Douglas-fir nutrition: Summary of results from the Regional Forest Nutrition Research Project and Stand Management Cooperative

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University of Washington.

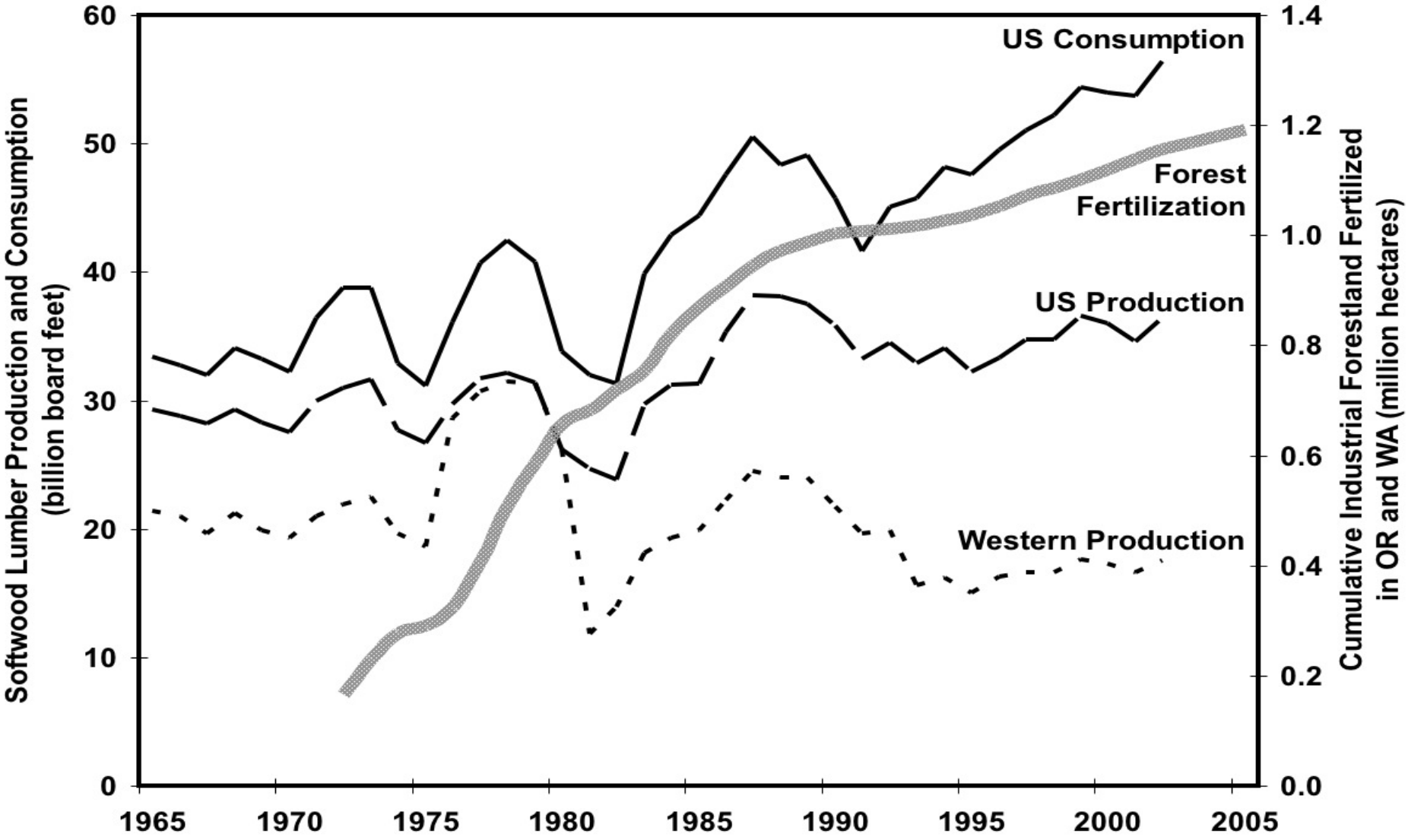
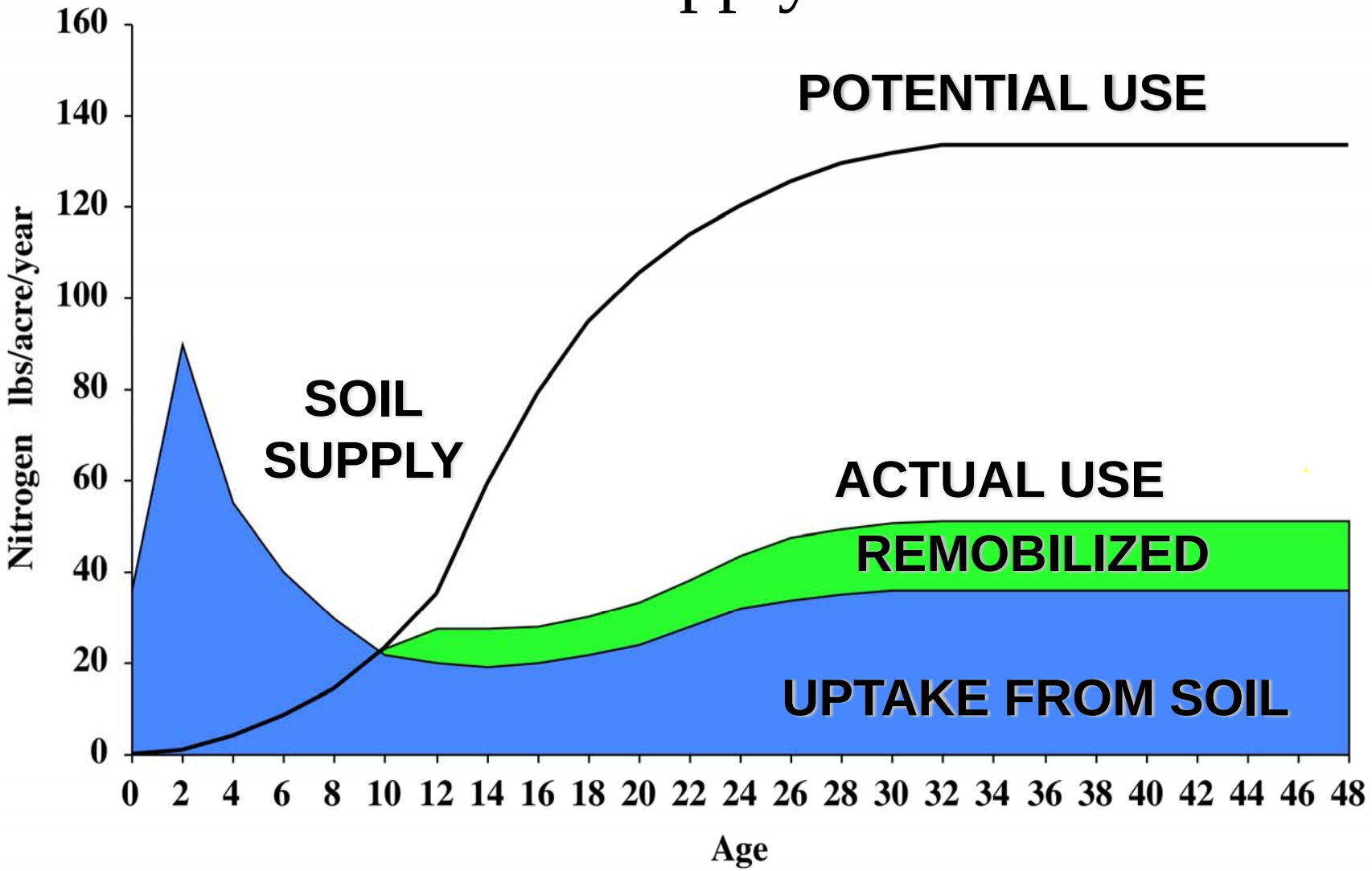


Table 1 US Timber trends. Data from: Howard, James L. 2003. U.S. timber production, trade, consumption, and price statistics 1965 to 2002. Res. Pap. FPL-RP-615. Madison, WI: U.S. Department of

Nutrient Supply and Use



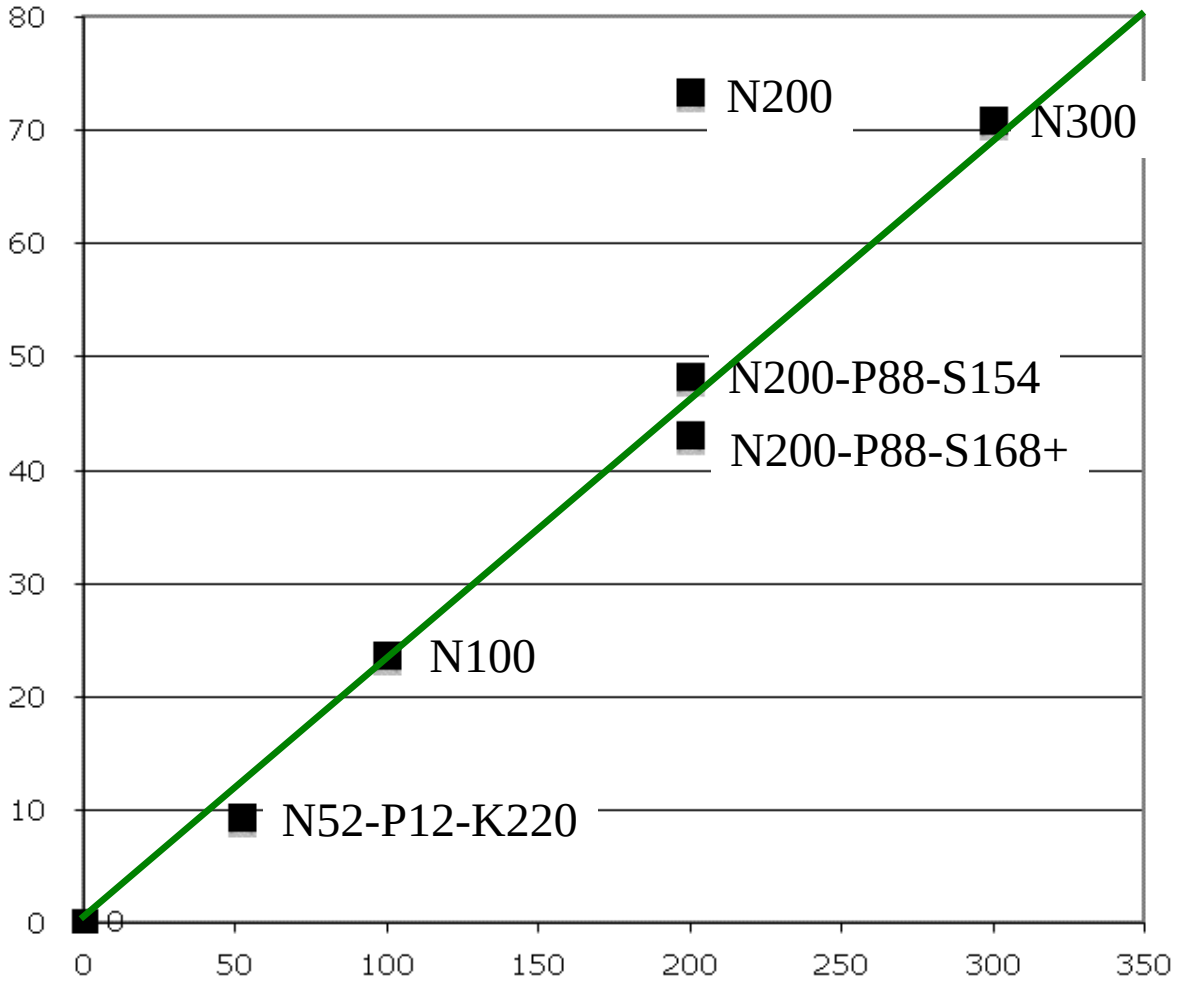
Source: Forest Nutrition Cooperatie

Results:
Pre-RFNRP
1950’s through 1960’s

Shelton-Carson Lake study. Each treatment 2 reps

Measure	Initial (1958)	Final (1965)	Increment	Percent	Rel to Control
	cubic feet			%	%
Control	4,512	5,706	1,194	25	0
N52-P12-K220	3,775	4,795	1,020	27	9
N100	4,921	6,455	1,534	31	24
N200	3,804	5,420	1,616	43	73
N200-P88-S154	3,316	4,324	1,008	37	48
N200-P88-S168+	4,054	5,503	1,450	36	43
N300	4,509	6,459	1,950	43	71

Percent volume response

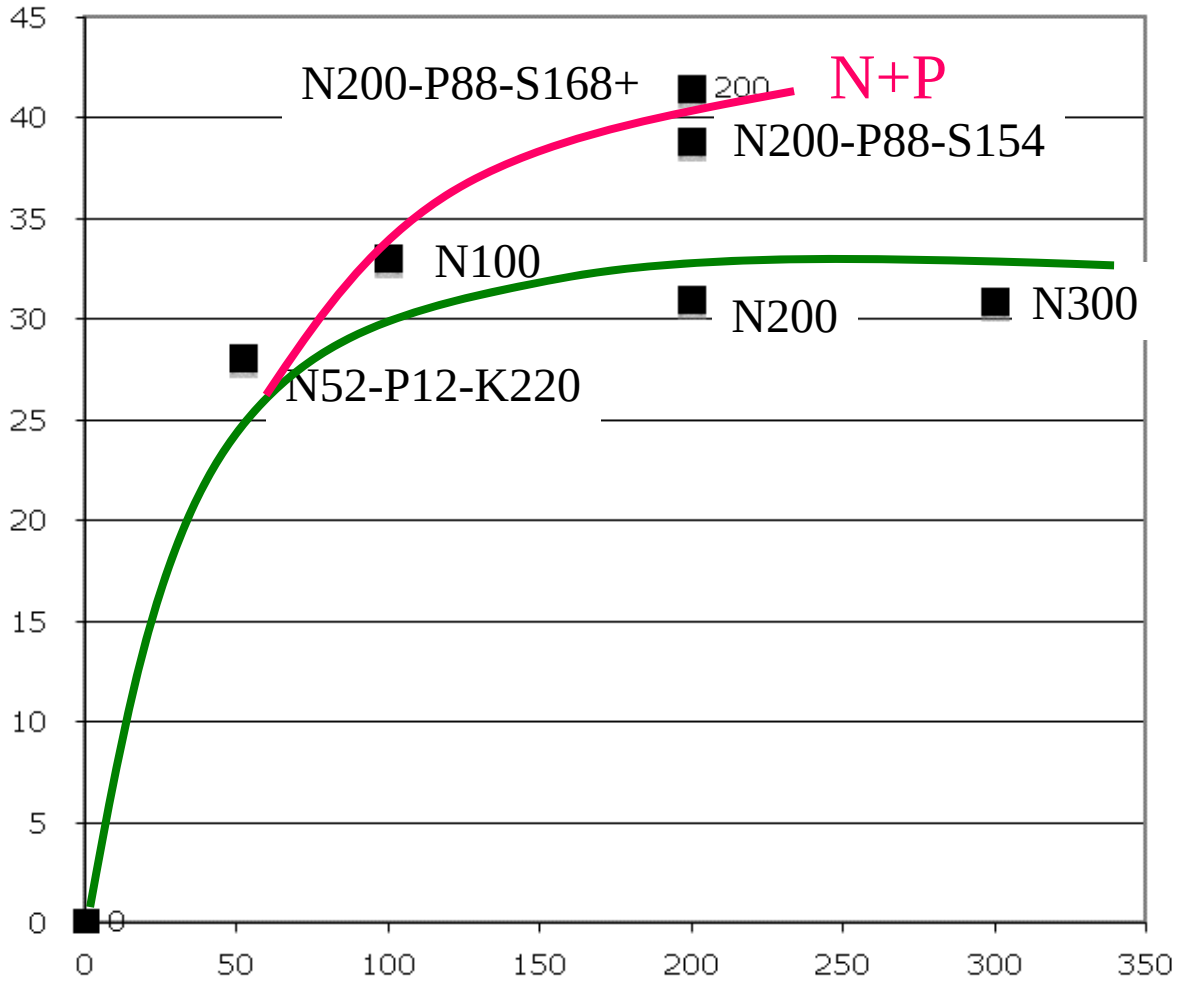


N rate (lb N/acre)

Shelton-Matlock study. Each treatment 2 reps

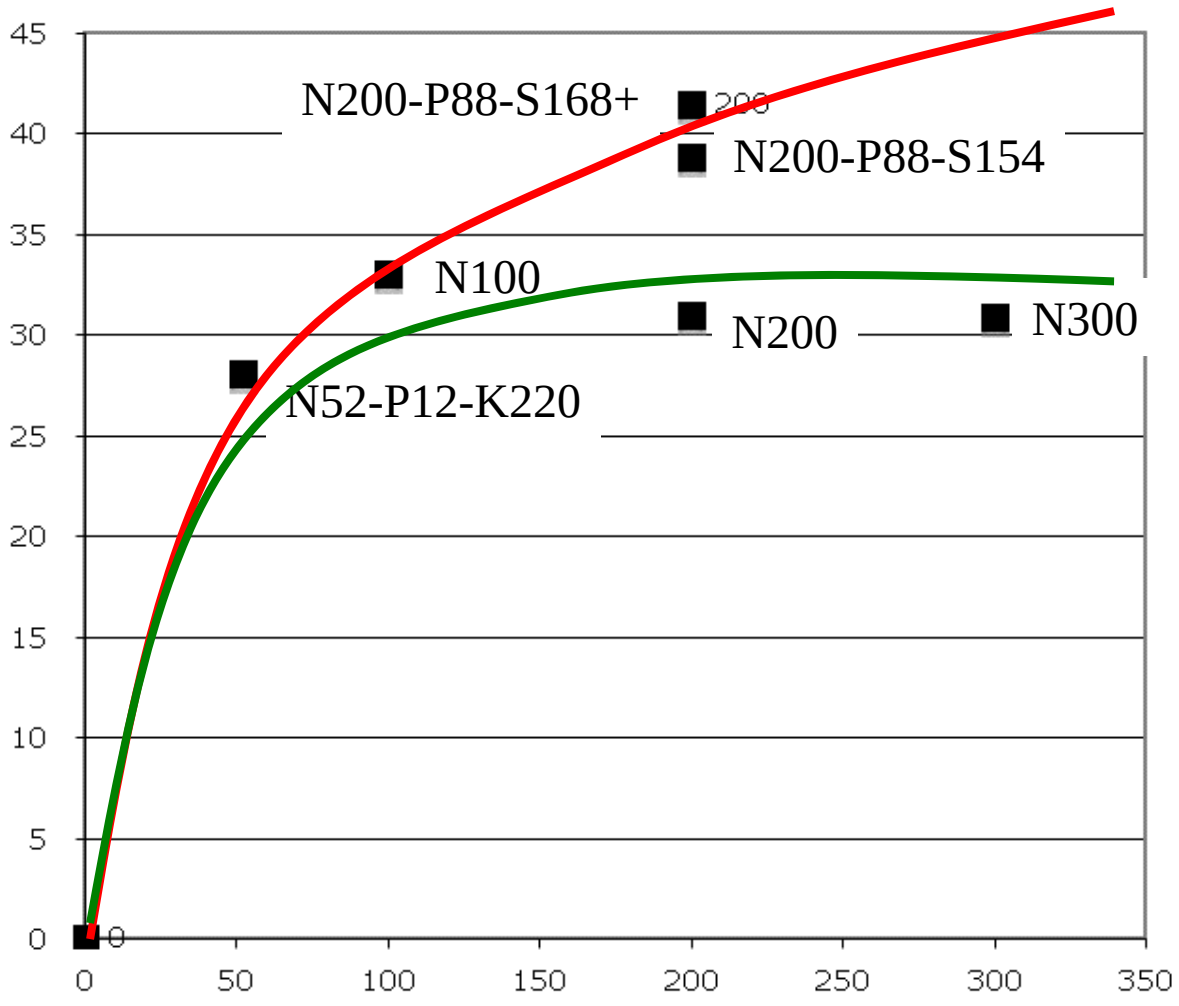
Measure	Initial (1958)	Final (1965)	Increment	Percent	Rel to Control
	cubic feet			%	%
Control	4013.3	5759.8	1746.5	44.0	0
N52-P12-K220	3027.5	4749.5	1722.0	56.4	28
N100	3197.0	5069.0	1872.0	58.6	33
N200	3679.0	5802.5	2123.5	57.7	31
N200-P88-S154	3263.5	5277.0	2013.5	61.1	39
N200-P88-S168+	3220.5	5231.5	2011.0	62.3	41
N300	3340.0	5272.0	1932.0	57.6	31

Percent volume response

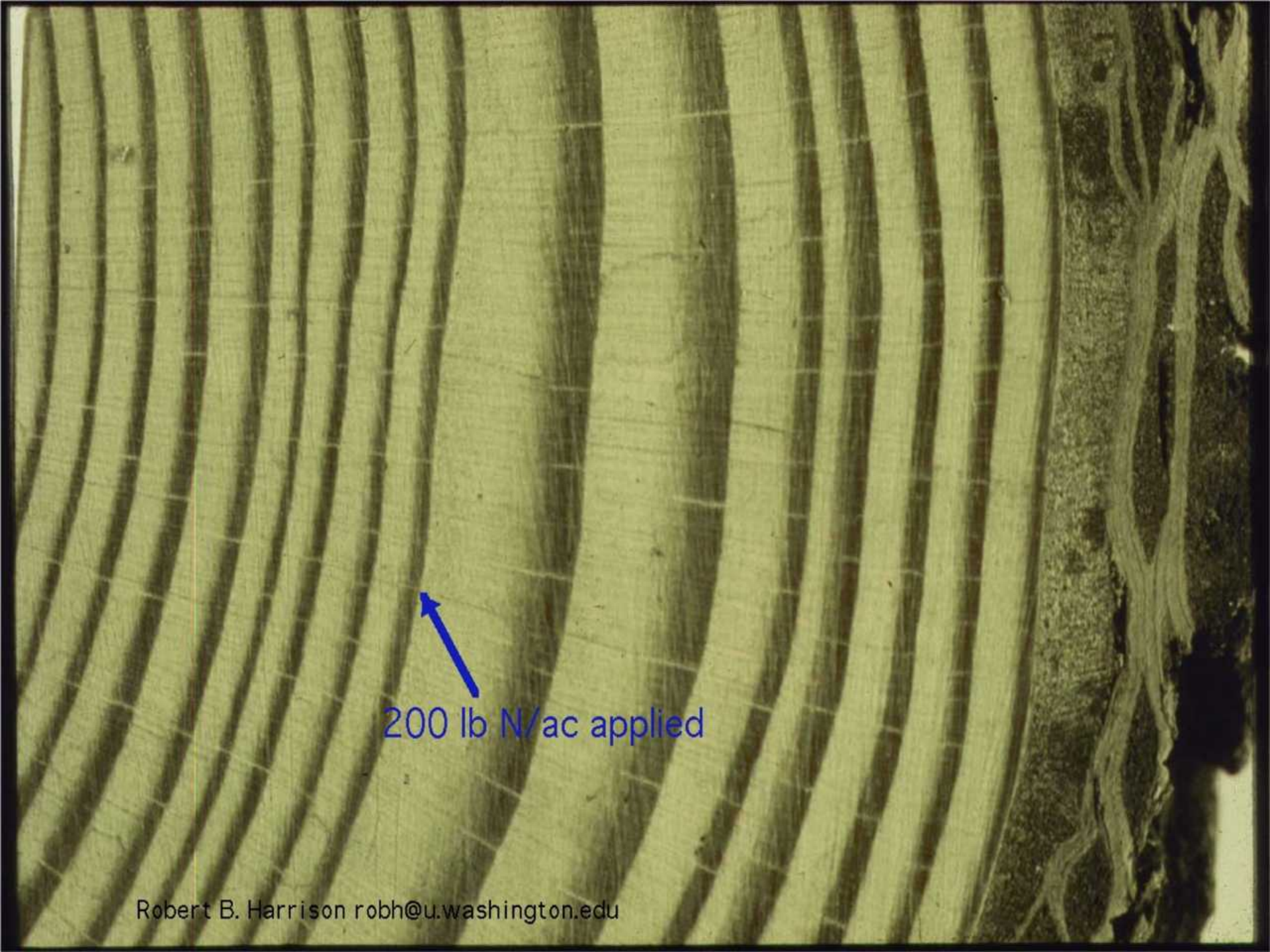


N rate (lb N/acre)

Percent volume response



N rate (lb N/acre)



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Results of other studies

1) Hodge-podge of nutrients other than nitrogen makes conclusions difficult. Several studies indicate results similar to the 2nd above, and many indicate the central role of N.

2) Clearly, both response to N and other nutrients is site controlled. Indicates need for larger scale studies on a wide variety of sites to pin response to site variables.

Conclusions of early studies

1) “Nitrogen application evoked a growth response throughout a range of growing conditions. Magnitude of response is related to amount of nitrogen applied and response is still evident in 1975 from a 1962 application”.

2) “Apparent response to the application of other elements is quite variable and no consistent picture emerges. There is no evidence of an economic response to the other elements”.

RFNRP
1969-pres.

Installations of the PNW Stand Management Cooperative

Stand Management Cooperative
SILVICULTURE ■ NUTRITION
WOOD QUALITY ■ MODELING

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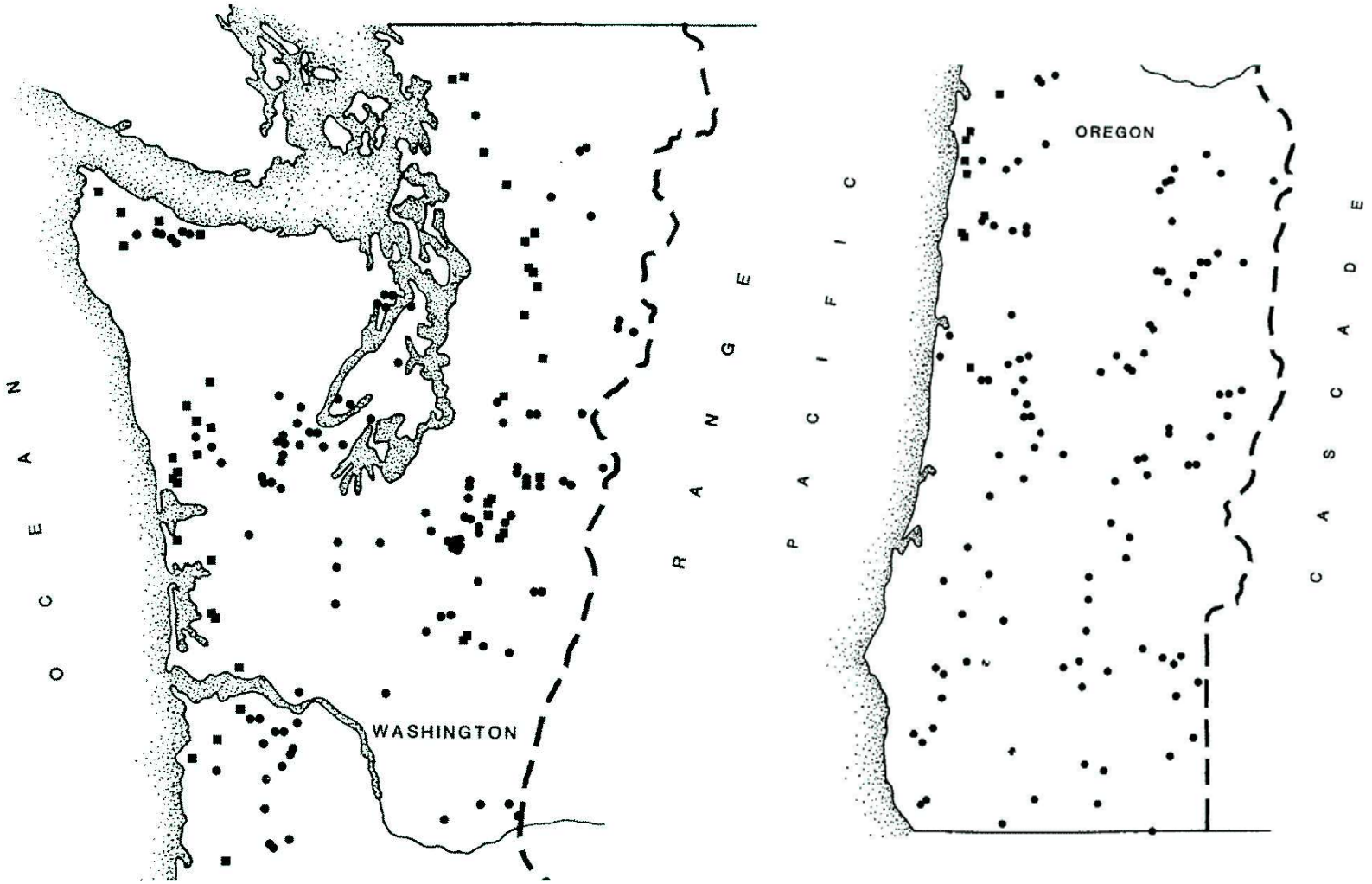
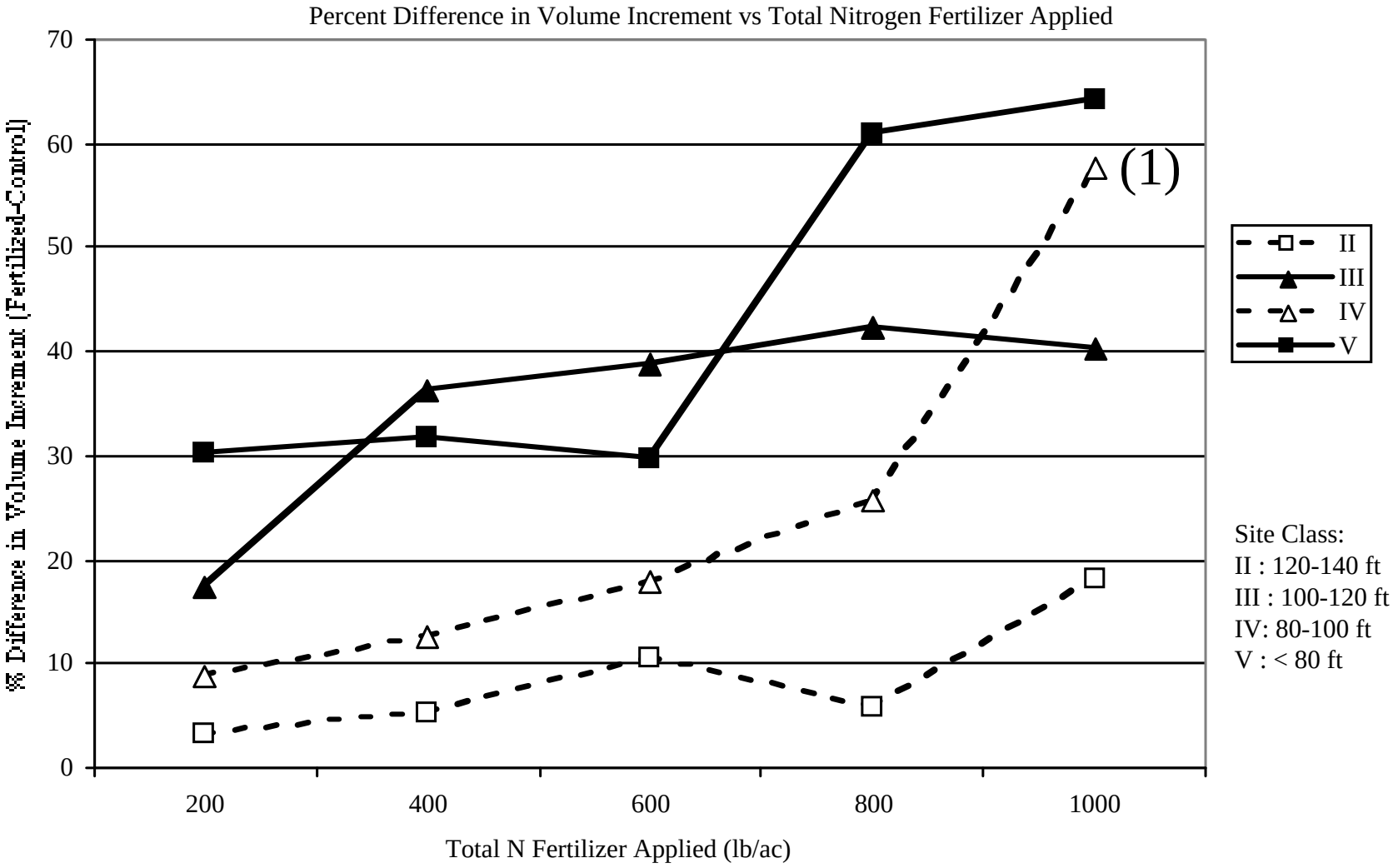


RFNRP Installations

- **Phase I Unthinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1969/70
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase II Thinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1971/72
  - up to 4 fertilization treatments
  - 20 years growth remeasurements

RFNRP Installations

- **Phase III Young, Thinned Plantations**
  - Douglas-fir & western hemlock
  - established in 1975
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase IV PCT Plantations**
  - Douglas-fir & western hemlock
  - established in 1980
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase V Single Tree Screening Trials**
  - young noble fir & pacific silver fir
  - established in 1986/88
  - one fertilizer application
  - 6 years growth remeasurements



Overall results of SMC studies Response vs. N rate. Sidell thesis.

Table 2. Pilchuck Tree Farm study established 1994, measured through 2002 (8 y growth). Each treatment is replicated 6 times (two each installation).

Measure	Control	N200	N200-P200	Control	N200	N200-P200	Control	N200	N200-P200
	initial			relative to control			change		
QMD (in)	8.06	7.83	7.65	100.0	97.1	94.9	2.26	2.26	2.58
Volume (ft3/ac)	2485	2664	2184	100.0	107.2	87.9	3167	3256	3068
BA (ft2/ac)	104.7	110.9	94.6	100.0	105.9	90.3	65.0	72.2	64.7
HT40 (ft)	56.0	56.0	55.9	100.0	100.0	99.8	28.1	28.5	27.7

Table 2. Pilchuck Tree Farm study established 1994, measured through 2002 (8 y growth). Each treatment is replicated 6 times (two each installation).

Measure	Control	N200	N200-P200	Control	N200	N200-P200	Con. vs. N200	Con. vs. N200-P200
	------ percent change ------			----- relative percent -----			--- probability ---	
QMD (in)	31	34	38	0	2	6	0.178	0.078
Volume (ft3/ac)	166	187	185	0	21	19	0.164	0.143
BA (ft2/ac)	67	79	75	0	12	8	0.152	0.227
HT40 (ft)	55	59	56	0	4	1	0.255	0.406

Table 1. Oregon Dept. Forestry study established 1995, measured through 1999 (4 y growth). Each treatment is replicated 6 times (two each installation).

Measure	Control	N200	Complete750	Control	N200	Complete750	Control	N200	Complete750
	initial			relative to control			change		
QMD (in)	7.35	7.28	7.02	100.0	99.1	95.5	2.47	2.46	2.66
Volume (ft3/ac)	1136	1055	998	100.0	92.9	87.9	1499	1428	1493
BA (ft2/ac)	67.7	63.5	60.6	100.0	93.8	89.5	51.3	49.1	54.4
HT40 (ft)	42.7	42.9	42.2	100.0	100.5	98.9	13.2	14.2	14.4

Table 1. Oregon Dept. Forestry study established 1995, measured through 1999 (4 y growth). Each treatment is replicated 6 times (two each installation).

Measure	Control	N200	Complete750	Control	N200	Complete750	Con. vs. N200	Con. vs. Complete
	percent change			relative percent			probability	
QMD (in)	34	34	38	0	0	5	0.424	0.039
Volume (ft3/ac)	134	138	152	0	3	17	0.370	0.079
BA (ft2/ac)	76	80	91	0	4	15	0.253	0.011
HT40 (ft)	31	33	35	0	2	3	0.408	0.243

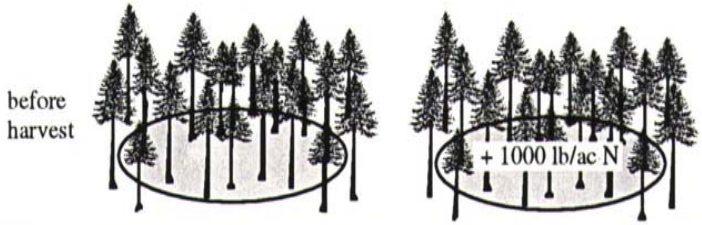


Figure 1. Douglas-fir stands at beginning of the study.

Figure 2. Stands after harvesting and slash distribution.

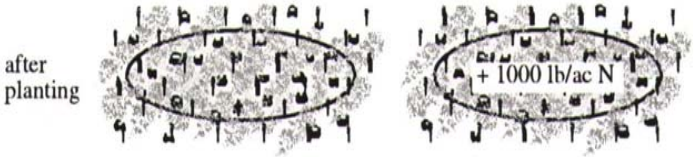


Figure 3. Stands following planting with identical stock.

Figure 4. Growth of young stands, with possible differentiation.

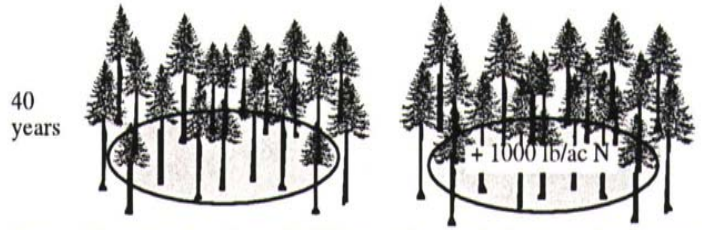


Figure 5. After 40 years. Possibility of studying subsequent rotations.

SMC carryover study results 5-7 years of growth

Install.	Name	App. Rate	yr since planting	Vol-ind Control	Vol-ind +N	% Vol-ind Difference
		- lbN/ac-	— y —	—— index only ——		— % —
17	Little Ohop Creek	1000	5	5.12	7.35	16
53	Camp Grisdale	1000	5	2.12	2.61	10
53	Camp Grisdale	400	5	2.12	2.15	16
134	Pack Forest	1000	7	3.36	6.24	22
156	Coyle	1000	5	2.79	5.05	17
167	Hanks Lake	1000	6	1.58	3.40	11
167	Hanks Lake	400	6	1.58	4.03	25
168	Simpson Log Yard	1000	6	1.75	2.69	8
168	Simpson Log Yard	800	6	1.75	2.37	11
168	Simpson Log Yard	200	6	1.75	1.32	-1
177	Pack Forest Lookout	1000	6	2.70	2.50	13
177	Pack Forest Lookout	800	6	2.70	3.98	28
					Average	**15**
					prob =	**0.0017**

Volume index is not an actual volume, as it is calculated as diameter squared times the height…thus it is useful for comparison only.

Results of RFNRP studies

1) N response averaging 20% (unthinned) -30% (thinned) with 400 kgN, highly site dependent.

2) Clearly, both response to N and other nutrients is site controlled. Indicates need for larger scale studies on a wide variety of sites to pin response to site variables.

3) Effects of N fertilization appear to be very long-lived.

SMC (1991+)

No multi-element additions. SMC Type II, III and IV no fertilizer work at all

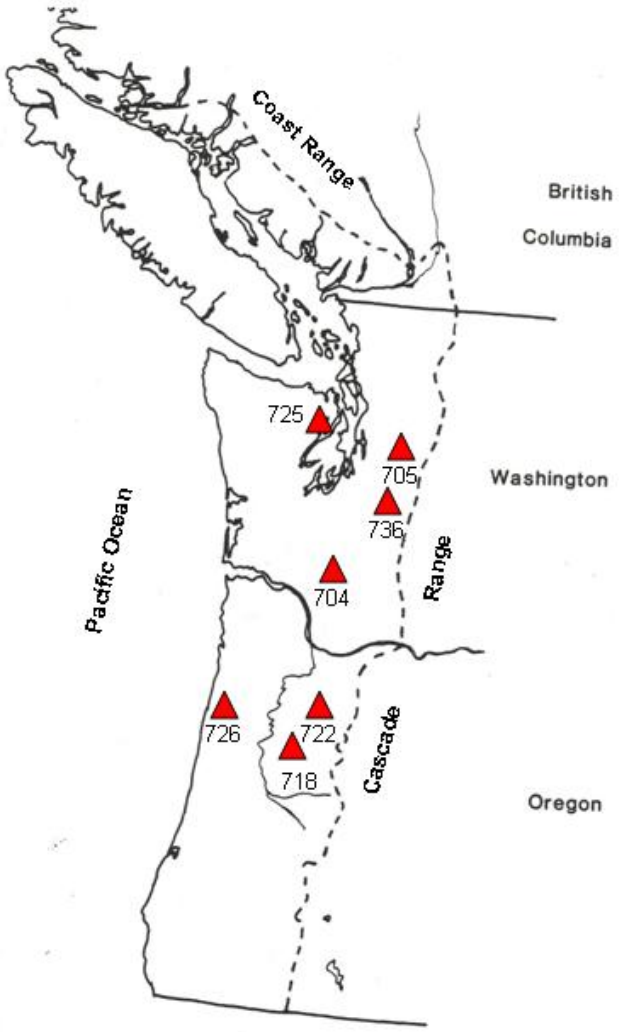
SMC Type I Installations
-plantations with initial stocking 300-680 spa
-Respace (PCT) before onset of competition

-7 core treatments (basic 7)
ISPA, ISPA/2, ISPA/4,
ISPA and ISPA/2 min thin
ISPA repeated thin
ISPA heavy thin

2-8 plots for other work, including fertilization

Eric Sucre did his M.S. on 7 fertilized sites

Location of SMC Type 1 Fertilized Research Installations



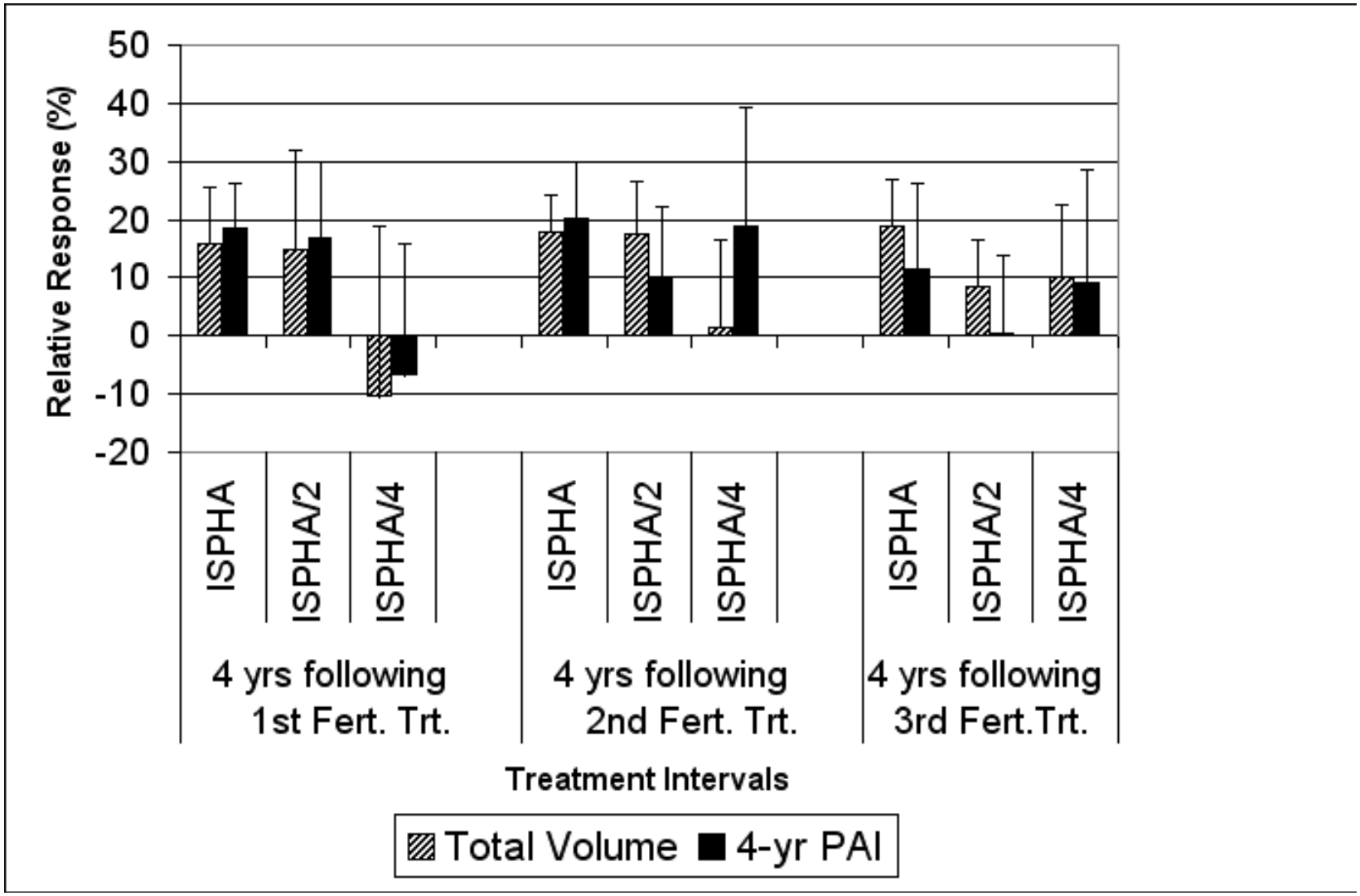
Site Descriptives

	Ostrander Rd (704)	East Twin Creek (705)	Roaring River (718)	Silver Creek (722)	Sandy Shore (725)	Toledo (726)	Twin Peaks (736)
Latitude	46°12'47.46"	47°10'35.97"	44°39'10.8"	44°52'27"	47°53'49.09"	44°41'29.99"	47°56'53.05"
Longitude	122°50'48.91"	121°43'4.22"	122°42'15.6"	122°33'57.6"	122°46'25.22"	123°56'34.4"	124°27'22.75"
Elevation (m)	183	823	335	671	168	18	183
Average Slope	20%	30%	10%	10%	0%	15%	40%
Precipitation (mm yr^{1})	1175	1449	1778	1190	751	1726	1552
USDA Soil Suborder	Palehumult	Dystroxerept	Palehumult	Dystrudept	Dystroxerept	Dystrudept	Durothod
Soil Texture	Fine-loamy	Loamy-skelatal	Fine	Fine-loamy	Sandy-Skeletal	Fine-loamy	Sandy-Skeletal
Stand establishment	1976	1976	1982	1982	1980	1984	1984
SI 50 (before treatment, m)	37	27	39	37	37	41	37

Soil & Site Properties Examined

- Climatic data
- Elevation
- % Slope
- Relative Density (RD)
- Quadratic Mean Diameter (QMD)
- Site Index (SI)
- bulk density (Db)
- pH
- C:N ratio
- cation exchange capacity (CEC)*
- Inorganic nitrogen (NO_3^- and NH_4^+)*

*Mineral Soil only



Total volume and 4-year PAI relative response for each treatment regime at the respected treatment intervals (224 kg ha^{-1} of N as urea every 4 years). Standard errors are shown.

Dependent Variable	N	Equation	Adj-R^2
All DMR's			
Total Volume	42	$-634.1 + 22.396RD + 7.00QMD$	0.592
		$61.8952pH_{30\text{-}50cm} + 0.00108C_{0\text{-}15cm} - 0.027PPT$	
4-yr PAI	42	$-13.59 + 0.08135NW_{FF}$	0.091
ISPHA			
Total Volume	14	$-398.96 + 54.43RD + 4.852CN_{FF} - 4.98CN_{0\text{-}15cm}$	0.722
	14	$164.541 - 7.566CN_{0\text{-}15cm}$	0.456
4-yr PAI	14	$-57.066 + 3.6397NH_{4(15\text{-}30cm)}$	0.622†
	14	$-37.339 + 2.824NH_{4(30\text{-}50cm)}$	0.368
ISPHA/2			
Total Volume	14	$-238.22 + 41.24RD$	0.712†
4-yr PAI	14	$-144.39 + 34.397pH_{15\text{-}30cm} - 9.973\%C_{30\text{-}50cm}$	0.666
ISPHA/4			
Total Volume	14	$-197.94 + 50.897RD + 12.29\%C_{0\text{-}15cm}$	0.882
		$- 3.68NH_{4(30\text{-}50cm)} - 0.041ELEV$	
4-yr PAI	14	$56.801RD - 5.56QMD + 77.51\%N_{15\text{-}30cm} + 0.002CW_{FF}$	0.881

† Strongest single indepent variables shown in Fig. 3

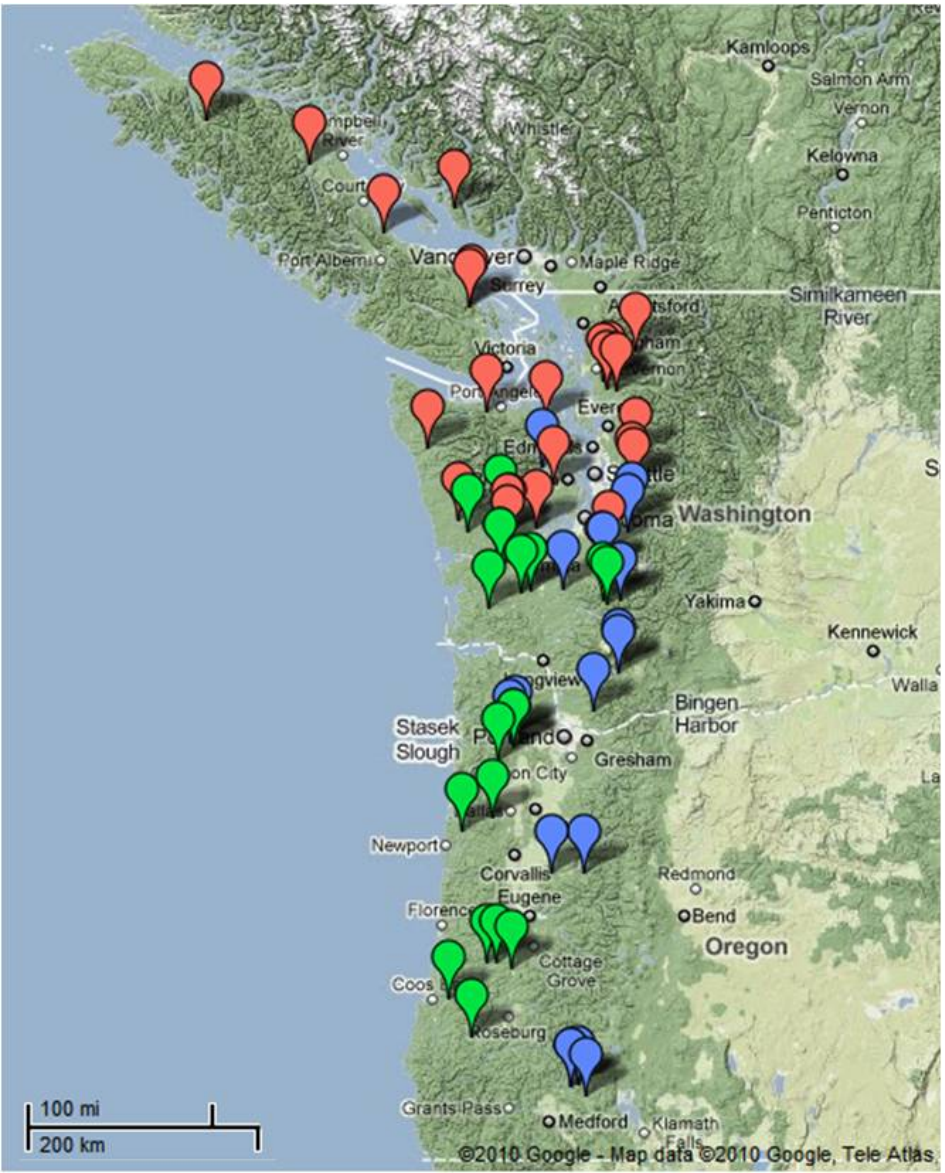
Multiple regression equations for the relationships between the unstandardized residuals of total volume (m^3 ha^{-1}) and 4-year PAI (m^3 ha^{-1} yr^{-1}) response to 224 kg N ha^{-1} as urea (dependent variables) and various soil, site and stand variables (independent variables).

Results of SMC studies

too few sites (7) for broad generalizations

1) Response to N is site and stand controlled. Indicates need to couple fertilization with other silvicultural treatments, particularly stocking, and use RD or other stand properties to drive time of fertilization.

Paired Tree Installations

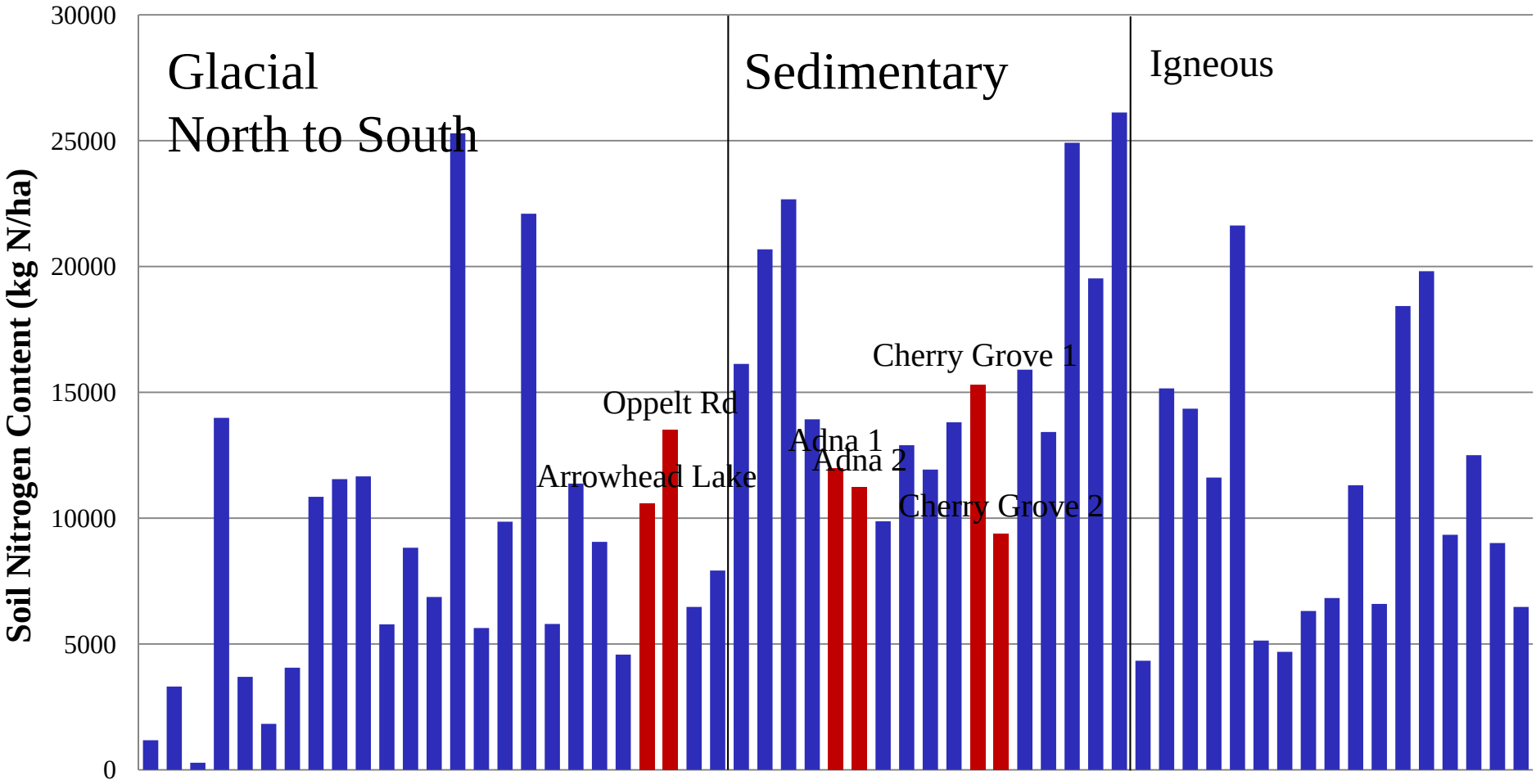


- Red Markers – Glacial parent material
- Green Markers – Sedimentary parent material
- Blue Markers – Igneous parent material

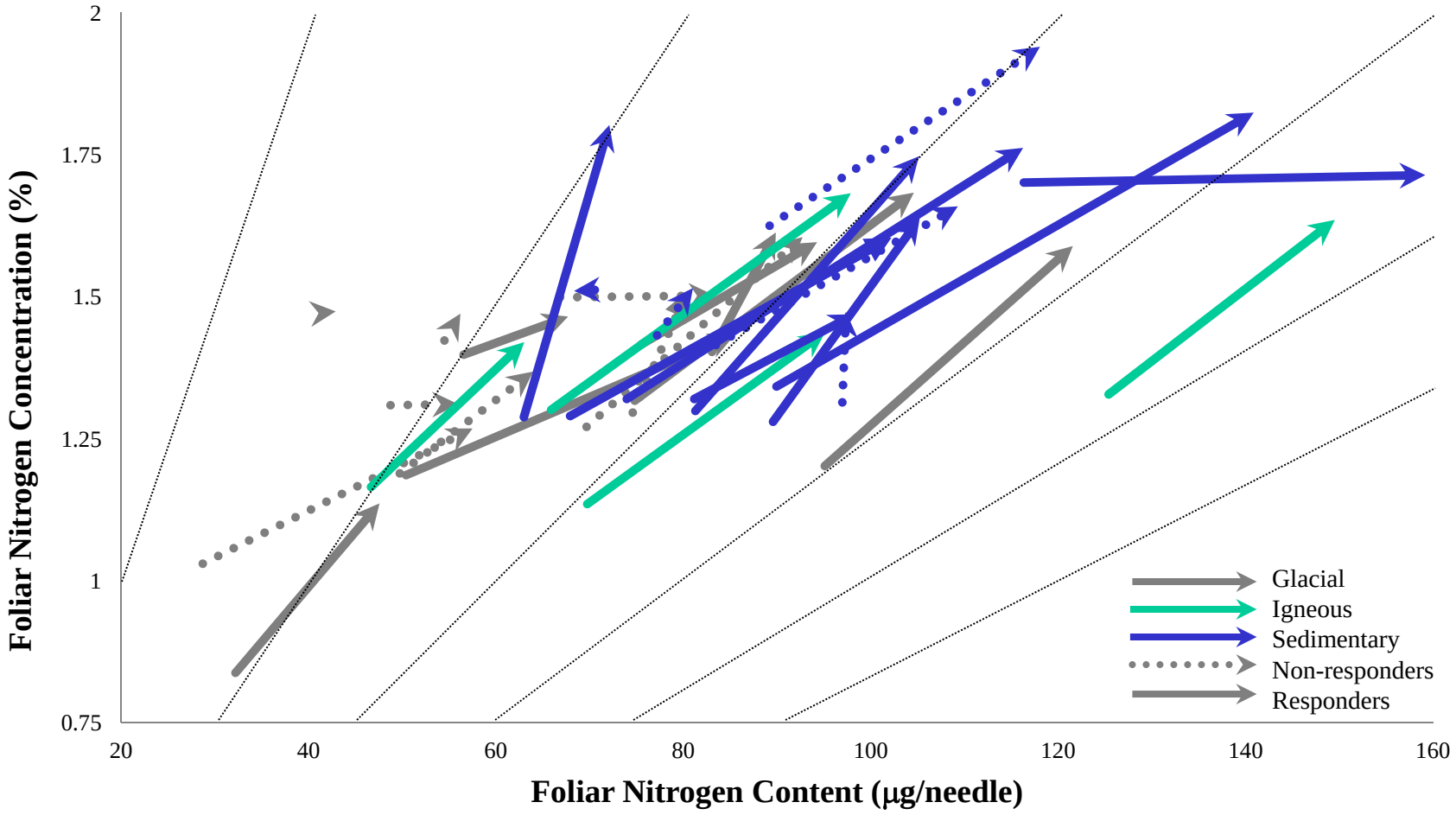
Objectives

- Test soil variables including bulk density, nutrient pools, temperature, and moisture
- Record non-soil variables such as site index, LAI, elevation, slope, precipitation, air temperature, and relative humidity
- Determine which factors can predict N fertilizer response
- Focus on variables that are easily obtained

Soil Nitrogen to 1 Meter



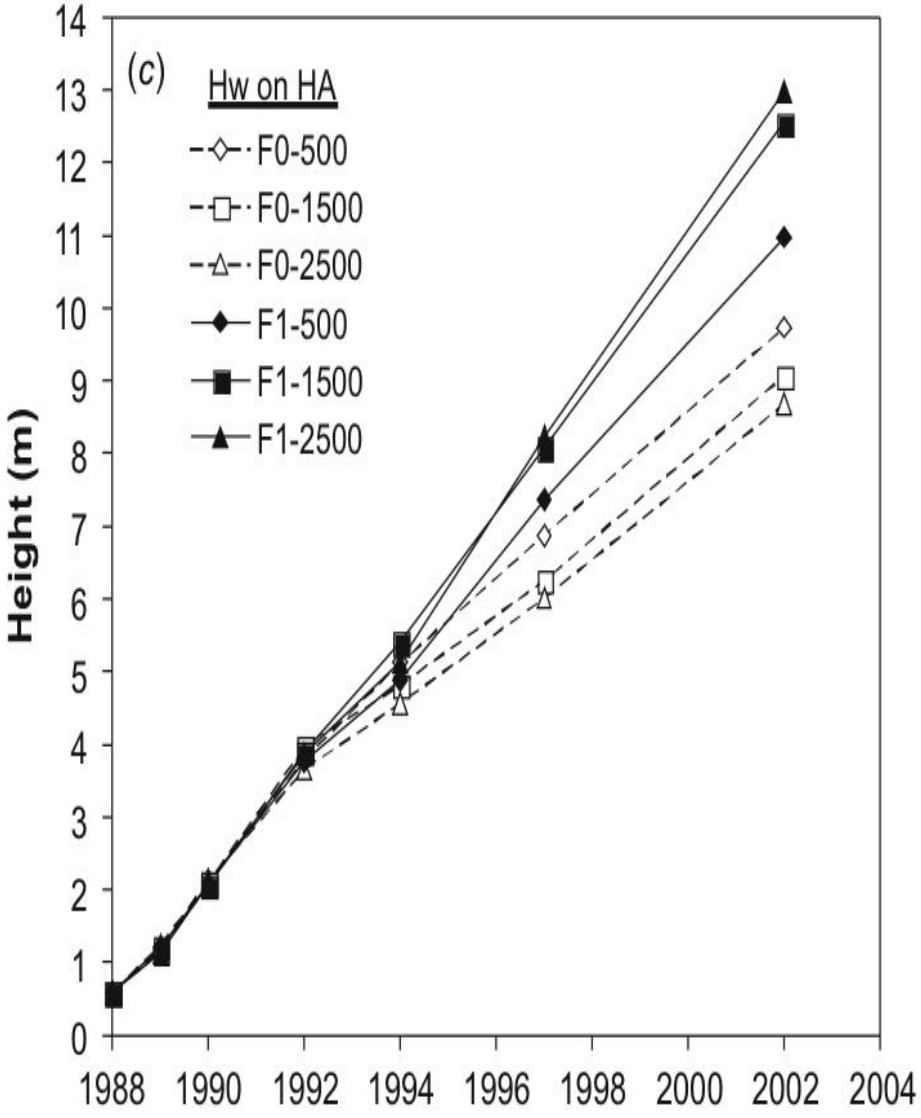
Foliar Nitrogen and Weight



Growth and foliar nutrition of juvenile western hemlock and western redcedar plantations on low- and medium-productivity sites on northern Vancouver Island: response to fertilization and planting density

R.W. Negrave, C.E. Prescott, and J.E. Barker

Abstract: A factorial trial was established to examine the effects of planting density and fertilization on the growth of western redcedar (*Thuja plicata* Donn ex D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) on nutrient-poor (CH) sites and nutrient-medium (HA) sites. Two levels of NPK fertilization were crossed with three levels of planting density (500, 1500, and 2500 stems/ha). Fifteen years after establishment and 10 years after the last fertilizer application, height, individual stem volume increment, stand volume, 5 year periodic annual increment (PAI), and 5 year periodic height increment were all increased by fertilization. Fertilization of CH sites increased annual stand volume increment by 753%–2552% and 122%–209% for hemlock and cedar, respectively; fertilization of HA sites increased PAI by 94%–264%. Volume growth response to fertilization was greater on HA than on CH sites. Increasing stand density reduced height growth on CH sites but not on HA sites. These results suggest that competition for nutrients can be a significant growth-limiting factor even before canopy closure occurs and that treatment of ericaceous sites may not be justified by productivity increases.


(c)
Hw on HA
F0-500
F0-1500
F0-2500
F1-500
F1-1500
F1-2500
Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1988
1990
1992
1994
1996
1998
2000
2002
2004

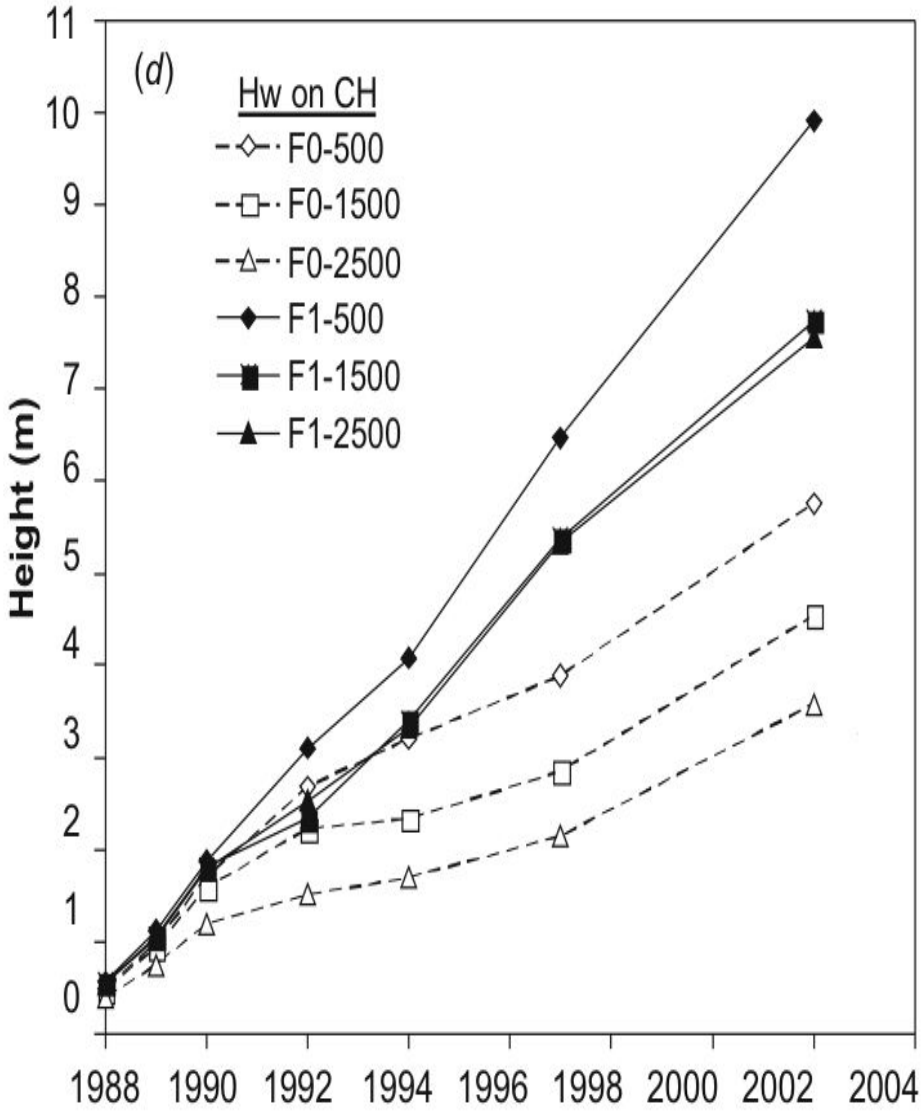

(d)
Hw on CH
F0-500
F0-1500
F0-2500
F1-500
F1-1500
F1-2500
Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
1988
1990
1992
1994
1996
1998
2000
2002
2004

Table 1. Size (2002), growth (1997–2002), and mortality (to 2002) variables.

Species[a]	Fertilization[b]	Stand density (stems/ha)	Height (m)	Stand volume (m^3/ha)	Mortality (%)	Height increment (m/year)	Stem volume increment (dm^3/year)	Periodic annual increment ($m^3 \cdot ha^{-1} \cdot year^{-1}$)
CH sites								
Cw	F0	500	5.36 (0.59)	10.39 (3.41)	0.8 (1.6)	0.39 (0.05)	3.38 (1.20)	1.65 (0.57)
Cw	F0	1500	4.53 (0.55)	15.17 (6.73)	0.4 (0.8)	0.31 (0.04)	1.54 (0.68)	2.27 (0.97)
Cw	F0	2500	4.08 (0.33)	17.49 (3.51)	0.4 (0.8)	0.24 (0.04)	1.00 (0.24)	2.50 (0.62)
Cw	F1	500	7.15 (0.49)	25.27 (5.35)	4.3 (3.5)	0.48 (0.04)	7.78 (1.57)	3.67 (0.74)
Cw	F1	1500	6.73 (0.61)	54.47 (17.05)	0.8 (0.9)	0.39 (0.05)	4.79 (1.43)	7.03 (2.15)
Cw	F1	2500	5.72 (1.05)	51.79 (23.74)	2.3 (2.7)	0.37 (0.07)	2.90 (1.27)	7.10 (3.17)
Hw	F0	500	3.65 (0.26)	1.63 (0.58)	6.3 (4.4)	0.20 (0.05)	0.55 (0.15)	0.25 (0.08)
Hw	F0	1500	3.17 (0.29)	2.28 (1.01)	5.9 (3.9)	0.20 (0.03)	0.27 (0.10)	0.38 (0.15)
Hw	F0	2500	2.27 (0.19)	1.03 (0.28)	3.1 (2.2)	0.10 (0.03)	0.08 (0.02)	0.19 (0.05)
Hw	F1	500	8.06 (1.21)	21.13 (8.38)	8.2 (3.7)	0.53 (0.12)	6.97 (2.73)	3.13 (1.24)
Hw	F1	1500	5.92 (1.01)	22.23 (9.43)	6.3 (6.1)	0.33 (0.11)	2.33 (0.98)	3.24 (1.44)
Hw	F1	2500	5.95 (1.35)	36.74 (24.21)	2.3 (2.7)	0.32 (0.14)	2.07 (1.39)	5.04 (3.45)
HA sites								
Cw	F0	500	5.85 (1.24)	13.87 (7.11)	5.5 (4.7)	0.35 (0.06)	4.14 (1.85)	1.90 (0.85)
Cw	F0	1500	5.08 (0.84)	22.01 (9.12)	1.6 (1.3)	0.32 (0.07)	2.14 (0.83)	3.11 (1.22)
Cw	F0	2500	4.23 (1.75)	30.22 (30.79)	1.6 (1.3)	0.21 (0.15)	1.70 (1.63)	4.19 (4.01)
Cw	F1	500	7.29 (0.99)	26.87 (10.53)	7.4 (8.1)	0.47 (0.07)	8.28 (3.38)	3.68 (1.38)
Cw	F1	1500	7.66 (1.17)	85.63 (33.51)	3.5 (4.5)	0.49 (0.10)	8.22 (3.51)	11.48 (4.63)
Cw	F1	2500	7.27 (0.78)	114.07 (34.18)	3.1 (2.9)	0.46 (0.03)	6.36 (1.89)	15.14 (4.21)
Hw	F0	500	7.65 (1.99)	19.36 (14.00)	5.5 (2.7)	0.46 (0.12)	5.83 (4.12)	2.71 (1.94)
Hw	F0	1500	7.12 (2.67)	40.82 (34.55)	7.0 (6.6)	0.43 (0.23)	4.29 (4.01)	5.61 (4.91)
Hw	F0	2500	7.04 (3.45)	61.69 (63.27)	7.4 (5.6)	0.44 (0.27)	3.83 (3.85)	8.59 (8.74)
Hw	F1	500	9.65 (0.63)	39.61 (6.83)	16.4 (13.6)	0.61 (0.05)	13.51 (2.52)	5.39 (0.96)
Hw	F1	1500	11.68 (0.73)	148.75 (29.26)	12.9 (9.0)	0.81 (0.09)	15.95 (2.98)	20.48 (4.27)
Hw	F1	2500	11.61 (1.16)	190.40 (59.13)	8.6 (0.9)	0.83 (0.09)	11.27 (3.01)	25.56 (6.98)

Note: CH site, nutrient poor conditions; HA site, nutrient medium conditions.Values are means with SEs given in parentheses.
[a]Cw, western redcedar; Hw, western hemlock.
[b]F0, unfertilized; F1, fertilized.