2019 Forests For Tomorrow Coastal Field Tour (April 30, 2019)

North Island District

Tuesday April 30, 2019		
Time	**Topic**	**Speakers**
8:00 AM	Meet at North Island District Office 2217 Mine Rd, Port McNeill	
8:15 AM	Depart North Island District Office	
8:40 AM	SCHIRP Research Sites	
8:40-8:45 AM	Western Forest Products Welcome and Safety Briefing	Annette Van Niejenhuis
8:45-9:00 AM	Salal Cedar Hemlock Integrated Research (SCHIRP) Introduction	Cindy Prescott
9:00-11:10 AM: 3 groups, rotate stops (40 minutes each), snacks/break on the go	Hemlock and Cedar Growth in the Salal-Dominated Sites (CH sites)	Annette Van Niejenhuis , Cindy Prescott
	Hemlock and Cedar in the 'Upland' Sites (HA sites)	Joel Mortyn
	Ecological Classification in SCHIRP sites	Jeff McWilliams
11:15 AM	Depart for Beaver Lake Recreation Site	
11:30-11:50 AM	Revisiting SCHIRP: Results After 30 Years	Bianca Eskelson, Woongsoon Jang
11:50-12:05 AM	General Group Discussion on Sites Visited and Next Steps for the Coastal Fertilization Program	Ann Wong, Neil Hughes
12:15-12:30 PM	Spacing and Thinning in Second Growth Stands	Joel Mortyn
12:40-1:40 PM	Lunch at Beaver Lake Recreation Site	
2:00-2:30 PM	Fertilization with N-only in Mixtures of Cedar and Hemlock Growth Response and Foliar Analysis (at South Port Hardy Main 342)	Cosmin Filipescu
3:15-4:00 PM	2 Talks: "Messy data" - Using Soil Fertility to Clarify Conifer Growth Response in Silviculture Experiments. A New Hypothesis Regarding Soil C Sequestration in Temperate Rainforests (at EP 1206)	Marty Kranabetter
4:10 PM	Back North Island District.	
5:00-6:00 PM	Archipelagos Bistro Restaurant Open for Drinks (Dalewood Inn. 1703 Broughton Blvd)	
6:00-7:00 PM	Evening Dinner	
7:00-7:30 PM	Stand Management Co-op Updates on Douglas fir and Hemlock Fertilization Research	Kim Littke
7:30-7:50 PM	FCI Funded Coastal Fertilization Economic Analysis	Jake Bapty, Kathryn Willis
7:50-8:10 PM	Summary, Next Steps and Closing Remarks	Neil Hughes

*Snacks, lunch and dinner provided. Please bring your own water bottle for filling at water station and personal protective equipment (e.g. hard hat, high vis vest, rain jackets, safety foot wear, etc.)

2019 Forests For Tomorrow Coastal Field Tour (April 30 – May 1st 2019)

North Island District

Tuesday April 30, 2019		
Time	**Topic**	**Speakers**
Evening Presentations (Optional) at the Archipelagos Bistro Restaurant, Dalewood Inn (1703 Broughton Blvd, Port McNeill)		
7:00-7:30 PM	Stand Management Co-op Updates on Douglas fir and Hemlock Fertilization Research	Kim Littke
7:30-7:50 PM	FCI Funded Coastal Fertilization Economic Analysis	Jake Bapty, Kathryn Willis
7:50-8:10 PM	Summary and Next Steps for a Coastal Fertilization Program	Neil Hughes
Wednesday May 1st, 2019		
Time	**Topic**	**Speakers**
7:30 AM	Depart from North Island District Office (2217 Mine Rd, Port McNeill)	
08:00-08:20 AM	Parking, Gear Up with Personal Protective Equipment	
8:20-11:30 PM	FESBC Cedar Release and Alder Management split FFT group into 2.	
	Group 1 start with Alder Management Site then Cedar Release	District-Paul Barolet
	Group 2 start with FESBC Cedar release then Alder Management	Murray Estlin, Shawn Tougas Jason Hutchinson, Jeff McWilliams
12:00-1:00 PM	Lunch – Telegraph Cove	
1:00- 1:15 PM	Depart and Travel to next site	
1:15 pm to 2:45 pm	North Island Chipping Plant and Utilization Tour	Shane Murdock (Owner)
2:45 pm to 3:00 pm	Travel to next site	
3:00-3:30 pm	Wood Waste Opportunities	Murray Estlin, Shawn Tougas, Melanie Plett, Paul Barolet
	Travel to next site	
4:00- 4:30 pm	Reforestation in Fires and wrap up	Murray Estlin, Shawn Tougas
5:00 pm return home	Arrive at North Island District Office	

*Snacks and lunch provided. Please bring your own water bottle for filling at water station. Strongly recommended personal protective equipment (hard hat, high vis vest, caulk boots). Recommended PPE (gloves, googles, waterproof wear).

Revisiting SCHIRP: results after 30 years

Prepared by Woongsoon Jang (PhD) and Bianca Eskelson (MSc Statistics, MSc & PhD Forest Biometrics) for FFT Coastal Field Tour April 30 – May 1 2019

Treatment description

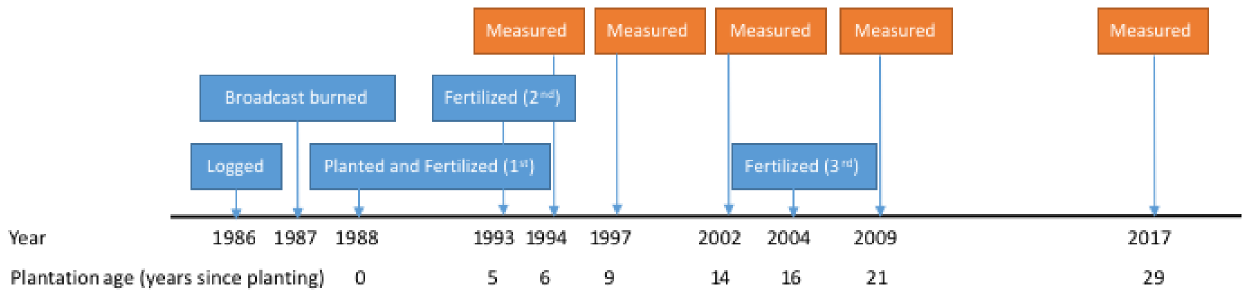

Figure 1. Timeline of SCHIRP trial.

- Implemented in CH (nutrient-poor) sites and HA (nutrient-medium) sites
- Logging in 1986 and broadcast burning in 1987
- Hw and Cw seedlings (64 seedlings per plot) were planted in Feb. 1988
- Three different densities (500, 1500, and 2500 TPH) + Scarification (only at 2500 TPH)
- 3-time-fertilization (60 g Nutricote™ at planting, 225N+75P in 1993, 225N in 2004)
- 128 plots (2 sites × 4 density/scarification × 2 fert x 2 species × 4 replicates)

22-year-results (Prescott et al., 2013)

- Both species benefit more by the fertilization on HA sites than CH sites
- The excess moisture hypothesis:
    - Poor drainage and aeration in soil → Impeded nutrient mineralization → low productivity (as well as limited fertilization response) in CH sites
- Monitoring and long-term research is important to fully understand complex ecological interactions and responses to fertilization treatments

Revisiting SCHIRP – 30-year-update

- Still consistent with the 22-year-results (Fig. 2)
- In 2017, across all densities, fertilized plots had:
  - 185.1 (Cw) and 187.5 m^3/ha (Hw) more volume than control in CH sites
  - 197.0 (Cw) and 281.0 m^3/ha (Hw) more volume than control in HA sites
- From ANOVA results, stand volume is significantly affected by:
  - Species, fertilization, density, and fertilization*density

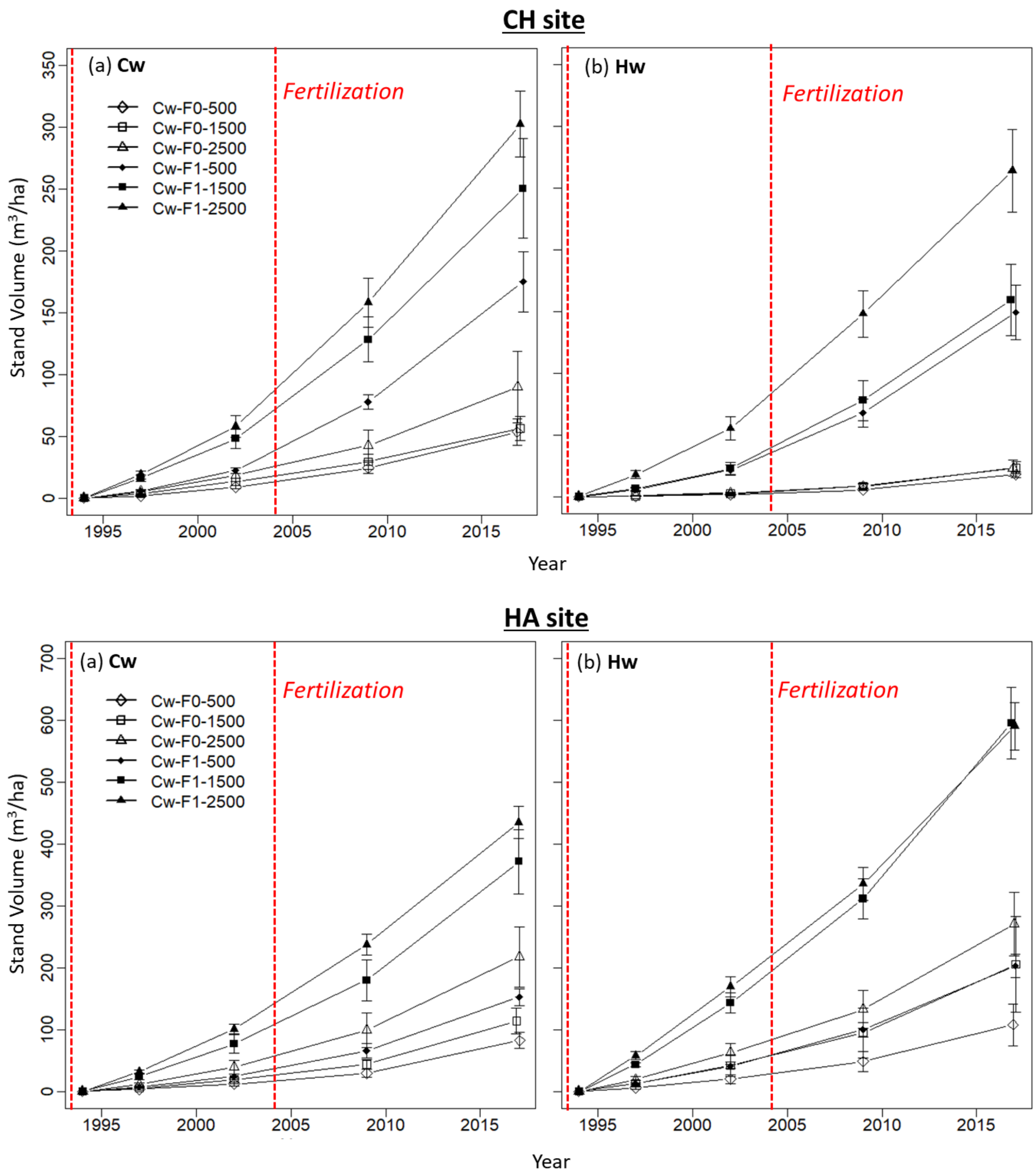

Figure 2. Stand volume yields for CH and HA sites. Notation: Cw: western redcedar; Hw: western hemlock; F0: unfertilized control, F1: Fertilized; following numbers represent planting densities (trees/ha).

Tree damage and mortality

- Tree damage
    - In 2017, a total of 3191 damages recorded from 2780 trees (planted + ingrowth)
    - Excluding mortality and missing trees, Cw and Hw had 773 and 1689 damage records from 494 and 782 trees, respectively
    - Majority (>90%) of total damage records were 'form/leader' damage
    - Disease/insect agents are minor: Cedar leaf blight (35 trees; Cw) and Armillaria root disease (13 trees; Hw)
- Tree mortality (planted trees; Fig. 3):
    - Majority of mortality occurred within the first 10 growing seasons
        - Fertilized > unfertilized
        - Hw > Cw
        - HA > CH
    - Varied by planting density

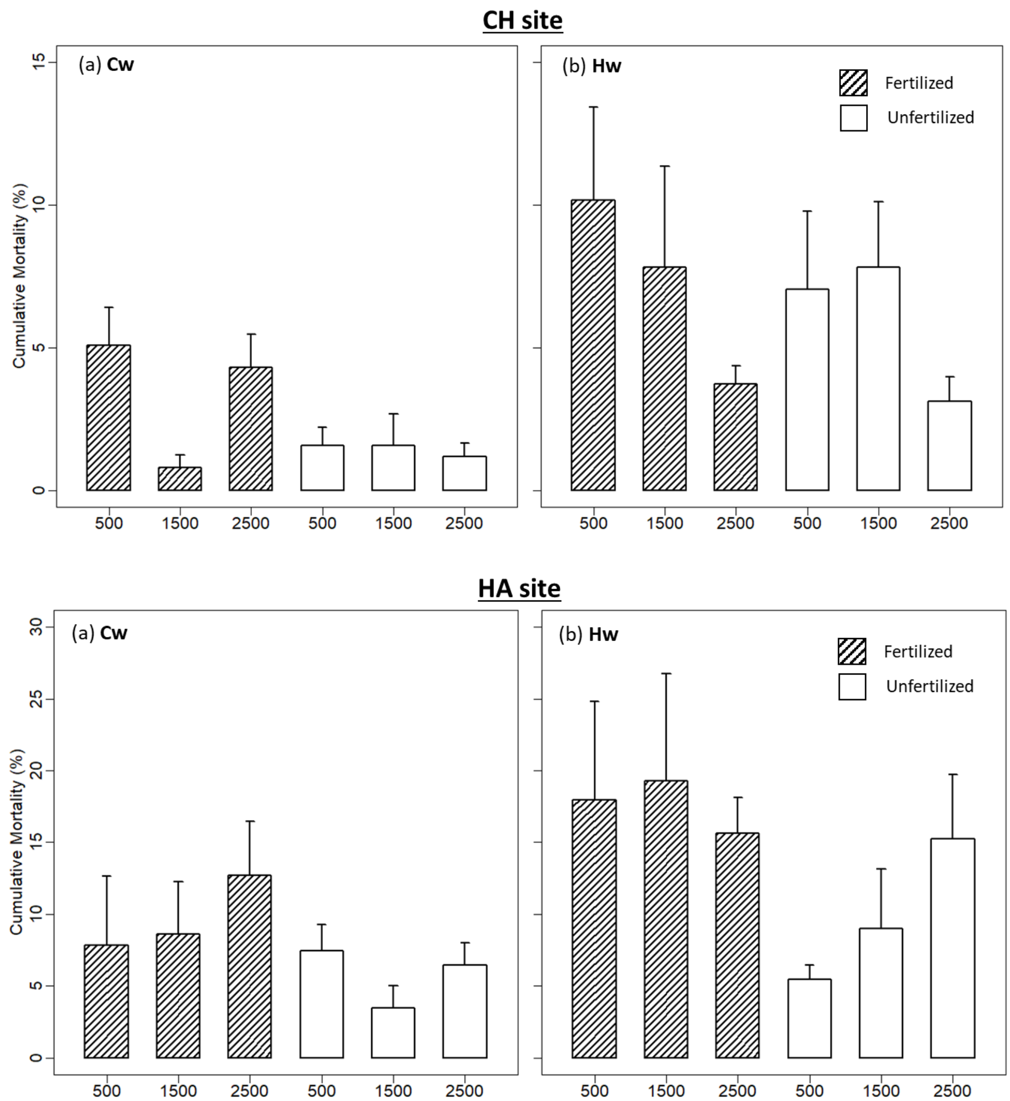

Figure 3. Cumulative mortality of planted trees after 30-year growing seasons. Numbers in x-axis stand for planting density (trees/ha).

Ingrowth

- Ingrowth = naturally regenerated trees that reached breast height (1.3 m)
- Huge variability in volume (0-235 m^3/ha, mean: 6.2 m^3/ha) and species composition
    - Varied by site, fertilization, planting density, and planted species (Fig. 4)
    - The variability might partially be attributed to indirect effects such as vegetation competition (e.g., salal and planted trees)

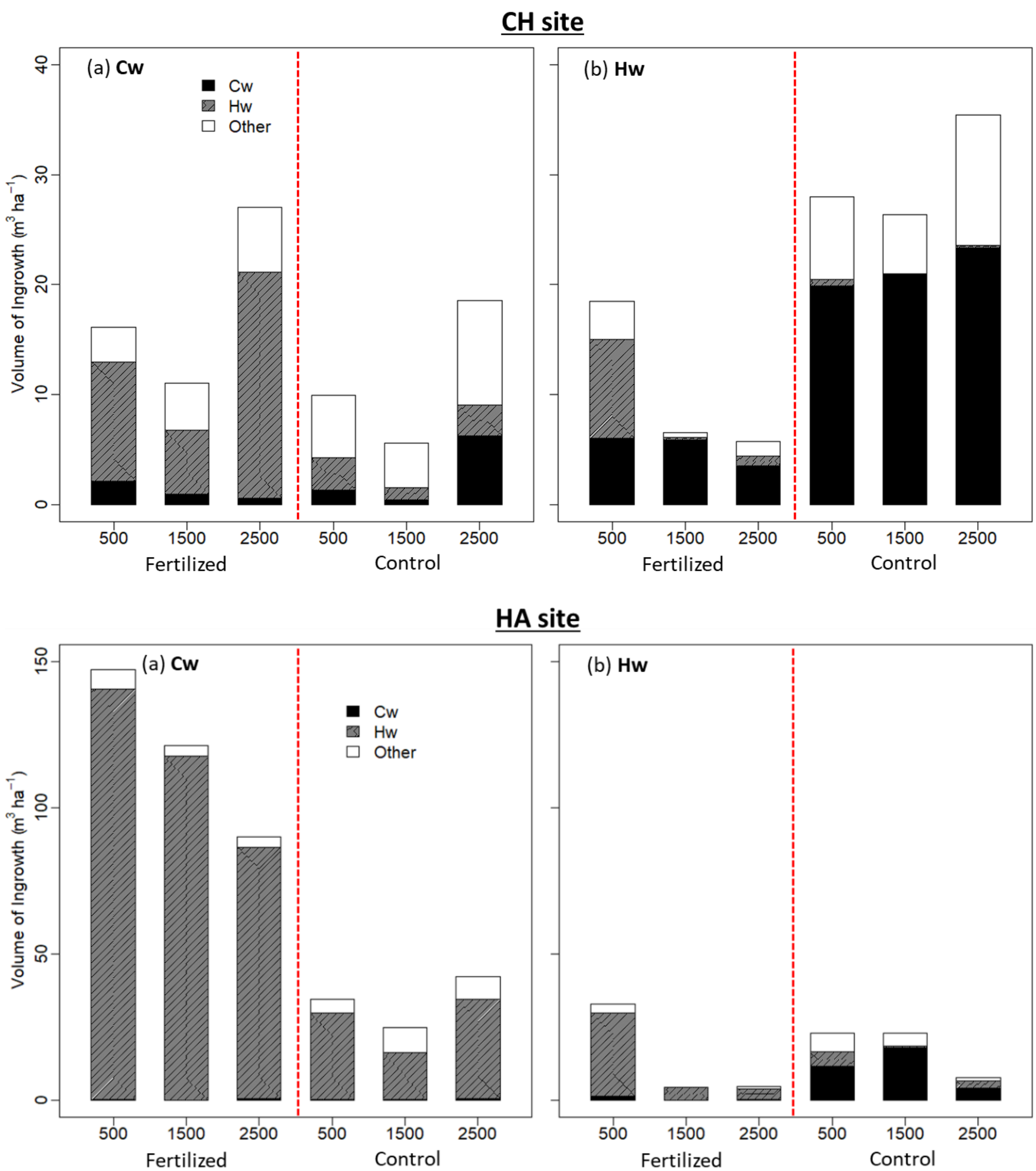

Figure 4. Volume of ingrowth after 30 year growing seasons. Numbers in x-axis stand for planting density (trees/ha).

Site classification

- Previous analyses used Lewis' site classification: CH vs. HA sites (Lewis 1982, 1985)
- Inhomogenous or waterlogged plots (34%) were identified as unsuitable for research (McWilliams and Klinka 2005)
- McWilliams and Klinka (2005) recommended to use CWHvm1 site series from the BEC system:
    - Considers soil moisture and nutrient regime
    - 84 suitable plots (bold font in below figure) were reclassified (Fig. 5)

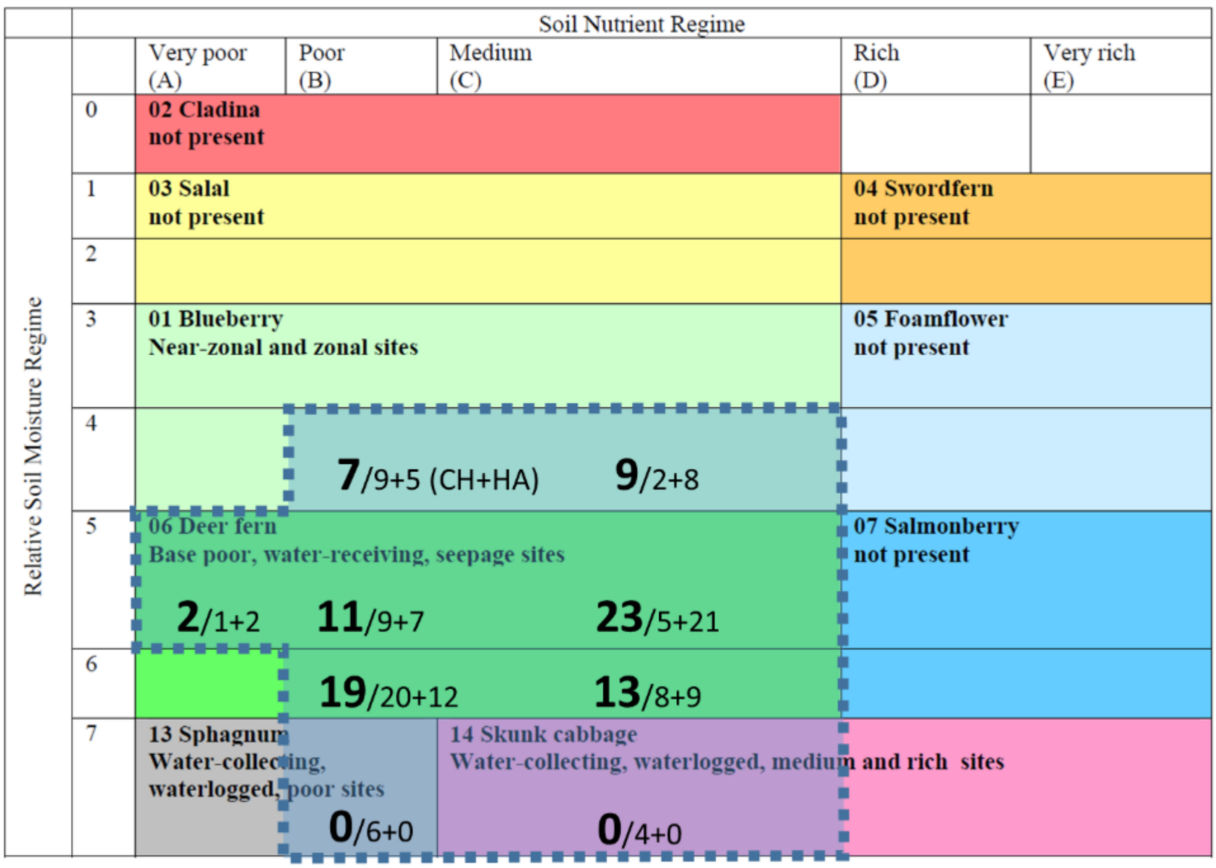

Figure 5. Number of plots (bold font) after exclusion of waterlogged and multi-stratum plots. Following numbers represent the number of plots classified as CH and HA sites by Lewis' classification, respectively. Redrawn from McWilliams and Klinka (2005).

- Re-analysis using the BEC site series (quick exploratory analysis):
  - Original CH and HA blocking ignored, waterlogged and/or multi-strata plots were excluded
  - On average in 2017, fertilized Cw and Hw had additional 174 and 230 m^3/ha volume than control across all BEC sites (Fig. 6)

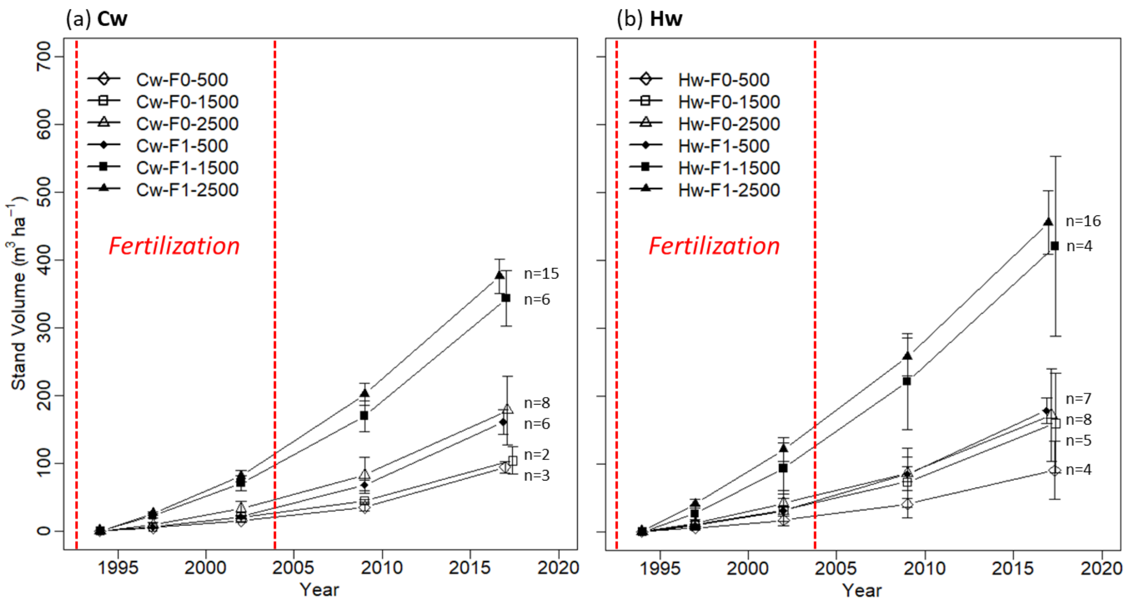

Figure 6. Recalculation of stand volume growth for a) western redcedar and b) western hemlock using BEC site series classification system (McWilliams and Klinka 2005). Plots with waterlogged and/or multi-strata were excluded.

Comparison of TIPSY simulation with SCHIRP – Cw only

- TIPSY settings for Cw fertilization simulation:
    - Initial density: 1500 TPH, no Operational Adjustment Factors (OAF) and 100% Fertilization effectiveness
    - Used Coastal Douglas-fir %volume response model
    - Cw SI 21 (avg. SI of CH sites) and 24 (avg. SI of HA sites)
    - Fert treatments: F0 (controls), F15 (@ age 15), F25, F35, Fx3 (@ ages 15,25,35)
    - Response = Volume yield after fertilization – Volume yield of control
- SCHIRP
    - 1500 TPH
    - waterlogged and multi-strata plots excluded from analysis
    - CH/HA classification ignored
    - SCHIRP results still showed superior responses (Fig. 7)
    - However:
        - Should note that SCHIRP was fertilized multiple times and earlier than represented in any of the simulation scenarios
        - Should keep in mind that the TIPSY simulation used the FDC fertilization response model
        - Moreover, be cautious because control plots in SCHIRP dominate nutrient-poor sites while fertilized plots were mostly in nutrient-medium sites (Fig. 8)

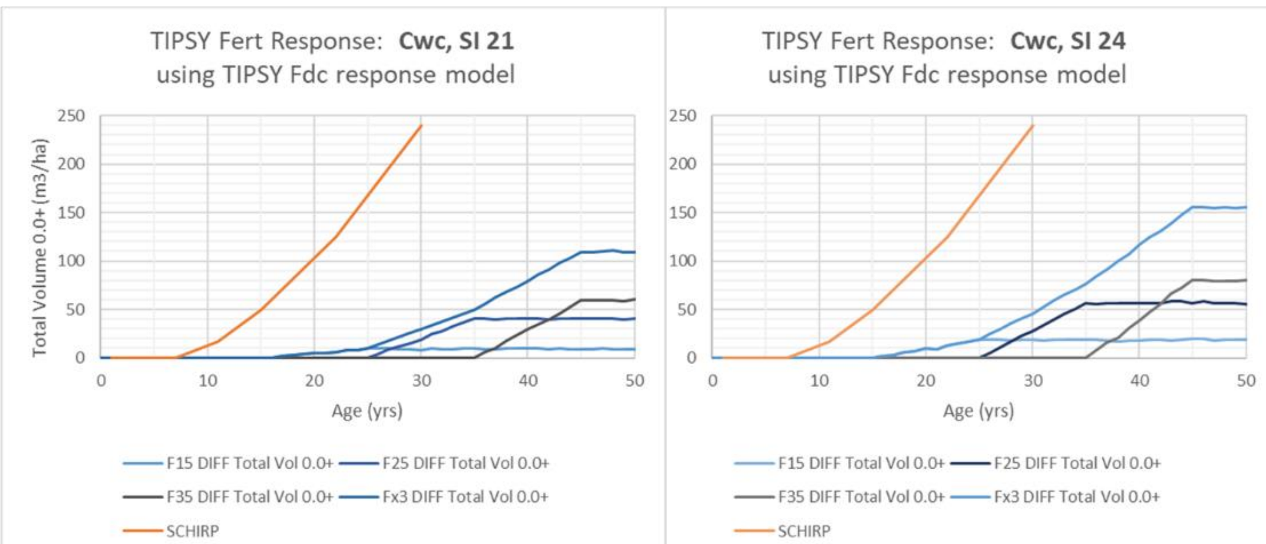

Figure 7. Comparison of SCHIRP results (orange line) with TIPSY fertilization simulations from two different SI; 21 (Avg. of CH sites) and 24 (Avg. of HA site). Y-axis represents the absolute volume response. Simulation run and figure generated by Steve Stearns-Smith.

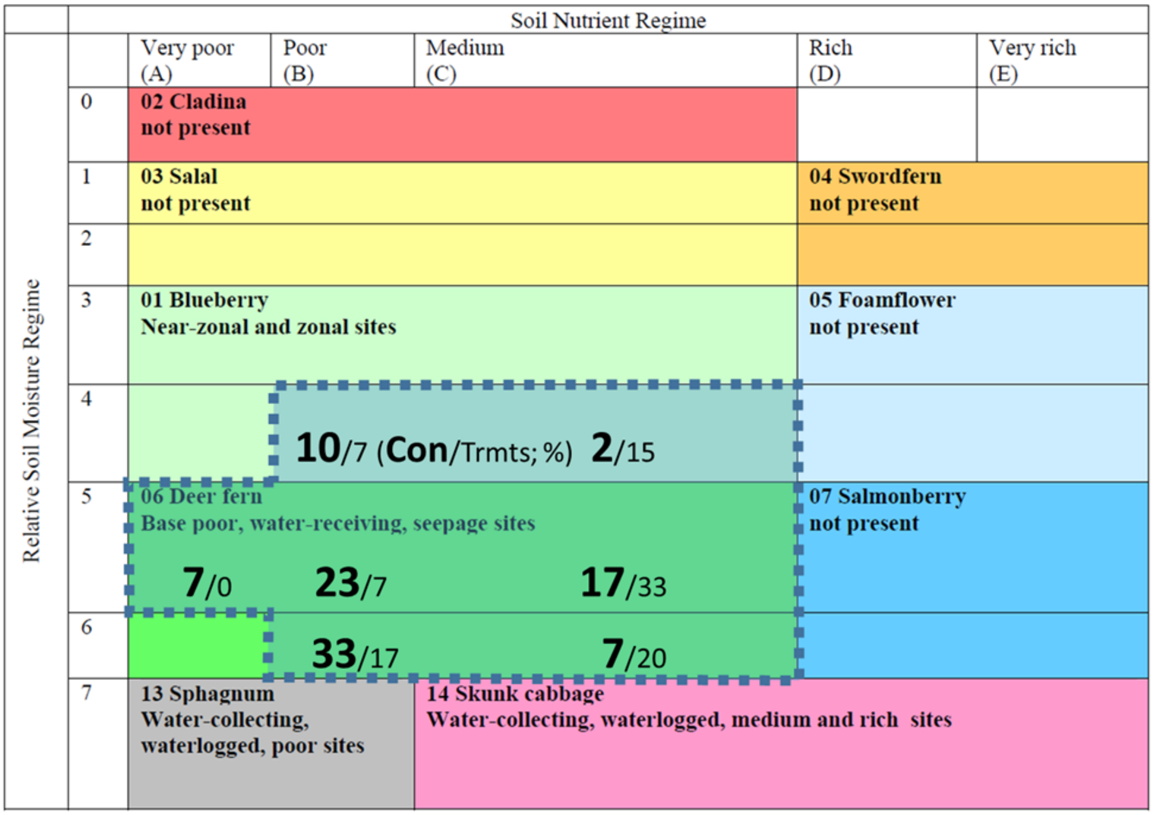

Figure 8. Proportion (%) of control (bold fonts) and treatment plots (followed by division sign) on each BEC site series. Redrawn from McWilliams and Klinka (2005).

Further research suggestions:

- Re-analyze SCHIRP trial considering the differences in site between control and fertilized plots through the lens of the BEC classification system
- Additional fertilization trials to assess the Cw and Hw responses according to site condition details (e.g., BEC site series), different age, and fertilization treatment (blend and frequency)
- Develop TIPSY/TASS fertilization module for Cw and Hw by re-analyzing existing trials together
- Expand the excess moisture hypothesis and new site classification to explain seedling mortality, understory vegetation dynamics, and natural regeneration on SCHIRP sites

References

Lewis, T. 1982. Ecosystems of the Port McNeill Block (block 4) of Tree Farm License 25. Unpublished Report to Western Forest Products Ltd., Vancouver, BC.

Lewis, T. 1985. Ecosystems of Quatsino Tree Farm License (TFL 6). Unpublished report to Western Forest Products Ltd., Vancouver, BC.

McWilliams, J., Klinka, K. 2005. TFL 6 SCHIRP installation: Site Identification of the SCHIRP Plots using the Biogeoclimatic Ecosystem Classification System. Unpub. Rep. 32 p.

Prescott, C.E., Nery, V., van Niejenhuis, A., Sajedi, T., Marshall, P. 2013. Nutrition management of cedar and hemlock plantations in coastal British Columbia. New Forests 44: 769-784.

Note from Cindy Prescott (updated May 23, 2019) the SCHIRP website has been updated and all publications are now available in pdf form: http://schirp.sites.olt.ubc.ca/

SCHIRP – THE STUDIES **Objectives:**

- To develop and implement strategies that improve site productivity on northern Vancouver Island's salal-cedar-hemlock cut blocks that are known to exhibit regeneration growth check by age 8.
- To determine the cause(s) of regeneration growth check on northern Vancouver Island's salal-cedar-hemlock cut blocks.
- To understand the effect of fertilization on site ecology and quantify site ecological services.

http://www.forestry.ubc.ca/schirp/homepage.html

Initiation	Description	Refereed Publications	Findings
SILVICULTURAL STUDIES (GROWTH AND VOLUME)			
1983	Ss, Hw, Cw Screening Trials	Weetman et al 1989, CJFR 19: 1501 – 1511	Diagnosis: Need N and P
1983	Demonstration Trials	Weetman et al 1990, 7th N. Am. For. Soils Conf. pp 451 – 499	determine rates of N and P
		Blevins et al 2006, For Ecol Manage 234: 116 – 122	P not required in 2nd broadcast fert
1984	Salal Eradication Trials	Weetman et al 1989, CJFR 19:1512 – 1520	Salal removal response
		Bradley et al 2000, Plant and Soil 223: 195 – 206	Fertilization improves site quality
		Bennett et al 2003, CJFR 33: 1516 – 1524	N+P = sustained site quality change
1988	SCHIRP Installation	Fraser et al 1995, For Ecol Manage 75: 27 – 39	on CH salal competes with Hw, not Cw
		Keenan et al 1994, For Ecol Manage 68: 251 – 261	Benefit of scarification not seen
		Messier et al 1995, New Forests 9:163 – 179	Scarification min effect on conifers
		Prescott et al 1996, For Chron 72: 293 – 302	Summary info to date
		Prescott and Blevins 1999, For Chron 75: 447 – 451	Best practices, ecology, partnerships
		Blevins and van Niejenhuis 2003, J Ecos Manage 3: 41 – 43	Stand Establishment Decision Aid
		Negrave et al 2007, CJFR 37: 2587 – 2599	Fertilization volume response larger on HA
		Nery 2012, Silviculture Magazine Fall: 11	Fertilization volume response larger on HA
		Prescott, Nery, et al 2013, New Forest 44: 769 – 784	Fertilization response continues; largest on HA
1988	Shore Pine Nurse Trial	Bothwell et al 2001, CJFR 31: 1272 – 1279	No nurse effect
1990	Organic Trials	McDonald et al 1994, CJFR 24: 297 – 301	Organics (except ash) effective fertilizer
		Weetman et al 1993, CJFR 23: 1815 – 1820	Sewage sludge effective fertilizer
		Prescott and Brown 1998, CJFR 28: 1328 – 1334	Organics equivalent (not better) than fert
1992	Compost Trials	Prescott and Zabek 1997, CJFR 27: 598 – 602	Straw, fish compost effective fertilizers
		Prescott and Blevins 2005, CJFR 35:211 – 214	Biosolids effective fertilizer
1996	Extreme Fertilization	Bennett et al 2004, CJFR 34: 502 – 506	High N detrimental to salal
	Transitional, Kennedy Lake Installations		
1997	Suquash Drainage Installation		
1999	Vaccinium Installations		
ECOLOGICAL FUNCTIONS STUDIES			
1987	Vegetation biomass	Messier 1992, Can J Bot 70: 2271 – 2276	Light controls salal growth
		Messier and Kimmins 1991, For Ecol Manage 46: 275 – 294	Salal recovery after clearcutting
		Messier et al 1989, CJFR 19: 1470 – 1477	Light requirements for salal
1987	Microtopography	Messier and Kimmins 1992, CJFR 22: 273 – 278	Cw growth factors
1987	Nutritional Stress	Messier 1993, For Ecol Manage 60: 181 – 206	Nutrients and competition limit growth
		Messier and Kimmins 1991, Wat Air Soil Pollut 54:257-267	Salal competition and end of assart
1987	Competition, Biomass Allocation	Chang et al 1996, For Ecol Manage 83: 1 – 11	Salal removal improves tree ht growth
		Chang and Trofymow 1996, J Biol Fert Soils 23: 145 – 152	Reduced soil respiration in post harvest
1998	Salal Competition	Mallik and Prescott 2001, Agron J 93: 85 – 92	Salal not allelopathic
		Prescott and Sajedi 2008, For Chron 84: 29 - 36	Salal a symptom of problem
1989	Soil Fauna	Battigelli et al 1994, CJFR 24 : 1557 – 1566	Identifying soil fauna in CH, HA
1990	Nutrient Availability	Prescott et al 1993, CJFR 23: 605 – 610	Low supply of N and P in CH floors
		Keenan et al 1993, CJFR 23: 1052 – 1059	Low N on CH not due to detritus loads
		deMontigny et al 1993, Can J Soil Sci 73:9 – 25	On CH - higher tannin, higher C:lignin
		Prescott and Preston 1994, CJFR 24: 2424 – 2431	N mineralization corr to initial N, C:N
		Prescott and McDonald 1994, CJFR 24: 2432 – 2438	Not C nor lime improve N-mineralization
		Fox et al 1994, Can J Soil Sci 74: 1 – 15	Forest floor components
		Keenan et al 1995, CJFR 25: 1850 – 1857	Nutrient cycling varies btw CH and HA
		Keenan et al 1995, For Soil Sci Soc Am pp 547 – 568	Low N in Cw foliage
		Prescott et al 1995, For Soil Sci Am pp 377 – 396	CH OG forest floor has less N and P
		Keenan et al 1996, Can J Bot 74: 1626 – 1634	Cw litter of poorer quality for N release
1990	Ericoid Mycorrhizae	Xiao and Berch 1992, Mycologia 84: 470 – 471	identifying salal mycorrhizae
		Xiao and Berch 1996, Can J Bot 74:337 – 346	Ericoid mycorrh fungi in OG and cutover
		Monreal et al 1999, Can J Bot 77: 1580 – 1594	4 mycorrhizal fungi, one prev. unknown
		Berch et al 2002, Plant and Soil 244: 55 – 66	identifying salal mycorrhizae
1991	Labeled N Fertilizers	Chang et al 1996, CJFR 26: 313 – 321	Trees compete poorly with salal for N
		Chang and Preston 1998, Soil Biol Biochem 30: 1023 – 1031	*Soil N extraction methods*[1]
		Chang et al 1999, For Ecol Manage 117: 199 – 209	*Indicators of soil N availability*[1]
		Chang and Handley 2000, Functional Ecol 14: 273 – 280	Salal, nutrient deficiency depress Cw
		Chang and Preston 2000, CJFR 30: 1379 – 1388	Low N and competition = poor seedlings
1992	Microbial Biomass	Chang et al 1995, CJFR 25: 1595 – 1607	Nutrient status = OG>3-yr old>10-yr old
1992	Phosphorus forms	*Cade-Menum and Preston 1996, Soil Sci 161 : 770 – 785*	*Improved P cycling measures methods*[1]
		Cade-Menum and Berch 1997, Can J Bot 75: 1226 – 1235	P compounds affect Cw growth
		Cade-Menum and Lavkulich 1997, Commun Soil Sci Plant Anal 28: 651 – 663	*Soil P determination methods*[1]
		Cade-Menum et al 2000, CJFR 30: 1714 – 1725	No difference in P btw CH and HA soils
		Cade-Menum et al 2000, CJFR 30: 1726 – 1741	SP Burning shifts P to inorganic forms
1996	Nitrogen and CWD	Brunner and Kimmins 2003, CJFR 33: 1670 – 1682	CWD N fixation not cause of diff N avail
1996	Cw, Hw, and Salal Roots	Bennett et al 2002, CJFR 32: 1208 – 1216	Cw, Hw, and salal rooting habits
1997	Cw Survivorship	Weber et al 2003, CJFR 33: 854 – 861	Cw needs disturbance for seedling est.
		Weber et al 2005, Oecologia 143: 148 – 156	Cw arbuscular mycorr. on CH, not HA
1999	Soluble Organic Nitrogen	Hannam and Prescott 2003, CJFR 33:1709 – 1718	Soluble org N lower in cutovers than OG
2001	Humus Microbes	*Leckie et al 2004, Soil Biol Biochem 36: 529 – 532*	*Humus microbial measures methods*[1]
		Leckie et al 2004, Microbial Ecol 48: 29 – 40	CH and HA differ in soil microbes
		Leckie et al 2004, CJFR 34: 1426 – 1435	Fert-improved Hw benefits soil microbes
2004	Hw Mycorrhizae	Wright et al 2009, Mycorrhiza 19(4):267-76	Abundance differs btw fert/control
2006	Greenhouse Gases	Basiliko et al 2009,CJFR 39: 1220-1235	no short term effect on soil GH gas flux
2006	Soil moisture and aeration	Sajedi et al 2012, J. Ecol. 100:605-618	redox threshold limits biological processes, growth
2014	Succession	Weber et al 2014, CJFR 44: 1145 – 1155	multi-pathway succession

[1] *Italicized papers present scientific methodology developments*

Data and research needs to improve fertilization modules

Prepared by Bianca Eskelson (MSc Statistics, MSc & PhD Forest Biometrics) for FFT Coastal Field Tour April 30 – May 1 2019

1) What methodology and data should be collected so that it'll be useful in improving the fertilization module in TASS?

Understanding the potential of fertilizer response across gradients of stand conditions:

Paired-tree installations can be used across gradients of stand age, stand density, and site productivity to assess if trees under certain stand conditions respond to fertilizer treatments. For example, what increases the probability of a positive response?

The data collected in paired-tree studies do not provide enough information about stand-level responses to fertilization, which are needed for incorporating fertilization effects into models like TASS/TIPSY. Stand dynamics with regards to stand differentiation are impossible to quantify.

→ good for screening trials, but not useful for modelling

Incorporation of fertilization effects into TASS/TIPSY:

We need to understand the response of the dynamics of the full stand to fertilization treatments, rather than responses measured on individual, paired trees. Collecting information about full stand dynamics after fertilization will require the establishment of experimental trials such as EP703 or the Shawnigan Lake research trial.

Trial characteristics should include the following:

- Selection of stands of similar characteristics with regards to stand age, stand density, and site productivity
- Random assignment of treatments to stands, including untreated controls.
- Fixed area plots
- Tagged trees – keep track of mortality and ingrowth
- Tree measurements taken for all trees on the plot:
  - DBH
  - Height
  - Height to base of live crown
  - Crown radii (4 minimum)
  - Damage indicators
- Foliar samples prior to fertilization (see suggestion in synthesis report by Addo-Danso et al. 2019)
- Soil and foliage studies
  - Where do the nutrients go? And which trees get the nutrients? (see Holger Brix' experiment at Shawnigan Lake and synthesis report of the study; see Stand Management Cooperative protocols?)

  - Possibility to link paired-tree installations with larger fixed area experiments via similar soil/foliage sampling protocols? → run coarse-scale screening trials using paired-tree installations + implement larger, fixed area experimental plots at site conditions where we expect positive treatment effects to quantify treatment effects for model development/improvement.

Short-term solution ('quick fix'):

Use data sets listed in Addo-Danso et al. (2019) and re-analyze the data across trials similar to what was done for Rob Brockley's interior BC trials in Jang et al. (in revision with CJFR). Then use the model results to update/create TIPSY tables that can be used in the short-term while new trial data are being analyzed and incorporated into TASS.

2) Identify research needs to help us improve our knowledge of fertilization response in Fd, Cw, and Hw on the BC coast

In their synthesis report Addo-Danso et al. (2019) identified the following research needs:

1. **Continued monitoring of established installations and fertilization trials → assess duration of fertilization response**
   - Currently, TASS and TIPSY assume that fertilization response ends after 10 years. Existing trials provide some data beyond 10 years. Therefore, re-measuring and re-analyzing existing trials beyond 10 years could shed light on the duration of treatment effect.
   - Detailed analysis of existing trial data needed? For TASS simulations, the following is of interest: How does the competitive tree status or the relative tree size and crown size influence its ability to respond to fertilization? → This would require a tree-level analysis of the existing research trial data, which have mainly been analyzed at the stand-level. This has been proposed by Jang and Eskelson (2019), in their NSERC ENGAGE final project report to Western Forest Products.
   - There is an existing body of literature on response duration and types of response (e.g., direct vs. indirect; Type 1 vs. Type 2).
     - Direct response = growth increases as a result of improved nutrition
     - Indirect response = growth increase caused by changes in stand structure and tree sizes (e.g., bigger trees grow faster even after nutritional effect is gone)
     - Type 1 response: shorten time to get to a certain stage of stand development
     - Type 2 response: change in long-term site productivity – it has been suggested that P fertilization can do this
   - Revisit existing literature to see what exactly we do not know about duration of fertilization response?
   - The duration of fertilization effect in repeatedly fertilized stands is not well documented. There may be room for research here as well.

2. **Additional fertilization trials are needed at sites outside of northern Vancouver Island. New field experiments should be designed to assess specifically how growth responses to addition of N-only and N+P fertilizers vary with stand age, stand density, and site quality.**
    - Establish new fertilization trials (control, N-only, N+P) for cedar and hemlock across stand age, stand density, and site productivity gradients.
    - Conduct foliar nutrient analysis prior to fertilization as suggested by Addo-Danso et al. (2019), who identified these as most reliable indicator of potential growth response to fertilization. The results of this analysis could be delivered within a 3-year timeline. This kind of analysis will provide valuable insights.

3. **Quantify potential influences of fertilization of coastal forests on carbon storage and fluxes of greenhouse gases.**
    - To address this research need, one needs to fully understand stand dynamics including growth, mortality, and ingrowth to quantify carbon storage and fluxes. This requires experimental trials with fixed area plots and tagged trees that are monitored over time.
    - To capture ecosystem carbon storage, the trial establishment could have components that look at surface fuel carbon (i.e., small and coarse down woody material, litter, and duff) and soil carbon in addition to tree carbon. This could be linked with existing protocols from other ongoing studies (e.g., partial cutting, post-fire fuel dynamics).

4. **More information is needed with regards to fertilization effects on amabilis fir.**
    - See 2. As described for cedar and hemlock.

References

Addo-Danso, S.D., C.E. Prescott, and L. de Montigny. 2019. Responses of western hemlock, western redcedar, and amabilis fir to fertilization: a synthesis. Prov. B.C., Victoria, B.C. Tech. Rep. xxx. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Trxxx.htm

Brix, H. 1993, Fertilization and thinning effect on a Douglas-fir ecosystem at Shawnigan Lake: A synthesis of project results. FRDA Report 196.

Jang, W., B.N.I. Eskelson, L. de Montigny, C. Bealle Statland, D.F. Sattler, and S. Ahmed. (in revision) Stand growth responses after fertilization for thinned lodgepole pine, Douglas-fir, and spruce in forests of interior British Columbia, Canada. In revision with the Canadian Journal of Forest Research.

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TASS AND TIPSY FERTILIZER MODULES

Prepared by Eleanor McWilliams, MSc, RPF for FFT Coastal Field Tour April 30 – May 1 2019

OVERVIEW

The fertilization modules for TASS and TIPSY are inter-related but nevertheless substantially different. The modules in both models incorporate assumptions about fertilizer response that compensate for the limitations of data available from research trials. Those assumptions are based on the interpretation of the research results by the modelers, and reflect their experience and judgment about how best to extrapolate those results to the problems and decisions faced by silviculturists, analysts and forest managers.

TASS FERTILIZER MODULE

TASS is a spatially explicit individual tree model that simulates crowns and crown competition in three dimensions. Individual tree growth is a function of the simulated crown size and the photosynthetic efficiency of the crowns. This model structure provided an ideal basis for incorporating the understanding of how Fdc responds to fertilization. Our detailed understanding of the Fdc response comes from an incredible body of work completed by Dr. Holger Brix and his team at the Shawnigan Lake research site.[1] Key findings from this work show that the Fdc fertilizer response is due to both an increase in photosynthetic efficiency and foliar biomass. Based on this work, coefficients were derived to modify the foliar volume of simulated tree crowns in TASS, mimicking the increases in the photosynthetic efficiency and biomass of foliage. Other functions modelled the increase in height growth.

When incorporated into TASS, the predicted increases in foliar volume and height growth translated to increases in bole volume increment and increases in associated attributes such as basal area and DBH. After the relationships were incorporated into TASS, the magnitude of the simulated responses in Fdc height, basal area and volume were calibrated to conform to the stand-level statistics observed in research trials, with the most weight given to the results from EP703. One key assumption is that fertilizer response for Fdc is zero when site index is greater than 37 m.

We do not have comparable detailed research on other species which could be used to develop coefficients to modify foliar volume and height increments. Therefore for other species (Fdi, Lw, Pw, Py, Pl, Pj, Sw, Bl, Sb and Se) bole increment multipliers were developed that are a function of site index and years since fertilization. They are applied for a 9 year period after fertilization. For example, for Pl, site index 19 the bole increment multipliers are 1.35, 1.20, and 1.10 for years 1-3, 4-6, and 7-9 respectively. These were developed based on research data and expert opinion and TASS was calibrated to all available research data. The extensive research done by Rob Brockley on interior species and his expert opinion contributed significantly to this effort.

For all species except Ss, the assumed fertilizer dosage is 225 kg N/ha.

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[1] An excellent summary of the work completed at Shawnigan Lake and highly recommended reading is: Brix, H. 1993, Fertilization and thinning effect on a Douglas-fir ecosystem at Shawnigan Lake: A synthesis of project results. FRDA Report 196.

Ss fertilizer response is modelled in TASS using the Fdc version of the fertilizer module and assumes an application of 250 kg N/ha plus 100 kg P/ha.

TASS does not have a fertilizer module for Hw or Cw. This is due to a lack of consistent responses in the research data for Hw and a lack of data for Cw. It is possible to have custom TASS runs completed by the TASS modelling group.

Multiple fertilizations can be simulated in TASS but each is treated as independent event with no recognition that a fertilization treatment is the second or third in a series.

TIPSY Fertilizer Module

The TIPSY fertilization module is described in detail in the TIPSY "Help" facility. The level of response for a particular application is derived by interpolating the percentage responses found in the "Ministry Recommended Fertilization Response Tables" (partial example provided in Table 1) based on the site index of the stand and the top height at the time of application.

The absolute gain in total volume (m^3/ha) over ten years is computed from the percentage gain multiplied by the ten-year growth predicted for the stand without fertilization. The total volume gain is implemented as an increase in top height, which then translates the effects of the fertilization to all the associated stand statistics. After the ten-year response period is over, the absolute gain is assumed to be fixed for the remainder of the simulation (Figure 1).

Table 1. Abridged table of Douglas-fir fertilization response for TIPSY.

Site Index (m)	Top Height (m)	10-year Volume Response (m^3/ha)	10-year Volume Response (%)
15	5	6	*19*
15	*10*	*13*	*33*
15	*20*	*9*	*53*
15	*25*	*4*	*44*
25	*5*	*18*	*23*
25	*10*	*35*	*33*
25	*20*	*40*	*50*
25	*30*	*25*	*43*
35	*5*	*2*	1
35	*10*	*4*	2
35	*20*	*4*	*2*
35	*30*	3	*2*
35	*40*	*3*	*3*
35	*45*	*2*	*3*

Example of TIPSY fertilizer response

- Fdc, Site Index 25, 1200 planted, fertilized at top height 20 m (age 40)
- Ministry response table indicates a 50% response (highlighted row in Table 1)
- Aerial application adjustment of 80%
  - 50% * 80% = 40% response
- Projected unfertilized growth over 10 year period = 101 m^3/ha
- Response = 40% x 101 = 40 m^3/ha
- Total fertilized growth over 10 year period = 101 + 40 = 141 m^3/ha

The total response is implemented linearly via an increase in top height over the 10 year period (e.g., Figure 1).

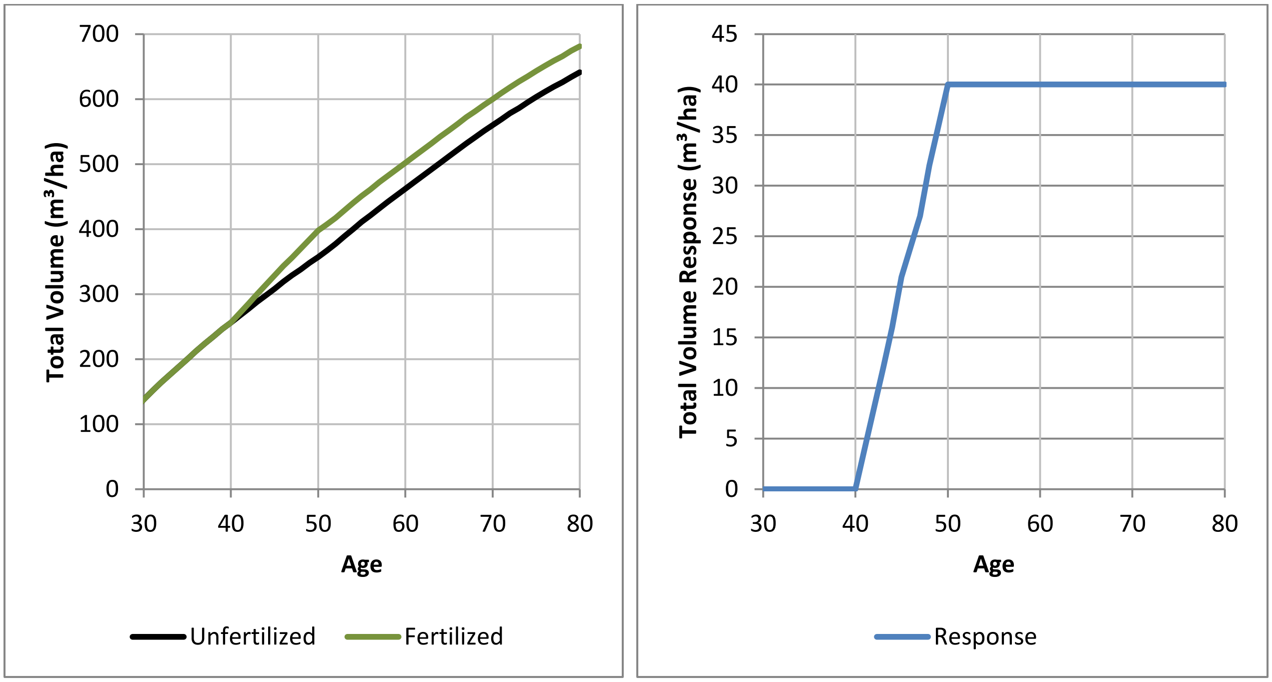


Figure 1. Example TIPSY fertilizer response for coastal Douglas-fir, site index 25, 1200 planted, fertilized at age 40 (no OAFs, 80% fertilizer efficiency).

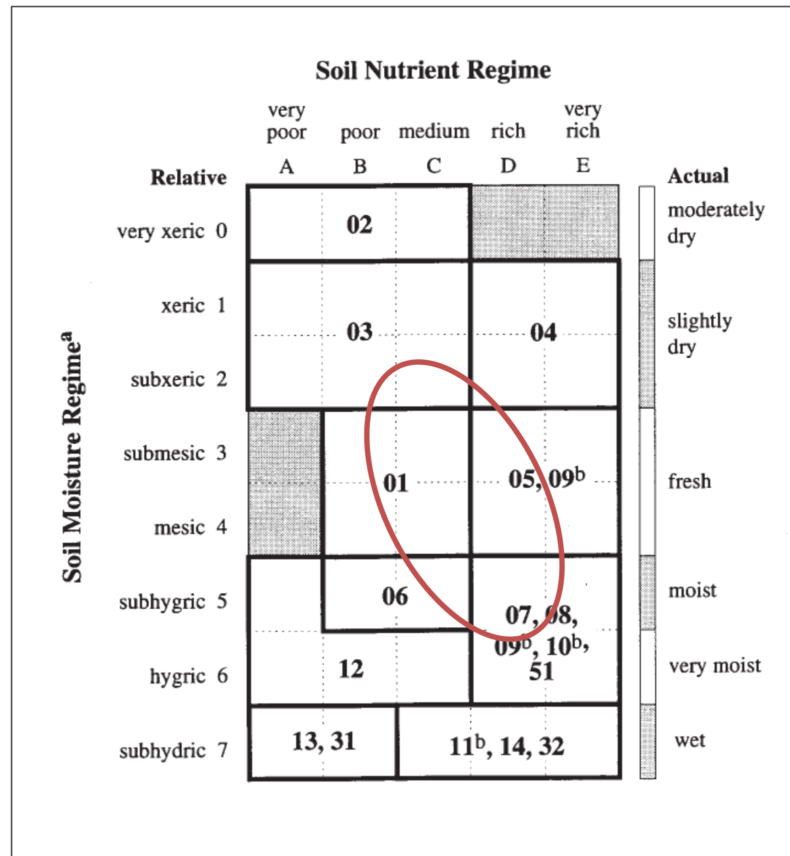
The TIPSY Response Table for Fdc was produced directly from TASS simulations with initial density fixed at 1200 trees/ha and represents the relative gain expressed as a percentage for a ten-year period. For all other species, the tabular values were developed for the same density conditions based on experimental results and expert opinion. Similar to the TASS fertilizer module, values for interior species were based on research conducted by Rob Brockley and Rob's expert opinion. TIPSY also allows the user to input custom fertilizer responses.

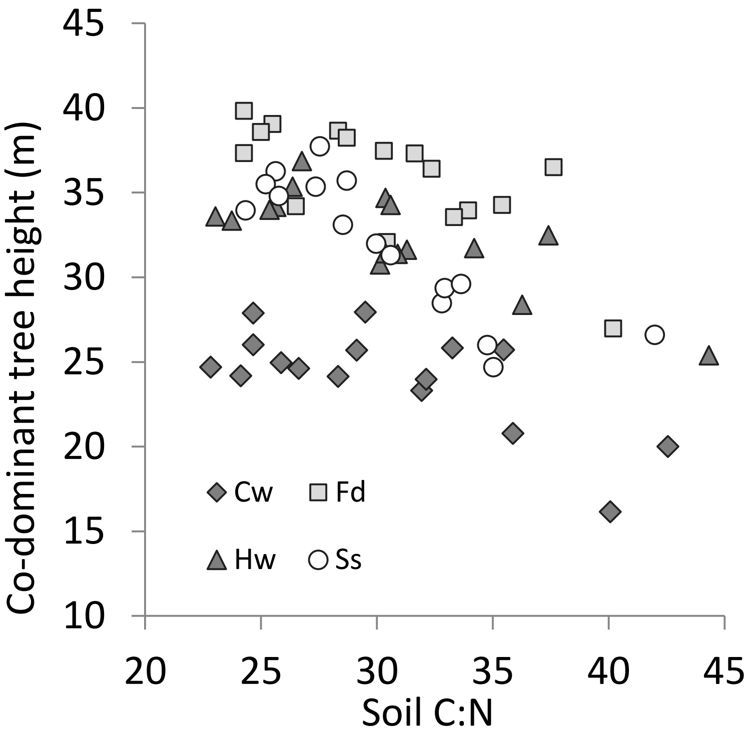
TIPSY fertilizer applications are restricted to a single dosage. Multiple applications are permitted at ten year intervals, but each application invokes the fertilizer module independently. That is, there is no explicit recognition that a particular application is the first, second or third in a series.

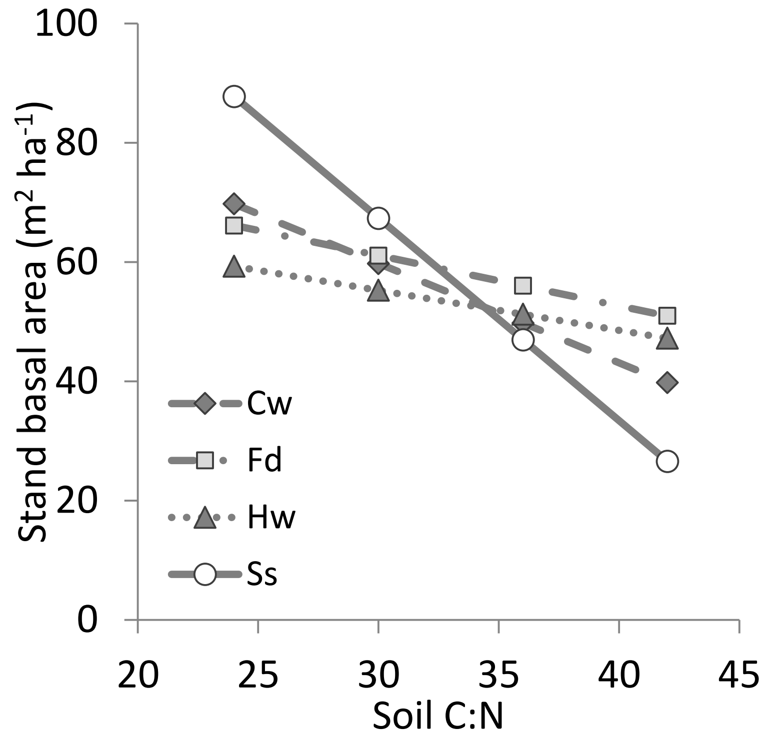
Marty Kranabetter

EP571 Planting density trial

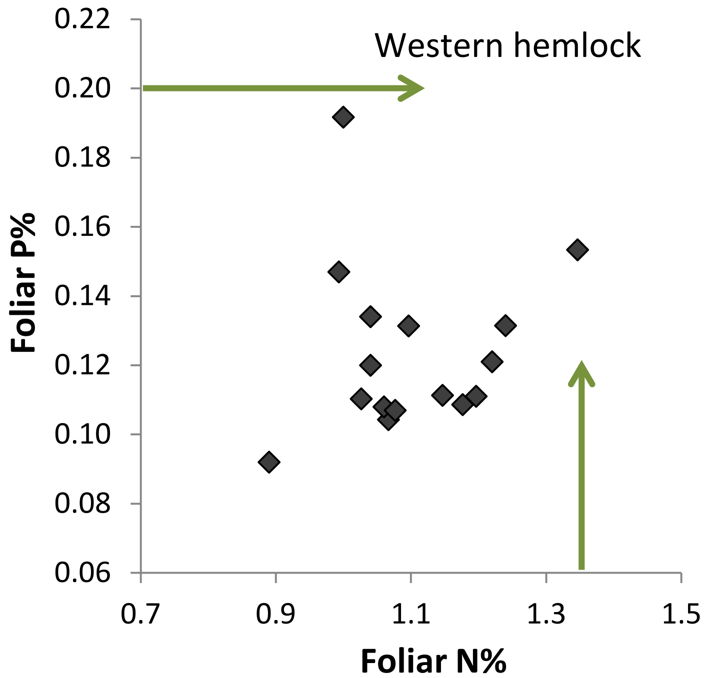
- 3 spacings (2.7, 3.7 and 4.6 m) and 4 conifer species (Cw, Fd, Hw, and Ss)
- replicated over 7 sites near Bamfield and Port Renfrew (CWHvm1)
- established in 1962, last re-measurement 2014 (52 years)

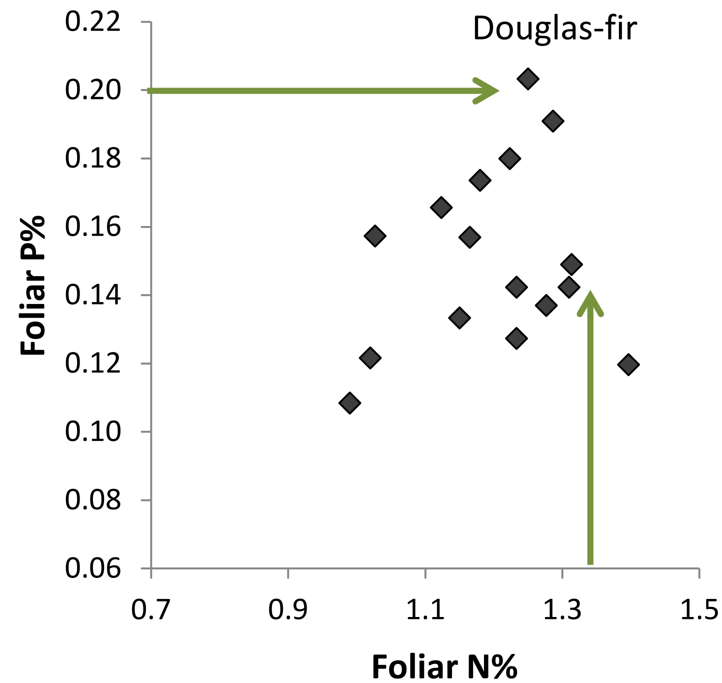




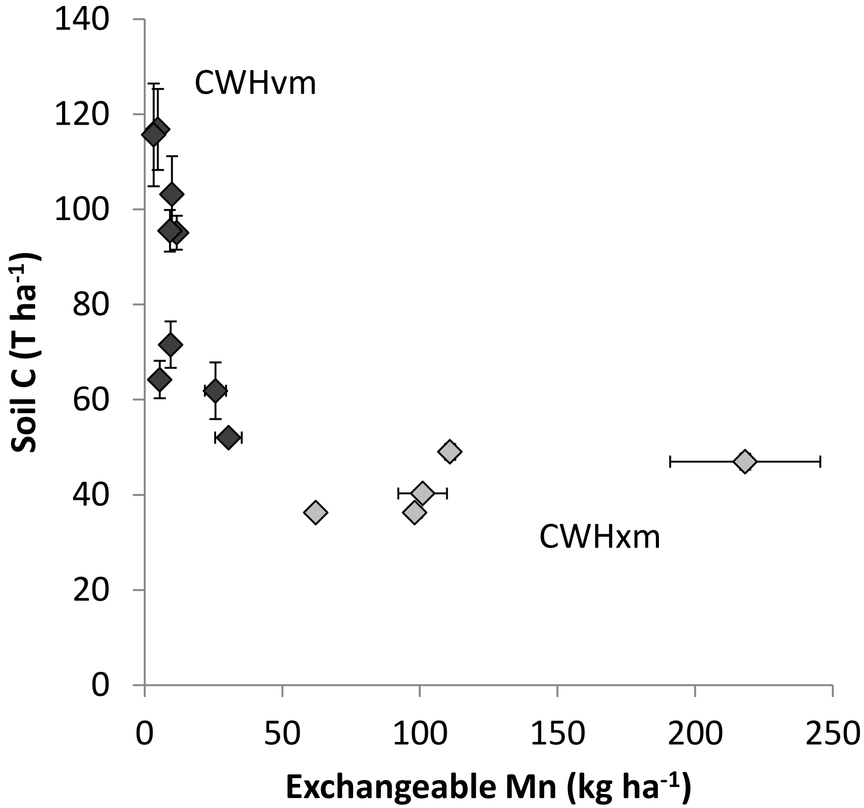


- low C:N = high N availability, all species grow better on richer soils but at different response rates
- Sitka spruce thrives on high N soils (competitive species) while western hemlock is less responsive (stress-tolerant species)
- 73.6 $m^2 ha^{-1}$ for 2.7 m spacing, 65.8 for 3.7 m spacing, and 55.5 for 4.6 m spacing, on average, at C:N = 27.5





- Bray P typically < 5 ppm and majority of foliage had deficient P; average foliar P = 0.14%. Average foliar N = 1.15%
- pervasive N + P deficiencies (or P alone) in the CHWvm1
- any effect of tree size (age) in foliar attributes?



$450\ mg\ kg^{-1}\ Mn$

- soils of the CWHvm have very little exch. Mn, possibly excluding saprotrophic fungi that produce Mn-peroxidase (e.g., *Pseudohydnum gelatinosum*)

Recent Research on Douglas-fir Fertilizer Response

Kim Littke

University of Washington

Stand Management Cooperative

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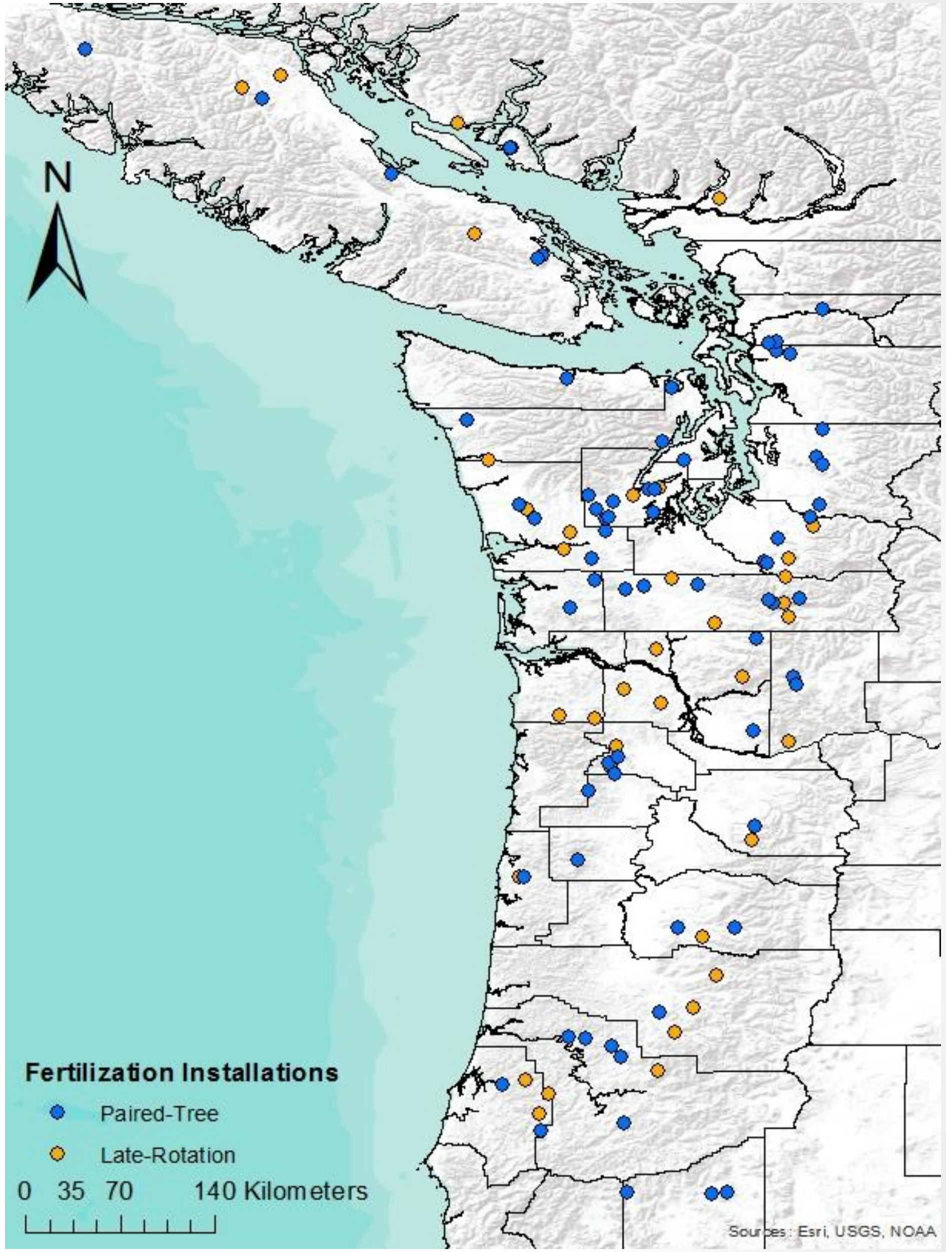
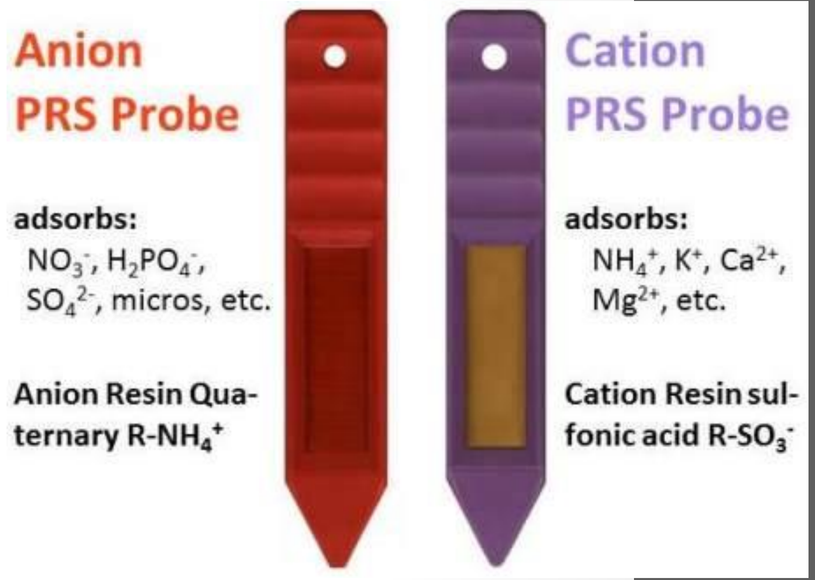
Douglas-fir Fertilization

- 71 Paired-Tree installations
  - Tree-based study
  - 7-27 years old
  - 6 installations in BC
- 38 Late-Rotation installations
  - Plot-based study
  - 23-45 years old
  - 6 installations in BC



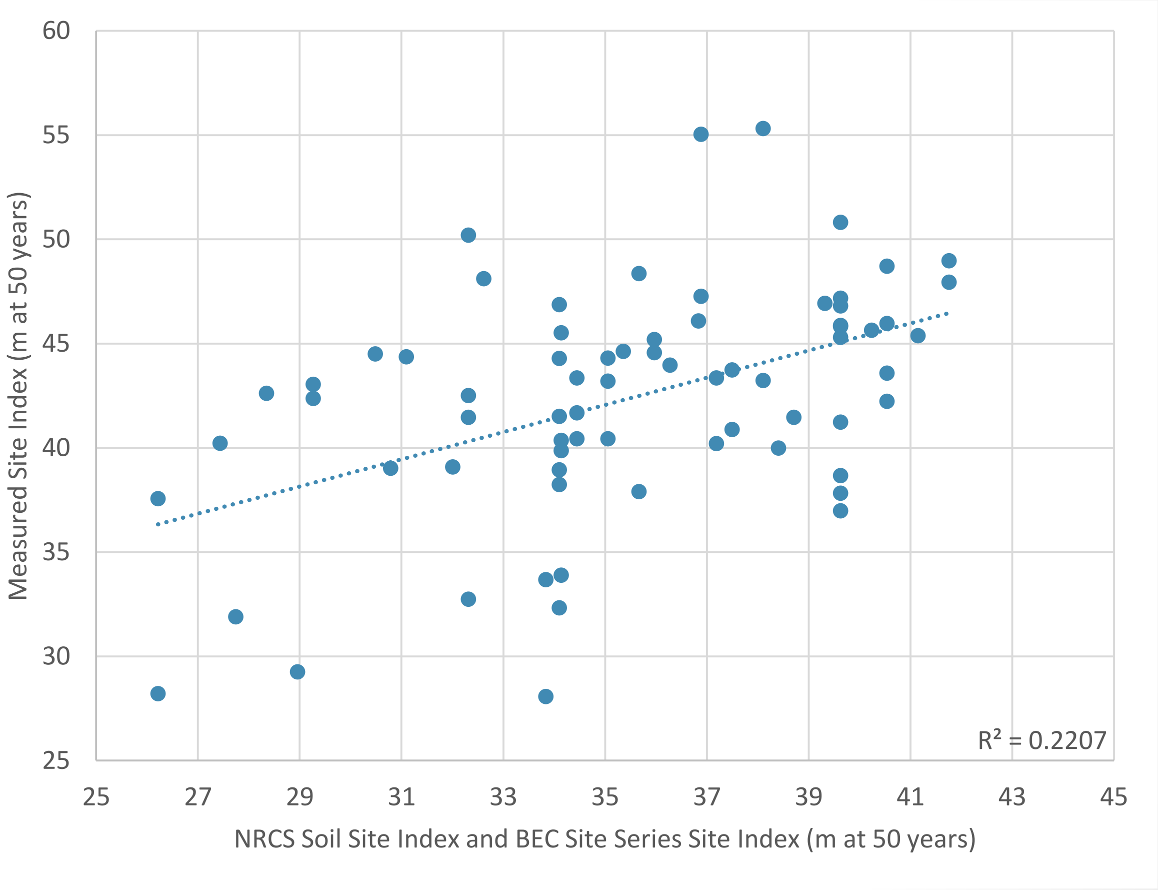
Study Sampling

- Forest floor and soil samples taken to 1 meter depth
  - Analyzed for total C and N, available N (NH_4 and NO_3), exchangeable cations, and Bray P
- Plant Root Simulator (PRS) probes installed in the shallow soil prior to fertilization
  - Mostly Late-Rotation study
  - Removed 12 weeks later
- Fertilizer response per tree and plot measured from 2-8 years
  - Paired-tree – 65 installations with per tree response at 4 years
  - Late-Rotation – 12 installations measured for 2-year response



Methods

- Mapped variables
  - Monthly Climate – Climate WNA
  - Location (latitude, longitude, and elevation)
  - Site Index
- Boosted regression tree models
  - Machine learning and regression trees



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Predicting Response using the Paired-Tree Study

Predictor Variables	Range	Relative Influence
Elevation	>400 m	40
Site Index	<43 m	22
April Temperature	<8 C	21
September Precipitation	<60 mm	11
Latitude	<45°	6

- Greatest response found at higher elevations
  - Low-moderate site index
  - Colder April temperatures
  - Dry September precipitation
  - South of Salem, OR
- Model performs well for predicting non-responders (91% predicted correctly)
- 65% of responders predicted correctly

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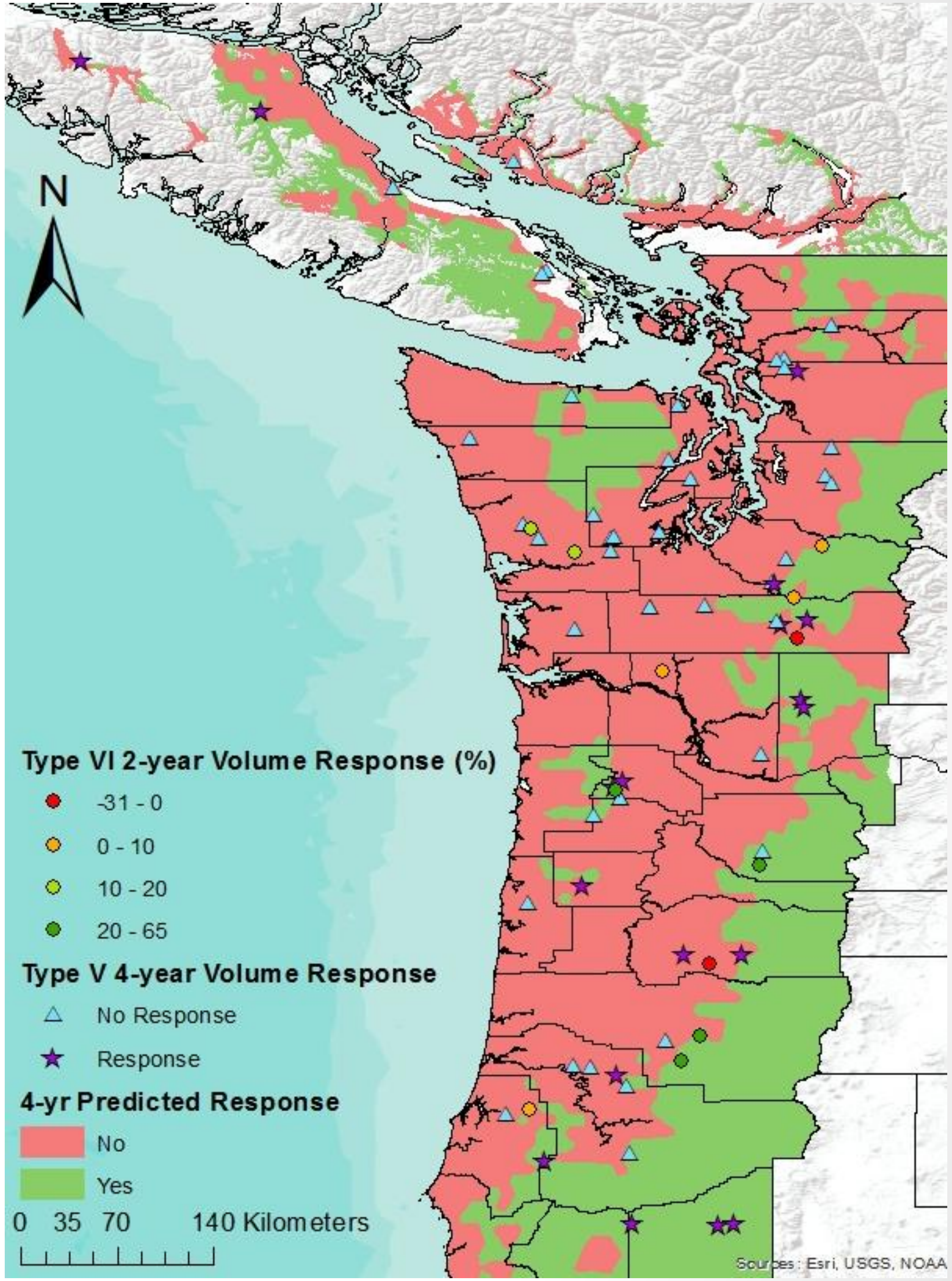
Comparing Response

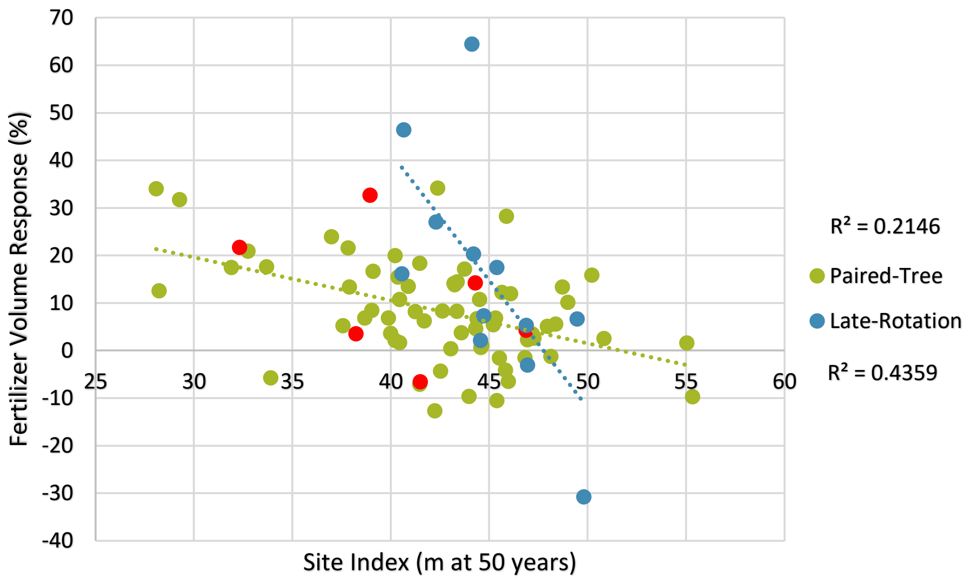
- 4-year tree response from Paired-tree study (Type V)
- 2-year tree response from Late-Rotation Study (Type VI)
- Measured response matches predicted response
  - Especially in Oregon
  - Unpredicted response in WAW

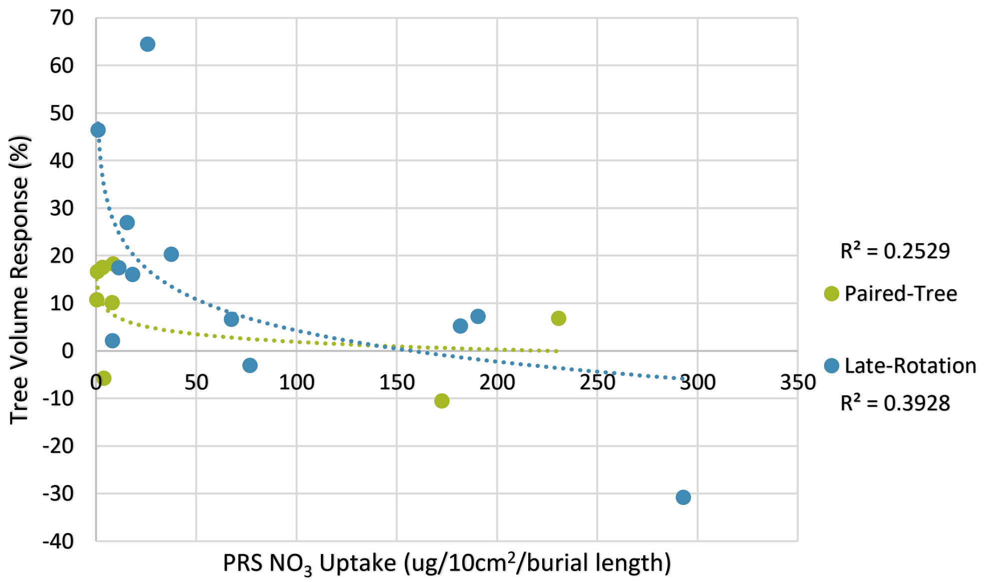
Predicted	Tree Response	Plot Response
No Response	8%	0.7 ± 6 m^3/ha/yr
Response	28%	4.6 ± 7.4 m^3/ha/yr



Fertilization Response

- Greatest volume response at low site index
- Best response at low PRS NO_3 uptake





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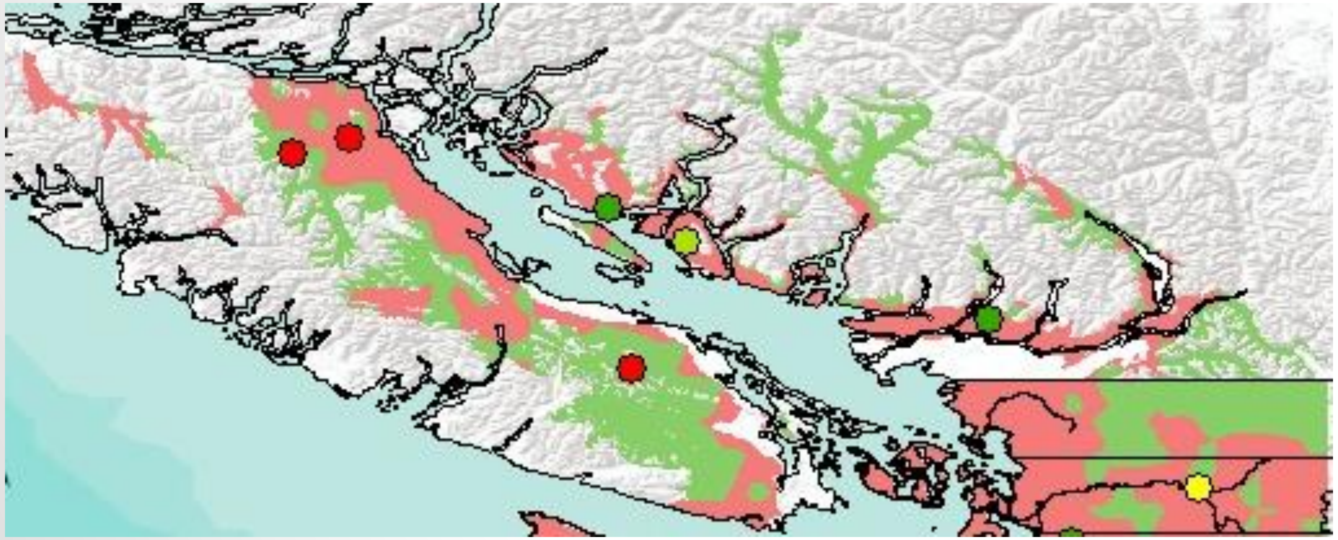
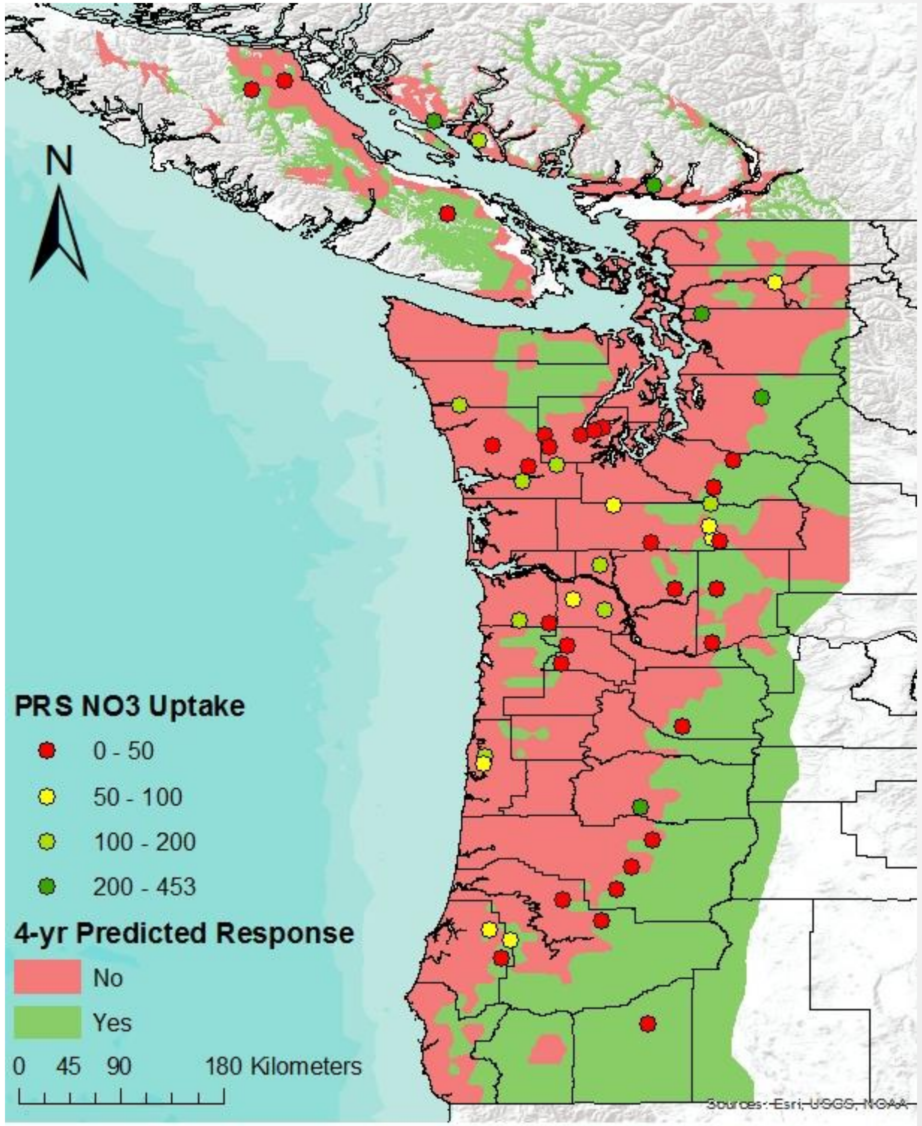
Regional PRS NO_3 Uptake

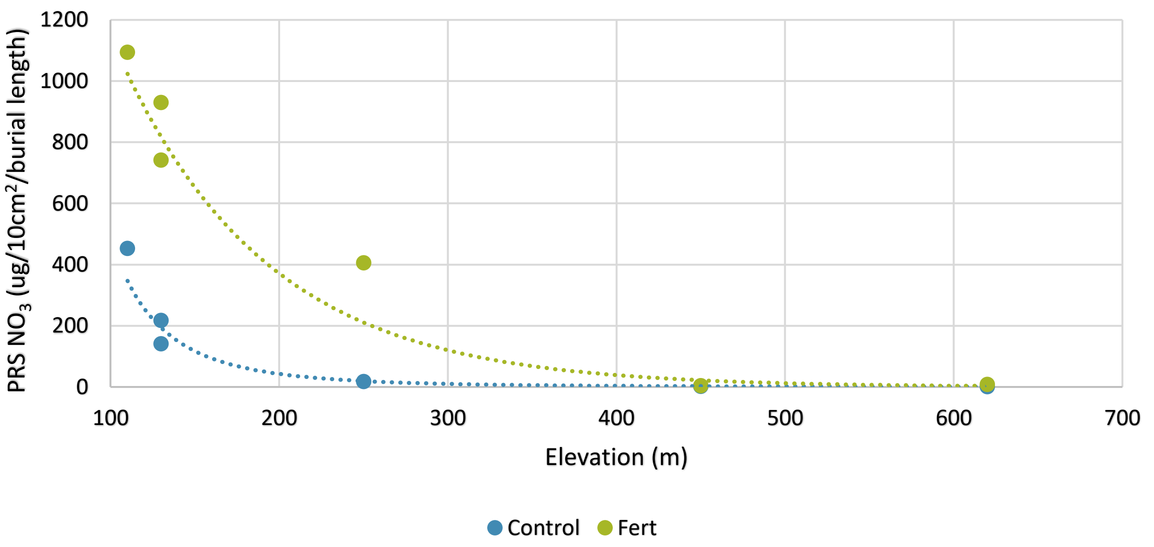
- Low PRS NO_3 uptake found in regions of predicted response
- Suggests greater response to N fertilization in predicted response regions

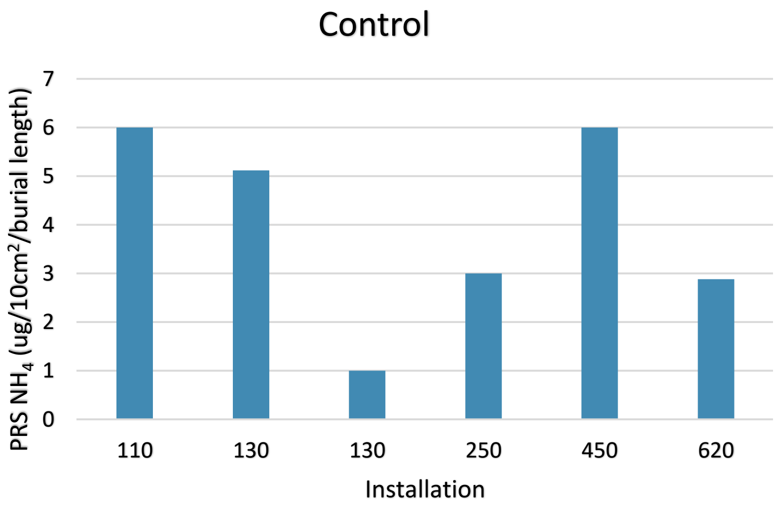


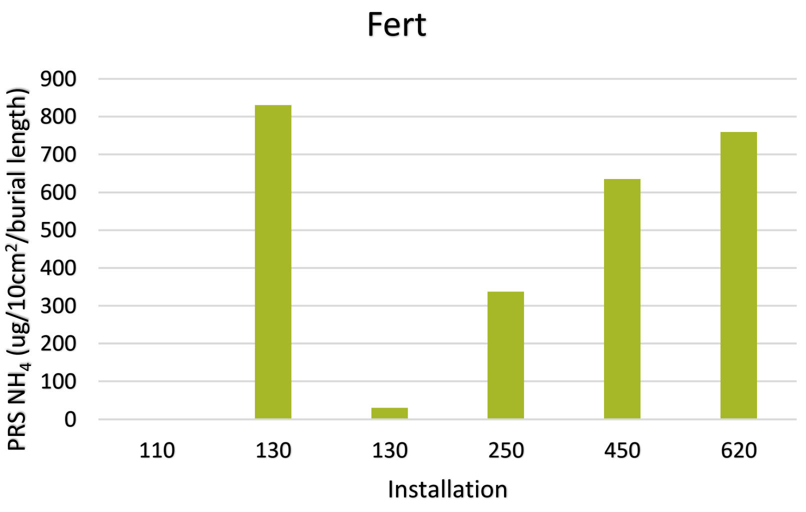


Effect of Elevation on N Availability in BC

- Greatest NO_3 availability at low elevations
  - Fertilization increased NO_3 availability the most at low elevations
- Slightly greater NH_4 at low and moderate elevations
  - Fertilization increased NH_4 at the highest elevations

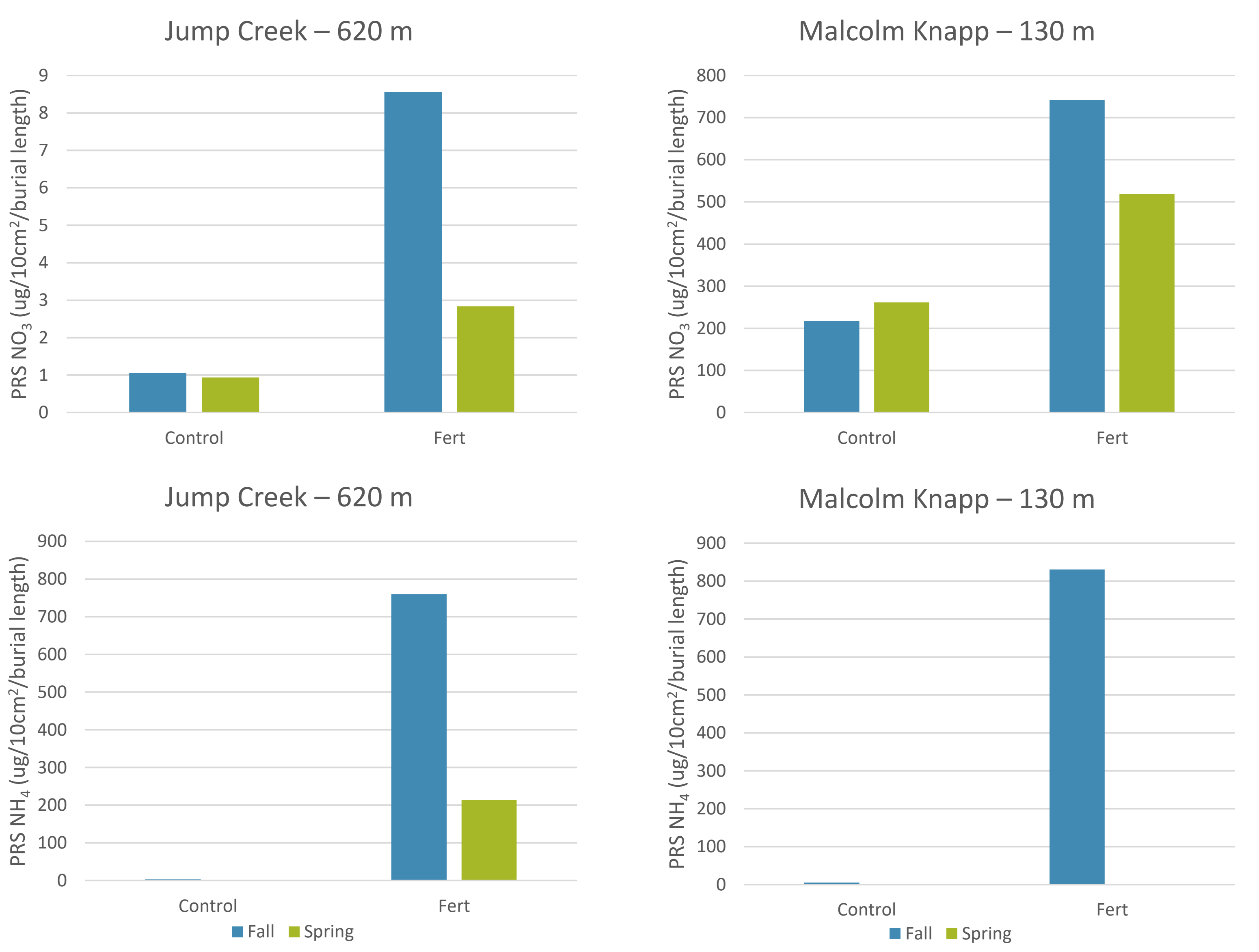






Change in N availability after Fertilization

- Plots were fertilized in the fall
    - 8 months later lower NO_3 and NH_4 available
- In control plots, available N did not change much between fall and spring



Discussion

- Climate, elevation, and site index give easy projections of volume response to fertilizer
- PRS probes are showing promise to describe fertilizer response
  - Easier than carrying out multiple analyses
  - Also describe site productivity
- Predicted response areas are responding better
  - Younger tree-based study versus older plot-based study

Review and Proposal for N and P Fertilization of Western Hemlock in the Pacific Northwest

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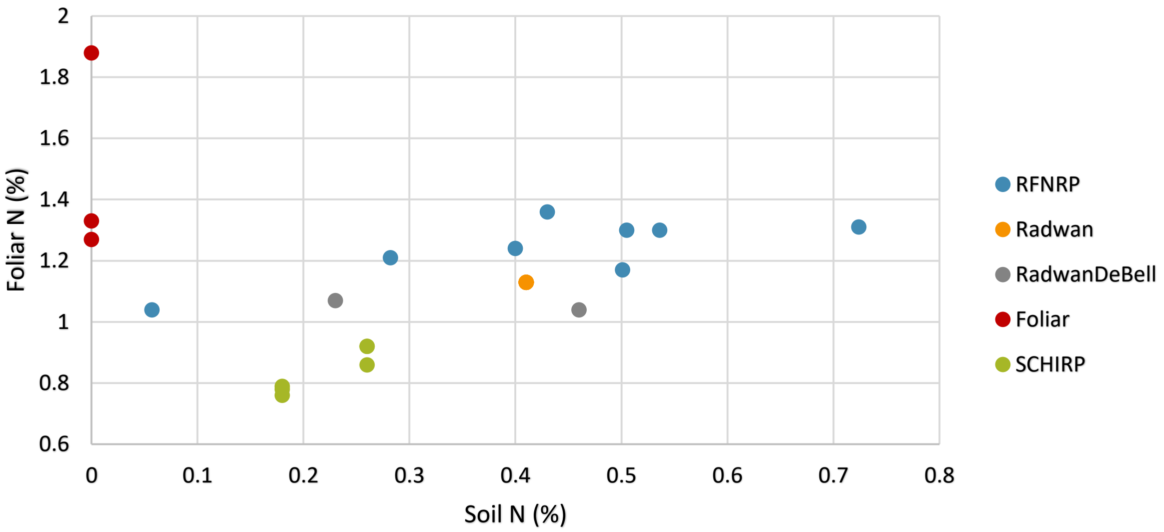
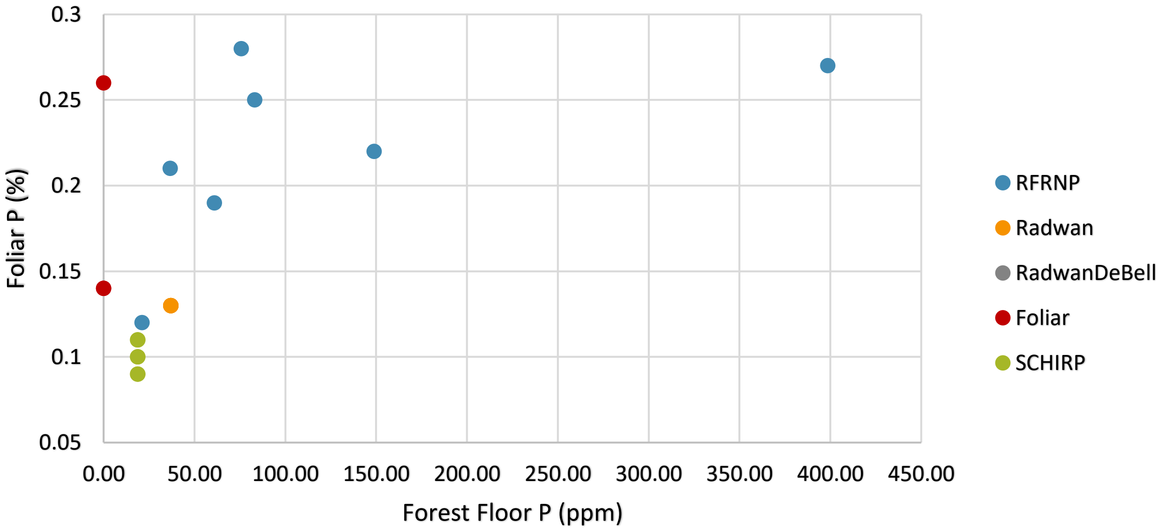
Previous Western Hemlock Fertilization Studies

Description	RFNRP	Radwan and DeBell	Radwan et al. 1991	Foliar Fert	SCHIRP
Established	1969-1980	1976 & 1980	1982	2014	1988
Location	WA and OR	WA and OR	WA	OR	BC
# of Sites	38	3	1	3	2
Age	18-56	19-28	20	15-18	0
SI	18-39 m	28-35 m	32 m	34-43 m	10-26 m
Fertilization	224 kg N/ha	224 kg N/ha	P (0, 100, 300, 500 kg/ha) N (0, 224 kg/ha)	P (11, 22, 45 kg/ha)	NPK at planting, 224 kg N/ha+75 ha P/ha at 5 years, 224 kg N/ha at 15 years

Comparison of N and P Nutrition

- Wide range in western hemlock soil and foliar N
  - Increasing foliar N with greater soil N
- Similar relationship between soil, forest floor, and foliar P
- SCHIRP study contains much lower N and P than WA and OR sites





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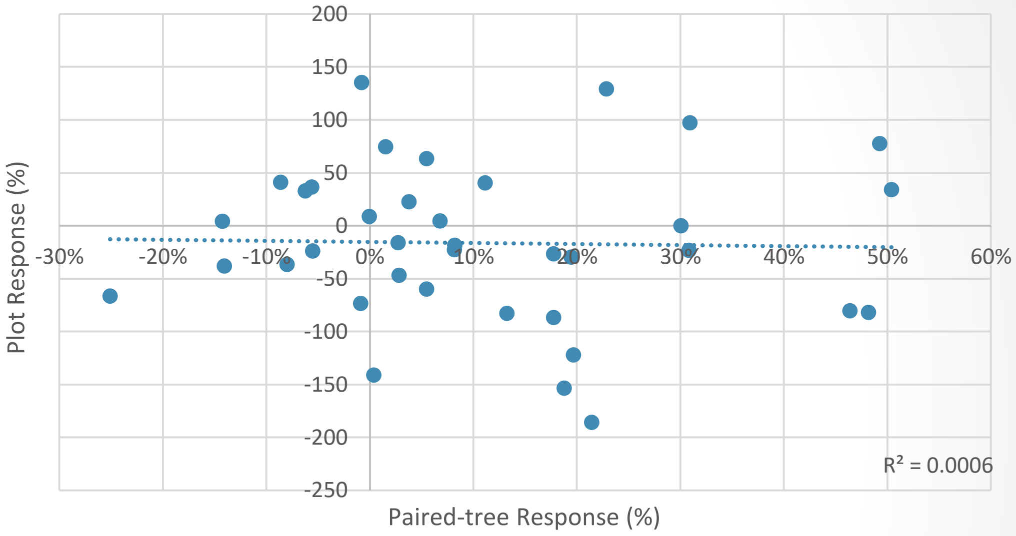
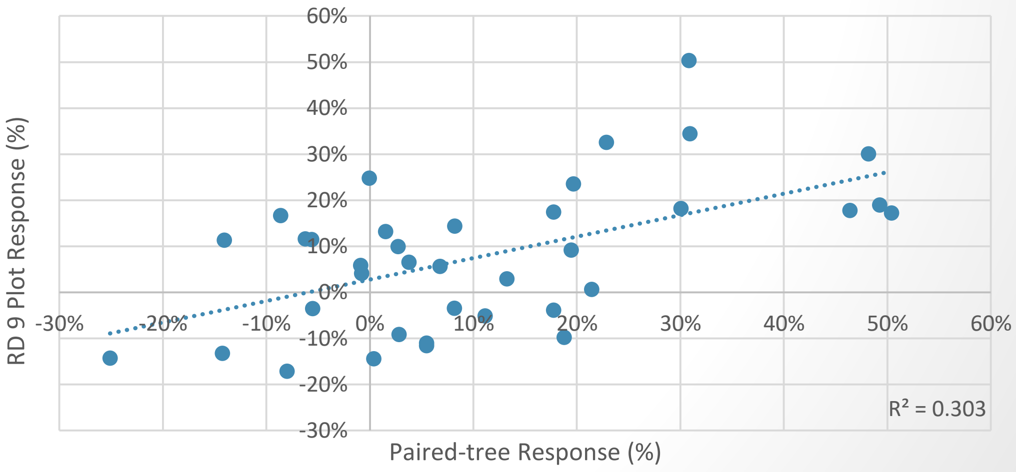
RFNRP Paired-trees versus Plot Response

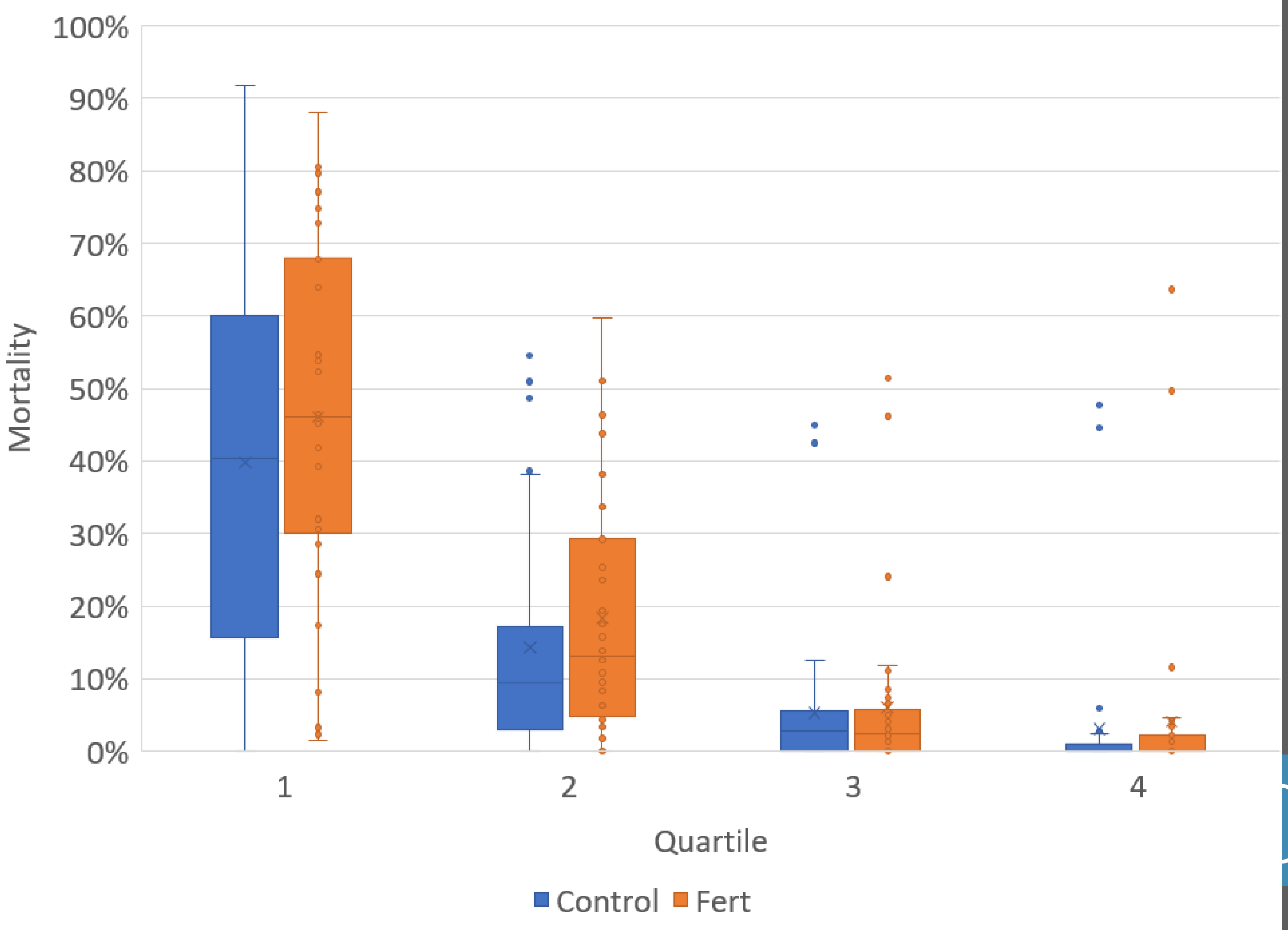
- Paired 30 trees per treatment by similar DBH and height at establishment
- No relationship between paired-tree response and total plot response
  - Large range in stand density and mortality
- Thinning each stand to RD 9 resulted in a better relationship with paired-tree response





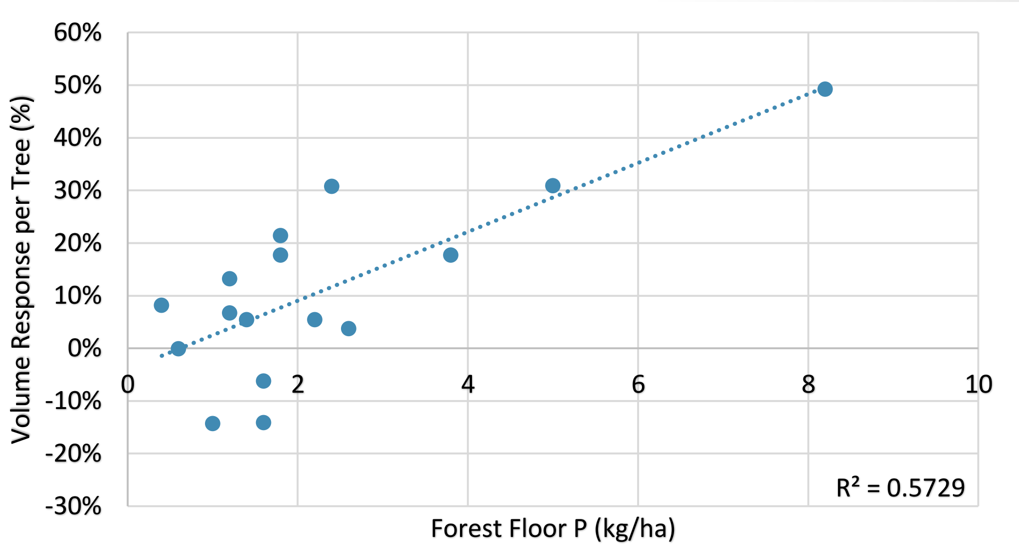
Mortality by Tree Size at Establishment

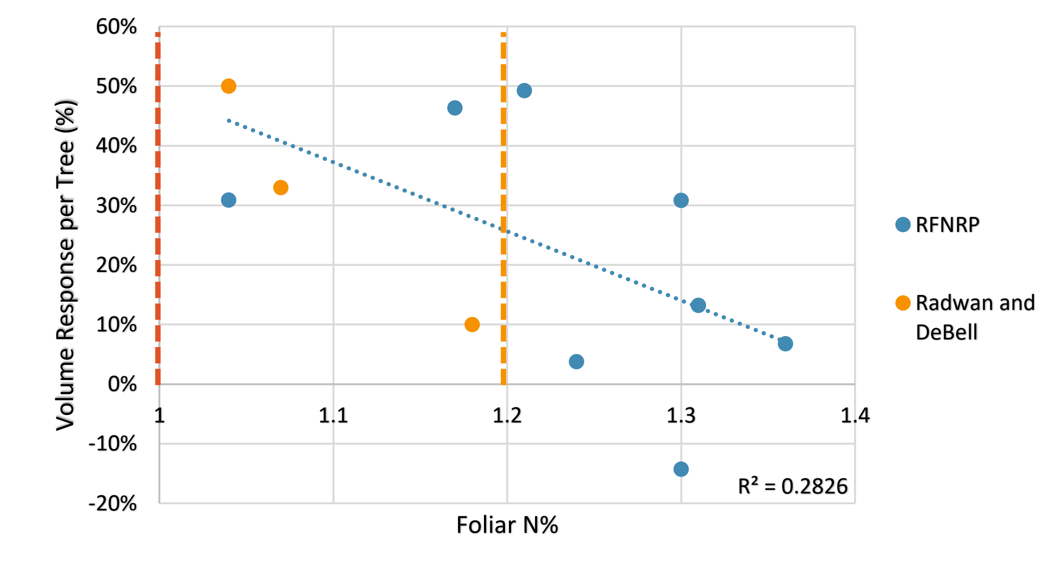
- High mortality of smallest quartile of trees in control plots
- Fertilization increased mortality in trees less than average DBH
- Suggests selection of only codominant-dominant trees when examining response

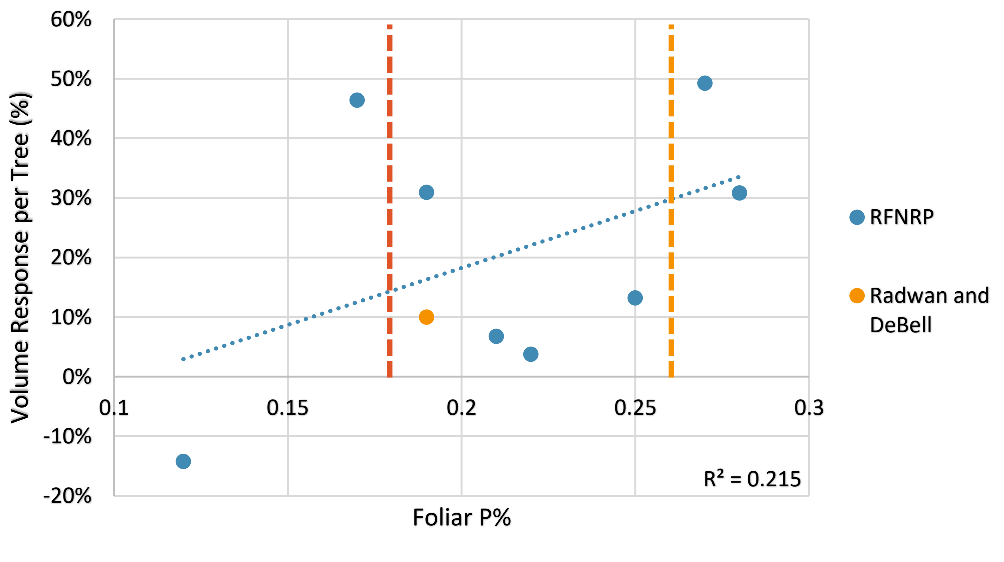


N Fertilization Response

- Greater response per tree on sites with high forest floor and foliar P
- Trees with lower foliar N respond better to N fertilization

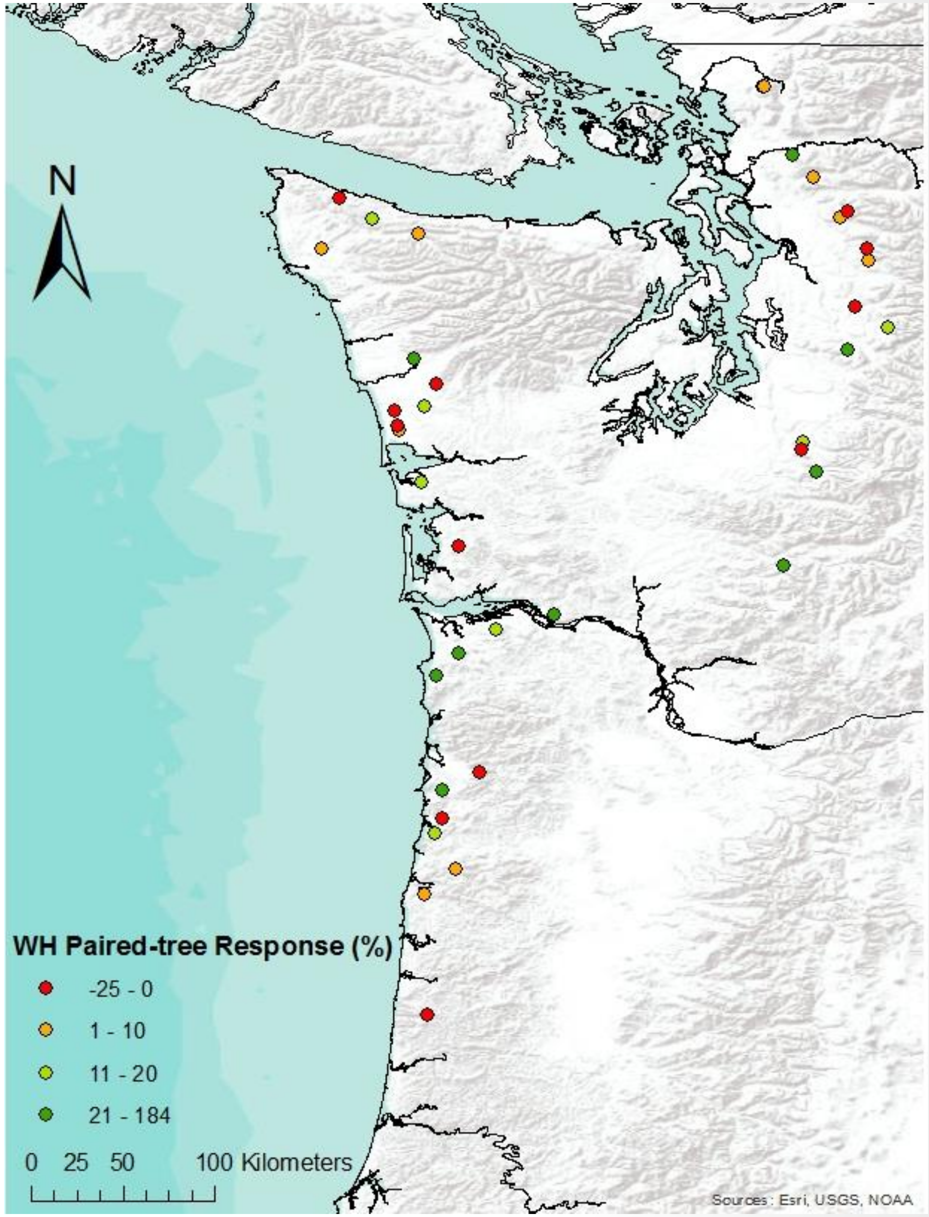






Regional WH Response to N

- Response is spotty throughout the region
- Past research has shown greater response in the WA Cascades
  - Lower N and higher P in this region



Modeling RFNRP WH Response to N

- Boosted regression tree model using significant response of paired-tree volume (paired t-test)
- Greatest response on soils with high P
- Colder January temperatures
- Greater site index and younger stands
- More June precipitation

Variable	Range	Relative Influence
Soil P	>25 ppm	51%
January Temperature	<3.5 C	15%
Site Index	>33.5 m	12%
Age	<35	11%
June Precipitation	>90 mm	11%

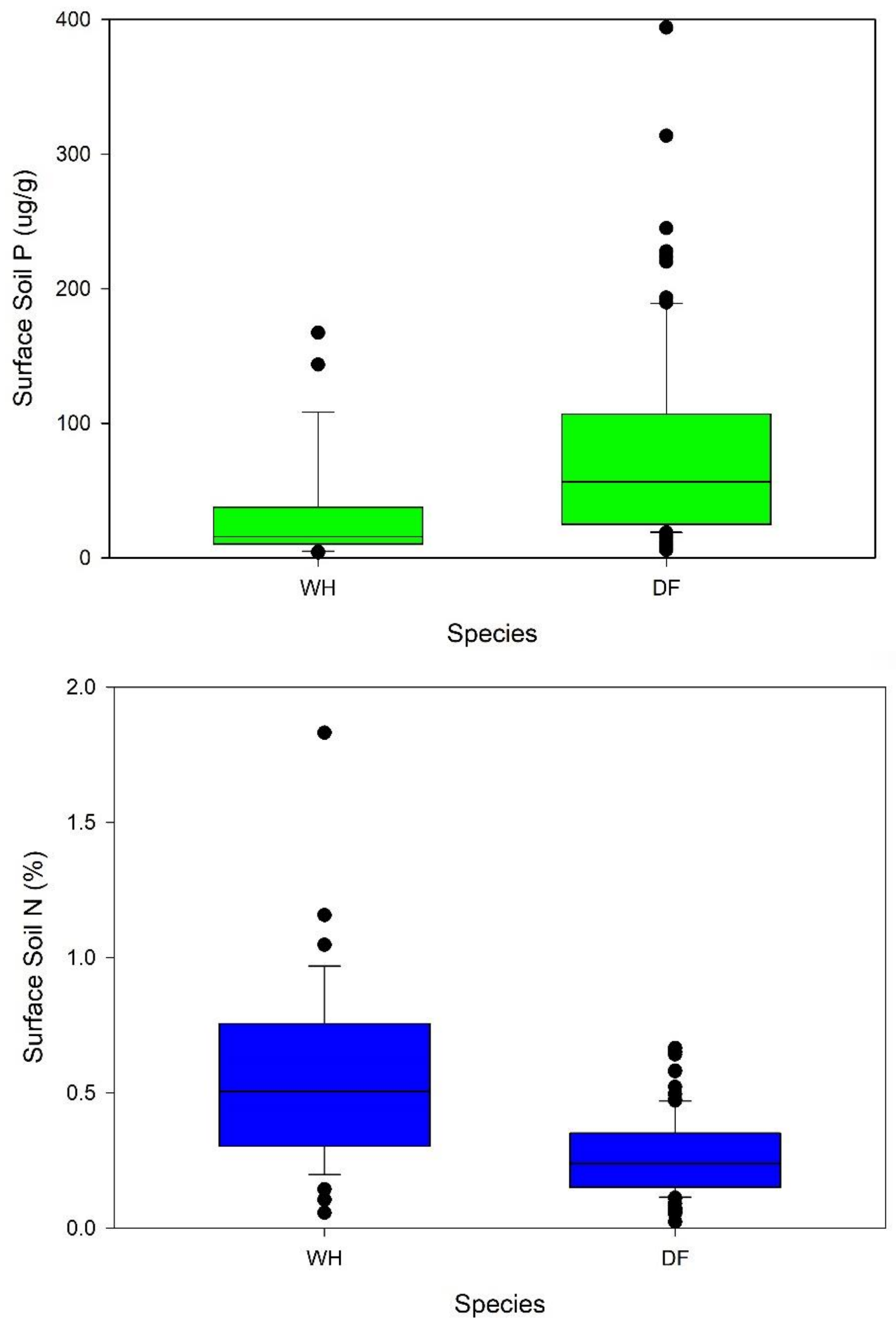
Modeling WH Response to N

- Model correctly selected 10/13 responders
  - 23/25 non-responders
  - Greater percent response on predicted response installations
- No data to test the model

Predicted Response	Measured No Response (count)	Measured Response (count)	Average Response per Tree
No	23	3	5%
Yes	2	10	25%

Soil N and P

- Surface soils from RFNRP western hemlock and Douglas-fir
- Average western hemlock soil contains ½ soil P and 2X soil N compared to average Douglas-fir soil



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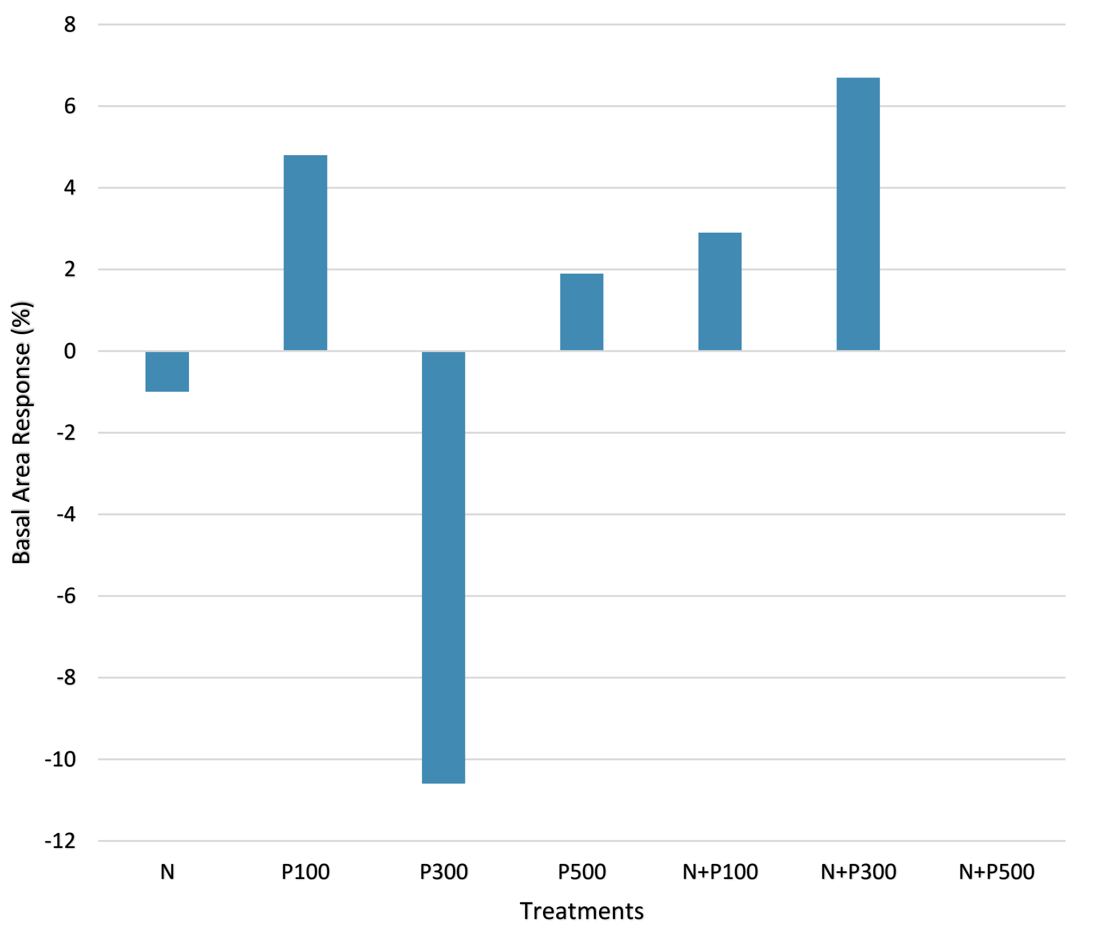
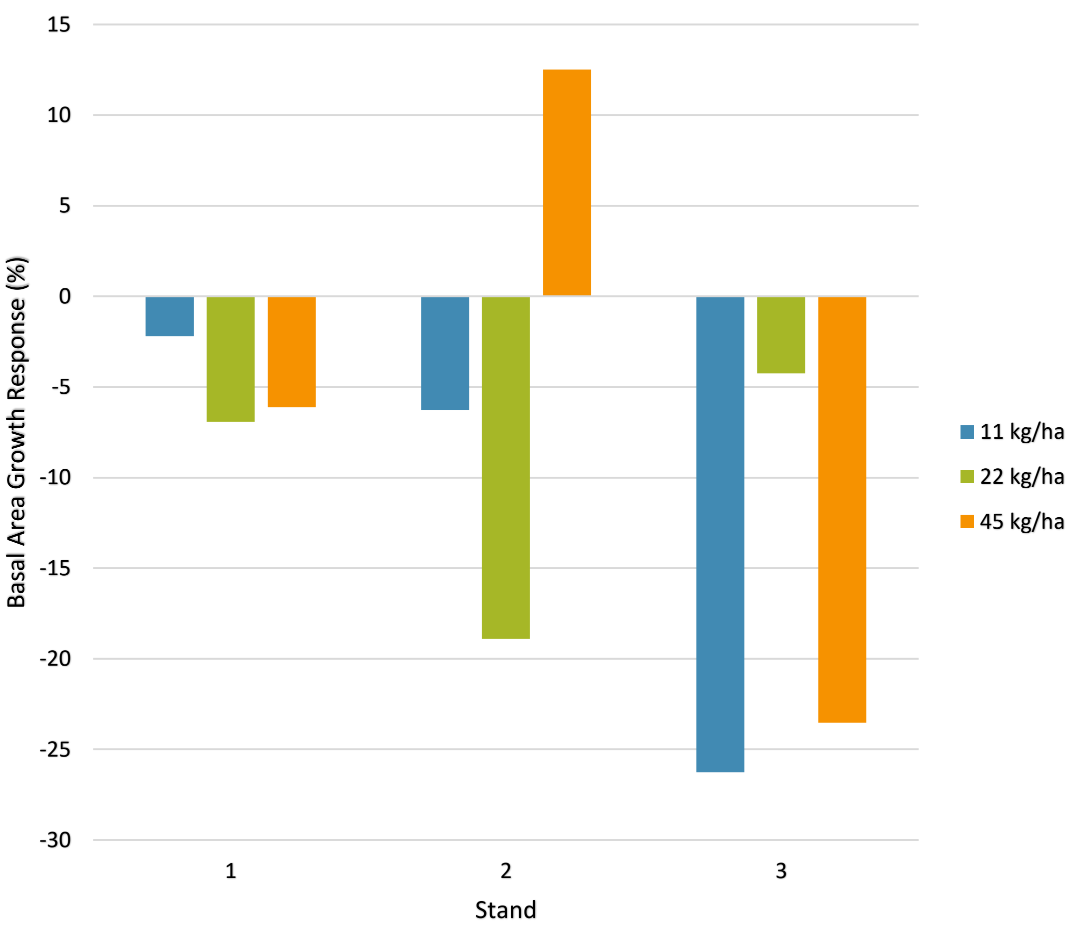
Radwan: N+P Fertilization in WA

- 1 stand fertilized with urea and/or triple superphosphate
- Average foliar N and low foliar P
- Mycorrhizal associations may make P more available to older trees
  - Western hemlock seedling study showed 200% response to 300 kg P/ha



Foliar P Fertilization

- Three sites fertilized with mono-ammonium P (foliar application)
- Only response at the highest P level in one stand
- High foliar N and moderate foliar P
  - No increase in foliar P suggests P levels were not high enough



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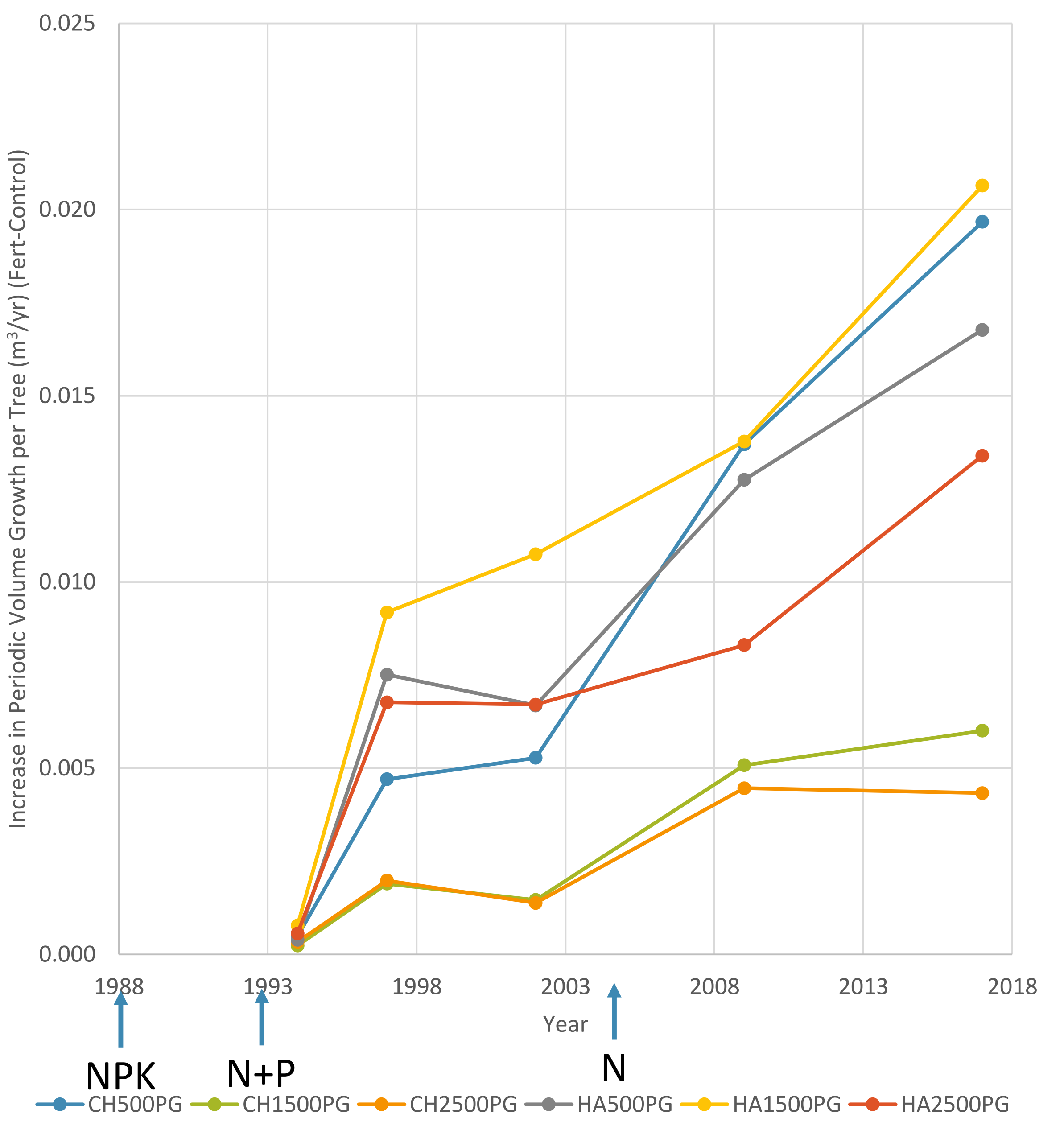
SCHIRP Response

- CH – Cedar-hemlock (similar to west of 101)
- HA – Hemlock-silver fir (similar to east of 101)
- Planting densities of 500 (200 tpa), 1500 (625 tpa), and 2500 (1000 tpa) trees per hectare
- Large response on HA stands and CH500
- 98-1277% greater volume per tree compared to controls



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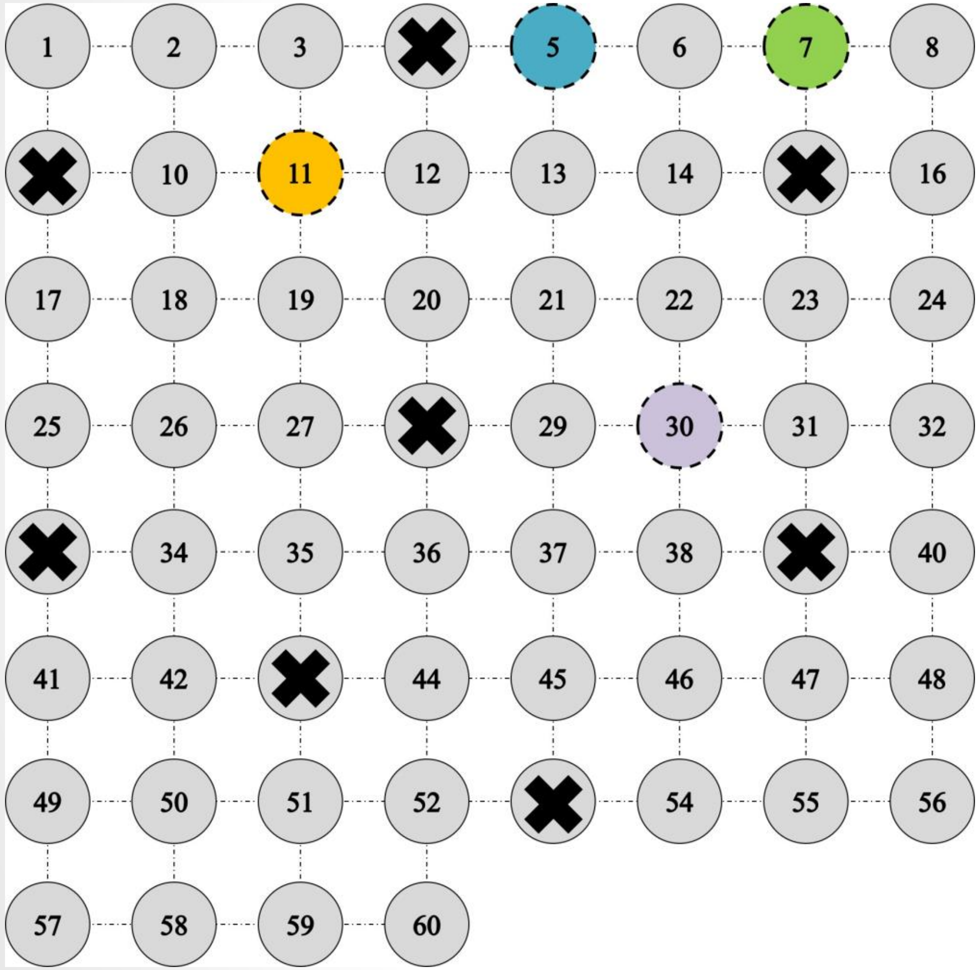
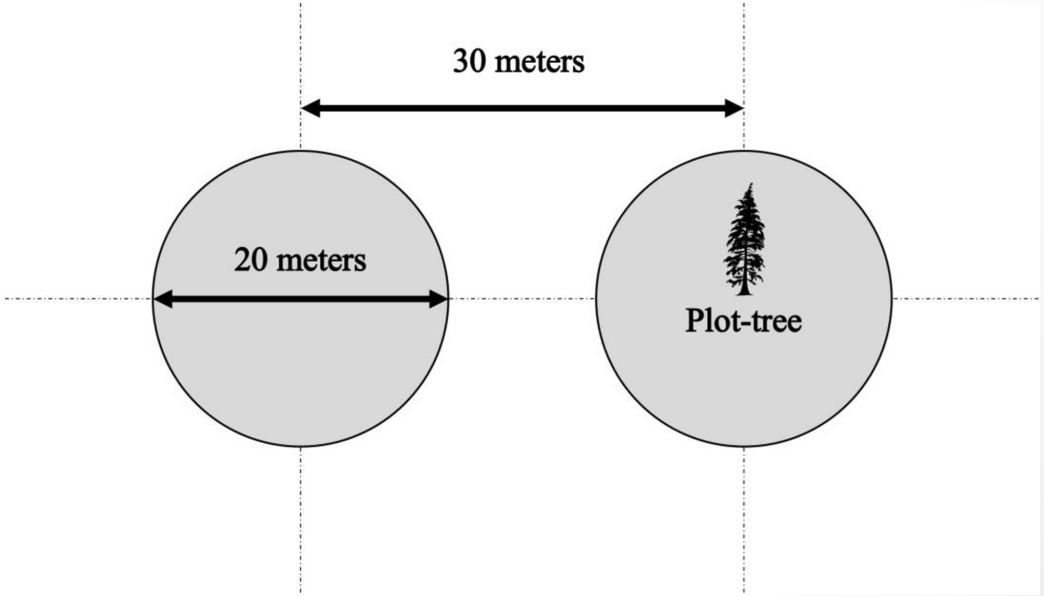
Proposal to Establish Western Hemlock Fertilization Installations

- Spread installations throughout western hemlock plantation range
- “Grouped” tree plots of N, P, N+P, and control
  - Similar to Beyond N CIPS study (Mainwaring et al. 2014)
  - 15-24 breast height age
  - 60 plot-trees for 12-15 replicates per treatment
  - Group trees by similar DBH quartile and height
- Treatments
  - N as urea at 224 kg N/ha
  - P as triple superphosphate at 100 kg P/ha

Grouped Fertilization Design



- Hemlock of 20 m height has a root radius of 10 m
- Wider spacing than Paired-tree Study



Budget

	Per plot time and cost estimates	
Task	Time	Cost
Locate and Measure Trees	1 day	$2,700
Apply Fertilizer and Re-measure	<1 day	$2,000
Fertilizer		$740
Soil Sampling and PRS Probes	1 day	$350
Total per Installation		$5,790

Questions?

Economic Analysis of Coastal Aerial Fertilization Opportunities
April 30, 2019

Kathryn Willis, RPF
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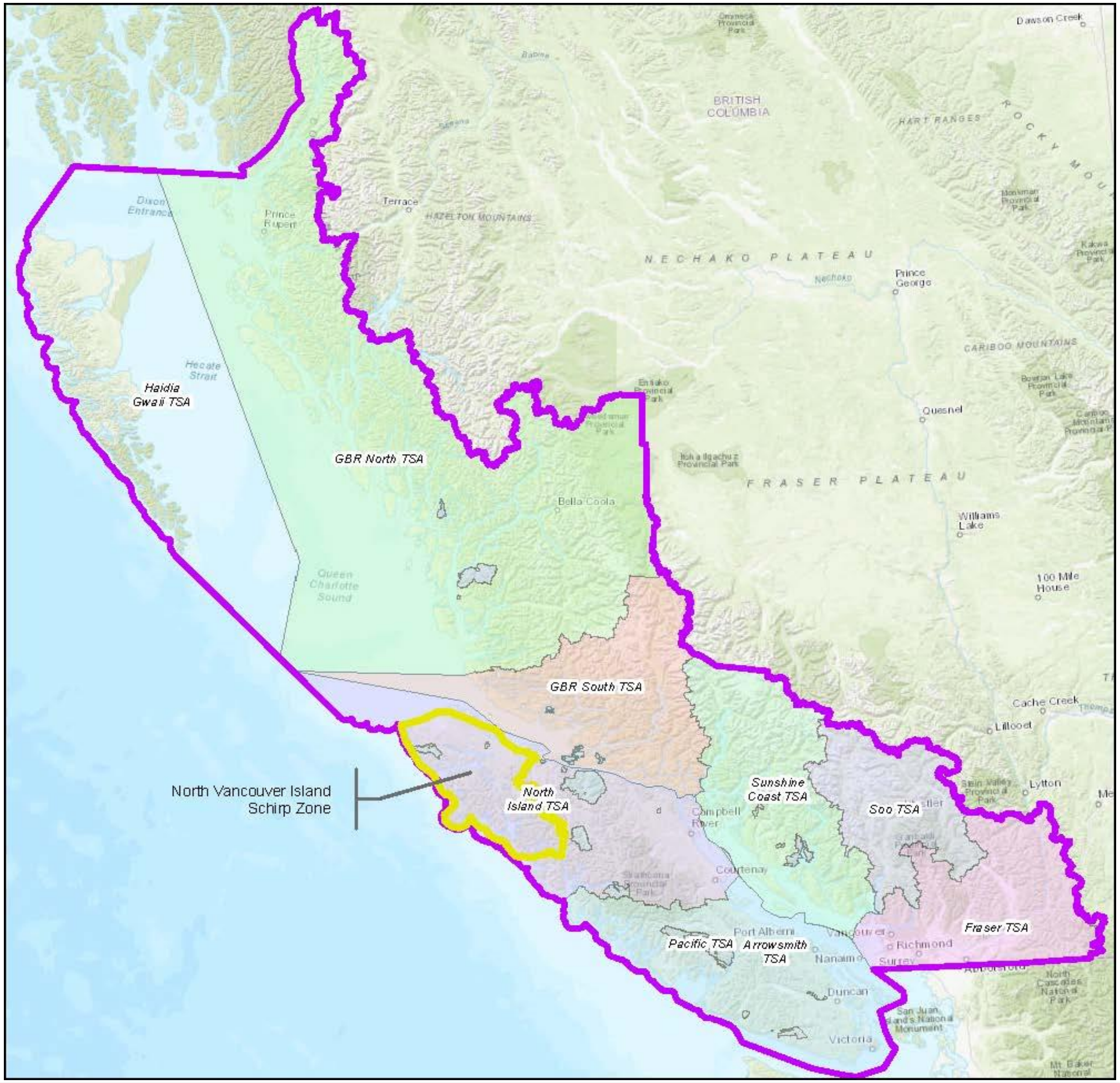
Background of SNRC Aerial Fertilization Programs

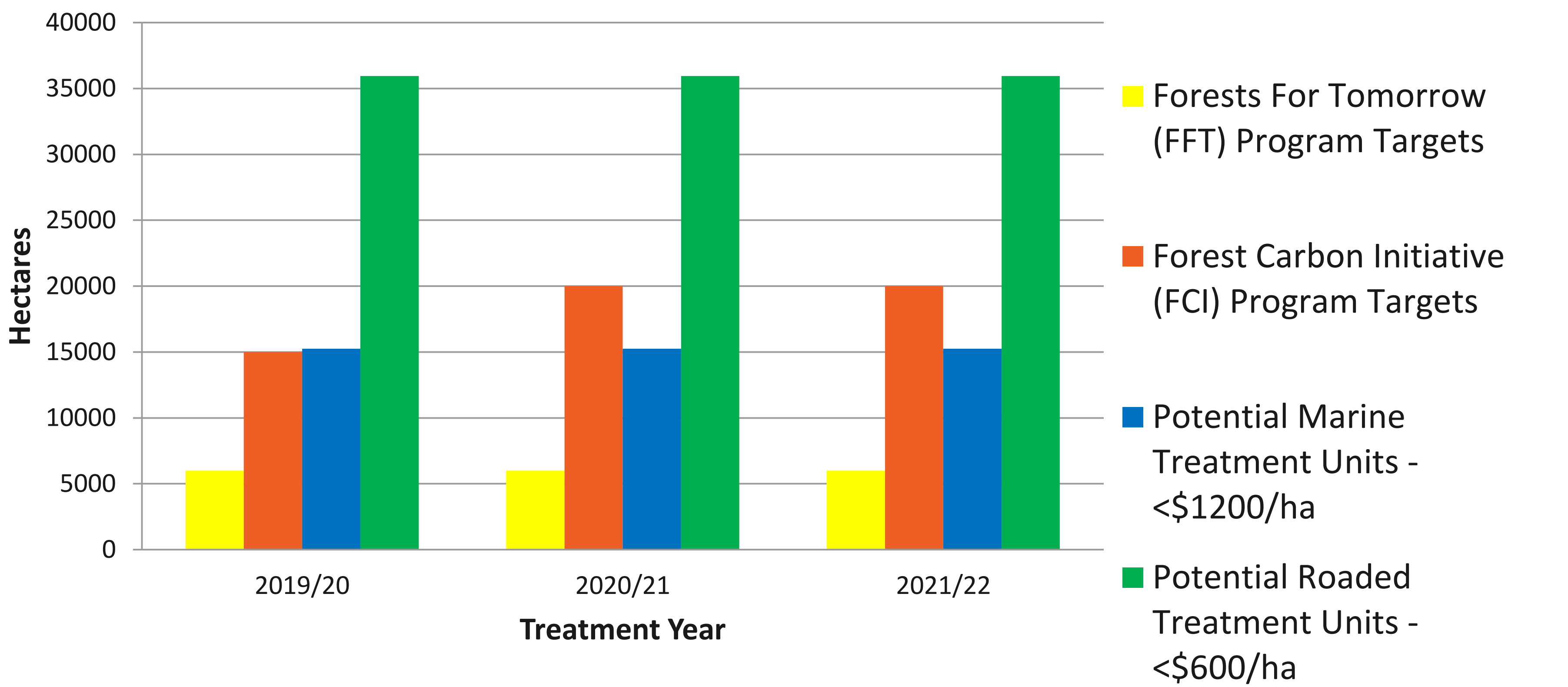
- Over a long history of completing this work, new challenges/ opportunities:
  - Challenges:
    - Increased program sizes from FFT plus FCI
    - Decreased licensee buy-in
    - Broadcast burns and large swatch of Fdc forests are less prevalent
  - Opportunites
    - FES can treat down to a 0% ROE
    - Non-THLB now available to treat
    - Large programs offer greater opportunities

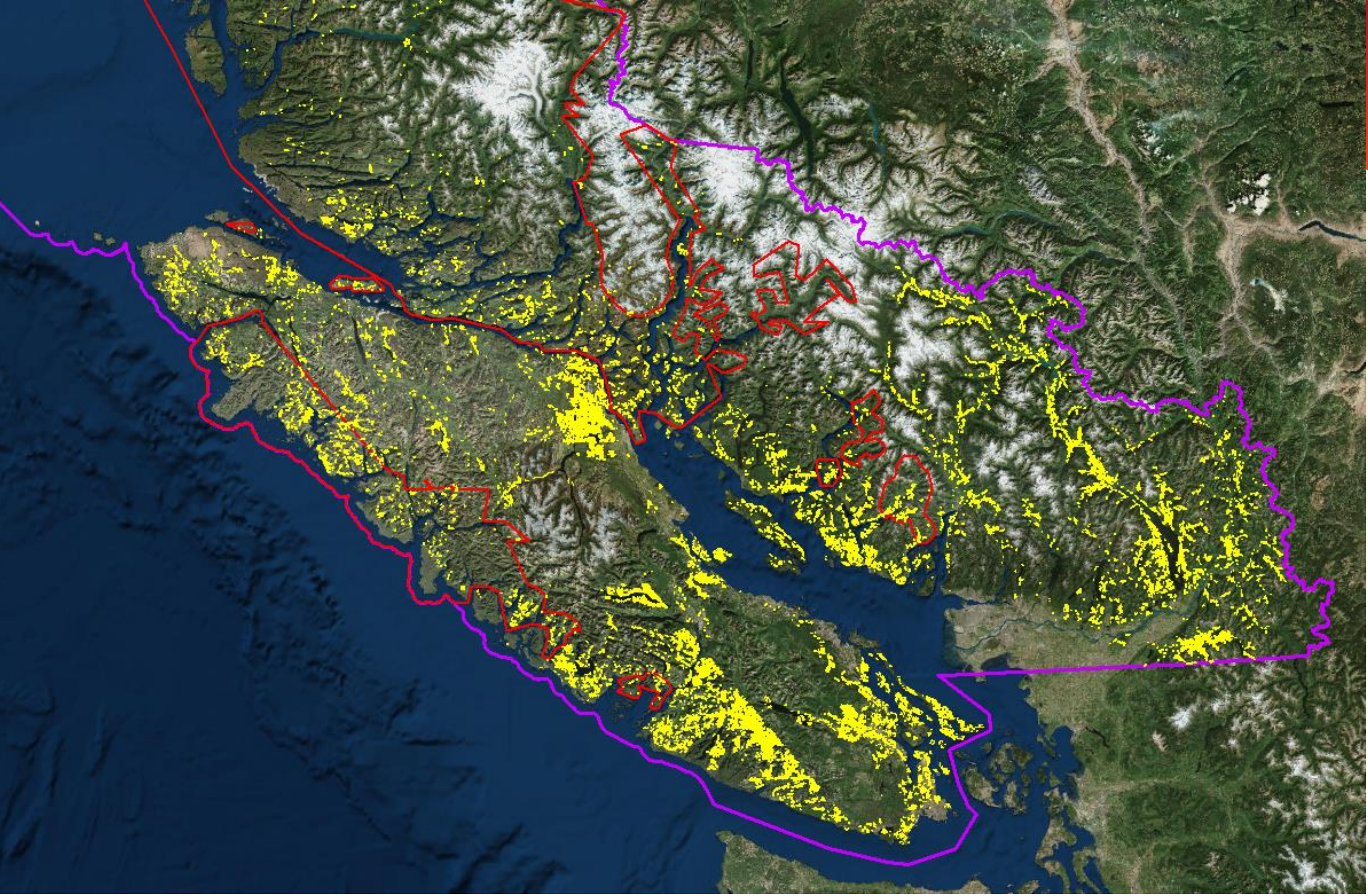
Study Area



BRITISH COLUMBIA
Haidia Gwaii TSA
GBR North TSA
GBR South TSA
North Island TSA
Sunshine Coast TSA
Soo TSA
Fraser TSA
Pacific TSA
Arrowsmith TSA
North Vancouver Island Schirp Zone
Hecate Strait
Dixon Entrance
Queen Charlotte Sound
Prince Rupert
Terrace
HAZELTON MOUNTAINS
NECHAKO PLATEAU
Prince George
Dawson Creek
HART RANGES
CARIBOO MOUNTAINS
Quesnel
FRASER PLATEAU
Bella Coola
Williams Lake
100 Mile House
Cache Creek
Lillooet
Lytton
Campbell River
Courtenay
Port Alberni
Nanaimo
Vancouver
Richmond
Surrey
Duncan
Victoria

Net Coastal Aerial Fertilization Targets





Costing Summary

Timber Supply Area (including TFLs)[1]	TSA Number	Marine Economic Zone	Marine Treatment Cost/ha[3]	Roaded Economic Zone	Roaded Treatment Cost/ha [3]
Soo TSA	31	-	-	Mainland	$463
Fraser TSA	30	-	-	Mainland	$463
Sunshine Coast TSA	39	South	$632	Mainland	$463
Arrowsmith TSA	38	West Coast	$665	Island	$479
North Island TSA	48	West Coast	$665	Island	$479
Great Bear Rainforest South TSA	47	North	$668	-	-
Great Bear Rainforest North TSA	46	North	$668	-	-
Haida Gwaii TSA	25	Haida Gwaii	$836	-	-
Pacific TSA	44	All except Haida Gwaii	-[2]	All	-[2]

[1]Management units are mapped in Appendix 1.

[2]Pacific TSA occurs in multiple locations throughout the AOI of this study and has multiple economic zones.

[3]Variables related to marine transportation are described in Appendix 5.2, and base roaded costs are shown in Appendix 5.4. All costs were derived from base program data provided by the Fert Working Group.

Marine Costing Variables

Potential Marine Program Location	Management Unit	Total Barge Costs[2]	Cost/ha assuming a 2100ha program[3]	Cost per kg to put in 1 tonne bags and deliver to the barge port	Transport from Train to Barge for 2100ha project	Cost/kg assuming 913,500kg of fert (2100ha*435kg/ha)	Total barge + survey costs	Cost/ha	Cost/kg	Total marine operation cost per ha	Total marine operation cost per kg	Total marine operation cost for 2100ha operation
Goliath Bay - Jervis Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
Stakawus Creek - Jervis Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
Vancouver Bay - Jervis Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
McNab Creek - Howe Sound	Sunshine Coast TSA	$157,500	$101.97	$0.062	$56,637	$0.17	$319,137	$151.97	$0.35	**$623**	**$0.78**	**$1,308,300**
Sechelt Creek - Salmon Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
Clowhom Lake - Salmon Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
Misery Bay - Salmon Inlet	Sunshine Coast TSA	$179,500	$112.45	$0.062	$56,637	$0.20	$341,145	$162.45	$0.37	**$633**	**$0.80**	**$1,329,300**
Gilford Island	GBR North TSA	$201,500	$122.92	$0.062	$56,637	$0.22	$363,132	$172.92	$0.40	**$644**	**$0.83**	**$1,352,400**
Gold River/Nootka Island	North Island TSA	$245,500	$143.87	$0.062	$56,637	$0.27	$407,127	$193.87	$0.45	**$665**	**$0.88**	**$1,396,500**
Haida Gwaii	Haida Gwaii TSA	$604,500	$314.83	$0.062	$56,637	$0.66	$766,143	$364.83	$0.84	**$836**	**$1.27**	**$1,755,600**
Jackson Bay	GBR South TSA	$201,500	$122.92	$0.062	$56,637	$0.22	$363,132	$172.92	$0.40	**$644**	**$0.83**	**$1,352,400**
Toba Inlet	Sunshine Coast TSA	$201,500	$122.92	$0.062	$56,637	$0.22	$363,132	$172.92	$0.40	**$644**	**$0.83**	**$1,352,400**
Yeo Island	GBR North TSA	$403,000	$218.87	$0.062	$56,637	$0.44	$564,627	$268.87	$0.62	**$740**	**$1.05**	**$1,554,000**

FCI Candidate Hectares

Management Unit	All Roaded ha	All Marine ha	Total Candidate ha
Soo TSA	23,353	0	**23,353**
Fraser TSA	30,613	0	**30,613**
Sunshine Coast TSA	23,974	8,490	**32,463**
Arrowsmith TSA	62,122	4,980	**67,102**
North Island TSA	73,101	11,944	**85,045**
Great Bear Rainforest South TSA	0	13,658	**13,658**
Great Bear Rainforest North TSA	0	7,554	**7,554**
Haida Gwaii TSA	0	32,714	**32,714**
Pacific TSA	2,563	12,153	**14,716**
TOTAL	**215,725**	**91,494**	**307,219**

Project Considerations

- Survey phase-
- Cost of tug and barge transportation
- Access
- Treatment Phase
  - Timing of planning/referrals

Treading New Waters

- Access conditions
- Weather
- Tendering and permitting
- Treatment from the shoreline off of the barge
    - Fisheries Oceans Canada
    - Navigable Waters Protection Act

Major Limitations Moving Forward

- Implementation
  - Survey conversion factor
  - Remoteness
    - Survey, monitoring, prescriptions
  - Finding consolidated project areas for economic feasibility
- Treatment and Application
  - Lack of applicators
    - $200,000 cost of entry for helicopter companies with existing annual commitments
  - Access to dry land sorts and scheduling with licensees
- Every drainage is different and it's hard to plan at a landscape level until boots are on the ground

Conclusions and Next Steps

- A FCI marine project requires well designed treatment units of minimum 300 ha per drainage, and well developed tendering process.
- Easier and faster to start with roaded versus shoreline projects. (authorizations and established infrastructure).
- 8000ha survey program in the Johnstone Straits and the Sunshine Coast underway in 2019.
- Potential marine project of 2000 ha ready for Spring 2020 application.

Thank you!

FFT Coastal Field Tour 2019 - FESBC Cedar Release Project

Objective

This FESBC project is considered an operational trial with the objective to convert a hemlock leading stand (Hw9Cw1) to a cedar leading stand (Cw8 Hw2 approx) to increase stand values at rotation (estimated to be 60 – 70 years). Although there may be some volume losses from this treatment, the underlying principle here is to trade volume for value. In addition, opportunities to fertilize may offset volume losses.

Stand History

Site Series	Site Index (SIBEC)	Logged	Planted	Free Growing	Cw Release Treatment
Classified as: CWH vm1 06 - More zonal?	CWH vm1 01: Hw-28 Cw-23 CWH vm1 06: Hw-25 Cw-23	2005	2006 - Cw62 Fd20 Hw18 (1250sph) - Cw750 Fd250 Hw250 sph	2015 - Inventory Hw100 (8700sph) - Silviculture: Hw87Cw13 (825sph FG)	Winter 2018/19

Pre Treatment Stand

	Density (total SPH)	Composition (%)	Avg Height (m)	Avg DBH (cm)	Age (yrs)
Hw	6200	84	7	6	14
Cw	1000	13	3	3	14
Ss	200	3	2.5	2	6
Total	*7400*				

Post Treatment

The target stand was expected to be Cw80Hw20 with a density of 1000 to 2500 stems/ha for the next rotation.
Survey information conducted in April 2019 is showing:

Rx1 (6ha)	Rx2 (14ha)
Silviculture: Cw100 (800 sph FG)	Silviculture: Cw71 Hw19 Fdc10 (880 sph FG) Inventory: Hw44 Cw42 Ss14 (2800 sph)

Treatment Instructions

1) Control area: 1ha

2) Rx1: 6ha

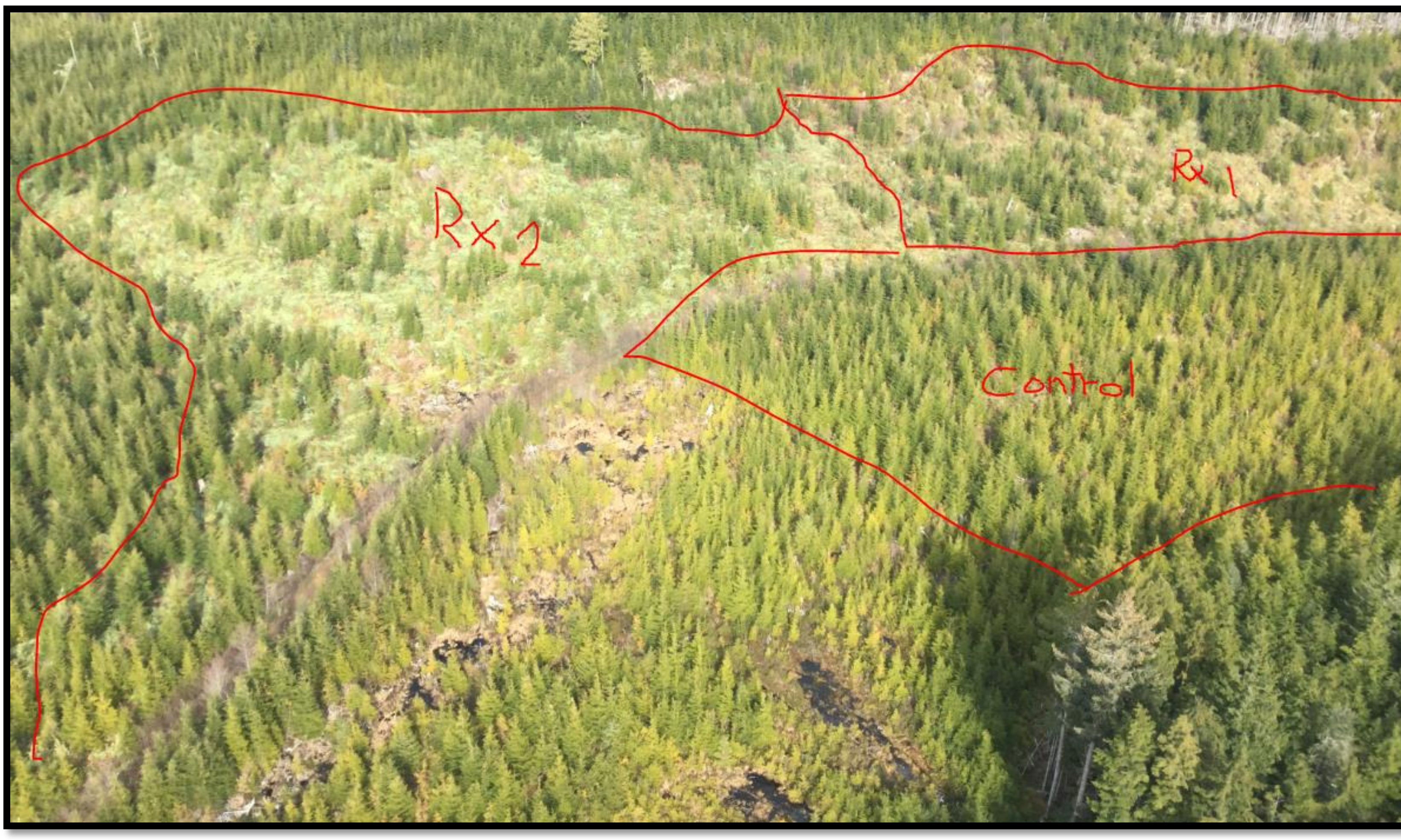
- Remove Hemlock and Alder trees that have branches or stems inside a 2.00m radius from the bole of the Cedar trees.
- Cedar trees have to be at least 1.5m tall.
- DO NOT CUT, NICK OR DAMAGE FIR TREES AND CEDAR TREES.
- Cut stumps have to be less than 20cm in height and have a cut angle of 30 degrees.
- No slash to be put on top off or leaned on Cedar trees. Cut trees to be laid flat on the ground
- Hemlock and Alder that are larger than 15cm (6in) in diameter at breast height are to be girdled and not cut with chainsaw.
- Do not remove Hemlock trees if there is no Cedar around it.

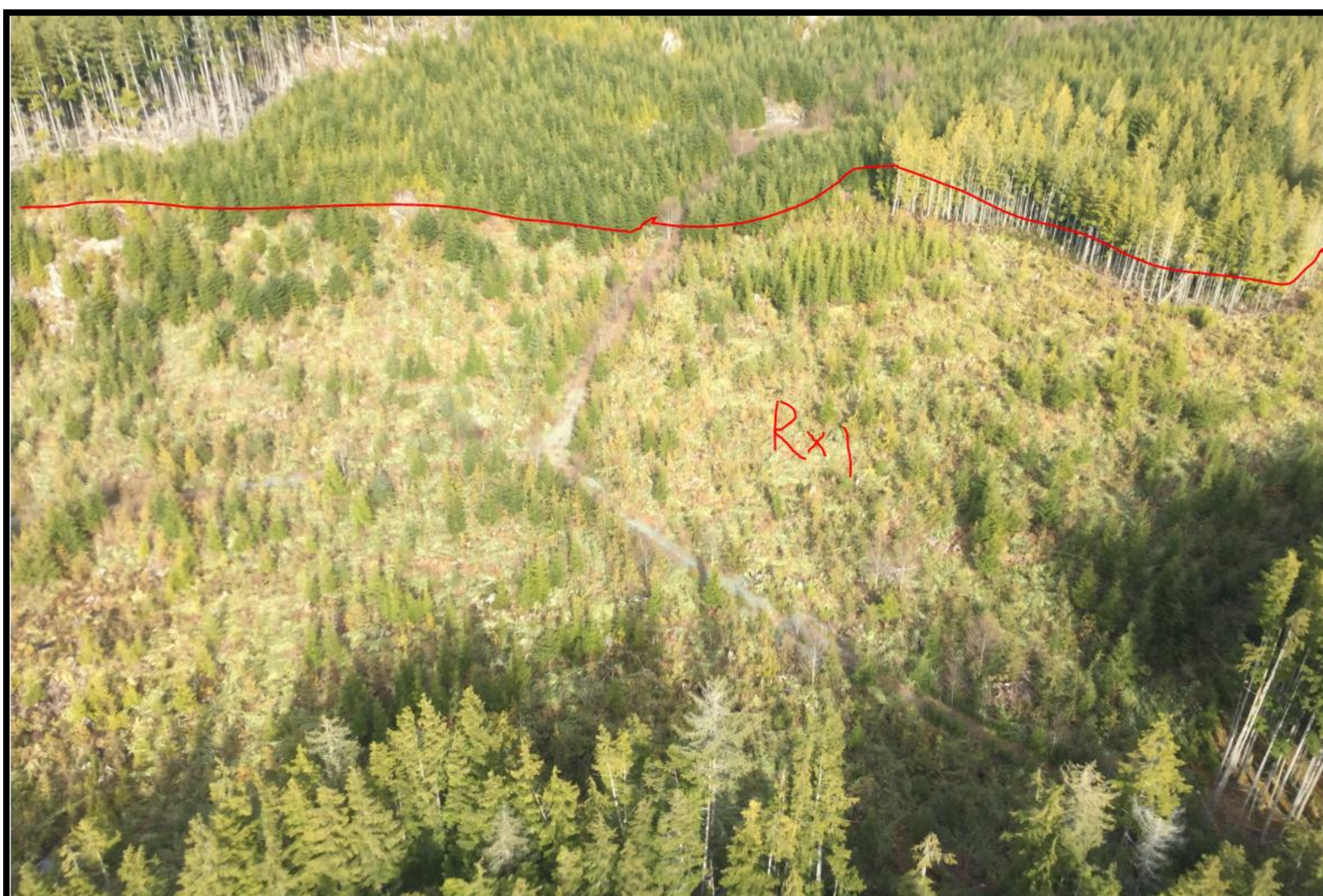
3) Rx2: 14ha

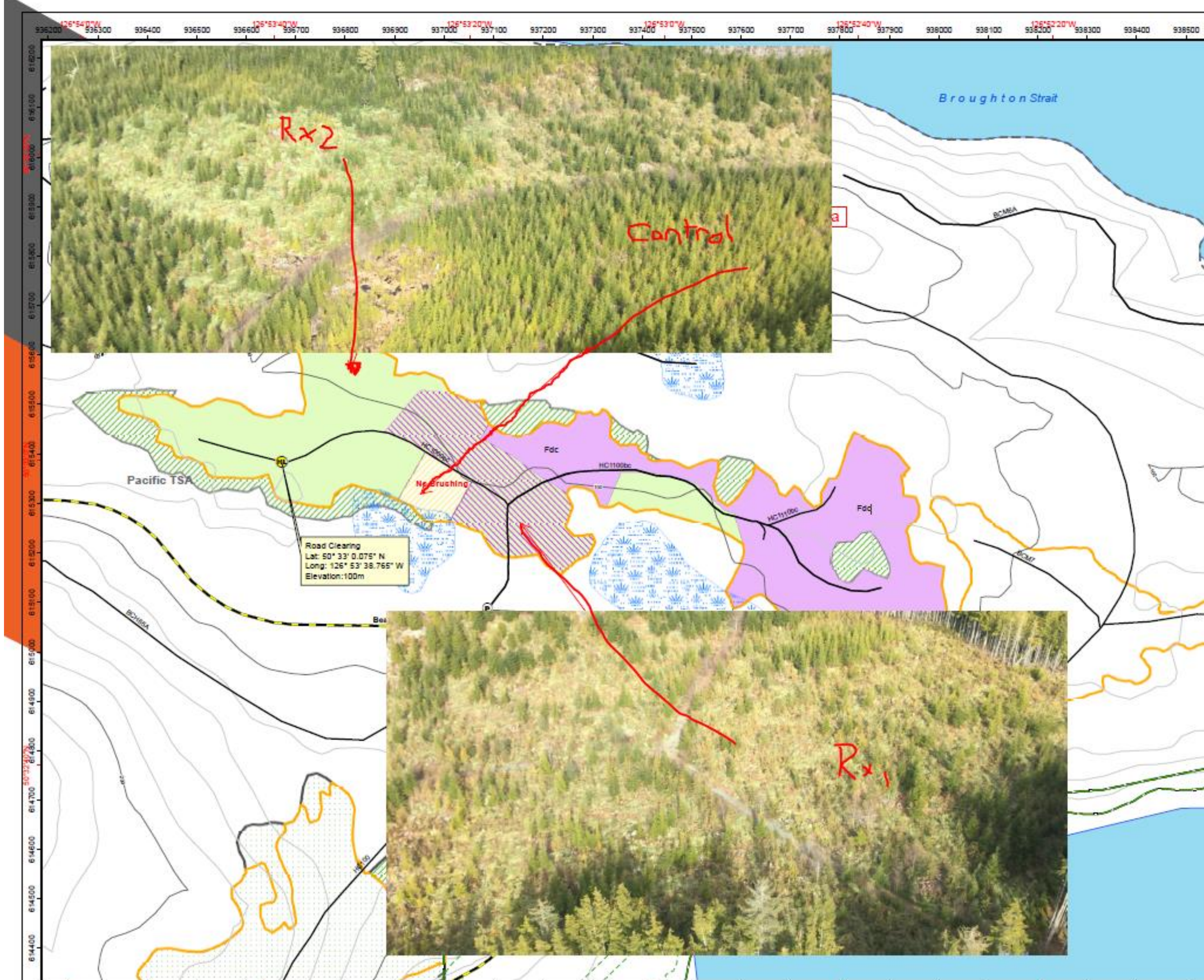
Same as Rx1 with the following changes:
- Cedar trees have to be at least 3m tall.
- Ensure Hw whips are cut.
- Do not favour the retention of Sitka Spruce due to forest health issues unless it is the only choice for a leave tree.
- Use discretion to leave Hw standing to limit gaps

Feedback

- Given what you've seen, what would you do differently?
- Feedback on the treatment instructions?
- How does this site compare to other existing or potential sites?
- Should this type of treatment be expanded further?


Rx 2
Rx 1
Control


Rx 1



Improving Stand Value of Cedar North Vancouver Island

117261 Brushing Map

Working Name	Beaver Cove
FES Project Number	PWC project # RB0000418
SNRC Project Number	18-1035-02
Prescribing Forester:	Jason Hutchinson, RPF
Treatment Area:	13.8 ha
BCGS Mapsheet:	092L056

Map Features

Control Area	Approved OGMA
Non Treatment Area	Community Watershed
Treated Area	Retention
Treatment Area	WTRA
Previously Harvested	Lake
Free to Grow	Wetland
Tenure Boundary	Ocean
Indian Reserves	Paved Road
Parks and Protected Areas	Stream
WMA	Index Contour (100m)
WHA	Intermediate Contour (20m)
UWR	Heli Landing Area
Blue Listed Ecosystems	Parking Area
Red Listed Ecosystems	

Map Center Coordinates

Easting: 937,367 LAT: 50°32'57.13"N
Northing: 615,284 LONG: 126°53'3.33"W

1:7,500 — 0 75 150 300 450 Meters

Datum\Projection NAD 1983 BC Environment Albers

Drafted By SNRC — Date Jan, 29, 2019 — STRATEGIC

Document Path: G:\Projects\FES_PWC_CwRelease_NorthIsland\Phase\Beaver Cove\FES-Beaver Cove-117261_Brushing_Map.mxd

FFT TOUR 2019 - Revisiting the Benefits of Red Alder Management

For this stop the District would like to revisit and promote red alder management on the coast for further consideration under FFT, FCI, and section 108 funding.

In 2007, the Coast Forest Action Plan (CFAP) presented a vision for a competitive and sustainable coastal forest sector including encouraging the utilization and management of deciduous species, the Coast Regional FRPA Implementation Team (CRIT) developed the Hardwood Management Strategy for the Coast Forest Region to address this.

https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%20(final%20July11V2).pdf

The goal was to have 1200 ha/yr of red alder (or broadleaf) management on the coast to yield 300,000 m3/yr of broadleaf volume. This amount of volume would support a milling facility in BC and the land-base required is only 1% of the coastal timber harvest land-baser (THLB) which seemed insignificant. This is roughly 200 ha per District on the coast.

The market value for quality red alder saw logs has appreciated more than other species on the coast in recent decades (Vancouver log market Dec 2018 $95/m3). Despite this appeal since 2007 the management of red alder has not increased to meet the logs supply proposed under the CFAP. Red alder harvest levels for 2007 to 2013 totalled 867,434 m3 and averaged approximately 145,000 m3 per year on the Coast Area. The area (ha) managed to red alder has increased slightly since 2009 from 3.6 ha to 241 ha (average planting 1300 sph) in 2014. This represents a total of 753 ha over this five year period of which 295 ha were spaced (intensive regime). This is level of management is approximately 87% short of the suggested target by CFPA and CRIT.

https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%205%20year%20review%20Final(Janua....pdf

Looking to other management benefits red alder not only sequesters carbon it can also be managed on short rotations compared to conifers while adding nitrogen to the soil from the time it is a seedling. These benefits will be discussed in more detail in the following paragraphs.

Red alder can be managed on short rotations of 25-35 years under intensive spacing regimes **or** 30-50 years under extensive regimes that require no spacing investment as red alder is a self-pruner when sufficient densities exist. Under a mixed-wood regimes consisting of both red alder and conifers in separate discrete patches rotations are estimated to be 50 - 70 years or less. Obviously, short rotations can benefit timber supply in terms of log supply but red alder could also be managed as a climate change adaptation strategy on the coast based on the following publication *"A Climate Change Strategy for Red Alder in British Columbia (2012)* ". https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr074.htm

The amount of branches and knot size determines if red alder is used for either firewood (low value) or specialty products (high value). The latter can be achieved through density management that keeps branching to a minimum. In general, the higher density of >=1000 sph of red alder stocking early (at regen date) will restrict branch growth on the lower bole as quickly as possible.

Given the right ecology as defined by CRIT for broadleaf management red alder should be considered to reduce mid-term timber supply shortages, provide a log supply to support a mill facility in BC, achieve reforestation objectives on the THLB, including areas burned by fire/site rehabilitation, and urban interfaces to reduce fire hazards, and to sequester carbon.

Nitrogen Fixation Key Points:

https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/tree-species-selection/tree-species-compendium-index

From the *The Distribution and Synopsis of Ecological and Silvical Characteristics of Tree Species of British Columbia (2000),* tree compendium *Silvics of Dr* (Klinka *et al*) outlines that red alder grows in even-aged, pure stands and, in later successional stages, with shade-tolerant conifers. Red alder after a fire can also become established in nitrogen-poor soils because of a symbiotic relationship with a nitrogen-fixing actinomycete.

Red alder develops an extensive, fibrous root system, with root nodules that fix atmospheric nitrogen. The nodules are a symbiotic association between the tree and an actinomycete (Frankia ssp.). Nitrogen fixed in the nodules is added to the soil in four ways: 1) direct excretion from living roots or nodules, 2) decomposition of dead roots or nodules, 3) leaching from foliage, and 4) decomposition of nitrogen-rich litter. Maximum fixation rates of **320 kg per ha per year** have been reported.

FRDA Report 240: *Red Alder Manager's Handbook for BC* (1996): https://www.for.gov.bc.ca/hfd/pubs/docs/Frr/Frr240.htm

Red Alder is capable of fixing nitrogen at the rate of 100-200 kg/ha/yr in pure stands and 50-100 kg/ha/year in mixed species stands. Red Alder can improve soil fertility, structure, and bulk density through high annual returns of organic matter, N, Ca, Mg, K, and P from alder litter, and from increased turnover of litter from other plant species. The positive effect of nitrogen levels is estimated to be approximately one tree-length and this would also benefit the next rotation if conifer based.

Carbon sequestration Key Points:

Current estimates are 1 m3 wood growth = 1 tonne C02 sequestered or 30 m3 = 26 tons C02 sequestered (not for all stands).

A report from 2012 *A Climate Change Strategy for Red Alder in British Columbia* states the following:

*"Another ecosystem effect of concern is the impact of alder management on **total ecosystem carbon**. Based primarily on assessment of above-ground biomass, an increased emphasis on alder management is likely to have a small (< 5%) but **positive** impact (Appendix 1). While overall growth rates are likely to increase, suggesting a higher rate of carbon capture, the rate of turnover is also faster due to substantial use of short-rotation management (25–30 years). Other elements such as changes in soil carbon are weakly understood, and there is no strong evidence to suggest that long-term changes in carbon pools occur under a landscape-level collection of pure and mixed wood stand regimes."*

History of the stand:

The second growth stand harvested by Weyerhaeuser in 2000 which at the time approximately 70% mature alder stand of 60 years. The obligation was then managed to mainly conifers of cedar (Ss, Ba) and browse protected at great expense to maintain the conifer objective. Red alder natural ingress was reported to be 20% at the time of the regeneration date forest cover update (year 6). At year 10 the licence holder representative for WFP contacted the District office regarding the recently published "CRIT Broadleaf Management Discussion Paper" about switching the site from conifer to alder management objectives under the approved FSP. Block was then field reviewed by the Silviculture Working Group and WFP staff and the managed as mixed wood leading to discrete patches of deciduous polygons and some pure conifer polygons.

PLOT 1 @ Year 17: 3.99m2 (MITD 2 meters): Well-spaced 10 Dr, 2000 sph
Total sph 38 Dr, 1 Cw = 7800 sph. Heights 13.6 meters tall, SI 30+, diameter range 3-13 cm, average 8 cm dbh.
5 BAF, 4 trees merchantable (>12.5 dbh) **90 m3/ha** gross. All trees 7 in 5 BAF = 158m3.ha

PLOT 3 @ Year 17: 3.99m2 (MITD 2 meters): Well-spaced 6 Dr, 1 Cw or 1400 sph
Total sph 10 Dr, 1 Cw = 2200 sph. Height 16 meters tall, SI 30+, diameter range 8.5 -21.5 cm dbh, average 14.1 cm dbh.
5 BAF : 4 Dr trees merchantable, average height 16 meters, gross **106 m3/ha**.

GHG Benefit of Conifer vs. Red Alder Plantation, CWHvm1

2019-04-29

Background

Simulations were conducted to compare the greenhouse gas (GHG) benefit for three management scenarios in a stand that was previously 70% red alder before harvest in 1999 and planted in 2000 (fill-planted in 2001). The three management scenarios were defined by planting in 2001:

A) Conifers (85% Cw, 13% Ba, 2% Ss), clearcut and slash burn at age 70
B) Alder, clearcut and slash burn at age 40
C) Alder, clearcut and slash burn at age 70

Simulations were conducted with TIPSY and CBRunner.py.

Results

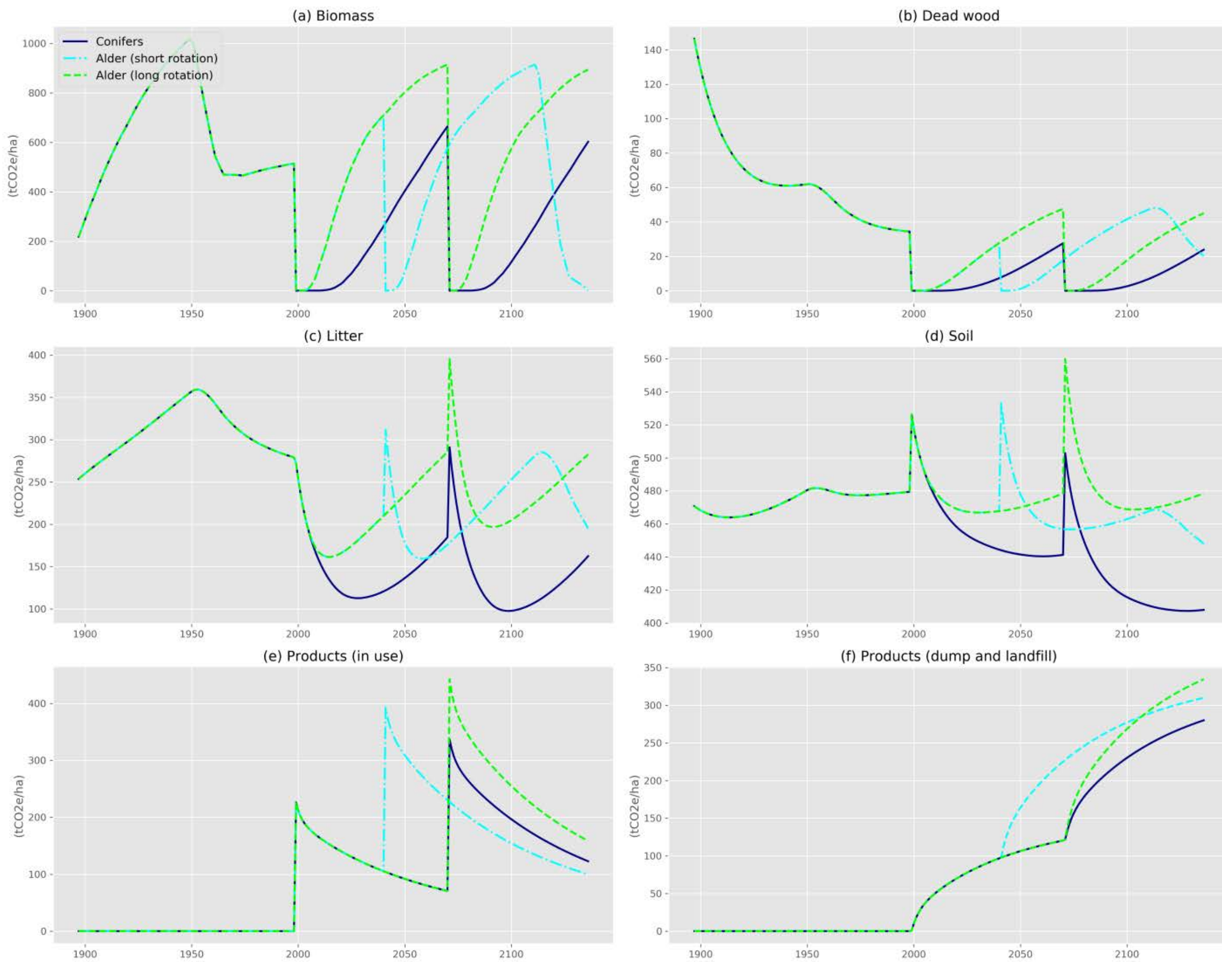


Figure 1. Carbon pools (expressed in tCO_2e/ha).

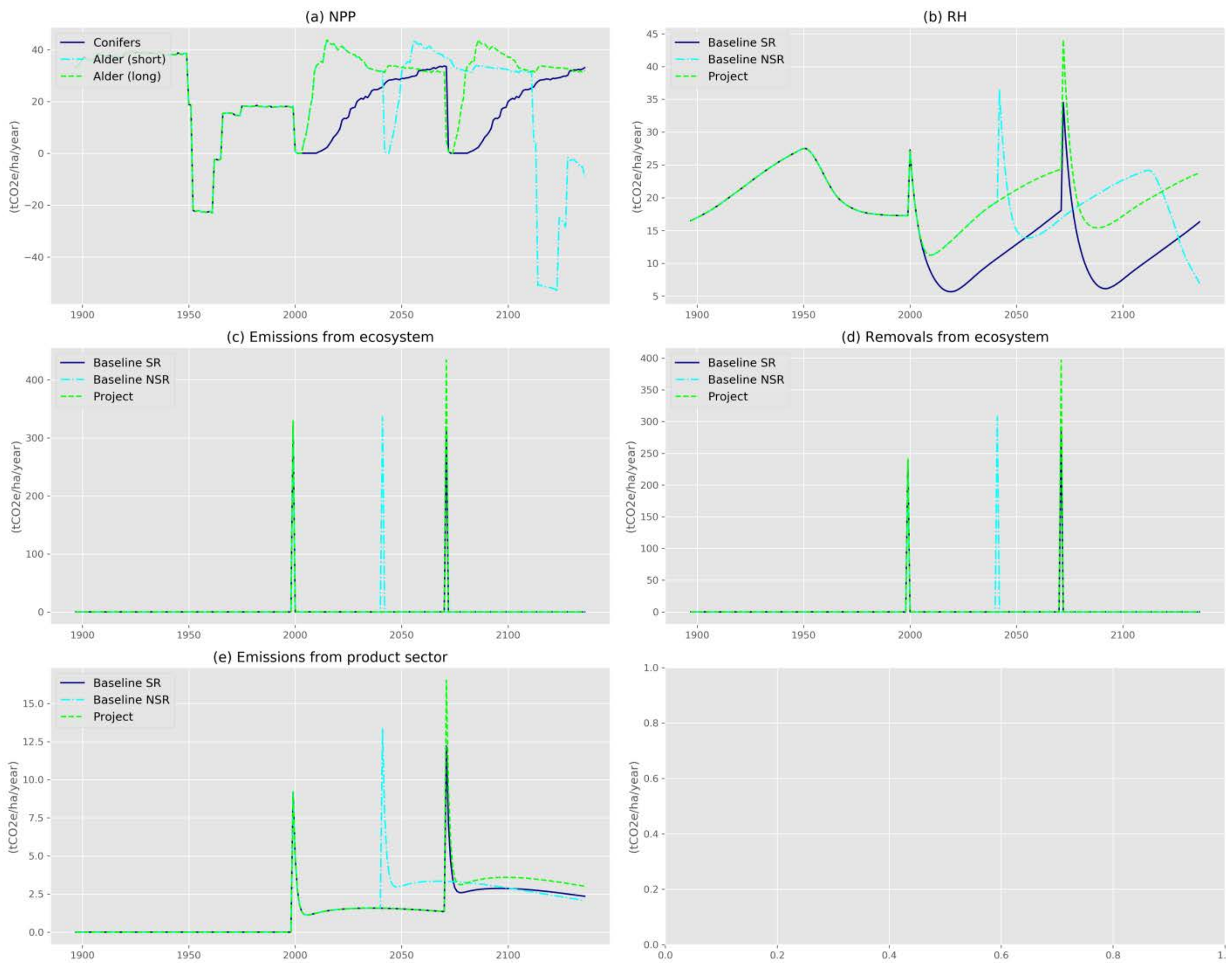


Figure 2. Carbon fluxes (tCO_2e/ha/yr).

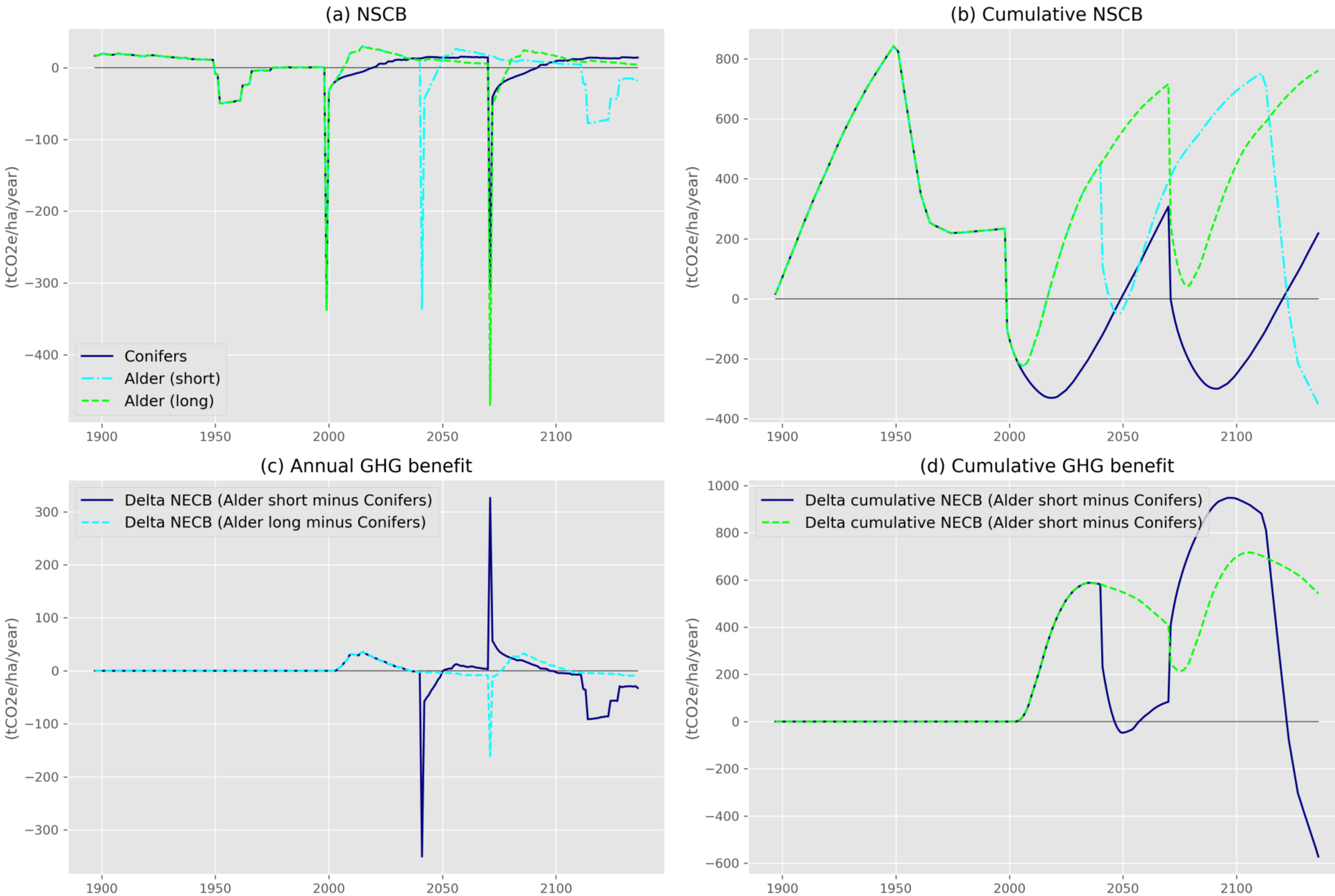


Figure 3. Net sector carbon balance and GHG benefit of the red alder management scenarios (relative to the conifer scenario).

FFT TOUR May 1, 2019 – Fire Rehabilitation Stop – A District Led Summary of Issues Experienced to Date.

Fall 2018 FFT/FCI FIRE Review with WFP (recap)

<u>Vernon Camp Fires - Lower intensity clear-cut burns/ lower elevation burn – observations:</u>

CWH mm1 zonal sites – looking really good, well stocked and vigorous with lots of soil and good vegetation cover.

Planted 2001 and burnt 2009 blocks that were due to be FG that very year. In 2011 replanted 100% Fd at 932sph.

By 2012/13 there was 859 well-spaced and 1010 total stems with a cost of $1600/ha according to WFP.

Lower slopes of the Vernon Camp fire there is natural ingress of cedar, white pine, some alder and willow occurring. WFP indicated they do not want to rely on the Pw natural due to forest health risks and blister that has yet to reveal itself. Other species would be selected during future surveys for forest cover reporting.

Inv-label
Total stem 1177

Fdc	50%
Hw	30%
Bp	10%
Yc	10%

Silvi-label
WS 859 sph total

Fdc	54%
Hw	26%
Bp	10%
Yc	9%
Cw	1%

The upper elevations of the blocks on Vernon Ridge in the photo above were only planted in 2006 so had only 3 seasons of growth when burnt. They are also looking pretty well stocked @1177 sph and vigorous again. However there was not much natural ingress at this time.

The Noble Fir in the photo to the left is a native to Oregon State has a wide and thick stem and branches compared to native species present on site. This species appears to be doing well and may be suitable for areas with snow press at higher elevations.

Unharvested areas on Vernon ridge at higher elevations were slowly filling in with naturals but below MSS in terms of stocking at this time. Standing dead timber that is not salvaged harvest by the licence holder presents challenges for the THLB.

Reforestation priorities are as follows:

Section 108 blocks where licensee obligations exist for young stands not free growing.

Young stands FG <6 m in height, THLB, DDM responsibility.

Subsequent years, assess stands >6 m in height that were previously free growing THLB.

Mature stands, no planned actions, anticipate naturals fill in, dangerous terrain plague with safety issues and $$$$.

Kinman Fire (intense burn over sensitive Karst terrain) higher elevation sites 600-900 meters

Kinman Creek was Logged in 2009, burnt 2013, planted 2014 with 410 plugs and fertilized at planting. Stocking was 888sph of Fd, Yc, Ba. It cost 45c/tree and $941/ha all. In 2016 survival showed 783sph which was Fd51Yc42Ba8 but then followed by some deer browse and drought occurred the decision was made to fill plant in 2017 (336 sph) given harsh site conditions. Final cost per tree is around $1.10 per tree. Total well-spaced is 636 top portions of the block and 833 on the lower sections both Fdc and Yc leading = section 108 success!

Hardly any soil left, just in pockets and not much organic matter anywhere. Soil erosion is the number one problem with karst ecosystems around the world our North Island sites are no exception after fire. The karst terrain itself may fan fire flames from below making the fires burn more intensely.

Areas of FFT DDM responsibility blocks in Kinman Creek are plantation failures from the District perspective at less than 200 sph on these harsh sites. Under FFT not sure if 2% ROI supports more fill planting? Stewardship needs to revisit these areas.

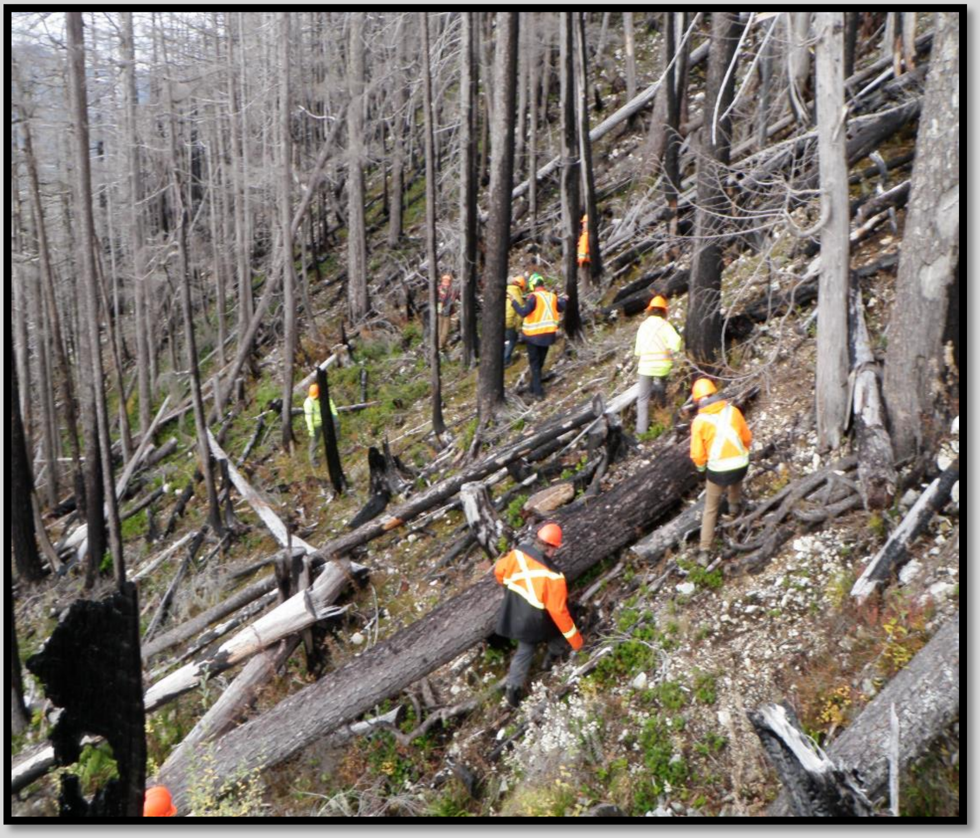
Summary of 2018 Fires in DNI

In 2018 the fires polygons indicated over 6,000 ha of burnt areas according to reported fire polygons, this is about 400 ha in obligation plantations, and about 200 ha are <6m. The plan was to assess and reforest the youngest and shorter stands first under section 108 and areas of DDM responsibility. There will be significant safety issues and cost will increase for reforestation for stands above 6 meters in height that burned. The decision was to plant what was formerly THLB the most productive and easiest sites (still a large workload) and to possibly fill plant harsh sites from intense burns (Kinman Creek).

In NICC, we have observed more intense burns are in the clear-cuts than standing forests although there are always some exceptions (referred to as black swans). Some of the largest fires since 2009 are on sensitive karst terrain. Again, the need to plant THLB clear-cuts that have burned – natural ingress is variable depending on severity of burn and terrain (over Karst), aspect, elevation, etc. Need planting to achieve densities greater than minimum stocking (MSS) on the THLB.

For standing mature timber, this represents significant challenges if the interest to salvage damaged timber remains low from the THLB. Non-contributing THLB such as an OGMA's observation natural fill-in is occurring where there are standing residual live or dead trees – lower intensity burns with some vet survivals likely leads a micro-climate that supports a seed source with shade, moisture, frost protection, less soil sterilization etc.

For example, the burnt OGMA below has 1400 sph of naturals consisting of cedar, Fdc, and Hw. Similar experiences in the Bella Coola Valley from 2005 fires that burnt WTP's with dead standing trees had 1100 sph of natural ingress (Fdc, Cw, Hw) while the clear-cut open areas on south facing slopes had less 200 sph (NSR).



A District overview flight revealed much of the mature timber impacted from fire is steep terrain with cliff and bluffs, poor access, standing dead trees and branches as hazards. The District stewardship position is not to pursue reforestation in the ncTHLB especially where Fdc vets have survived. In some polygons with >= 25 sph of old veteran trees these OGMA's may still continue to function as intended despite the fire.

District AOP Planning Challenges:

Some challenges with planning are fire polygon delineation is hit or miss (Pacific TSA example).

- Pacific TSA had 572 ha burned according to fire polygons
- After doing a recce flight, we found that the actual fire was half the polygon size in some cases, and missed parts of the fire in others
- Overall, there was likely 50 ha of THLB that burned, and much of that is in mature timber and not a severe burn
- Total area to survey for planting ended up being negligible
- Takeaways: the fire polygons can be alarming at first, but after fixing polygon errors, considering the severity of burns in mature timber, and netting out NC, the impact can be small. This won't be true in all cases but definitely worth the investment of a recce flight and taking a look at updated satellite imagery. Sentinel-hub is a good resource.
- The Fire Rehabilitation Tour concluded best approach is to plant THLB and get site going again at TSS if possible using improved seed sources for genetic gain.

Remember, a Clear-Cut Improves the View!