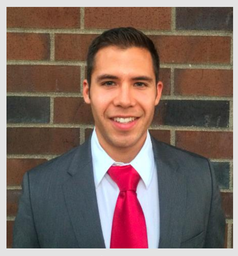
Root carbon contributions are uniform across intensive biomass removal treatments in a western Oregon Douglas-fir forest

Adrian Gallo[1], Jeff Hatten[1], and Scott Holub[2]

[1] Oregon State University, Corvallis, OR, USA

[2] Weyerhaeuser Company, Springfield, OR, USA



Oregon State University | College of Forestry

Introduction

Can intensive forest management remain productive while also harvesting residual biomass for fuels conversion? Forest management directly influences the amount of biomass left on site through harvest practices and soil porosity by heavy machine traffic (Powers 2005 & 2006). The objective of this study is to examine the role of the O-horizon (including forest harvest residuals i.e. slash) in regulating soil physical and biologic processes for Long-term Soil Productivity (LTSP).

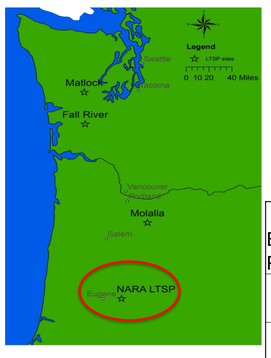
Q1: What is the role of the O-horizon & compaction in moderating soil moisture and soil temperature in the soil profile?
H1: The O-horizon, and residual slash, act as a barrier from solar energy and can limit the amount of water that infiltrates the profile. Due to direct solar radiation and precipitation inputs, treatments with less residual organic matter will be warmer and have higher total moisture content throughout the profile. Soil compaction increases bulk density and decreases total soil porosity. As a result of limited pore space, we expect compacted treatments to have higher soil moisture in the soil profile.

Q2: What is the role of soil temperature & soil moisture in regulating microbial activity in these forest soils?
H2: We posit the treatments that are warmer and have more moisture will have higher heterotrophic respiration in the growing season, also that maximum temperatures will be important drivers of these processes.

Q3: What is the role of biomass inputs to the source of OM in mineral soil?
H3: Root-C is in direct connection to the mineral soil and likely to remain part of Soil Organic Matter (SOM) pool. We expect this relationship to remain strong even with a high quantity of residual forest slash left on site.

SUMMARY
Direct solar radiation on the soil surface will increase soil temperature throughout the profile; this effect will be greater as biomass removal increases. This may promote a favorable environment for microbial activity leading to increased soil respiration & thus mineralization. Although there is a wide range of aboveground biomass left on site, root-derived C will be the main source of SOM due to physical proximity. Using Cupric-Oxidation (CuO) method we can distinguish between above vs. belowground sources of SOM to determine how SOM behaves following intensive biomass removals.

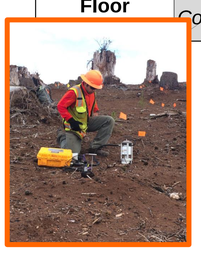
Materials & Methods



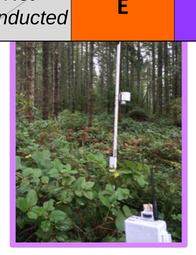
2012 Sites identified and pre-harvest measurements taken (~36.5m Site Index @50yrs).
2013 Treatments applied (2x3 RCB factorial design), 4 reps/treatment, 1-acre treatment plots.
2014 Seedlings planted with initial tree measurements. Decagon data collection begins (hourly), LiCOR soil respiration begins (monthly)
2015 Second year tree measurements, continuing soil observations.
Soil Sensors @10, 20, 30, 100cm (Decagon)
Soil Respiration @surface (IRGA-LiCOR 8100A)

BIOMASS REMOVALS	No Compaction	Compaction	
Bole Only Harvest	A	C	UNTREATED FOREST
Total Tree Harvest	B	D	
TT + Forest Floor	*Not Conducted*	E	

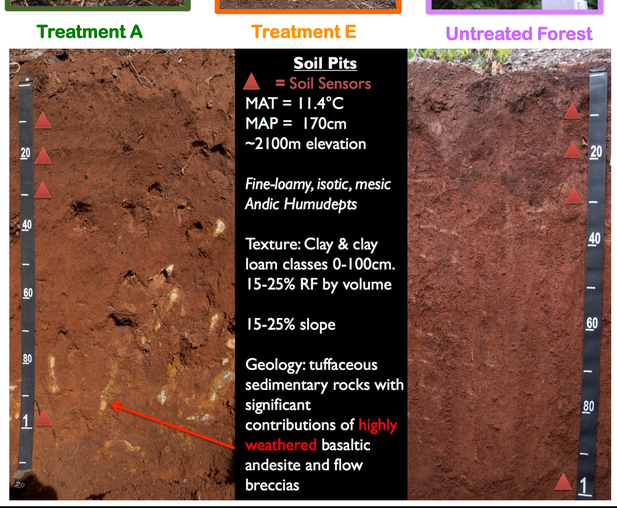
Treatment A



Treatment E

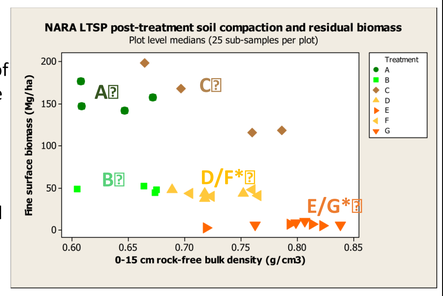


Untreated Forest



Results & Discussion

Figure 1
Treatments were very well separated by the quantity of biomass left on site and the bulk density indicating treatments should have substantially different chemical and biological processes occurring. F* and G* treatments will have fertilizer applied mid rotation.



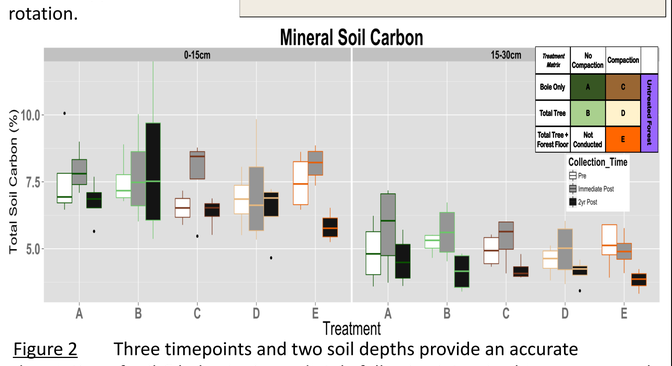


Figure 2 Three timepoints and two soil depths provide an accurate description of soil-C behavior immediately following intensive biomass removal and compaction treatments. 25 sample points/plot were composited, 4 replicates/treatment. Each box is an average of the 4 reps.

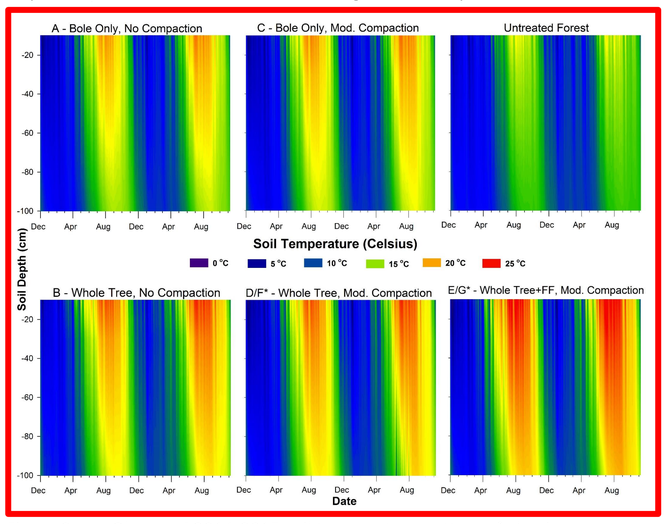


Figure 3 Observed 2014-2015 soil temperature patterns following treatments. Soil probes installed at 10, 20, 30, & 100cm mineral depth recorded hourly but represented on daily time steps. A linear average is used to interpolate between all probes. Growing season (May-Oct) average daily and maximum soil temperature (0-10cm) increased 2.7°C & 5.5 °C respectively due to Forest Floor removal compared to Bole Only Harvest, we also observed a **2.0°C increase in growing season average daily temperature at 100cm depth.**

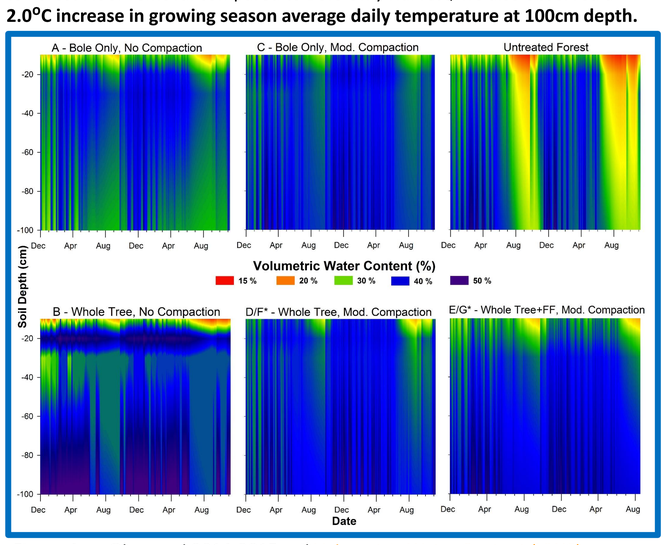
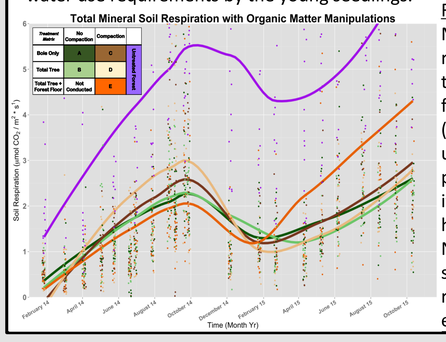


Figure 4 Observed 2014-2015 soil Volumetric Water Content (VWC) patterns following treatments. The estimated Permanent Wilting Point (PWP) for clay loam textures is approximately 18% VWC based on VWC-matric potential relationship curves (Saxton & Rawls, 2006). No statistically significant treatment effects were found likely due to high rainfall (~170cm MAP) & low water use requirements by the young seedlings.

Figure 5
Monthly heterotrophic soil respiration observations over two years immediately following treatments (3reps/plot). Due to the thick understory & mature trees present in Untreated Forest, it experienced consistently higher rates of CO_2 efflux. No other statistically significant differences in soil respiration were encountered.



Results & Discussion

The Cupric-Oxidation (CuO) method provides estimates of plant and microbial degradation products allowing us to trace the degree of decomposition and sources of lignin as well as some non-lignin sources like cutin & suberin (Goni & Montgomery 2000). All points are an average of four replicates within treatment, axis are normalized to (V) Vanillin. (3,5-Bd) dihydroxybenzoicacid; (P) para-hydroxyl phenols; (C) Cinnamyl phenols; (S) Syringyl phenols.

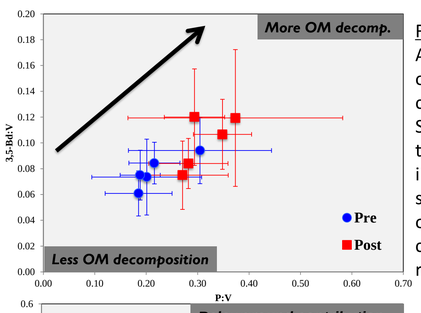


Figure 6 (*0-15cm soil depth*)
All treatments, independent of biomass removals or compaction, showed a shift in SOM that is more degraded two years following treatment implementation. The data show an overall increase in organic matter decomposition consistent with soil respiration data.

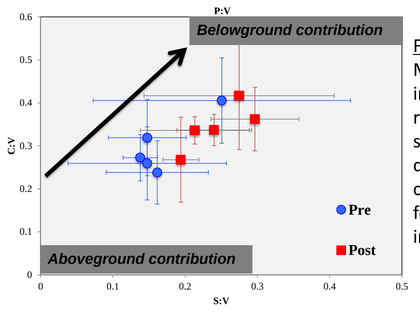


Figure 7 (*0-15cm soil depth*)
Most treatments, independent of biomass removals or compaction, showed a shift in SOM that is derived from a belowground components (roots) two years following treatment implementation.

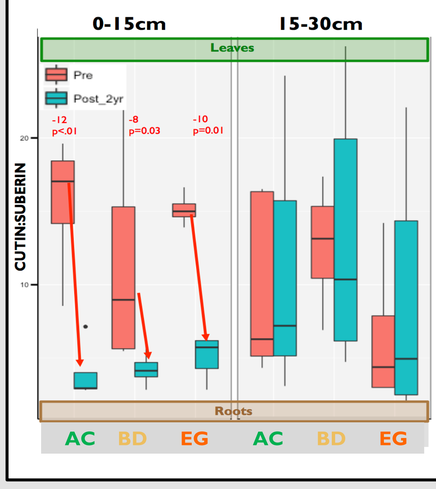


Figure 8 (*0-15 & 15-30cm*)
All three categories of biomass removal show consistent shifts in SOM derived from roots (suberin). The shift to a belowground carbon component is consistent for Bole Only removals (~150 Mg-C/ha surface biomass) and Whole Tree + Forest Floor removals (<10Mg-C/ha surface biomass). This response is most pronounced in surface soils and has yet to develop in the subsurface soils although these are two year responses.

Conclusions

Pulse changes in organic matter content and soil porosity due to forest management can have impacts on long-term forest productivity. Organic matter removals had substantially measurable impacts on soil temperature, moisture, and soil respiration compared with the Unharvested Forest Reference stand.

Daily average, and maximum, soil temperatures during the growing season increased as biomass removals increased. Maximum 0-30cm soil temperatures increased 3.7-5.5 ° C on Forest Floor Removal treatments compared to Bole Only harvests. Soil temperatures of Forest Floor Removal treatments reached the optimal window for nitrification rates which may contribute to an apparent resilience in tree growth early in this stands succession; fertilization applications commonly used in intensively managed forests should consider this potential nutrient cycling pathway in their nutrient management strategies.

The observed characteristics in **soil temperature** and **soil moisture** could not accurately explain the magnitudes of soil respiration over two years. Overall, these data suggest the large impact of harvest as a disturbance mechanism likely outweigh the incremental treatment differences especially in **soil moisture** and soil respiration. However the temperature changes on all treatments appear to shift decomposition towards readily available root-derived C rather than aboveground-C inputs from leaching of forest residuals or the O-horizon. The SOM 2-years after treatment show **significant shifts to being more decomposed and resembling more root-derived-C across all treatments**. More time is required to better understand whether these changes in SOM cycling immediately after treatments will become apparent in tree growth especially as canopy closure occurs when there is the greatest stress on soil resources.

Further information

@Gallo_Rocks

This research is being prepared for submission in late 2018. The poster template courtesy of Colin Purrington. You may access Adrian's Gallo's Dept. Website, M.Sci thesis, & OSU Forest Soils Lab

Literature cited

Goni & Montgomery. 2000. Alkaline CuO oxidation with a microwave digestion system: Lignin analysis of geochemical samples. Analytical Chemistry. 72:3116-3121.

Hedges and Mann. 1979. The characterization of plant tissues by their lignin oxidation products. Geochemica et Cosmochimica. 43(2):1803-1807.

Lavender & Hermann. 2014. *Douglas-fir: The Genus Pseudotsuga*. The Forestry Communications Group. Corvallis, OR USA. 378pgs. http://hdl.handle.net/1957/47168

Powers et al. 2005. North American long-term soil productivity experiment: Findings from the first decade of research. Forest Ecology & Management. 220(3):31-50.

Powers, R. 2006. Long-term soil productivity: genesis of the concept and principles behind the program. Canadian Journal of Forest Research. 36:519-528.

Saxton & Rawls. 2006. Soil water characteristics estimates by texture and organic matter for hydrologic solutions. Soil Science of America Journal. 70:1569-1578.

Acknowledgments & Partnerships

Yvan Alleau contributed significantly to the lab components as well as Franco Guerrero-Bolano, Brett Morrissette & Kylie Meyer. Kate Lajtha and Kevin Maguire were M.Sci. committee members. USDA Grant # 2011-68005-30416

Oregon State University College of Forestry | Weyerhaeuser | NARA Northwest Advanced Renewables Alliance