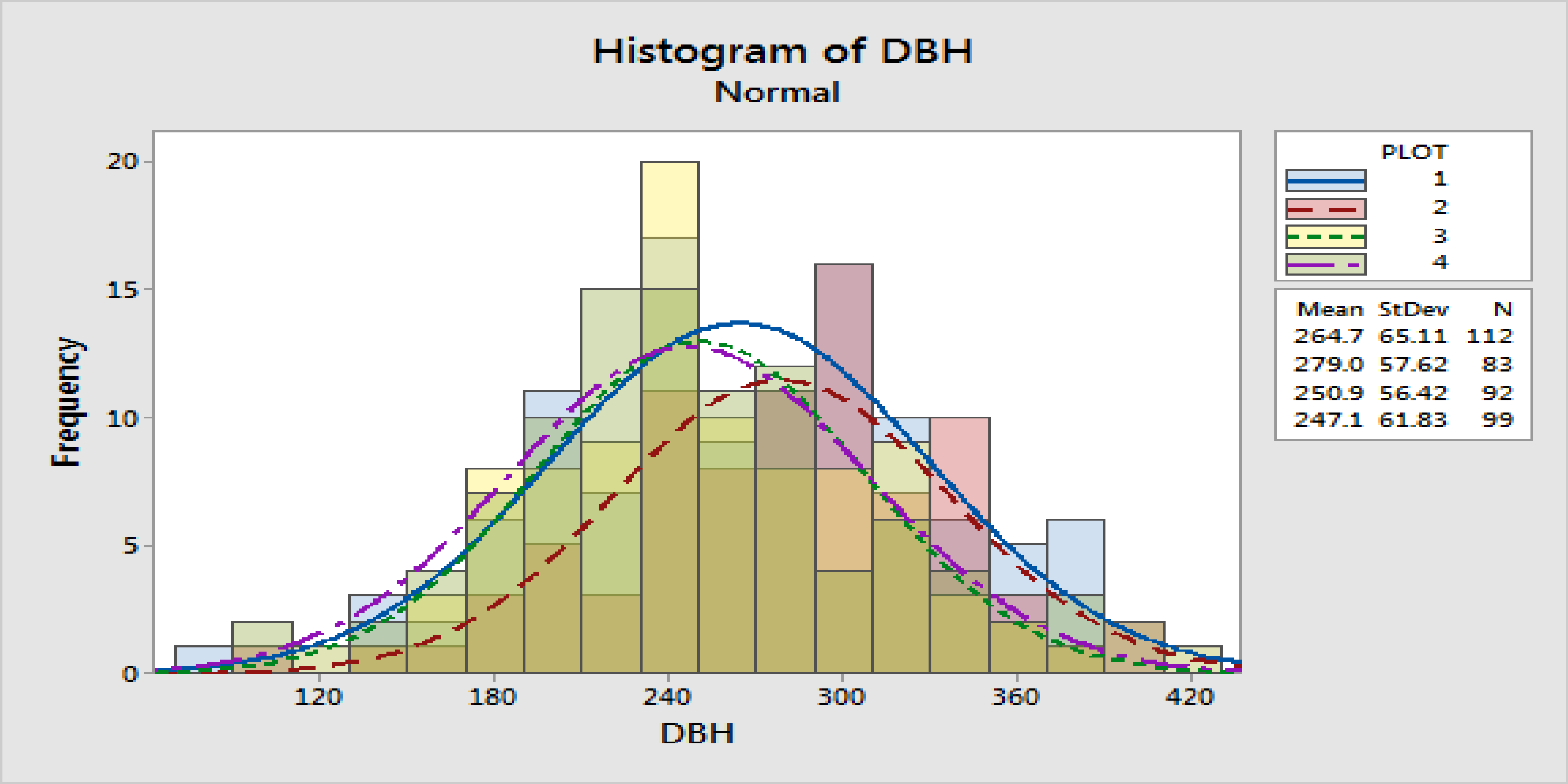
- 1st on the random list of 5 stands that met the criteria.
- 4 plots laid out in uniform area of the unit.
- 30 m radius plots

Test installation – Elma

PLOT	Basal Area_DF m2/ha	Basal Area_Total m2/ha	QMD_DF mm	QMD_Total mm	Stems_DF_ha	Stem_Total_ha
1	50.9	52.0	279	273	835	891
2	40.6	42.1	287	285	629	660
3	36.9	38.0	259	257	700	732
4	39.7	40.1	256	255	772	788
3vs4%	**7.1**	**5.2**	**-1.2**	**-0.8**	**9.3**	**7.1**

- Stand age: 29 years
- Douglas-fir and western hemlock
- Chose plots 3 and 4 as the most similar

Test installation – Elma



Budget: Late-Rotation Fertilization

	Per stand time and cost estimates[&]		
Task	Time	Who	Cost
Locate suitable stand	1 day	SMC crew (1 pers)	$400
Establish plots (4 / stand)	1 day	SMC crew	$1200
Measure & Apply Fertilizer	1 day	SMC crew	$1200
Total for 10 plots (1st year)	~ 30 days		$28,000
Travel time	~ 10 days		

[&] Assumed: SMC crew will perform tasks using 40-day 'extra capacity' over next four years (equivalent to ~ $1,200/day: includes vehicle, mileage, petroleum products, salary, benefits, per diem, lodging, misc. supplies & materials) Travel time is accounted for separately.

Approach: Late-Rotation Fertilization

- Definition of "Similar"
  - +/- 5% in BA; +/- 10% in TPA originally proposed
  - Examining Type II establishment measurements showed:

IID	mean, <10%		min, <10%		min, <=	
	5 plots	4 plots	5 plots	4 plots	5 plots	4 plots
801	3	1.8	1	0.6	1	0.6
802	2	1.2	1	0.6	1	0.6
804	4	2.4	3	2	4	2.4
805	6	3.6	3	1.8	3	1.8
806	5	3	1	0.6	1	0.6
807	4	2.4	3	1.8	3	1.8
808	1	0.6	0	0	0	0
809	1	0.6	1	0.6	1	0.6
810	6	3.6	2	1.2	2	1.2
811	6	3.6	2	1.2	2	1.2
812	1	0.6	1	0.6	1	0.6

Thank You For Your Support

SMC Faculty, Staff and Students

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