LONG-TERM SOIL PRODUCTIVITY

Authors	ORGANIZATION
Scott Holub	Weyerhaeuser
Greg Johnson	Weyerhaeuser
Nathan Meehan	Weyerhaeuser
Rod Meade	Weyerhaeuser

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS

LTSP Long-Term Soil Productivity.

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Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

EXECUTIVE SUMMARY

The Sustainable Feedstock Production Systems team, through our work at the NARA LTSP, has made significant headway toward our goal of providing needed information on the sustainability of residual biomass removal on the forested landscape. The second growing season for planted trees was completed and tree measurements collected. The trees on the plots that would be considered the least impacted are growing significantly less than trees on the other treatments. Our soil moisture and temperature data monitoring continues and is providing important clues to why this might be. The least impacted plots have cooler soil temperatures, so it appears that temperature effects are overriding other potential effects of nutrient removal. Our university collaborators have continued work on their projects using the study site to examine carbon and nutrient cycling mechanisms (Hatten, OSU), nutrient leaching (Harrison, UW), wildlife/pollinator abundance (Rivers, OSU) and water effects (Barber, U. Utah).

INTRODUCTION

The importance of ensuring environmental sustainability and carbon benefits of biofuel production cannot be understated. The sustainability of forest residual biomass harvesting is a potential concern in regions where this primarily branch and needle material is removed to provide a source of renewable energy. Concern arises from the removal of nutrients and carbon present in residual biomass, as well as from heavy equipment trafficking used to collect the material, both of which have potential to detriment forest productivity, water quality, and wildlife habitat.

The long-term goal of this research is to contribute to our understanding of the amount of residual woody Douglas fir biomass that can be removed during timber harvest without detrimental effects on soil sustainability, water quality, and wildlife. Moreover, understanding the effects of woody biomass removals and any associated soil compaction is necessary to demonstrate the sustainability (in a productivity and environmental sense) of harvesting woody biomass forest residuals as a source of biomass for bioenergy feedstock. We address this issue by installing a new Long-Term Soil Productivity (LTSP) site in the southern Willamette Valley of Oregon on Weyerhaeuser ownership, the "NARA LTSP", to round out our existing regional studies (Figure LTSP-Intro.1).

Our design aims to examine a range of above-ground biomass removal treatments in combination with compaction, and fertilization. The new installation leverages over ten years of intensive investigation of the effects on productivity and soil properties in the Northwest. We propose to quantify typical LTSP objectives such as forest productivity, soil nutrient and carbon pools and fluxes, and soil compaction. This study is unique in that, through our collaborations, we also plan to investigate wildlife and water quality effects following biomass removal and compaction treatments to round out environmental sustainability objectives on site. Our university collaborators have continued work on their projects using the study site to examine carbon and nutrient cycling mechanisms (Hatten, OSU), nutrient leaching (Harrison, UW), wildlife/pollinator abundance (Rivers, OSU) and water effects (Barber, U. Utah).

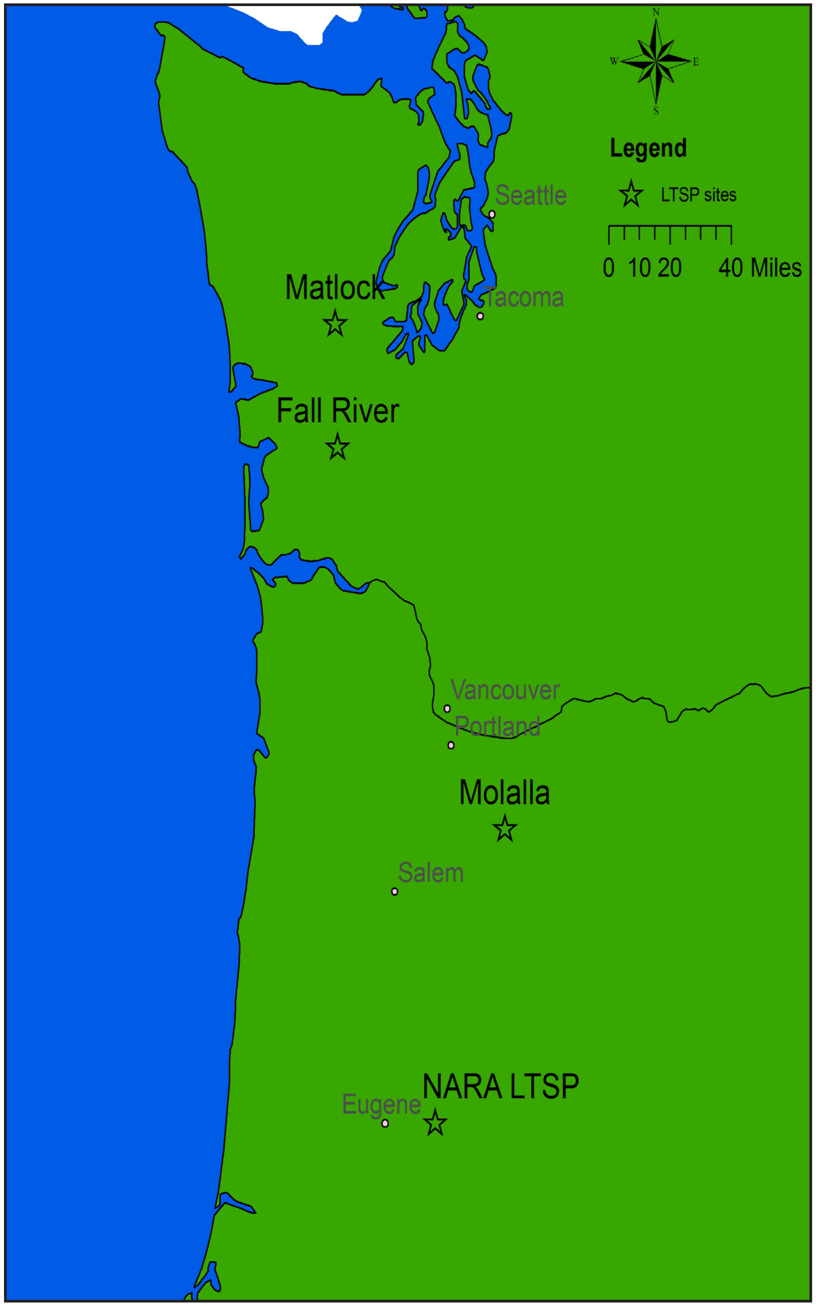

Figure LTSP-Intro.1. Map of the coastal Douglas-fir LTSP study sites in Oregon and Washington.

TASK 1. PRE-TREATMENT SITE SELECTION AND ASSESSMENT

Objective

The objective was to identify an appropriate forested site and determine suitability and pre-harvest conditions to determine underlying productivity on a plot level basis (Site Index and Soils) in order to determine the need for blocking to ensure that the treatments are applied across the range of conditions.

Methodology

A harvest unit was selected east of Springfield, OR and south of the Mackenzie River on Weyerhaeuser ownership on the Booth Kelly 400 Rd. (Sec 1 18S 01W). In addition to a current aerial photo, LiDAR DEM was available for this site as well as historical photos showing former skid roads and other features, which aides in determining appropriate plot locations.

Thirty 1-acre square treatment plots were laid out in preparation for initial plot characterization (where only 28 plots were needed to allow 2 plots to be dropped as outliers). Plots were laid out such that any plot could feasibly receive any treatment randomly assigned to it. All plots were laid in on a 9° azimuth to match site topography and simplify plot installation.

All pre-harvest data was collected. Extra plots were dropped. Statistical blocks were determined (using total soil nitrogen with spatial consideration) and treatments were randomly assigned across each block. (Figure LTSP-1.1.)

Results

Over 150 physical, chemical, and biological parameters were recorded for be-low-ground plot information. Average soil carbon to 1 m depth across the plots is 224 Mg ha^{-1}. Soil Nitrogen is 11,250 kg ha^{-1}. Rock volume is 1.5%. Clay in the surface 15cm is 30% and 47% to 1-m depth.

Above-ground, over 40 parameters were recorded on the plots. Highlights include 156 Douglas-fir stems and 4 other species' stems per ha; quadratic mean diameter of the Douglas-fir was 16.5 inches; tree volume in Douglas-fir was 104 cunits ac^{-1}; and tree biomass was 332 Mg ha^{-1}.

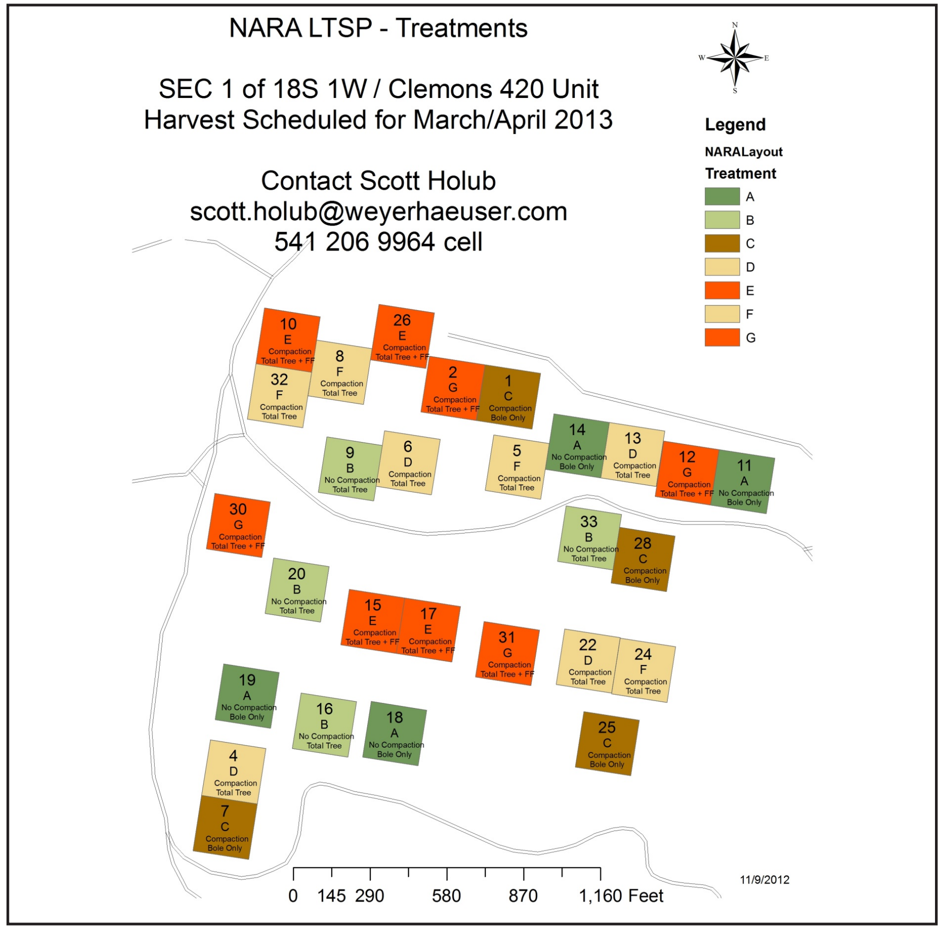

Figure LTSP-1.1. Varied treatments assigned to the NARA LTSP site. Treatment descriptions are provided in *Task 2: Implement treatments* in this report.

TASK 2. IMPLEMENT TREATMENTS

Objective

The objective was to establish a range of biomass retention conditions to assess the potential effects of biomass harvesting.

Methodology

Sections A through I describe specific treatments given to individual plots identified in Figure LTSP-2.1.

A. Bole Only, No Compaction (OM0 C0) – Bole only harvest to a saw log top (5" top) – all limbs and tops remain on the plot. No ground trafficking.– *This treatment is an LTSP baseline treatment and is required for "LTSP" status* (4 plots: 11,14,18,19).

a. Phase 2 a Cutting Method: Hand cut trees / fall IN plot area.
b. Phase 2 b Limbing/Bucking Method: Hand limbed and topped on plot.
c. Phase 3 Yarding Method: Reachable material should be done with a shovel provided it does not traffic adjacent plots. Trees outside of direct shovel reach will be pulled out using a choker held by the shovel. Some dragging ok (see phase 4).
d. Phase 4 (a) Organic Matter Manipulation: Minimal redistribution of material should be needed, if any.
e. Phase 4 (b) Compaction Method: NONE.

B. Total Tree, No Compaction (OM1 C0) – Whole-tree type harvest where 95+% of limb/top material is removed along with the bole. No ground trafficking (4 plots: 9,16,20,33).

a. Phase 2 (a) Cutting Method: Hand cut trees / fall OFF plot.
b. Phase 2 (b) Limbing/Bucking Method: Operational limbing and bucking off plot.
c. Phase 3 Yarding Method: Reachable material should be done with a shovel provided it does not traffic adjacent plots. Trees outside of direct shovel reach will be pulled out using a choker held by the shovel. Some dragging ok (see phase 4). Legacy wood remains.
d. Phase 4 (a) Organic Matter Manipulation: Branches broken during felling may remain up to 5% of total initial. Some edge material could be removed with shovel or excavator. Redistribute by hand, if needed.
e. Phase 4 (b) Compaction Method: NONE.

C. Bole Only, Modest Compaction (OM0 C1) – Bole only harvest to a saw log (5") top – all limbs and tops remain. *Fixed traffic lanes for harvest, slash/OM removal/ dispersal*. (4 plots: 1,7,25,28)

a. Phase 2 (a) Cutting Method: Hand cut trees / fall IN plot area
b. Phase 2 (b) Limbing/Bucking Method: Hand limbed and topped on plot.
c. Phase 3 Yarding Method: Shovel yarded primarily from outside of the treatment plot. Also use 3 parallel pre-defined tracks (34.8 ft from plot edge and 69.5 feet between on center) to remove logs. These passes are mandatory, if needed to remove logs or not, to ensure all compaction plots are treated the same. With slash in place.
d. Phase 4 a/b: Organic matter manipulation /Compaction Method:
    i. Using 6 traffic lanes equally spaced across the plot, windrow slash and intact legacy material on the plot parallel to planned compaction lanes to allow for compaction.
    ii. Compact cleared areas using enough excavator passes (track-to-track where possible) to cover the whole cleared compactable area (excluding stumps and impassible areas) with at least one pass under-track. Tracks need not be parallel, but work systematically across the plot to ensure even coverage.
    iii. Redistribute windrowed material across plot while compacting soil under the wind rowed areas (as above).

D/F. Total Tree, Modest Compaction (OM1 C1) – Whole-tree type harvest where 95+% of limb/top material is removed along with the bole. Remaining material will be dispersed and equal across like plots. *Fixed traffic lanes for harvest, slash/OM removal/dispersal* (8 total plots: 4,5,6,8,13,22,24,32).

a. Phase 2 (a) Cutting Method: Hand cut trees / fall OFF plot area as feasible.
b. Phase 2 (b) Limbing/Bucking Method: Off plot limbing and topping.
c. Phase 3 Yarding Method: Shovel yarded primarily from outside of the treatment plot. Also use 3 parallel pre-defined tracks (34.8 ft from plot edge and 69.5 feet between on center) to remove logs. These passes are mandatory, if needed to remove logs or not, to ensure all compaction plots are treated the same. Any slash or legacy wood remains in place.
d. Phase 4 (a) Organic Matter Manipulation: Remove branches and new organic matter with the excavator down to a level achievable in treatment B (where the line shovel was used). Branches broken during felling may remain <25% of total initial or target biomass left in Treatment A/C. Redistribute remaining material with the excavator and by hand if needed.
e. Phase 4 (b) Compaction Method:
    i. Compact 6 traffic lanes equally spaced across the plot, as in Treatment C to equalize compaction among compacted treatments. Very little slash should be present.
    ii. Compact entire plot using enough excavator passes (track-to-track where possible) to cover the whole compactable area (excluding stumps and impassible areas) with at least one pass under-track. Tracks need not be parallel, but work systematically across the plot

to ensure even coverage.

E/G. Total Tree + Forest Floor, Modest Compaction (OM2 C1) – Whole-tree type harvest where 95+% of limb/top material is removed along with the boles. Legacy woody debris also removed. 75-90% of Forest floor material removed. Old and new stumps remain. Any remaining material will be dispersed. Compaction on this treatment will be the baseline for all compaction treatments. *Fixed traffic lanes for harvest, slash/OM removal/dispersal* (8 total plots: 2,10,12,15,17,26,30,31).

a. Phase 2 (a) Cutting Method: Hand cut trees / fall OFF plot area as feasible.
b. Phase 2 (b) Limbing/Bucking Method: Off plot limbing and topping.
c. Phase 3 Yarding Method: Shovel yarded primarily from outside of the treatment plot. Also use 3 parallel pre-defined tracks (34.8 ft from plot edge and 69.5 feet between on center) to remove logs. These passes are mandatory, if needed to remove logs or not, to ensure all compaction plots are treated the same. Any slash remains in place during the passes, but large legacy wood may also be removed at this stage, especially if in traffic lanes.
d. Phase 4 (a) Organic Matter Manipulation: Remove 95+% of all slash, legacy woody material, and forest floor using 6 equally spaced traffic lanes and from the outside of the plot using an excavator. Old and new standing stumps remain.
e. Phase 4 (b) Compaction Method: Compact entire plot using enough excavator passes (track-to-track where possible) to cover the whole compactable area (excluding stumps and impassible areas) with at least one pass under-track. Tracks need not be parallel, but work systematically across the plot to ensure even coverage.

Ameliorative – These treatments are designed to assess if there were detrimental impacts and whether they can be ameliorated with the addition of nutrients as fertilizer.

H. Treatment D plus fertilization (OM1 C1 + Fertilization) – Same treatment as "D" plus fertilization with urea (200 lbs N/ ac) at mid rotation.

I. Treatment E plus fertilization (OM2 C1 + Fertilization) – Same treatment as "E" plus fertilization with urea (200 lbs N/ ac) at mid rotation.

Results

Treatments assigned to varied plots were conducted (Figure LTSP- 2.1) and post treatment soil compaction measurements were compiled (Figure LTSP-2.3).

Conclusions/Discussion

The treatments were successfully implemented, and the project is well positioned to assess the effects of these treatments.

Figure LTSP-2.1. NARA LTSP aerial photo September 2013.

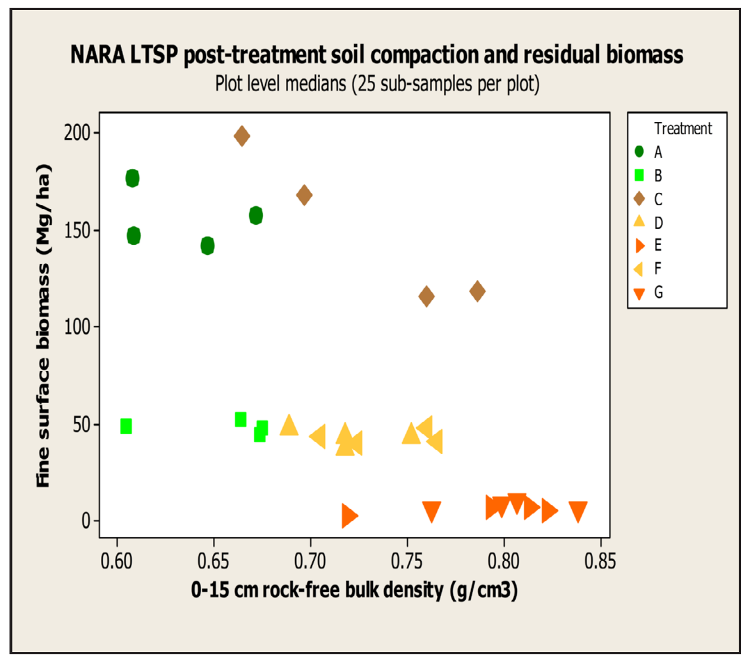

Figure LTSP-2.2. Post-treatment assessment of compaction and remaining biomass – NARA LTSP.

TASK 3. ON-GOING PLOT MAINTENANCE

Objective

The objective was to maintain the research site and collect necessary site data.

Methodology

Vegetation management (post harvest)– 2013.Q3 and 2014.Q1

In addition to the pre-harvest salal (Gaultheria shallon) control, weed control consisted of a site-wide post-harvest fall-site-prep spray (without Imazapir) at the latest possible operational date to allow competing vegetation that survived the pre-harvest treatment to be fully expressed and maximally controlled. After planting, a site-wide operational spring release spray was applied and a late spring operational application of Transline was also applied to reduce competition. Spot checks of vegetation cover and species composition was performed as warranted to determine the need for additional backpack spraying through the year.

We recognized that the forest floor removal treatments are likely to have higher weed invasion because of the exposed mineral soil, so managing this treatment was key. Efforts were made to keep competing vegetation at a similar % cover and species across all treatments and plots. Complete Vegetation Control (CVC) of herbaceous weeds was NOT the goal, but 10-20% cover was a target through the second year. After that, the goal was to allow the orderly reinvasion of a competing vegetation community equal across all treatments.

Hardwood, conifer in-growth, and Scotch broom was removed by either hand or by mechanical means or with spray as needed at least once per year.

Quantitative vegetation assessments, by life form, were recorded in July-August using standard 1 square meter plots – multiple (9 or 16) per plot, after any mid-summer directed spraying, if prescribed, had taken full effect.

Results

Fence maintenance and weather station maintenance were conducted. Some road repairs and improvements were completed within the budget.

Conclusions/Discussion

Study site maintenance is ongoing and site preparation has occurred as scheduled.

TASK 4: POST TREATMENT YEAR-2 ASSESSMENT

Objective

The objective for this task was to measure the short term effects of the organic matter manipulations on tree growth.

Methodology

Douglas-fir seedlings were measured using standard methods for height and caliper.

Tree measurement –2014.Q2&Q4, 2015Q4, 2016Q4, etc.

Aluminum trees tags were hung in measurement-plot trees after planting during the first measurement. In each plot, tree numbers started in the NW corner and proceeded in a serpentine pattern along the east/west rows. Every measurement-tree on the site had an individual unique number (0001 to 4900).

Measurement-plot trees were measured at planting (15cm caliper, height, status, damage, vigor, etc. (and microsite condition at planting only)) and annually using standard protocol. Measurements will continue through Year-5 and then every 2 to 5 years through the rotation (as funding allows) to determine if any differences in growth can be attributed to the treatments. NARA grant funding expired after the second growing season.

Results

Two growing-seasons into the study, preliminary results indicated that where biomass was removed, and even in the severe, non-economically feasible removals, planted tree growth was improved (Figure LTSP-3.1). The soil monitoring equipment was useful to understand why this happened, in that we saw that the treatments with more exposed soil were warmer, and this probably led to increased growth.

Conclusions/Discussion

Thus far our results show no cause for concern about the removal of biomass, but future results may differ as the stand captures the site and could perhaps become more nutrient limited.

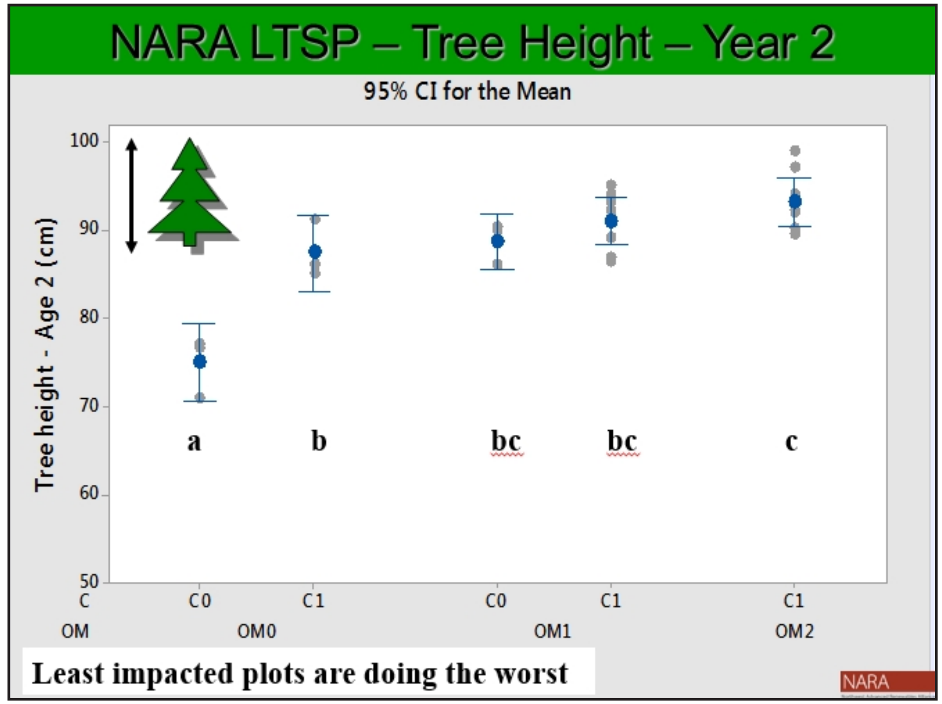

Figure LTSP-3.1. Tree height by organic matter (OM) removal level (0 – bole only removal, 1- total tree removal, 2 – full forest floor removal) and compaction (C) level (0 – no compaction, 1 – moderate compaction).

NARA OUTPUTS

Refereed Publications

Christiana A. Dietzen, Eduardo R.G. Marquez, Jason N. James, Rodolpho H.A. Bernardi, Scott M. Holub, Robert B. Harrison. (2016). Response of Deep Soil Carbon Pools to Forest Management Treatments in a Highly Productive Andisol (in Review at Global Change Biology).

Conference Proceedings and Abstracts from Professional Meetings

Holub, S.M., T.B. Harrington, J.M. Kranabetter, D.S. Page-Dumroese. (2016.) Organic matter removal and soil compaction effects in forests across the Pacific North west. Northwest Forest Soils Council / Society for Ecological Restoration meet ing. Portland, Oregon, April 4-7, 2016

Holub, S., N. Meehan, R. Meade, G. Johnson, J. Hatten, A. Gallo. (2015). NARA Long-term Soil Productivity (LTSP) Project – 2015 Update. Poster Presentation at NARA annual meeting, Spokane, WA. September 15-17, 2015.

Littke, K. R. Harrison, S. Holub, J. Hatten. (2016.) Evaluation of soil for sustained productivity of biofuel feedstock from coastal Douglas-fir plantations. Oral presentation at 2nd Northwest Wood-Based Biofuels + Co-Products Conference, Seattle, WA, May 3-4, 2016.

Root, A.M., R.B. Harrison, S.M. Holub. (2016.) The Effects of Biomass Removal and Competing Vegetation Control on Douglas-fir Foliar Nutrition in the Pacific Northwest, USA. Poster presentation at 2nd Northwest Wood-Based Biofuels + Co-Products Conference, Seattle, WA, May 3-4, 2016.

Dietzen, C., E. Marques, J. James, R. Bernardi, S.M. Holub, R. Harrison. (2015). Response of Deep Soil Carbon Pools to Forest Management Treatments in a Highly Productive Andisol. Oral presentation at Soil Science Society of America annual meeting, Minneapolis, MN, November 15-18, 2015.

Harrington, T.B., R.A. Slesak, S.M. Holub, S.H. Schoenholtz, D.H. Peter. (2015). Organic Matter Retention after Harvesting Coast Douglas-fir: Altered Micro climate, Vegetation Structure, and Soil Nutrient Pools Interact to Regulate Forest Productivity. Oral presentation at Soil Science Society of America annual meeting, Minneapolis, MN, November 15-18, 2015. *Forest, Range, and Wildland Division 2015 Best Paper Award.*

Hatten, J.A., A.C. Gallo and S.M. Holub. (2015). Soil Organic Matter Dynamics in an Intensively Managed Douglas-fir Forest. Poster presentation at Soil Science Society of America annual meeting, Minneapolis, MN, November 15-18, 2015.

Hatten, J., J. Dewey, A. Gallo, S. Holub, J. Mack, S. Roberts, E. Sucre. (2015). Assessing Long Term Soil Productivity in Intensively Managed Loblolly Pine and Douglas-Fir Forests. Oral Presentation Society of American Foresters National Convention. Baton Rouge, LA. November 4, 2015.

Scott, A. M.B Adams, S. Berch, M. Busse, R. Fleming, R. Harrison, S. Holub, J. Kabrick, M. Kranabetter, D. Morris, D. Page-Dumroese, B. Palik, J. Zhang. (2015). Organic Matter Removal from Forest Soils: Lessons from the Long-Term Soil Productivity Study. Oral Presentation Oral presentation at Soil Science Society of America annual meeting, Minneapolis, MN, November 15-18, 2015.

Scott, A. M.B Adams, S. Berch, M. Busse, R. Fleming, R. Harrison, S. Holub, J. Kabrick, M. Kranabetter, D. Morris, D. Page-Dumroese, B. Palik, J. Zhang. (2015). Sustaining Site Productivity: Lessons from 25 yrs of the Long-Term Soil Productivity Experiment. Oral Presentation Society of American Foresters National Convention. Baton Rouge, LA. November 4, 2015.

Hatten, J.A., J Sessions, K. Boston, R. Zamora-Cristales, G. Latta, D. Mainwaring, D. Maguire, R. Harrison, S. Holub, A. Gallo, J. Petrie, M. Barber, M. Hasan, B. Van Grouw, R. Wickam, K. Madsen, J. Rivers, H. Root, M. Betts, B. Lamb, and V. Ravi. (2015). NARA's Approach to Environmental Sustainability. NARA 2015 Annual Meeting. September 15-17. Spokane, WA

Videos and Webinars

Hatten, J., S. Holub (co-presenters) (2015). Long-term soil productivity and sustainability of forest harvest residue harvesting. NARA Wood-to-Biofuels Webinar Series. October 13, 2015. Invited speakers.

Physical:

- Harvest completed on the 83-acre site and applied biomass removal and compaction treatments to 28 1-acre plots.
- Post-treatment soil and biomass effects measured and recorded from 25 locations per plot (Figure LTSP-2.2).
- Weather stations and plot level soil moisture and temperature monitoring equipment were installed; data shared with collaborators.
- Fencing installed in November 2013 to keep deer and elk away from the young seedlings.
- 30,000 seedlings were planted across the site in March 2014, 5000 of which will serve as our primary indicator of productivity sustainability for the various treatments.
- Environmental monitoring data collected.

FUTURE DEVELOPMENT

Weyerhaeuser will continue to host the research site with the goal of determining the long-term effects of the biomass removal treatments.