The SMC, summary of results with emphasis of effects of thinning on fertilization response

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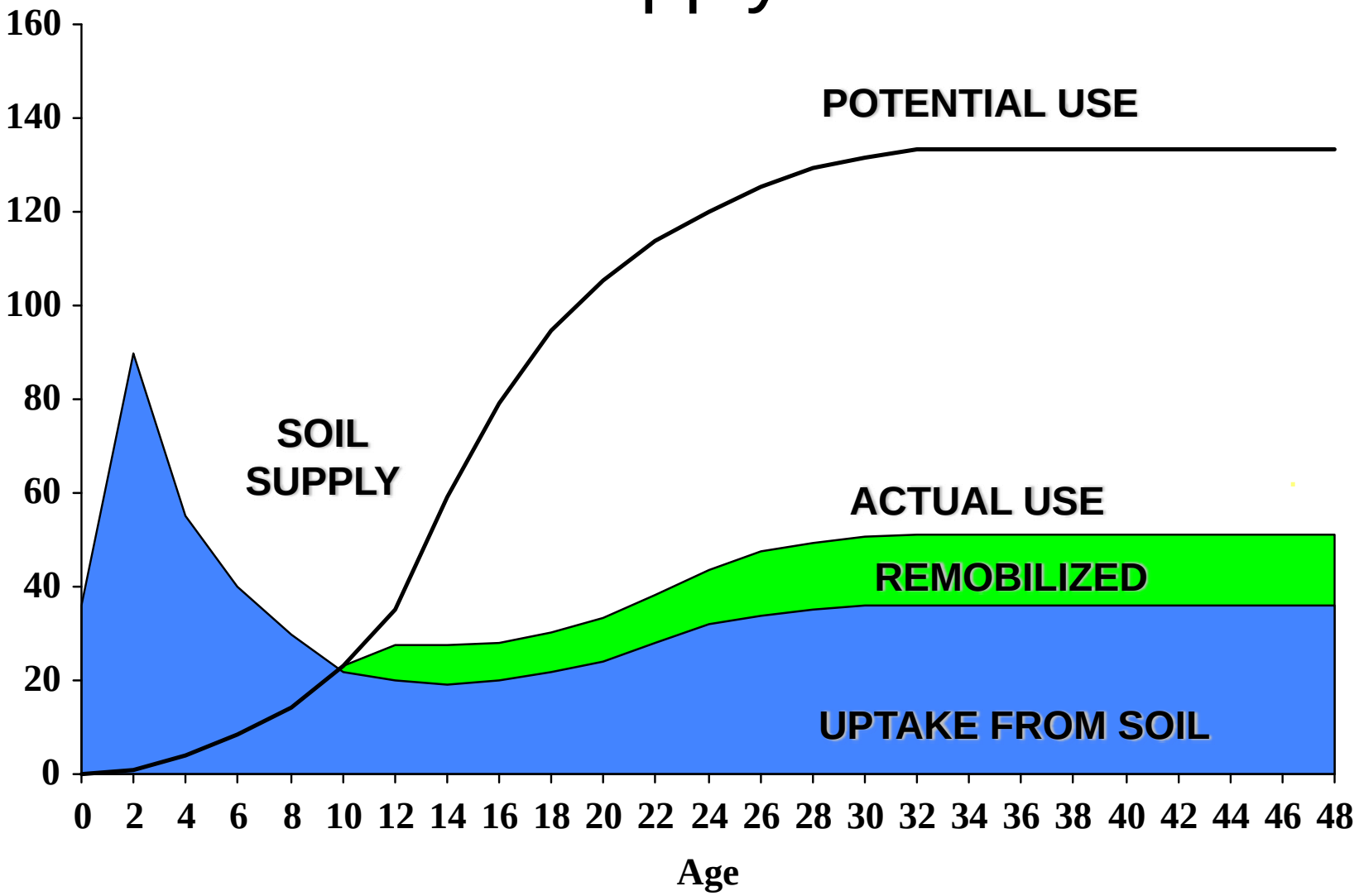
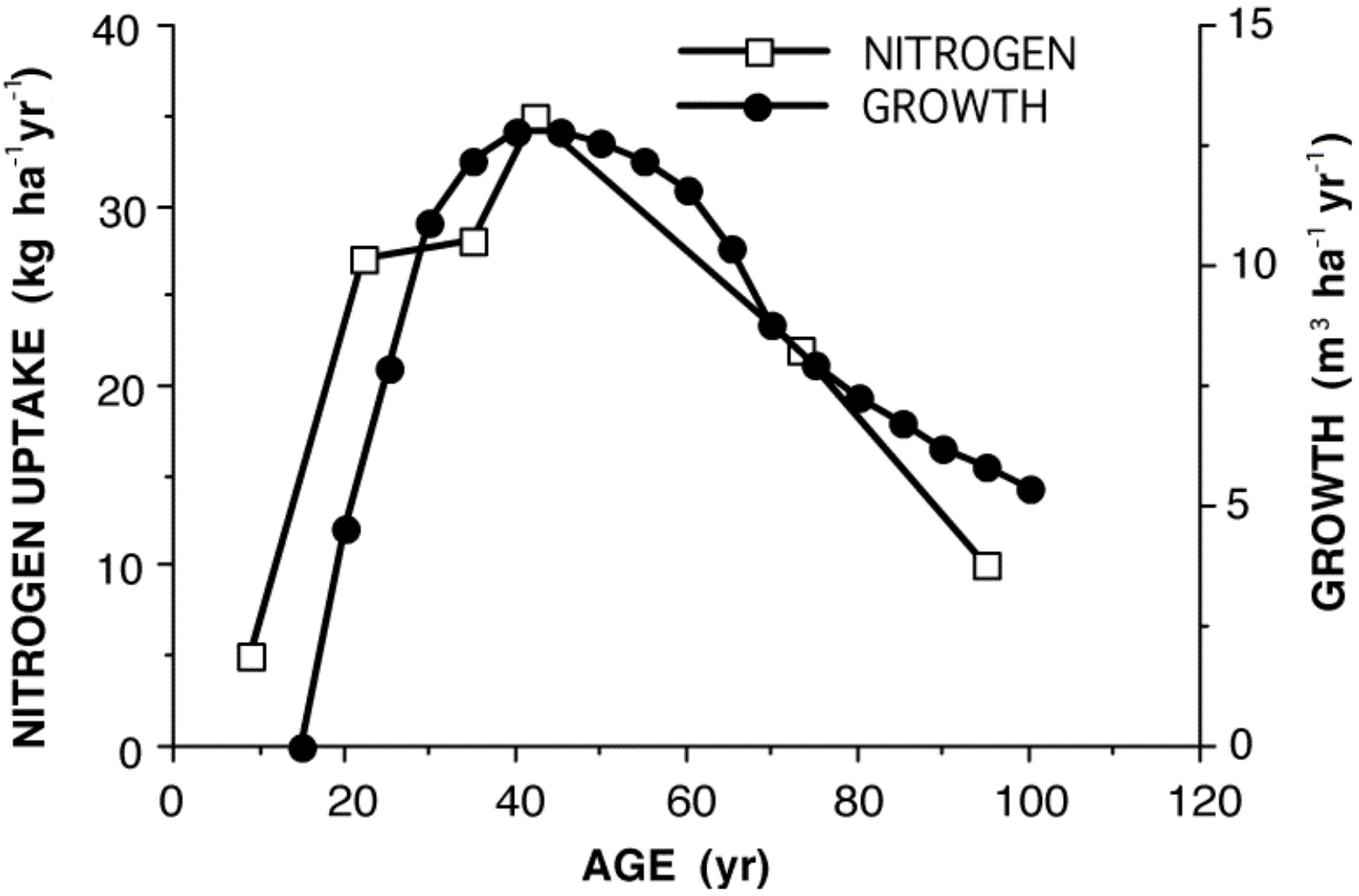
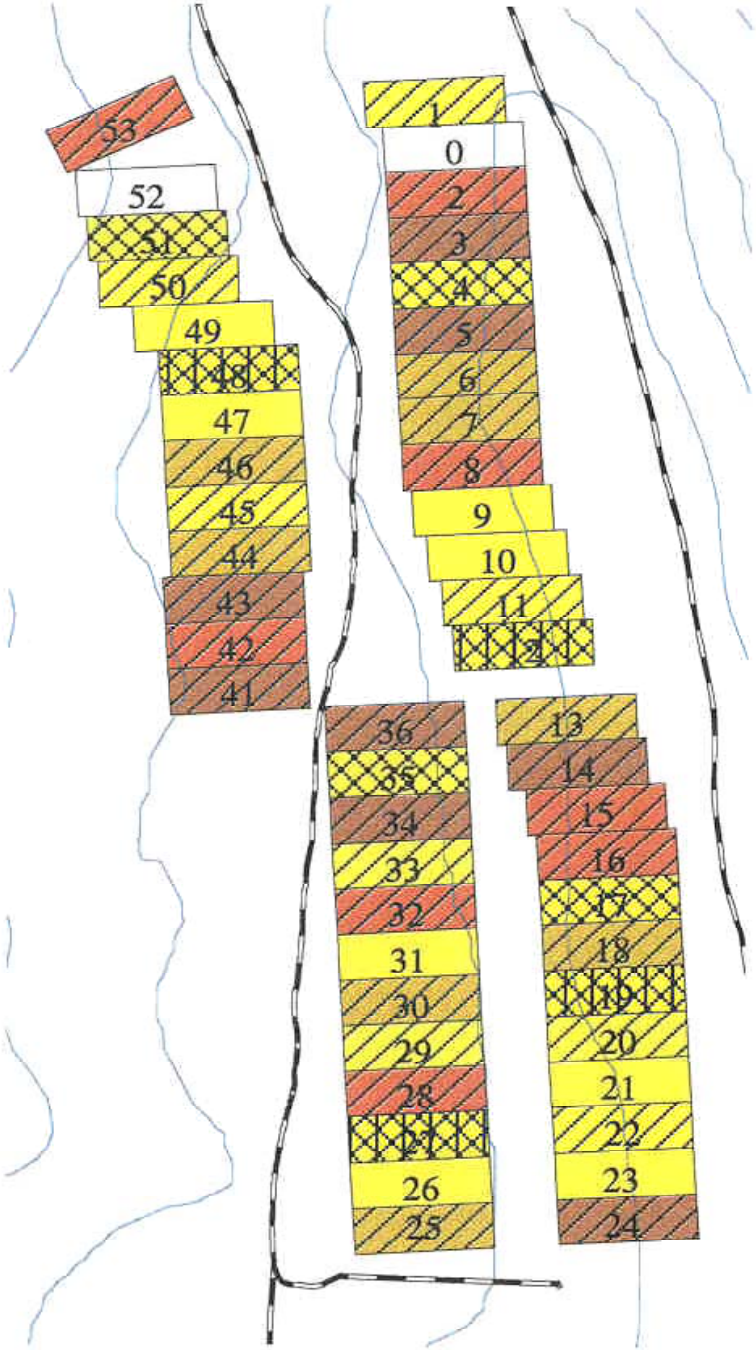
Nutrient Supply and Use




NITROGEN
GROWTH
NITROGEN UPTAKE (kg ha-1yr-1)
GROWTH (m3 ha-1 yr-1)
AGE (yr)
0
10
20
30
40
0
5
10
15
0
20
40
60
80
100
120



Fall River Study Plots

Roads

Harvest Level

- Bole only
- Bole only to 5 cm top
- Total tree
- Total tree plus
- No treatment

Vegetation control

- Vegetation control

Compaction

- Compaction

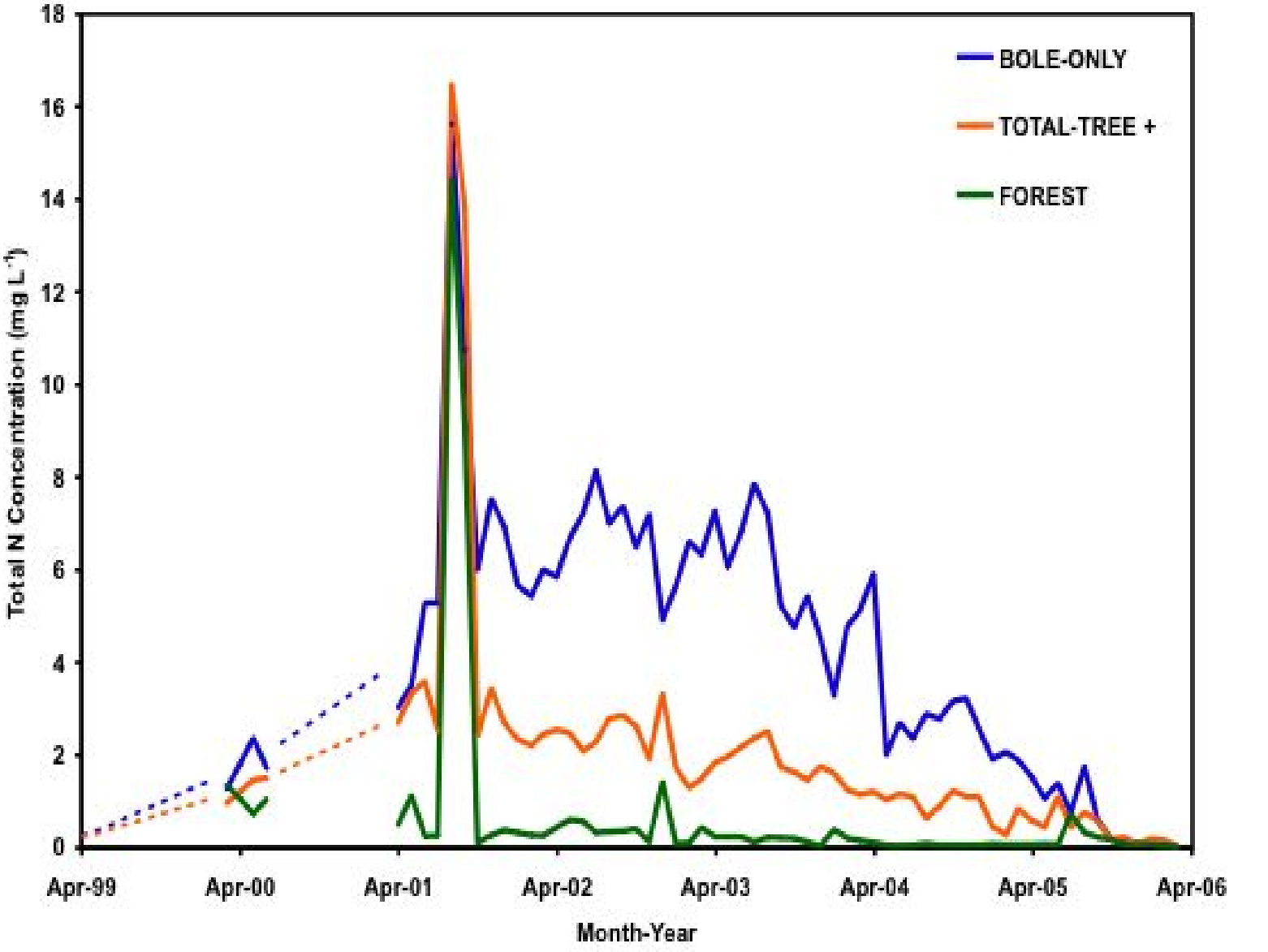
Tillage

- Tillage

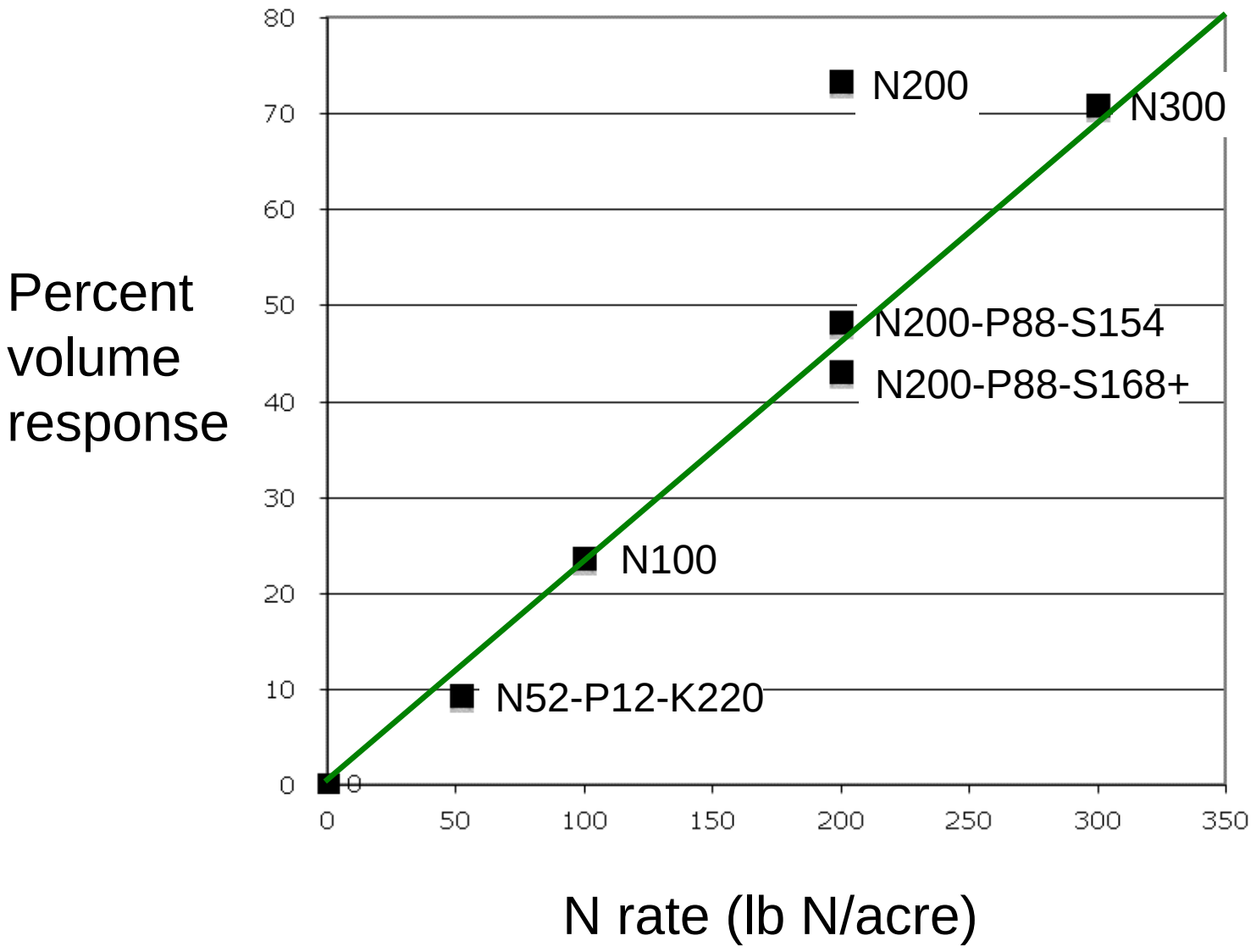
Contour Interval = 10 Meters

N

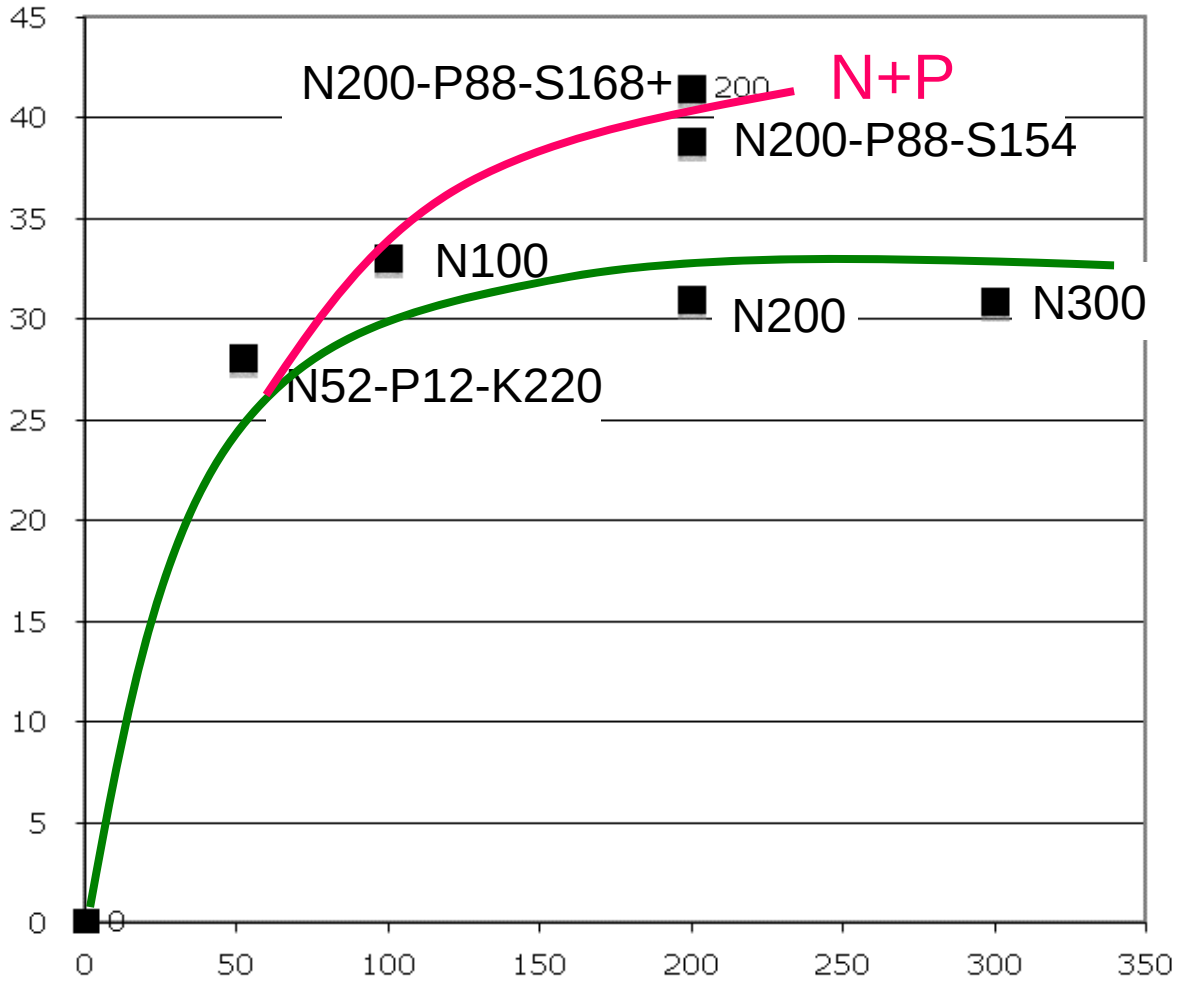
50 0 50 100 150 200 250 300 Meters


BOLE-ONLY
TOTAL-TREE +
FOREST
Total N Concentration (mg L-1)
0
2
4
6
8
10
12
14
16
18
Apr-99
Apr-00
Apr-01
Apr-02
Apr-03
Apr-04
Apr-05
Apr-06
Month-Year

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

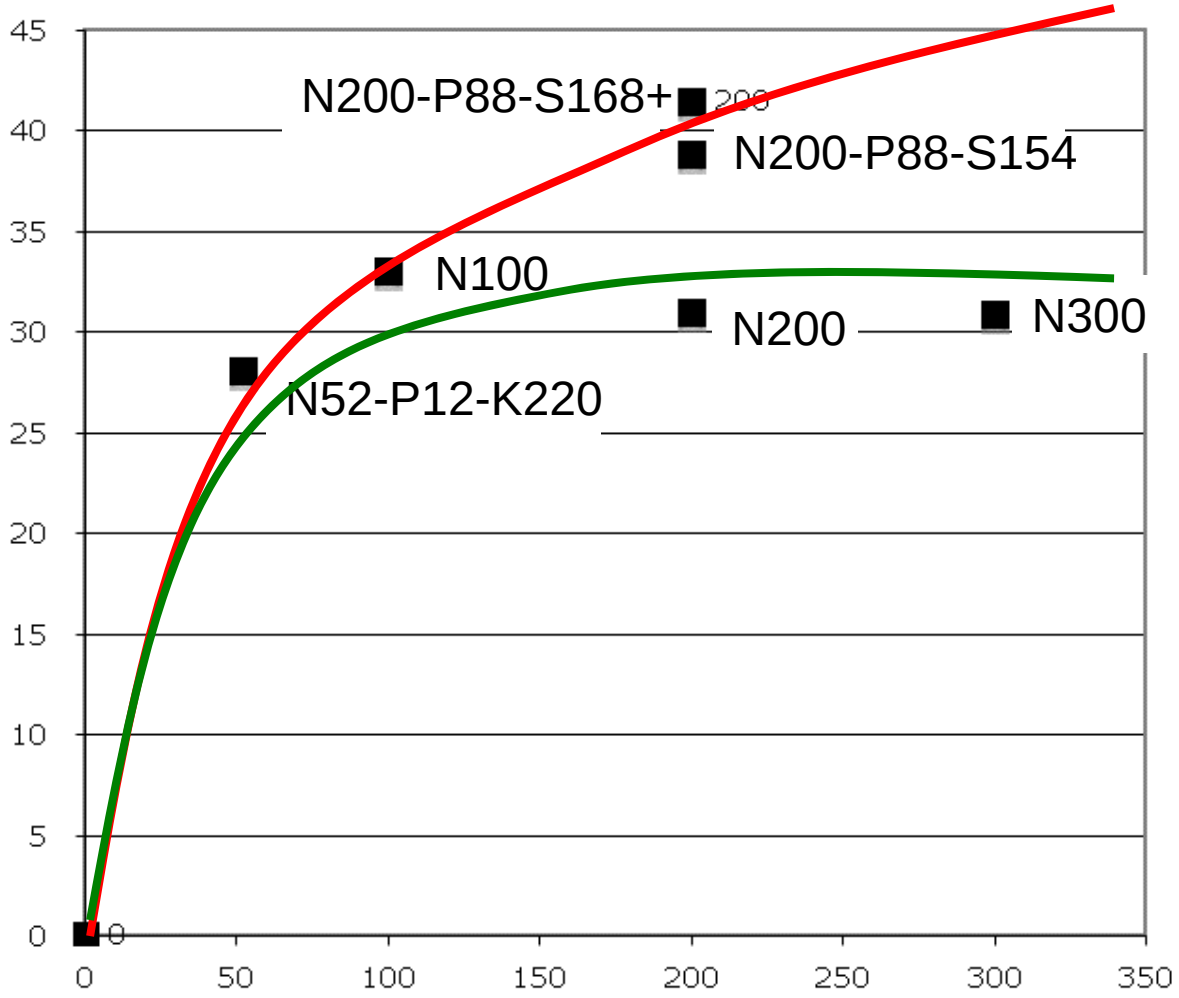

Percent volume response
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
N200
N300
N200-P88-S154
N200-P88-S168+
N100
N52-P12-K220
0
N rate (lb N/acre)

Percent volume response

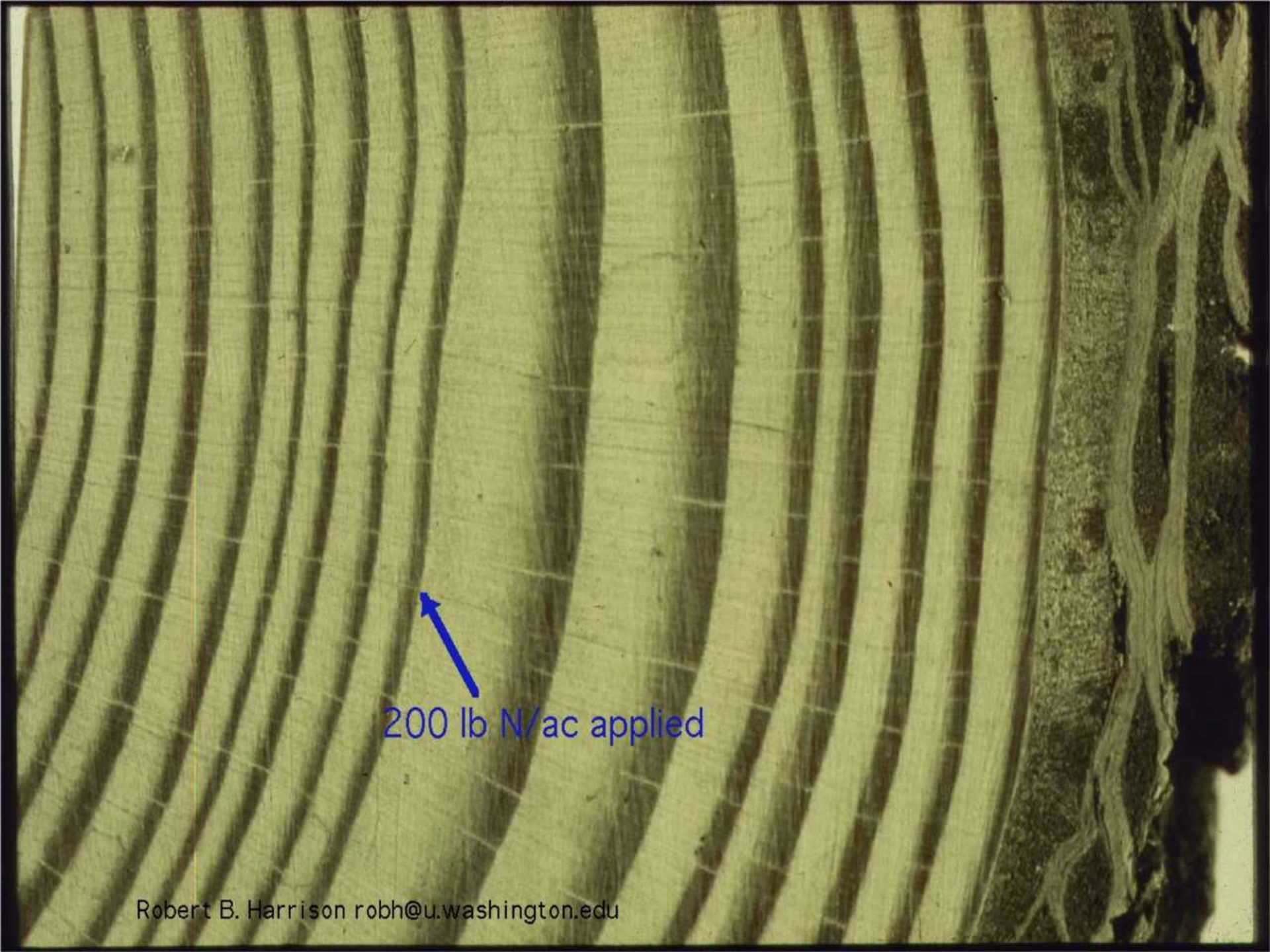


N rate (lb N/acre)

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”.

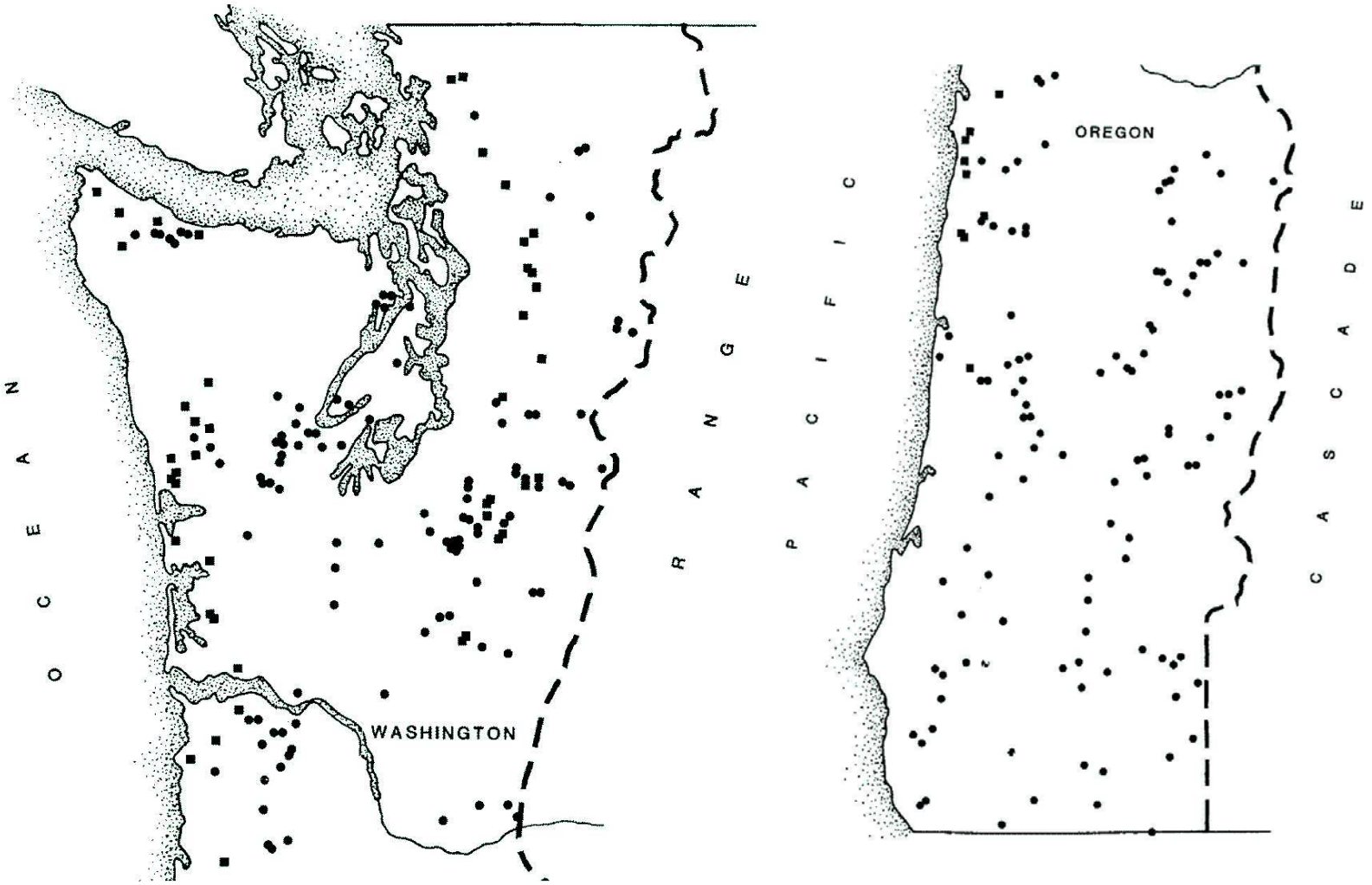
RFNRP
1969-pres.

Installations of the PNW Stand Management Cooperative

Stand Management Cooperative
SILVICULTURE ■ NUTRITION
WOOD QUALITY ■ MODELING

College of Forest Resources
University of Washington
Box 352100
Seattle Washington 98195-2100

206-543-5355 phone
206-685-3091 fax

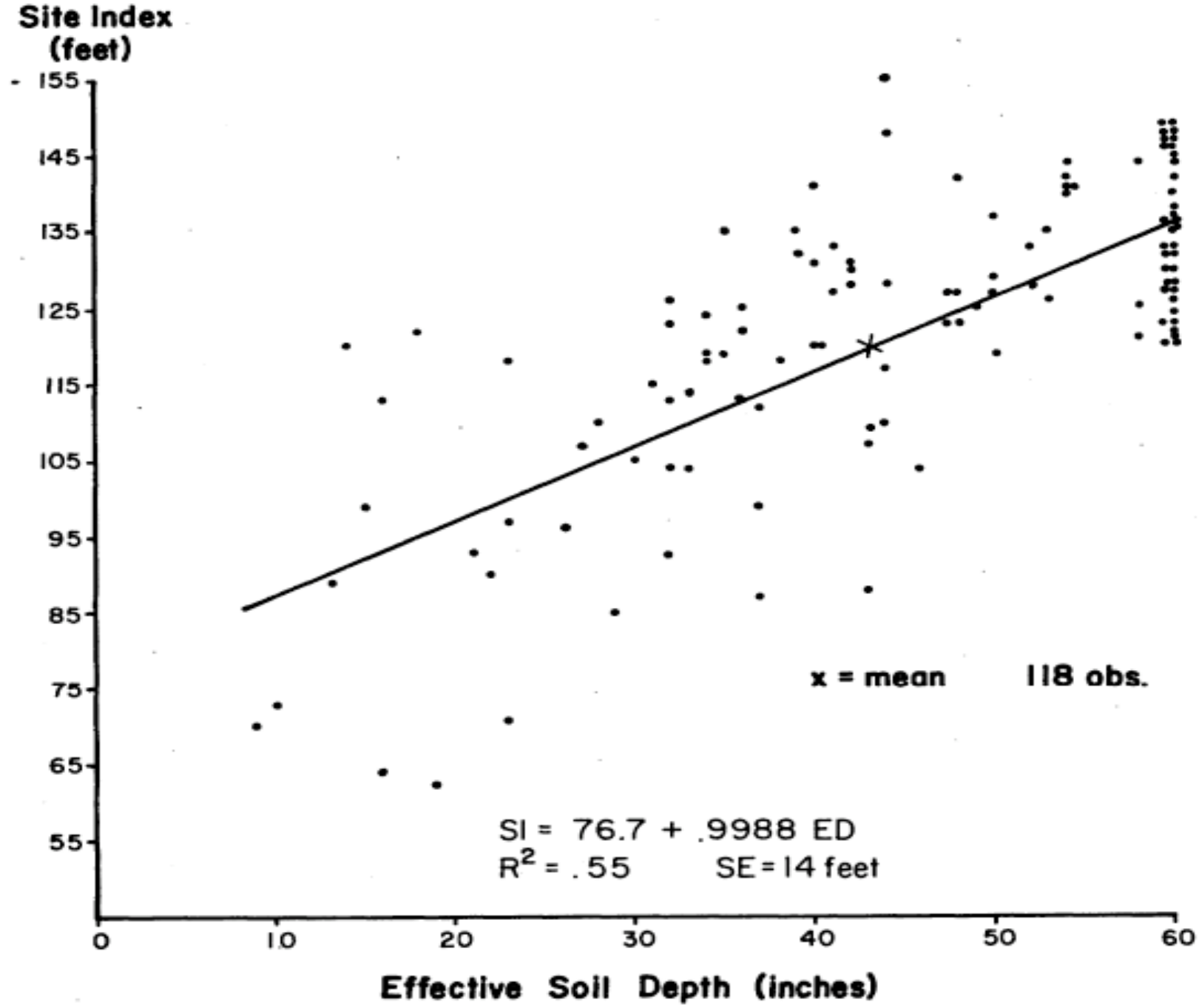


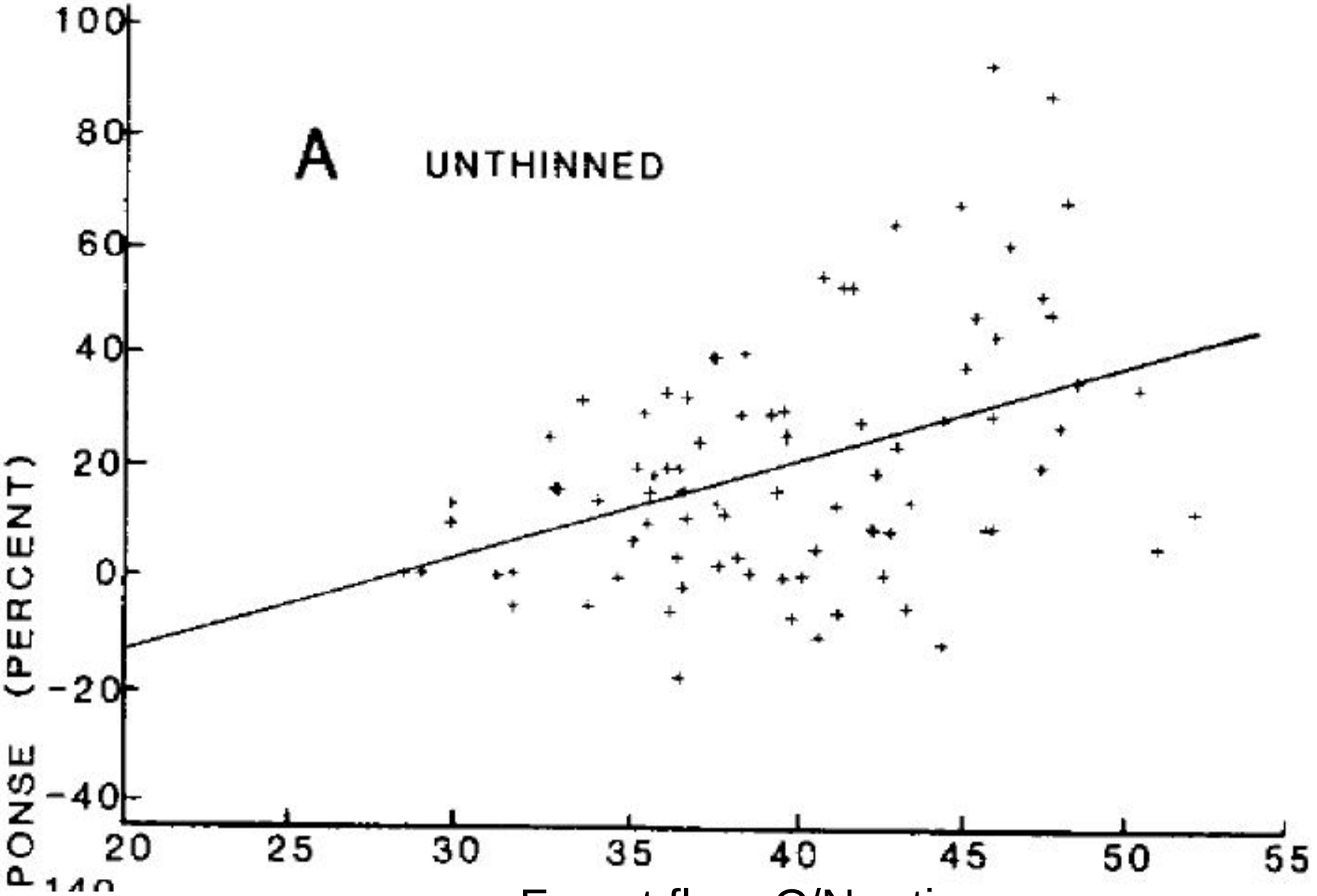
RFNRP Installations

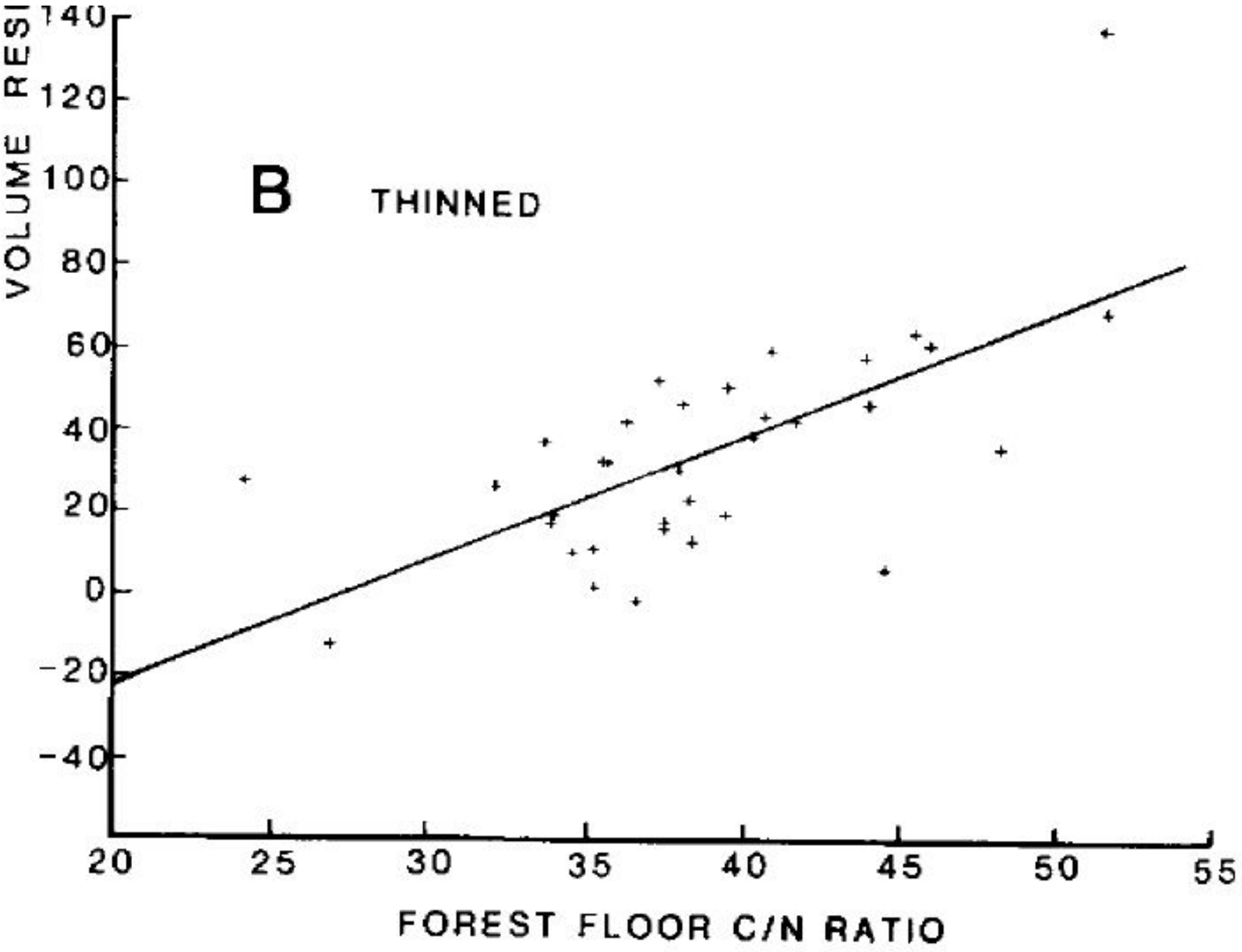
- **Phase I Unthinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1969/70
  - up to 4 fertilization treatments
  - 20 years growth remeasurements
- **Phase II Thinned Natural Stands**
  - Douglas-fir & western hemlock
  - established in 1971/72
  - up to 4 fertilization treatments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

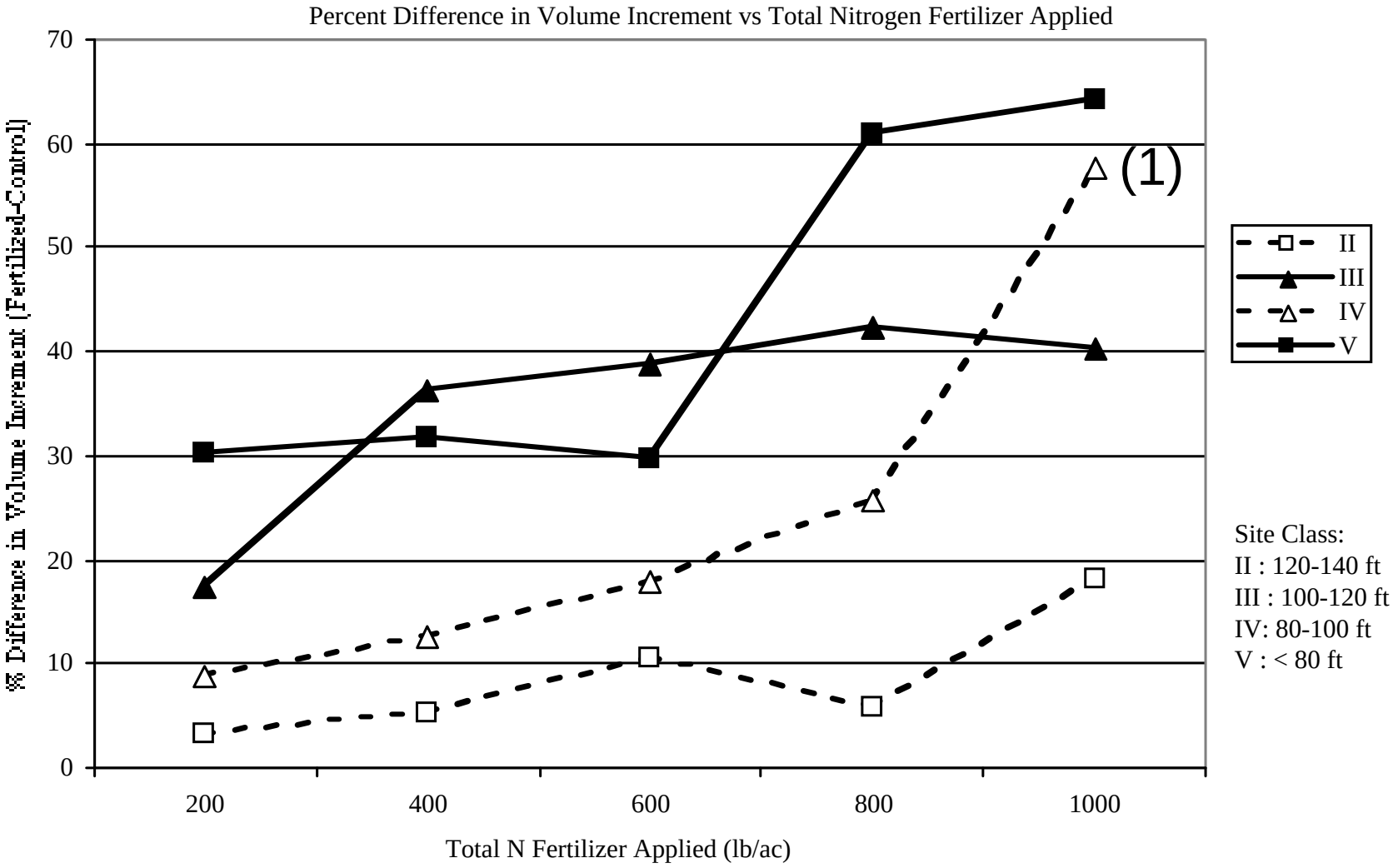
RFNRP Installations

- **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


Site Index
(feet)
155
145
135
125
115
105
95
85
75
65
55
0
10
20
30
40
50
60
Effective Soil Depth (inches)
x = mean
118 obs.
SI = 76.7 + .9988 ED
R^2 = .55
SE = 14 feet


A
UNTHINNED
100
80
60
40
20
0
-20
-40
PONSE (PERCENT)
20
25
30
35
40
45
50
55
Forest floor C/N ratio


VOLUME RESI
140
120
100
80
60
40
20
0
-20
-40
B
THINNED
20
25
30
35
40
45
50
55
FOREST FLOOR C/N RATIO



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	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	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

Results of RFNRP studies

1) N response averaging 20% (unthinned) -30% (thinned) with 400 kg N, 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

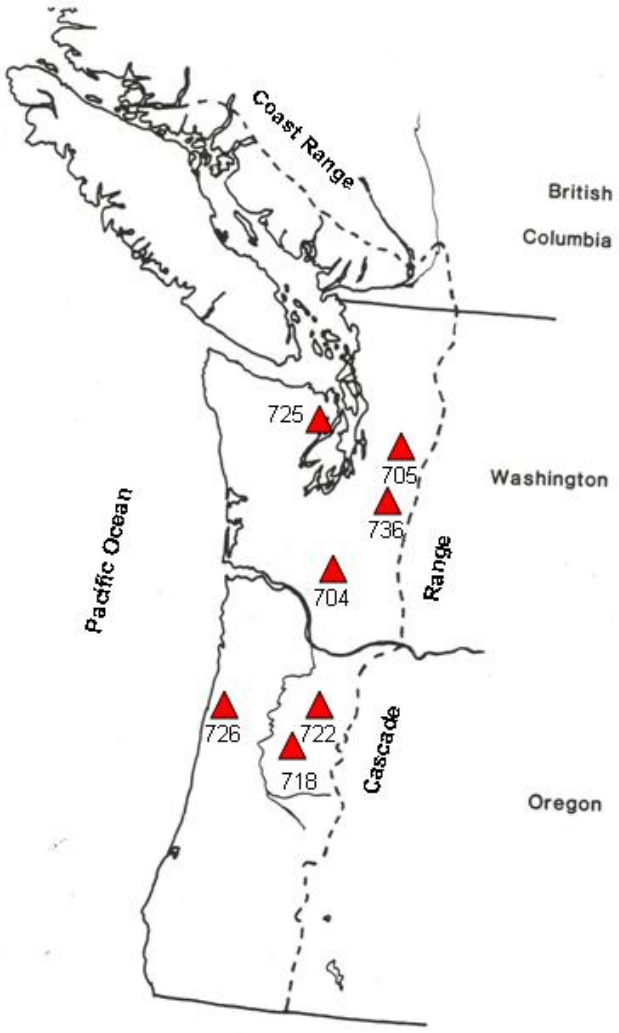
SMC Type I Installations
-plantations with initial stocking 300-680 spa
-Respace (PCT) before onset of competition

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



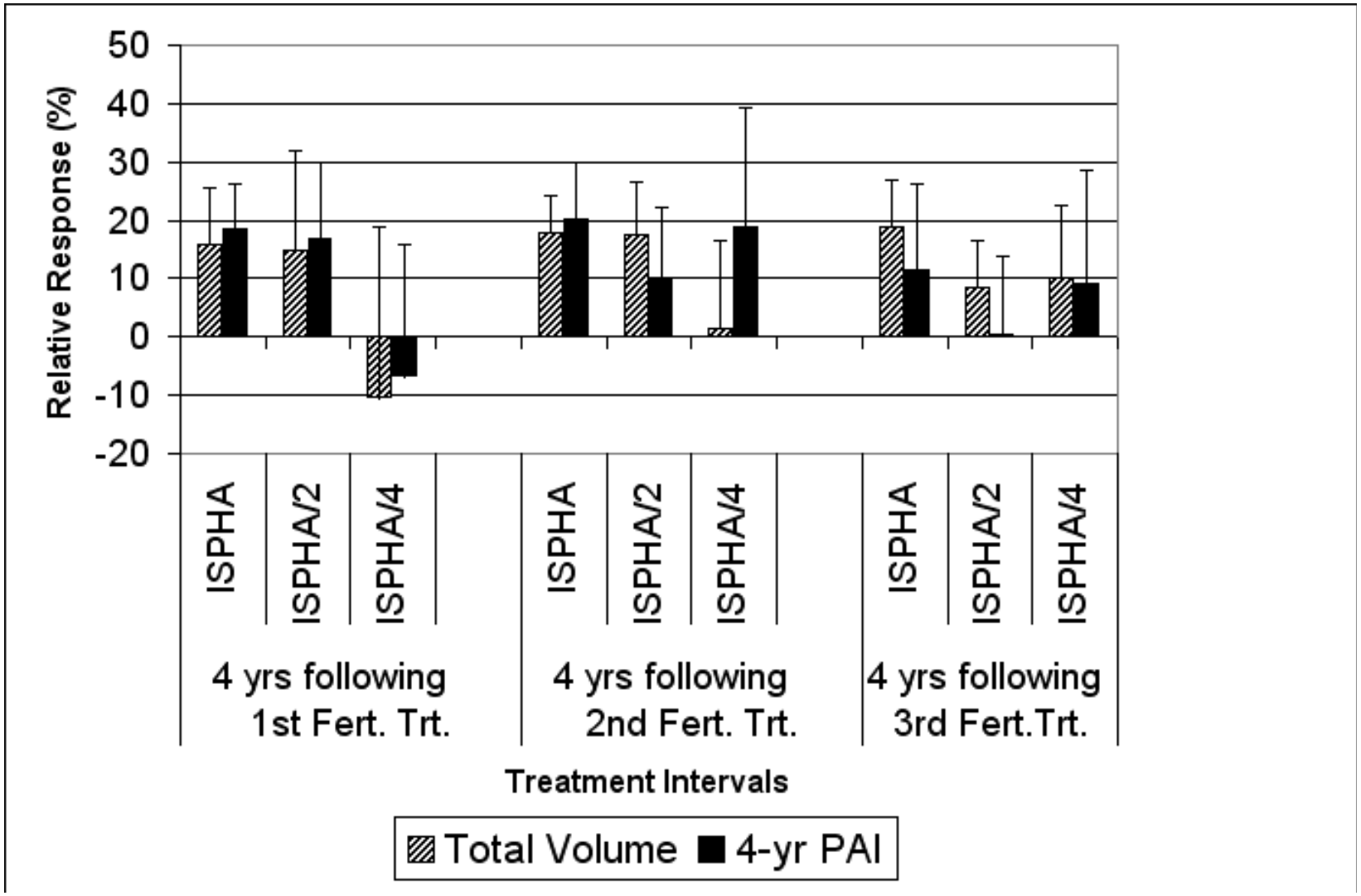
Site Descriptives

	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
<u>All DMR's</u>			
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
<u>ISPHA</u>			
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
<u>ISPHA/2</u>			
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
<u>ISPHA/4</u>			
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

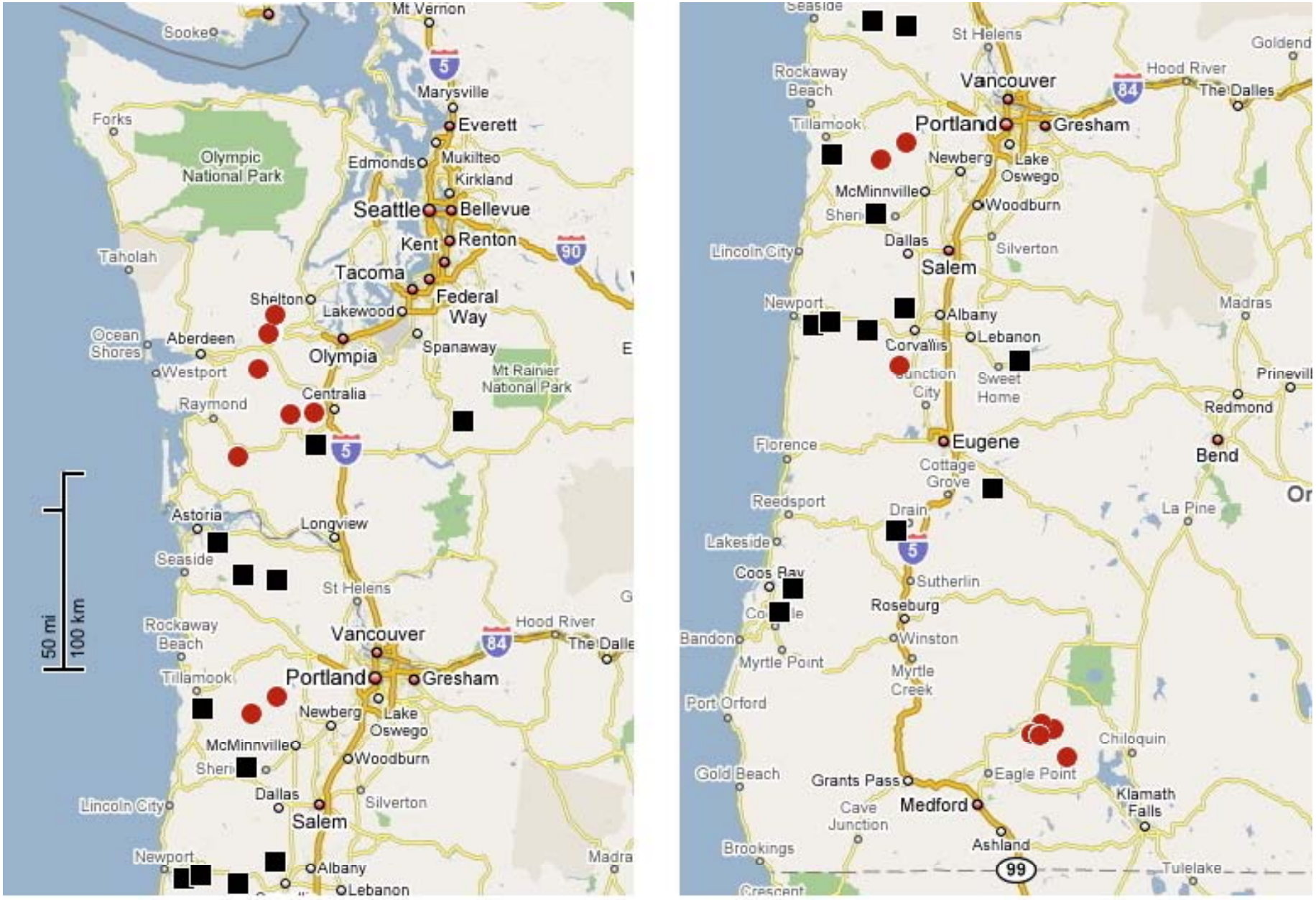
† Strongest single indepent variables shown in Fig. 3

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).

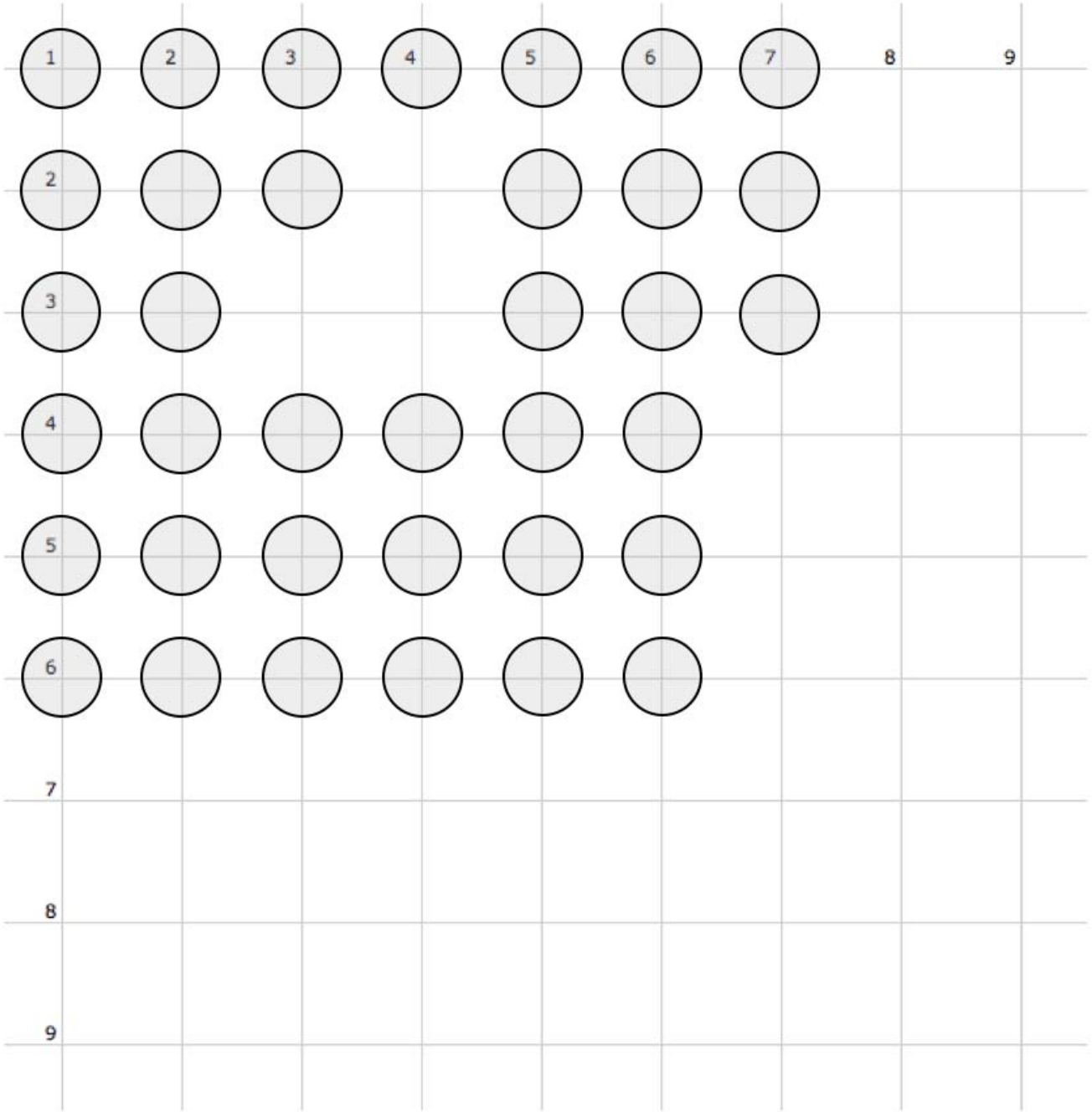
Results of SMC studies
too few sites (7) for broad generalizations

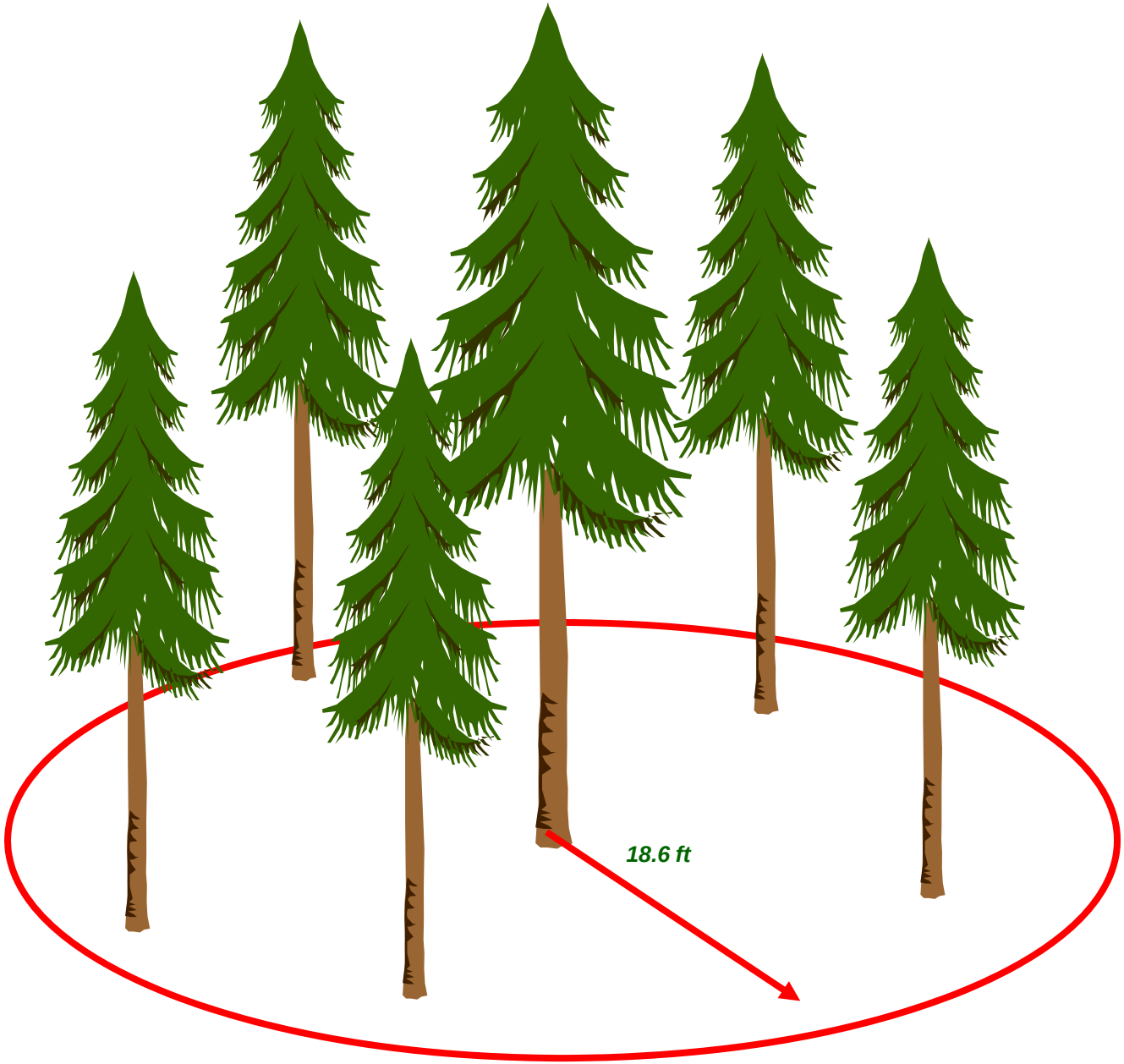
1) Response to N is site and stand controlled. Indicates need to couple fertilization with other silvicultural treatments, particularly stocking, and use RD or other stand properties to drive time of fertilization.

SMC “Type V” and CIPS paired-plot studies, now and future

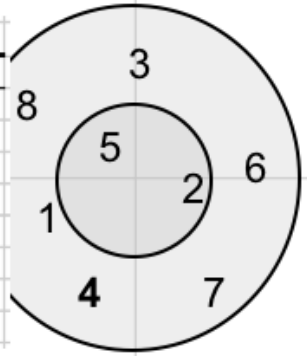


■ **Current CIPS** ● **Current SMC**

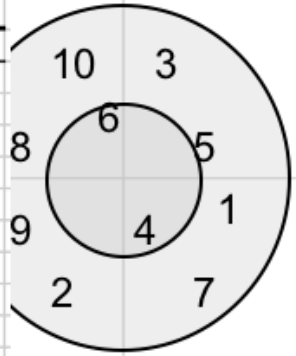

1
2
3
4
5
6
7
8
9
2
3
4
5
6
7
8
9


18.6 ft

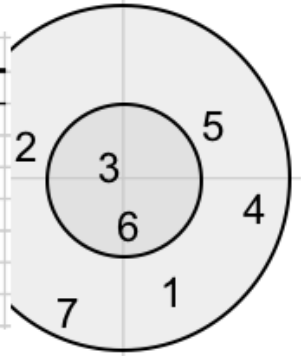
tree	DBH	ht
avg	7.9	37
1	3.5	35
2	3.7	35
3	4.9	35
4	5.3	36
5	7.4	37
6	9.8	39
7	10.2	39
8	10.3	39



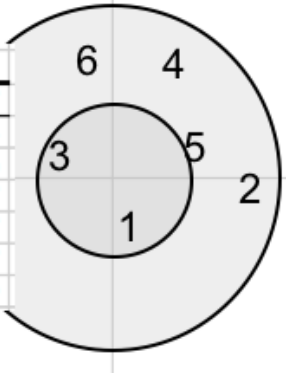
tree	DBH	ht
avg	7.9	37
1	3.7	35
2	4.2	35
3	4.6	35
4	5.9	36
5	6.0	36
6	7.6	37
7	7.8	37
8	8.1	38
9	8.5	38
10	10.4	39



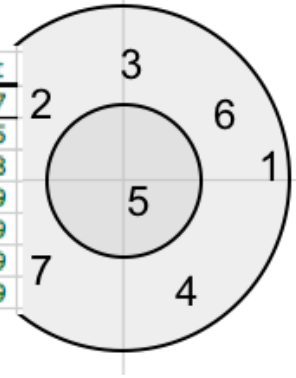
tree	DBH	ht
avg	7.9	37
1	3.7	35
2	4.4	35
3	7.9	37
4	9.5	38
5	11.0	39
6	11.2	39
7	13.0	39



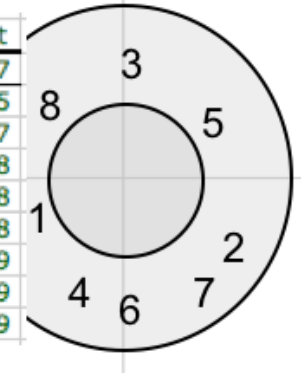
tree	DBH	ht
avg	7.9	37
1	3.4	35
2	6.2	36
3	7.1	37
4	8.5	37
5	8.5	37
6	11.8	39



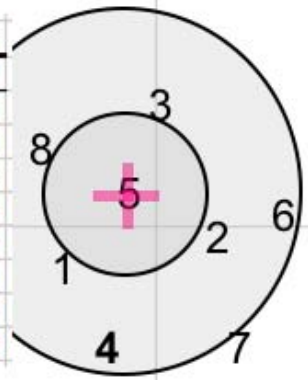
tree	DBH	ht
avg	7.9	37
1	4.3	35
2	8.5	38
3	9.6	39
4	10.4	39
5	10.7	39
6	11.0	39



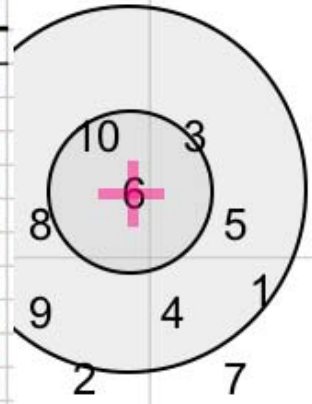
tree	DBH	ht
avg	7.9	37
1	3.6	35
2	6.5	37
3	8.0	38
4	8.5	38
5	8.9	38
6	9.6	39
7	10.4	39
8	10.7	39



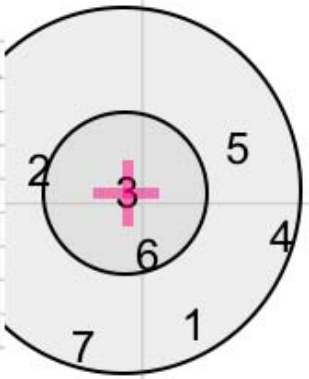
tree	DBH	ht
avg	7.9	37
1	3.5	35
2	3.7	35
3	4.9	35
4	5.3	36
5	7.4	37
6	9.8	39
7	10.2	39
8	10.3	39



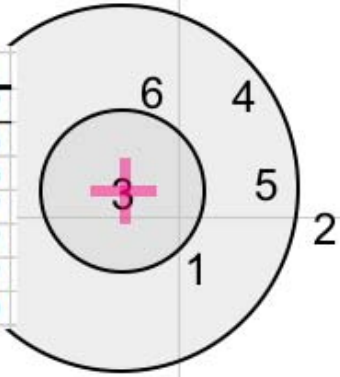
tree	DBH	ht
avg	7.9	37
1	3.7	35
2	4.2	35
3	4.6	35
4	5.9	36
5	6.0	36
6	7.6	37
7	7.8	37
8	8.1	38
9	8.5	38
10	10.4	39



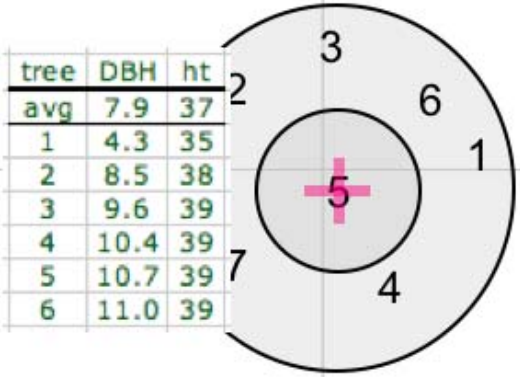
tree	DBH	ht
avg	7.9	37
1	3.7	35
2	4.4	35
3	7.9	37
4	9.5	38
5	11.0	39
6	11.2	39
7	13.0	39



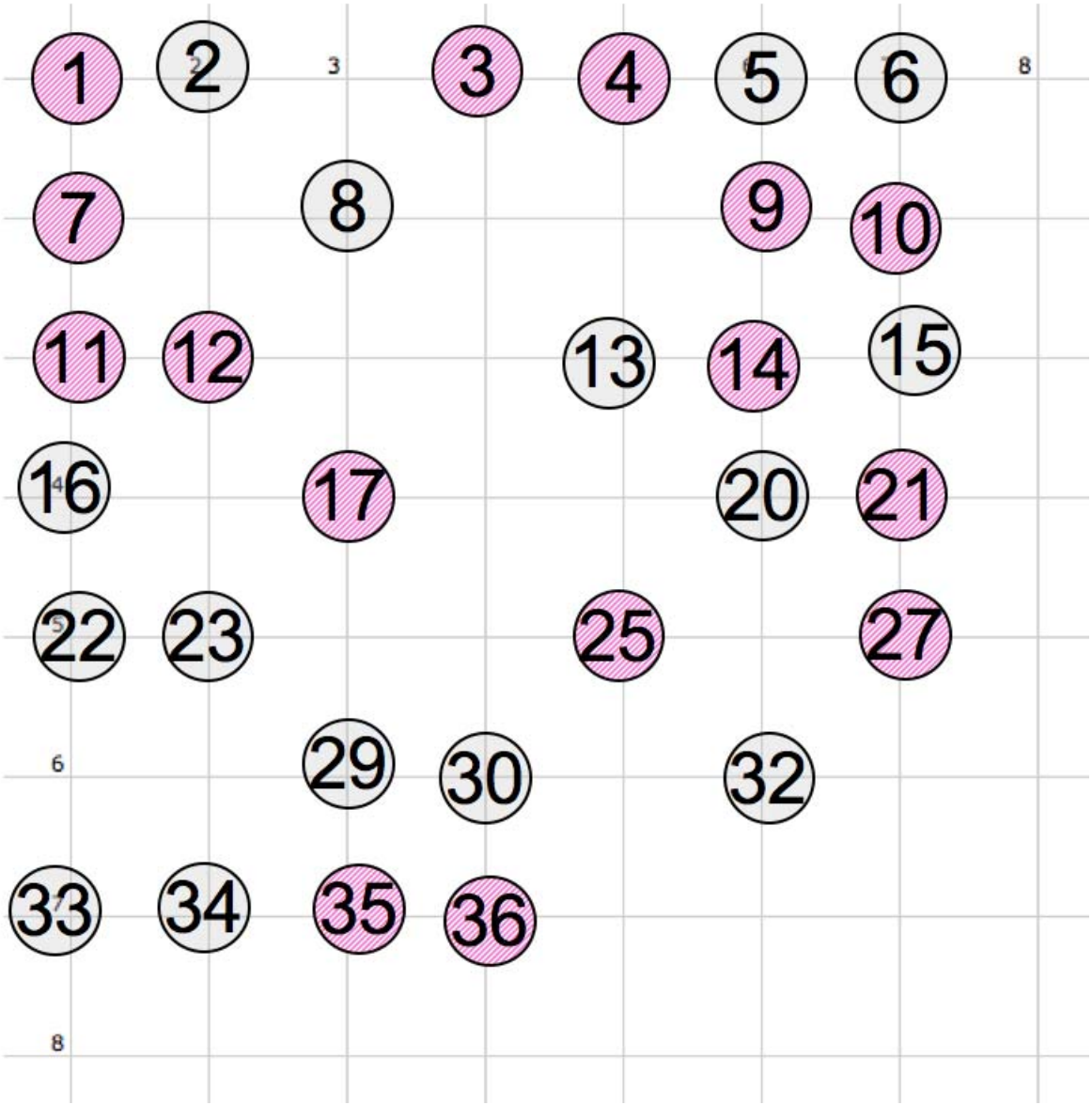
tree	DBH	ht
avg	7.9	37
1	3.4	35
2	6.2	36
3	7.1	37
4	8.5	37
5	8.5	37
6	11.8	39



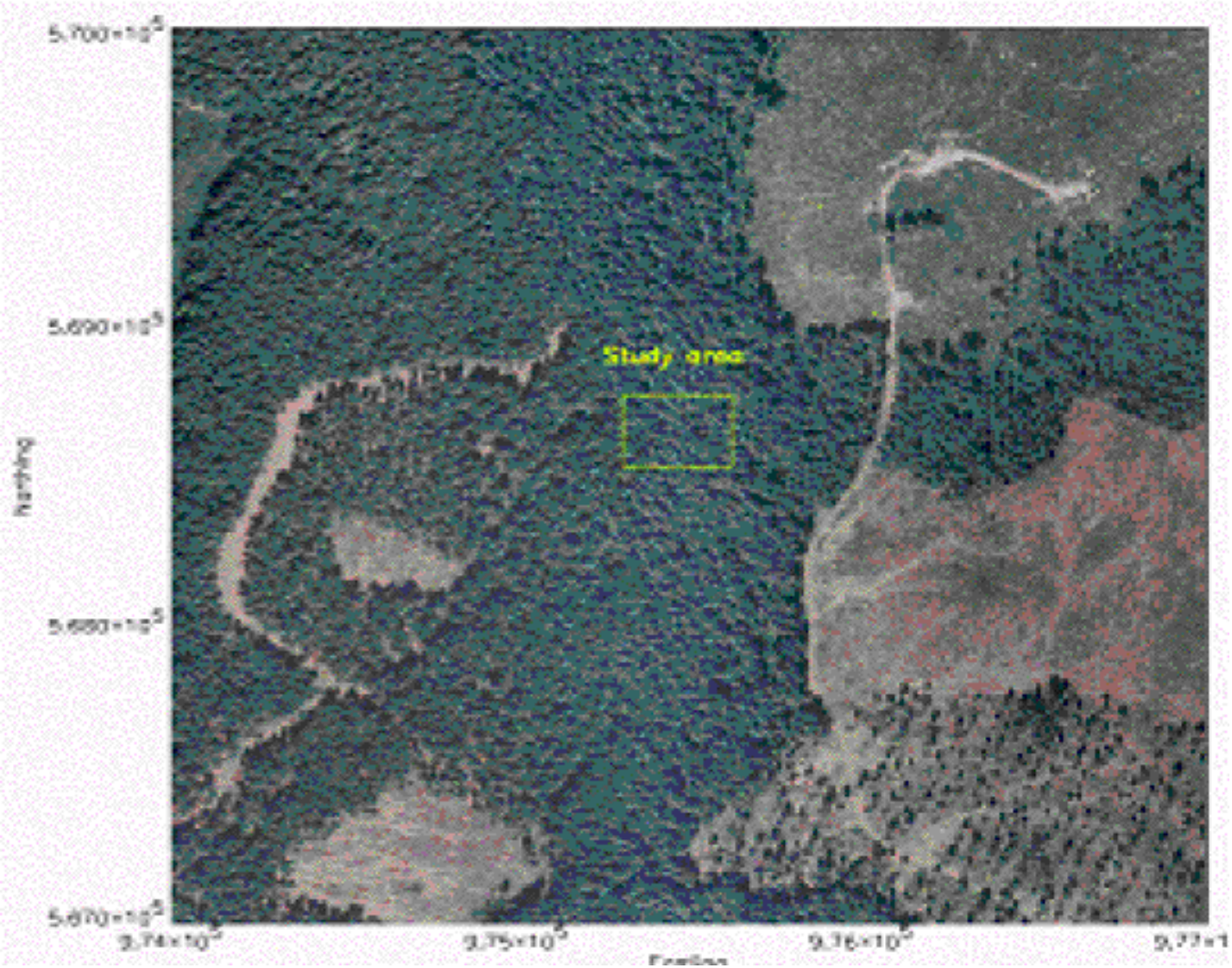
tree	DBH	ht
avg	7.9	37
1	4.3	35
2	8.5	38
3	9.6	39
4	10.4	39
5	10.7	39
6	11.0	39

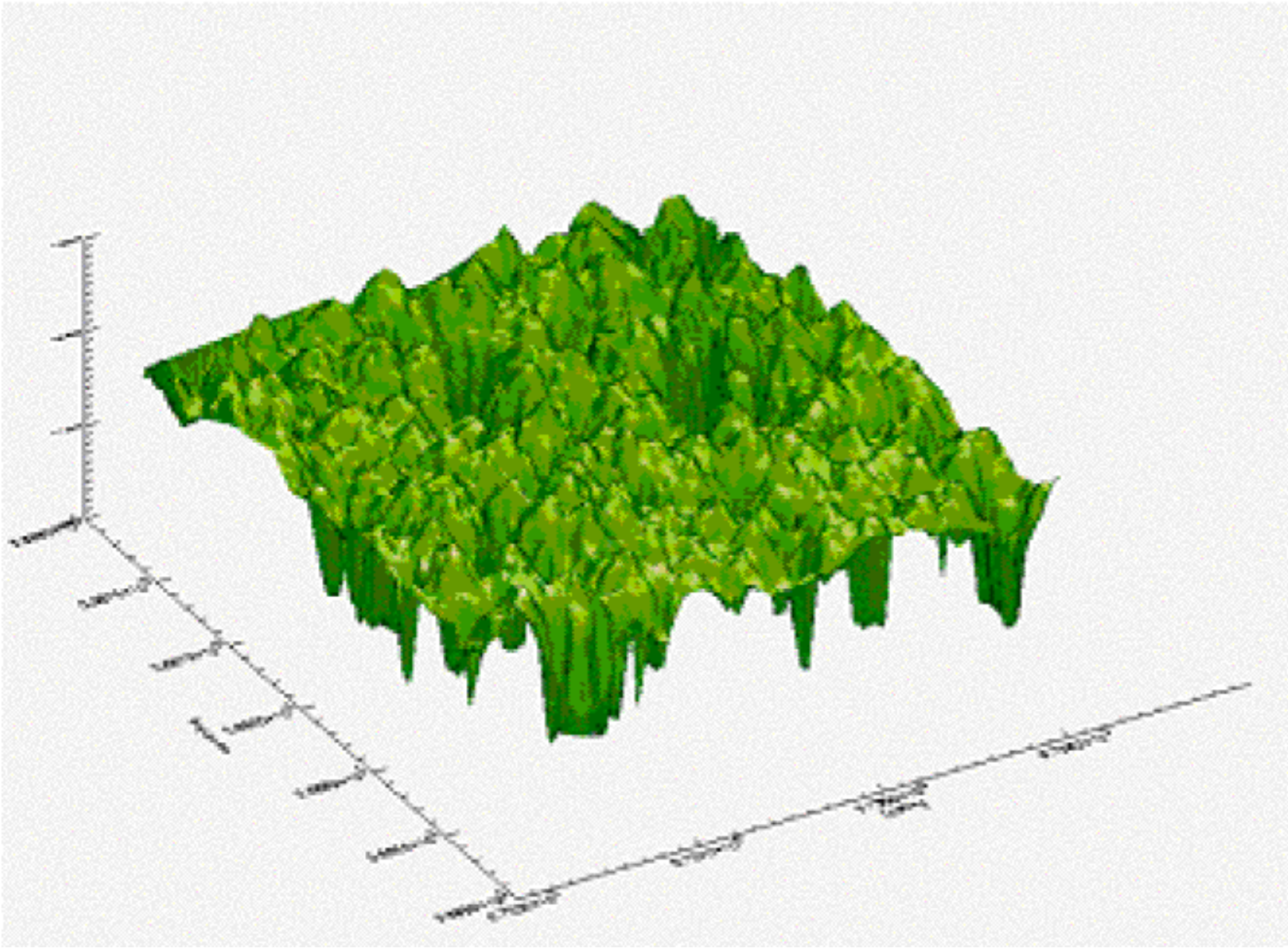


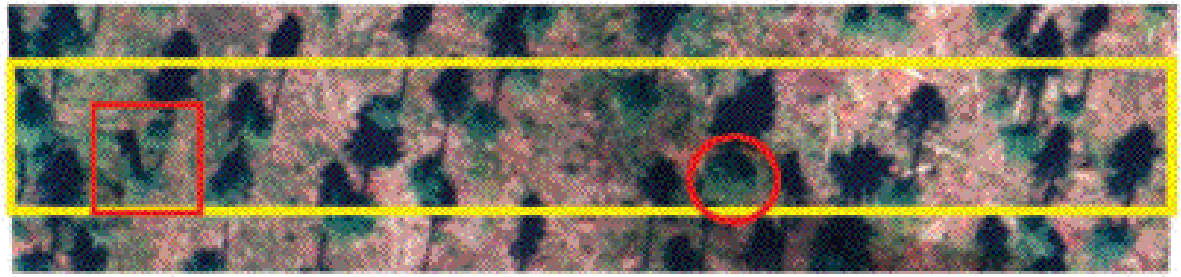
	plot	DBH	ht	
	#	7.90	37	
1	25	6.57	35	200N
	23	6.58	36	
	24	6.69	36	
2	33	6.76	35	
	12	6.79	39	200N
3	17	6.85	36	200N
	34	6.88	37	
	19	7.01	35	
4	10	7.23	35	200N
	5	7.26	38	
5	22	7.29	37	
	36	7.29	38	200N
6	13	7.44	38	
	21	7.46	37	200N
7	20	7.53	35	
	4	7.54	37	200N
	28	7.68	39	
8	32	7.84	35	
	9	7.88	38	200N
9	14	7.90	36	200N
	6	7.91	37	
10	7	7.97	39	200N
	30	8.03	36	
	26	8.23	35	
11	16	8.30	39	
	35	8.33	38	200N
12	8	8.55	35	
	1	8.55	36	200N
13	15	8.59	37	
	3	8.60	37	200N
	31	8.81	39	
14	27	8.91	37	200N
	29	8.93	36	
	18	9.03	37	
15	11	9.05	36	200N
	2	9.05	36	



SMC and CIPS “Star Wars” methods being developed for fertilization studies

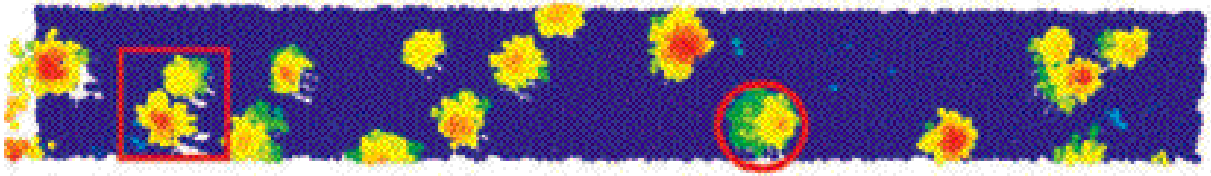

Study area
Northing
5.700×10^5
5.690×10^5
5.680×10^5
5.670×10^5
9.74×10^5
9.75×10^5
9.76×10^5



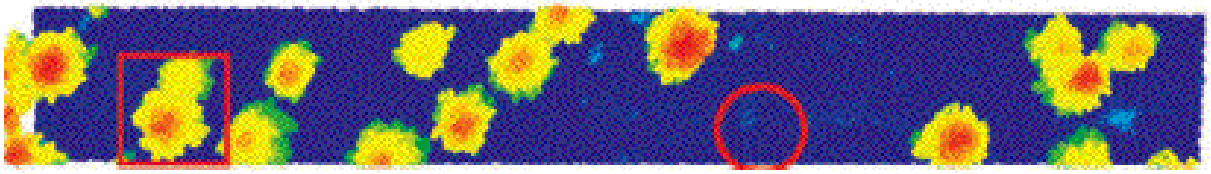


1999
orthophotograph

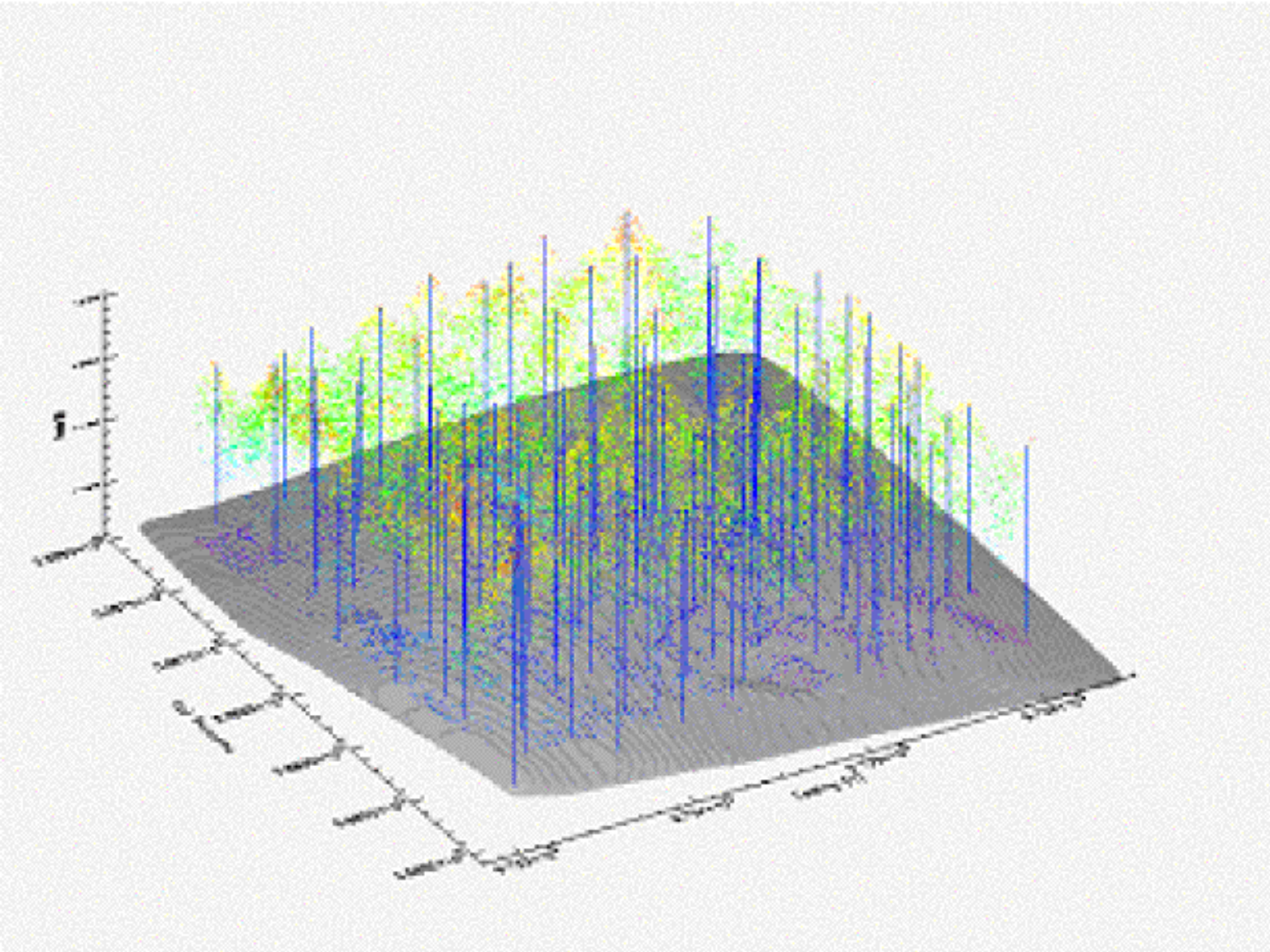
1999
LIDAR profile



1999
LIDAR plan view

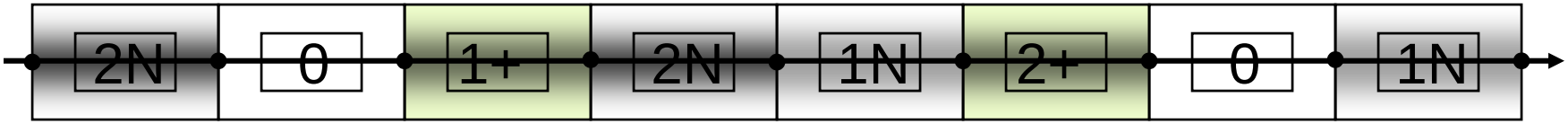


2003
LIDAR plan view

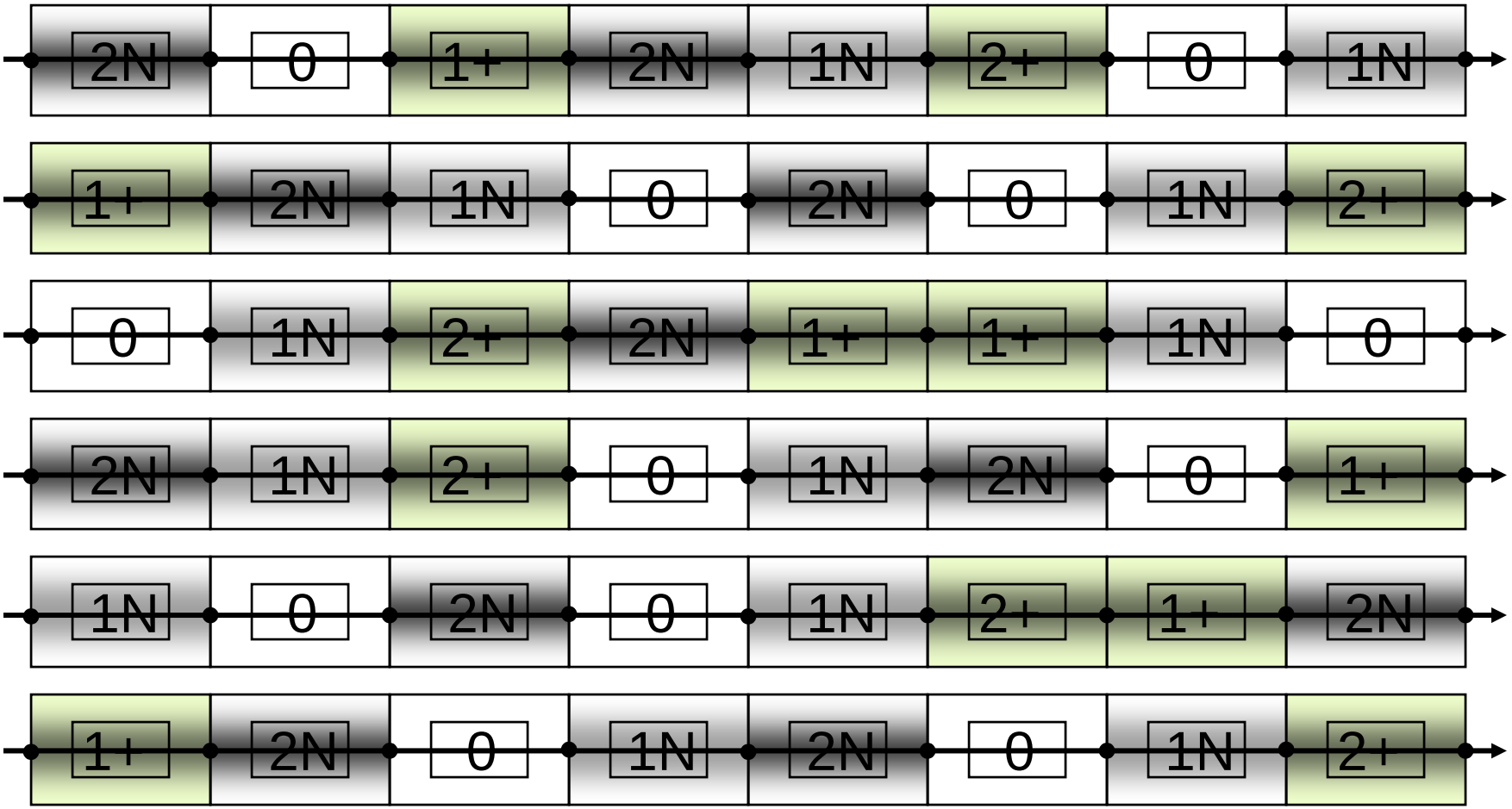


A single “line of flight”

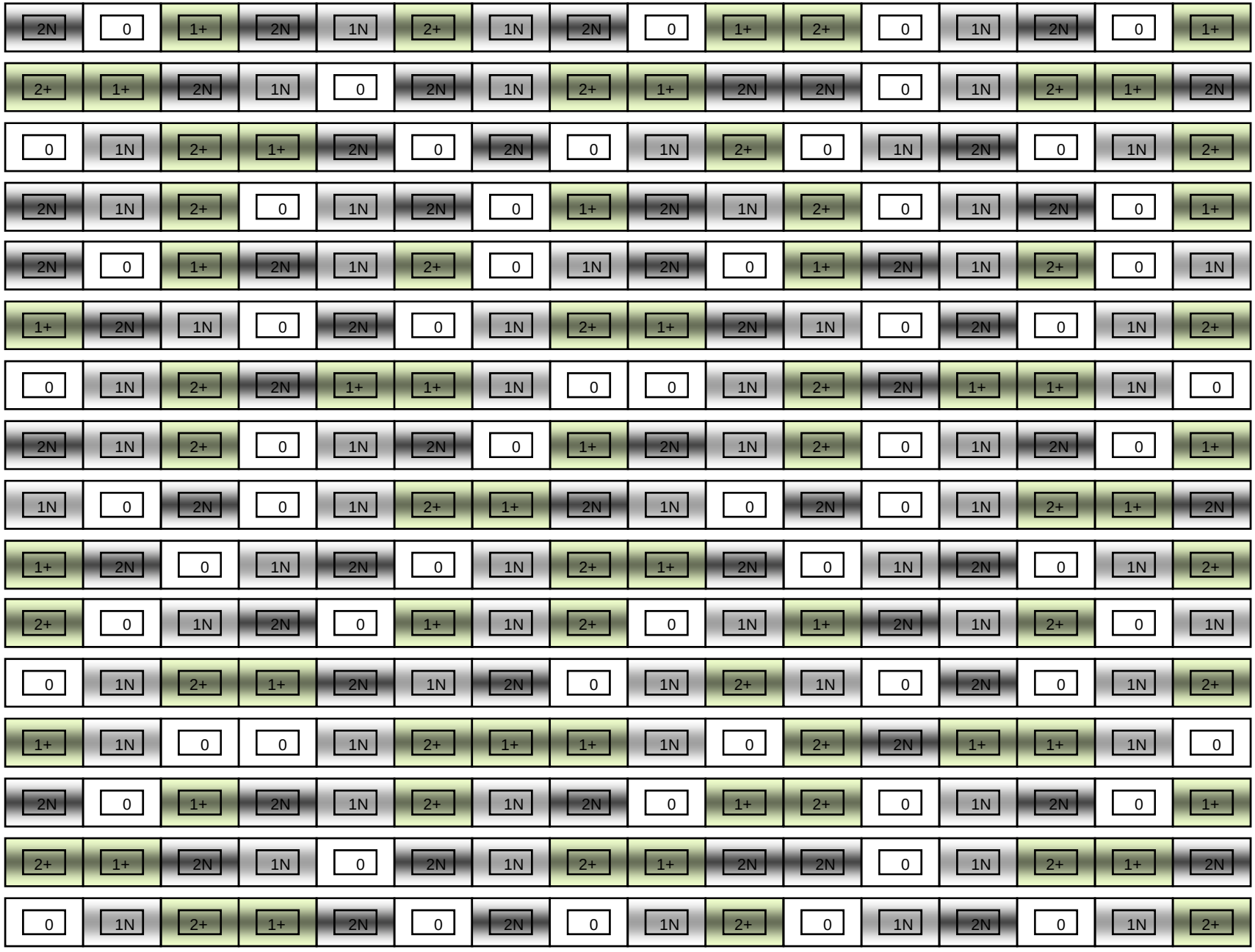
Random assignment of treatment



Random assignment of treatments along Multiple “lines of flight”



An “installation” with multiple plots of multiple treatments



SMC “Carryover” studies fo long-term impact of fertilization

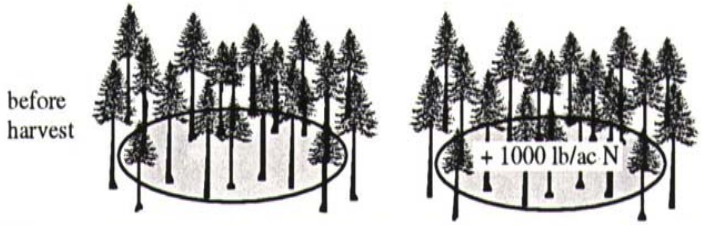


Figure 1. Douglas-fir stands at beginning of the study.

Figure 2. Stands after harvesting and slash distribution.

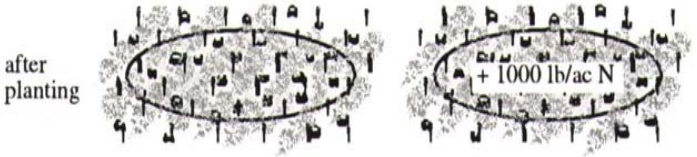


Figure 3. Stands following planting with identical stock.

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

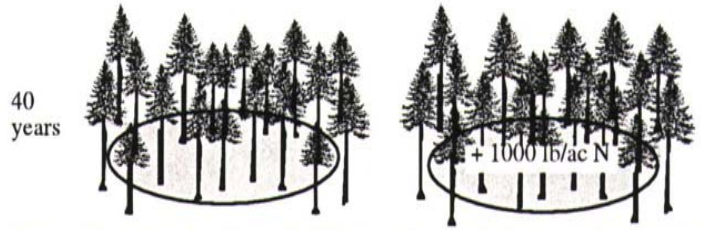
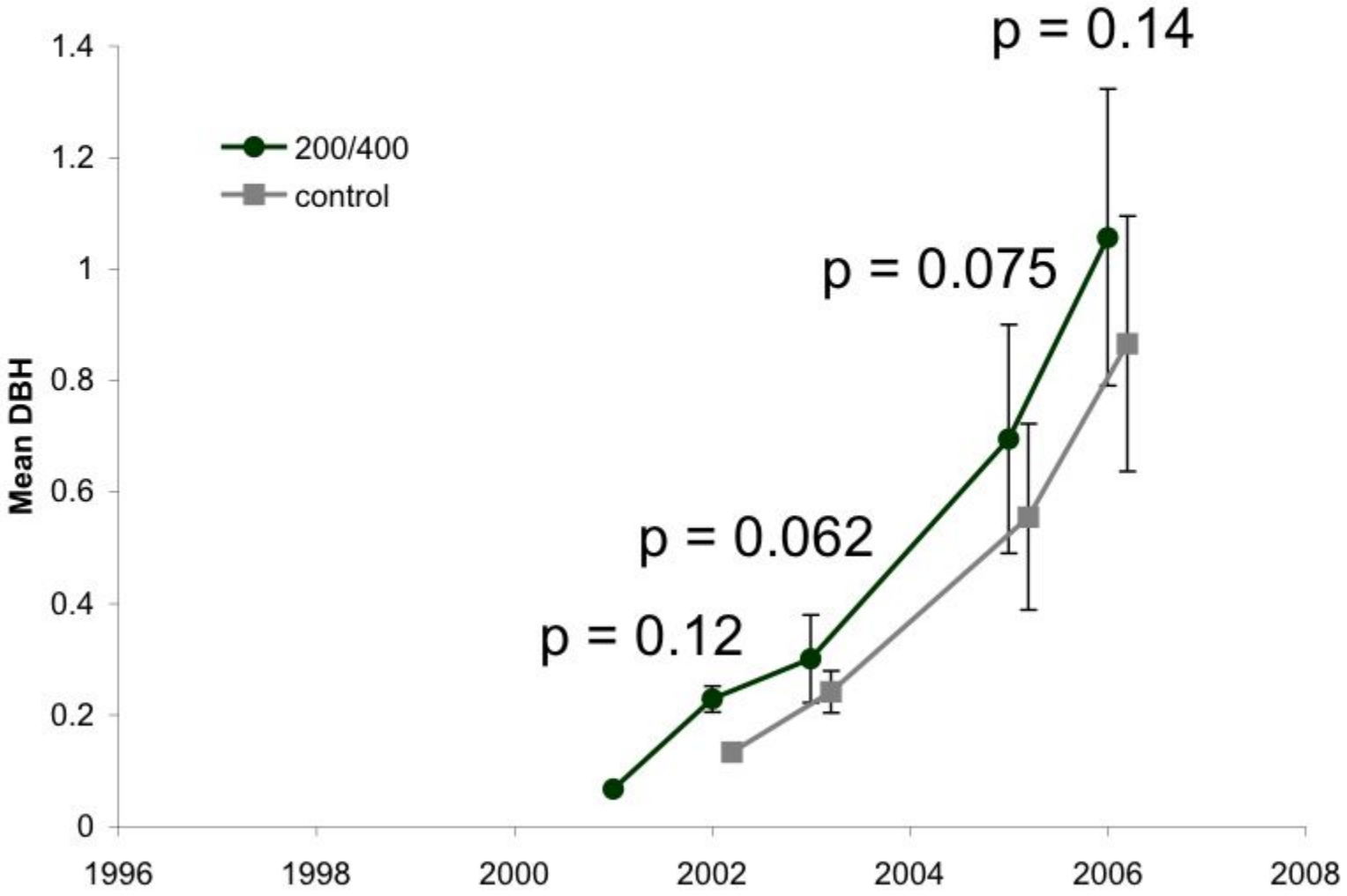
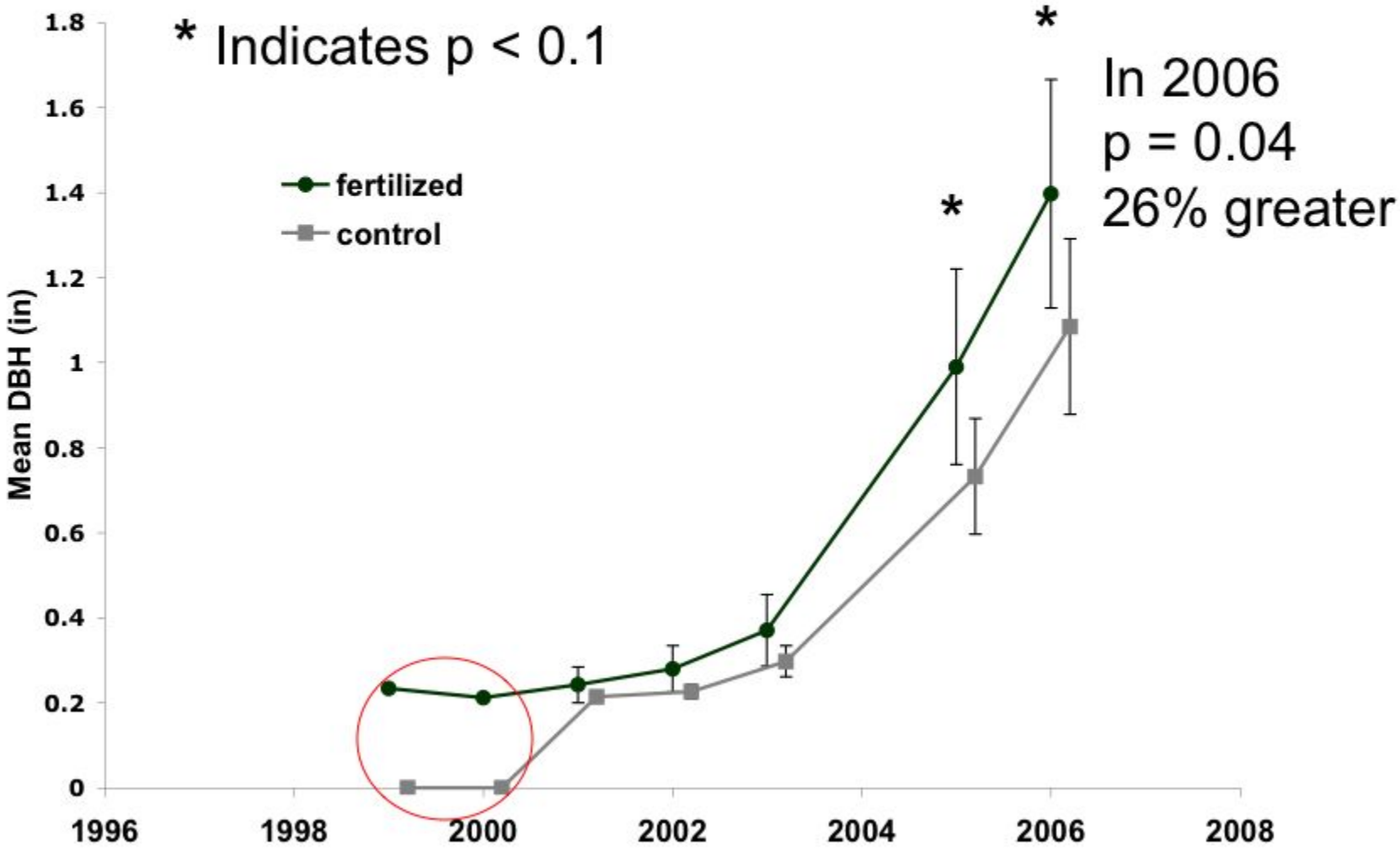


Figure 5. After 40 years. Possibility of studying subsequent rotations.

Regional Mean DBH with 200 and 400 lb Treatments



Regional Mean DBH with 1000 lb Treatments

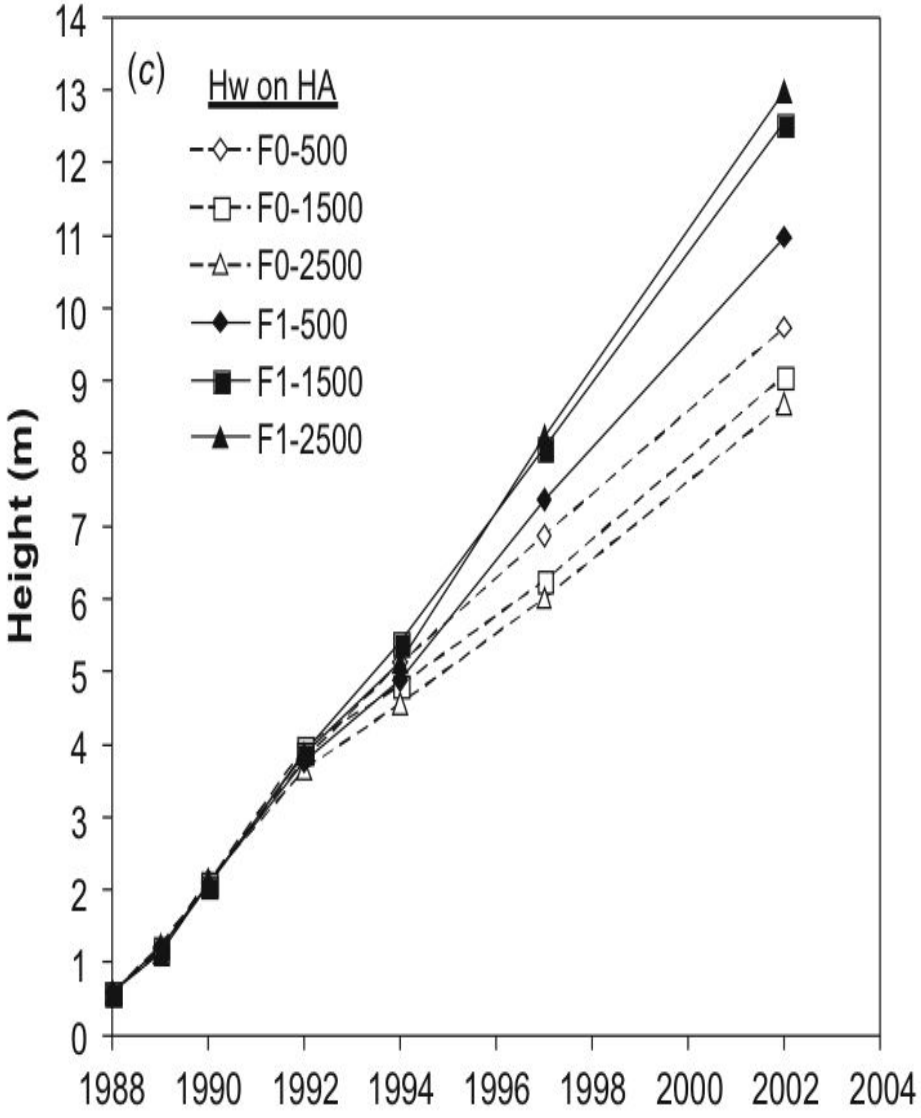


Non-SMC absolutely incredible results of fertilization from BC

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

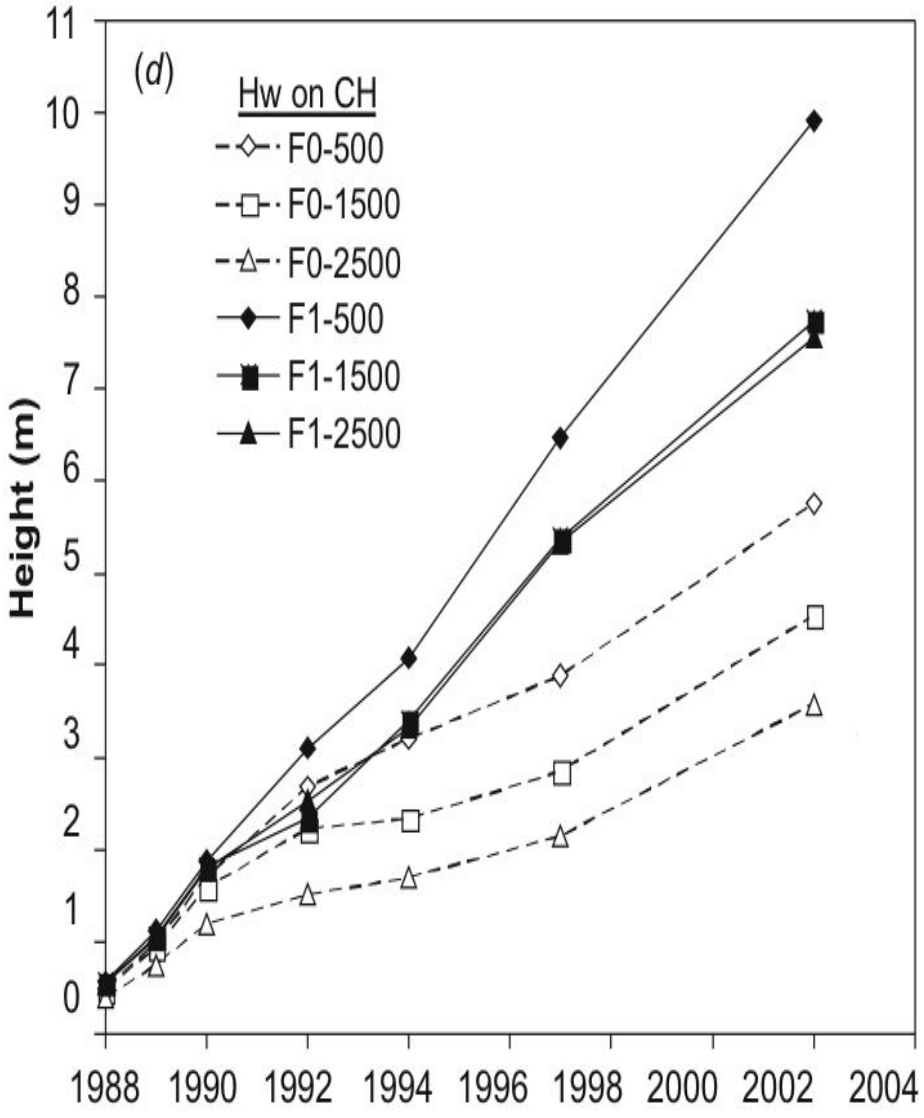

(d)
Hw on CH
F0-500
F0-1500
F0-2500
F1-500
F1-1500
F1-2500
Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
1988
1990
1992
1994
1996
1998
2000
2002
2004

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.