

Effects of organic matter removals and vegetation control on nutrients and growth at three Douglas-fir forests

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Long-term Soil Productivity Study

- World-wide study on soil and site productivity
- Identify the effects of intensive disturbance due to organic matter removals and compaction
- Affiliate sites incorporated vegetation control treatments







Pacific Northwest LTSP Research

- Determine the long-term effects of organic matter removals and vegetation control on soil and site productivity
- Organic matter removals
 - Bole Only (BO), Whole Tree (WT), WT plus coarse woody debris removal (WT+)
- Vegetation control
 - Initial (IVC) and 5 years of annual (AVC)





- **LTSP** Sites
- ≻ Fall River
 - ≥20 years old
- ➢ Matlock
 - ▶16 years old
- ➢ Molalla

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≻16 years old





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Stand Management Cooperative

Soil Moisture

- All tree sites have unique climates and soils which affect soil moisture availability
- Lowest soil moisture at Matlock
 - Coarse glacial outwash soil
- Fall River contains the greatest summer soil moisture
 - Silt loam-silty clay soil texture and cooler summer temperatures
- Moderate soil moisture at Molalla
 - Loam-clay loam soil and rocks with warmer summer temperatures





Differences in Soil and Site Productivity

- Fall River
 - 138 ft Site Index at harvest
 - 140 ft SI at 15 years
 - High soil N and low soil Ca & K
- Matlock
 - 118 ft SI at harvest
 - 90 ft SI at 15 years
 - Low soil N, Ca, & K
- Molalla
 - 118 ft SI at harvest
 - 113 ft SI at 15 years
 - High soil N, Ca, & K

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Organic Matter Removals

- Treatments removed a variable amount of debris by site
- Large amount of CWD in BO treatment at Fall River
- Matlock and Molalla treatments resulted in similar residuals
 - Contained much less CWD than Fall River





LTSP Timeline of Sampling



SILVICULTURE

NUTRITION
WOOD QUALITY

MODELING

8

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Fall River Vegetation Control

- Aimed for 95% vegetation control with varying treatments by year
- Presence of ferns, oxalis, and salmonberry
- More information in Ares et al. 2007



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Matlock Vegetation Treatments



- Heavy Scotch broom presence after harvest and in IVC treatment
- More information in Harrington and Schoenholtz 2010

BOIVC BOAVC



WTIVC WTAVC



Molalla Vegetation Treatments

- Operational vegetation control treatments
- Less control of hardwoods resulted in heavy presence of cascara and cherry in plots
- More information in Harrington and Schoenholtz 2010

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BOIVC BOAVC



WTIVC WTAVC

N Leaching after Harvest

- Fall River and Matlock: **Greater N leaching after** harvest in BO treatments than WT
- Molalla and Matlock: AVC resulted in greater N leaching than IVC
- Stand with the greatest soil N (Fall River) had the greatest **N** leaching
- Potential for leaching of other nutrients along with N



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Methods

- April 2017 Removed forest floor and shallow soil samples from four composited points per plot
 - Analyzed samples for C, N, available N (NO₃, NH₄), exchangeable cations (Ca, Mg, K), P, and pH
- Installed plant root simulator (PRS) probes at 5-cm soil depth
 - Four composited samples per plot
 - Removed PRS probes after 12 weeks





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PRS N adsorption and Productivity

- Regional Douglas-fir soils
- Greatest PRS NO₃ in forest floor C:N < 40 and surface soil C:N < 25
 - Matches C:N ranges indicative of fertilizer response in the region
- PRS NO₃ related to greater site productivity
 - Some stands have low PRS NO₃, but adequate PRS NH₄
- Greatest fertilizer response at low PRS NO₃ adsorption

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PRS NO3 Matches Fertilizer Response

- Green polygons are regions predicted to respond to urea fertilization
- Low PRS NO₃ adsorption mostly in predicted response regions
- Western Washington does not follow that trend
 - Higher NH₄ adsorption
 - Low Ca adsorption as well









Competing Vegetation Methods

- August 2018 and 2019 Sampled competing vegetation
 - Ten 0.2 m² samples per plot were composited
 - Samples were split into understory (herbaceous and small shrubs) and overstory (large shrubs and trees)
 - Understory and overstory samples were ground separately and analyzed for total N, Ca, Mg, K, and P





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Douglas-fir Methods

- Stand volume measured at 5, 10, 15, and 20 years
- Fall 2018 and 2019 Sampled Douglasfir biomass
 - One tree of mean DBH and height from each plot
 - Sampled branches and boles up the stem
 - Branches and needles were subsampled to determine total biomass for each tree
 - Analyzed for total N, Ca, Mg, K, and P







Statistical Analyses

- Sites were analyzed separately because of the differences in treatments, plot size, and experimental design
- An alpha level of 0.1 was used to determine significance for all analyses
 - n=4 or 8
- Interaction of organic matter removals and vegetation control at Matlock and Molalla
- No interactions used at Fall River due to fractional factorial design
- Treatment effects on nutrient concentrations and Douglas-fir stand volume growth was examined using Anova
- Significant treatments effects were determined using Holm-Bonferroni method

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Soil Treatment Effects at Fall River

- Whole tree plus coarse woody debris removal decreased soil and PRS Ca
 - Reduction of an already limiting nutrient
- Both WT treatments decreased soil and PRS K and NO₃
 - Permanent removal of organic matter
 - Greater mineralization after harvest
- AVC treatments contained lower soil N, Ca, and Mg concentrations
 - Forest floor N, Ca, K, and Mg were also reduced, and Al was increased
 - More leaching of nutrients and/or greater uptake?

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Fall River Foliar Nutrition

- Decreases in foliar Ca concentration support a decrease in availability of soil cations due to intensive treatments
 - Already low foliar Ca compared to other LTSP sites (0.2-0.3)
 - Large decrease due to coarse woody debris removal (WT+) to severely deficient levels
- Foliar Al concentrations are higher in WT and WT+ treatments
 - Resulting in further reduction in availability of base cations





Matlock Competing Vegetation

- Heavy Scotch broom cover in IVC and WT treatments
 - BO treatment has greater effect on Scotch broom than AVC
- At 15 years, the BO treatment resulted in greater understory and less overstory biomass than in WT treatment
 - Greater cover of native understory species
 - No significant differences between IVC and AVC treatments



Nitrogen Availability at Matlock

- Scotch broom colonization in WT and IVC treatments added N to the forest floor, soil, and foliage
 - No excess nitrate adsorption found in BOAVC treatment

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 Additional forest floor N in IVC treatments decreased C:N ratios



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Matlock Cation Availability

- Low soil cations at Matlock yet minor changes in soil cations
- Whole tree removal decreased soil exchangeable K and increased Al
 - Similar to Fall River
- Annual vegetation control increased foliar Mg and Al
 - Decreased competition from understory







Molalla Competing Vegetation

- At 15 years, there was no effect of treatments on understory and overstory biomass of competing vegetation
- Large quantity of overstory vegetation due to release of hardwoods by herbaceous vegetation treatments



Molalla N Availability

- Harvest treatments changed the type of available N
- WT treatment resulted in greater PRS NH₄ adsorption
 - Also greater forest floor mass
- More NO₃ adsorption in BO treatment

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- No significant effect of vegetation control on N availability
 - AVC did have greater soil total N increase after 10 years
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Molalla Cation Availability

- High base cations at Molalla
- Lower soil Ca, K, and Mg due to AVC treatment
 - Follows 10-year soil data where base cations increased more in the IVC treatment
- No significant effects on Douglas-fir foliar nutrition due to high soil nutrient availability





Stand Volume Growth due to WT and WT+ treatments

- WT removal resulted in mostly non-significant decreases in stand volume growth compared to BO
 - Fall River WT stand volume growth was significantly lower from 0-5 years
 - Stand volume growth continues to decrease at Matlock and Molalla
- WT+ treatment at Fall River started to decrease from BO treatment from 10-15 years
- Greater effect of nutrient removals on volume growth as stands reach canopy closure when nutrient demands are highest

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Years since Treatment



Stand Volume Growth due to AVC

- AVC increased stand volume growth
- Fall River increased from 0-10 years
 - Effects of AVC on microclimate have decreased
- Matlock increased significantly from 0-15 years
 - Scotch broom is still affecting stand volume growth in IVC treatment
- Molalla growth increased, although not significantly different
 - Competition from hardwoods causing variability within treatment





Overview of Whole Tree Removal



- ► No one size fits all answer
 - Dependent on soil nutrition and treatment severity
- Permanent removal of nutrients from the soil
 - ► Loss of N and K
- No effect or negative effect on volume growth
- Allowed colonization of invasive species





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Overview of Annual Vegetation Control



- Loss of soil N and cations
- Increase in Al in forest floor and foliage
- Improved volume growth at most sites
- Controlled invasive species

Summary of Treatments on Soil and Stand Productivity

- Stand Management Cooperative
- Whole tree harvesting removed nutrients that could be returned to the soil
 - + Short-term improvement in microclimate
 - Released invasive species
 - Most detrimental during the canopy closure stage
- Additional coarse woody debris removal
 - Potential to affect long-term soil productivity through nutrient losses
- Annual vegetation control improved microclimate especially on the low productivity stand (Matlock)
 - + Greater soil moisture and less competition from understory
 - + Improved stand volume
 - Losses of nutrients due to greater leaching

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Fall River Volume Growth

- BOAVC with till and compaction has significantly greater stand volume than WT+, WT, and BOIVC treatments
 - BOAVC significantly greater than WT and BOIVC
- However, stand volume growth is greater in BOIVC treatment compared to starting relative density

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Current Fall River DBH Growth

- 10-15 year DBH growth is negatively correlated with relative density
 - Similar, but weaker relationship in 15-20 year DBH growth
- BOIVC treatment was growing the fastest in DBH the last 10 years
 - 12% greater than BOAVC treatment

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• 15% greater than WT+AVC treatment



40

0.5

0.0

30



BOAVC BOIVC

WT+AVC

10-15 yr; R²=0.54

15-20 yr; R²=0.30

WTAVC

60

50

Relative Density (10 or 15)

Questions?

- Thanks:
 - NCASI
 - Stand Management Cooperative
 - Green Diamond
 - Port Blakely
 - Weyerhaeuser





