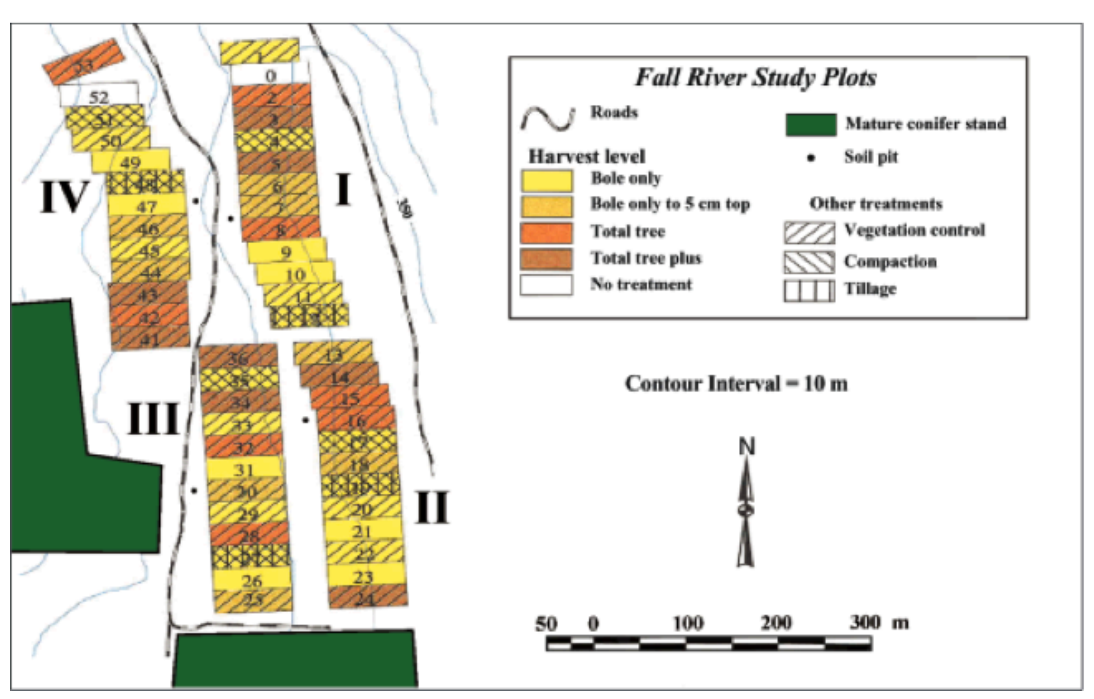
Response of deep soil carbon pools to forest management treatments in a highly productive Andisol

Christiana Dietzen, Eduardo-Marques, Jason James, Rodolpho Bernardi, Scott Holub, & Rob Harrison
University of Washington, Seattle WA 98195-2100; cdietzen@uw.edu

Abstract

Soil contains more carbon than the atmosphere and plant biomass combined. Consequently, it is the most important long-term sink for carbon within terrestrial ecosystems. An understanding of the potential to induce carbon sequestration in soils through management is crucial in light of increasing anthropogenic CO_2 emissions. Additionally, deep soils are important to growth of forests, as the maximum depth of Douglas-fir rooting is often ~3 m. This deep rooting provides biogeochemical interactions with deep soil through uptake, root exudates, and turnover. Nevertheless, soil has historically been under-represented in carbon cycling research, especially in regards to subsurface (>30 cm) layers and processes. Research on the effects of forest management practices on deep soil carbon has been particularly lacking. In order to study the effects of various biomass removal and vegetation control treatments on deep soil carbon, soil samples were obtained from the Fall River Long-term Soil Productivity Site in western Washington. These samples were obtained from 8 depth intervals, reaching a maximum depth of 3 meters. Soils at this site are Andisols of the Boistfort series. Treatments were installed 15 years previously in a randomized complete block design with four replicates. Results indicate that there is no statistically significant difference in total soil carbon between treatments, but that there is a significant difference in soil carbon concentration and content at the deepest level measured (250-300 cm). These results suggest the stability of soil carbon pools at Fall River and indicate that more intensive management practices may not deplete carbon pools at this site, but imply that deep soil pools at this site may be more sensitive to change than shallow pools. 58.1% of the soil carbon pool is located below 30 cm, which suggests that previous research may be significantly underestimating soil carbon pools. This underestimation may influence current understanding of global carbon cycling and limit the accuracy of climate models. It also highlights the importance of quantifying deep soil carbon pools and understanding the processes that control them.



Research Site and Experimental Design

Fall River Long Term Soil Productivity Site:

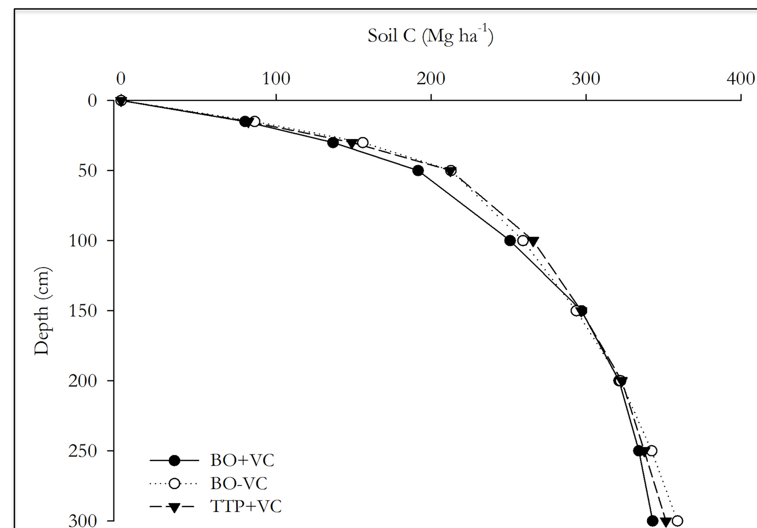
- Designed to study management impacts (including vegetation control and slash harvest for biofuel feedstock) on future growth
- This project assessed the affects of these treatments on deep soil carbon
- Understanding deep soils is particularly important at sites like Fall River, which has soils that are many meters deep.
- The soils at this site are Andisols of the Boistfort series, and are some of the most productive and carbon-rich soils in the Pacific Northwest. They developed on Miocene basalt and have been influenced by the deposition of volcanic ash, which is likely an important factor driving the carbon richness of these soils.
- Four replicates of 12 treatments are included in a complete, randomized block design
- This study focused on three of these treatments:

1. Commercial bole only removal with vegetation control by annual herbicide application (BO+VC) (an estimated 175 Mg C/ha and 432 kg N/ha removed by BO treatments)
2. Commercial bole only removal without vegetation control (BO-VC)
3. Total-tree plus removal with vegetation control (TTP+VC) (an estimated 244 Mg C/ha and 925 kg N/ha removed by TTP+ treatments)

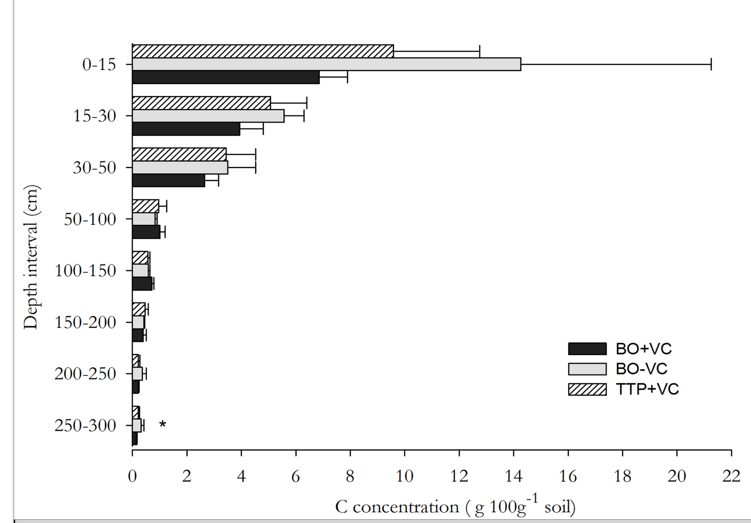
Methods

- Randomly selected one sampling location per treatment type in each block, for a total of 12 plots sampled.
- Bulk density samples were taken to a depth of 3 meters at 8 depth intervals using an AMS soil auger and split-core sampler
- Samples were analyzed for C and N content using PerkinElmer 2400 CHN analyzer
- Carbon and nitrogen content on an areal basis were determined by multiplying the bulk density by concentration and the height of the sample depth interval.
- A two-way ANOVA with block as a random factor (α=0.10) was used to compare carbon pools between treatments.

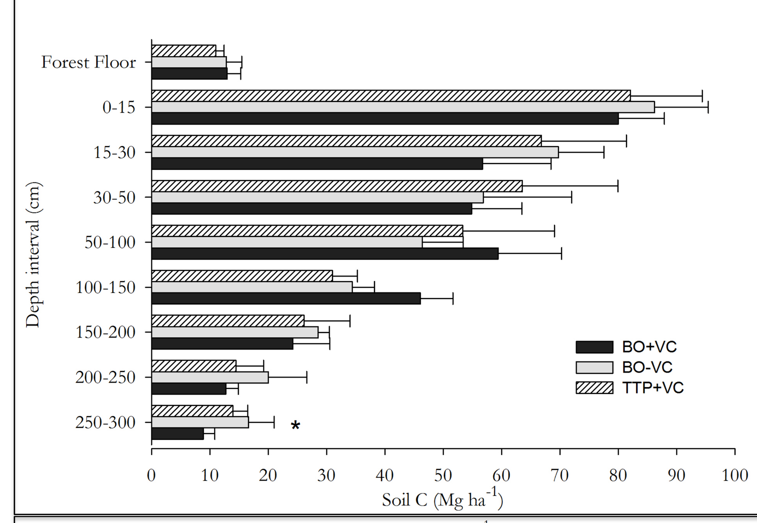
Results:



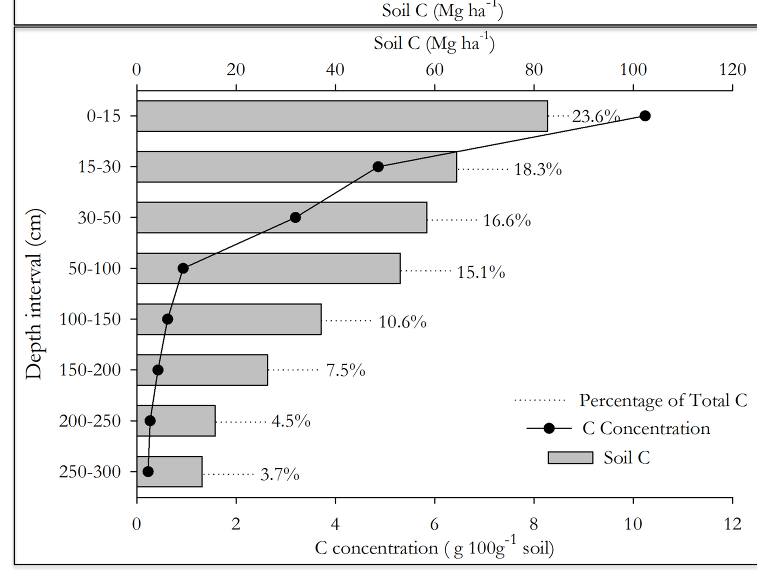
Cumulative soil carbon content by depth to 300 cm. Each point indicates the cumulative carbon content down to that depth interval. **No statistical difference between cumulative carbon contents was found at any depth interval measured (α=0.10).**



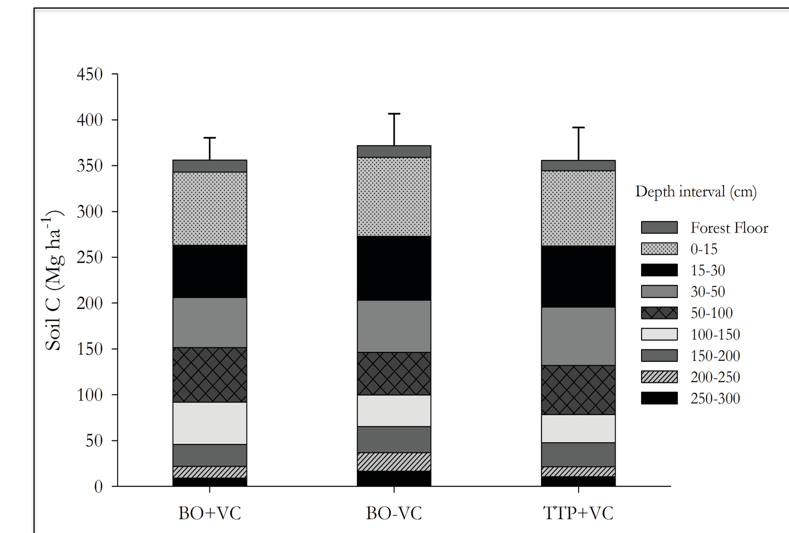
Mean soil carbon concentration by treatment at each depth interval. Error bars indicate standard error. Significant difference (p<0.10) between treatments is indicated by an asterisk (*). **A significant difference in carbon concentration between BO+VC and BO-VC was found at the deepest interval measured**.



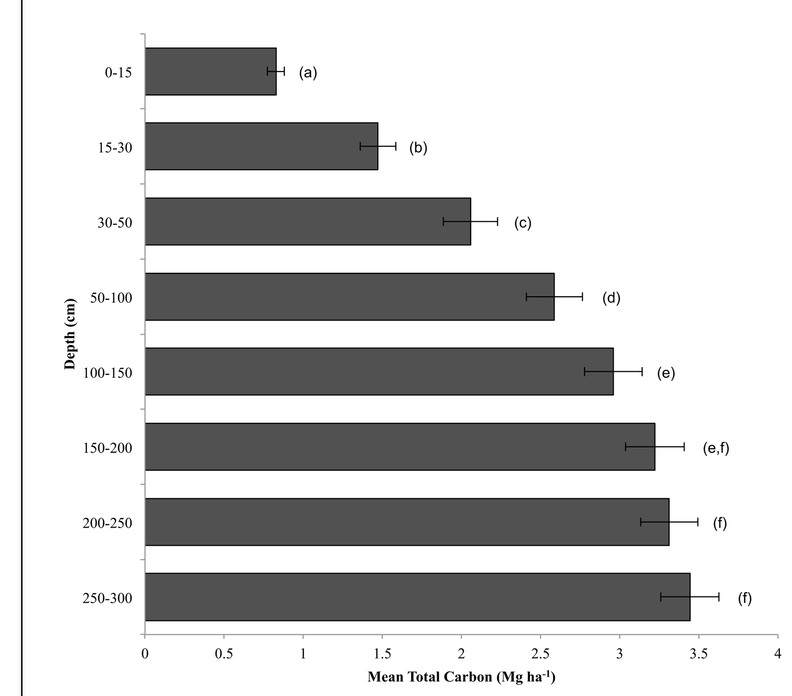
Mean soil carbon content by treatment at each depth interval. Error bars indicate standard error. Significant difference (p<0.10) between treatments is indicated by an asterisk (*). **A significant difference in carbon content between BO+VC and BO-VC was found at the deepest interval measured.**



Mean soil carbon content and carbon concentration across all measured soil profiles. **58% of the soil carbon pool was found to be located below 30 cm.**



Mean soil carbon (Mg ha^{-1}) by treatment within each sampled depth interval. Error bars indicate standard error of the total mean. **On average, more carbon was stored in the deepest interval measured (13.10 Mg C/ha) than in the forest floor (11.57 Mg C/ha), indicating that though concentrations may be low, the sheer volume of soil at depth results in a large pool of carbon, which is often overlooked.**



Mean total carbon at each depth interval. Error bars indicate standard error of the mean. Mean carbon is not significantly different between intervals followed by the same letter, as indicated by Tukey's Honestly Significant Difference (p< 0.10). **Multiple comparisons between sampling depths indicated that each sampling interval to a depth of 150 cm significantly increased the total measured carbon content of the profile. Further, sampling to 250 significantly increased the total carbon content of the profile over sampling to 150.**

Conclusions

- Results indicate stability of soil carbon pools at Fall River
- More intensive management practices may not deplete carbon pools at this site, though the deepest pools may be the most sensitive to change
- Trees at this site are just beginning to show difference in treatments- it is possible that difference in soil carbon may appear in the following years
- Analysis of the role of soil mineralogical properties at this site may provide insight into the drivers of sustained carbon retention at Fall River.
- This information may be crucial to understanding how similar soils across the Pacific Northwest may respond to intensive management practices.
- Previous research may be significantly underestimating soil carbon pools
- This underestimation may influence current understanding of both global and ecosystem carbon cycling and limit the accuracy of climate models
- The large amount of carbon stored at depth highlights the importance of quantifying deep soil carbon pools and understanding the processes that control them

References:

Ares, A., Terry, T. A., Piatek, K. B., Harrison, R. B., Miller, R. E., Flaming, B. L., … Kraft, J. M. (2007). *The Fall River Long-Term Site Productivity Study in Coastal Washington : Site Characteristics , Methods , and Biomass and Carbon and Nitrogen Stores Before and After Harvest. General Technical Report PNW-GTR-691*. Pacific Northwest Research Station.

Knight, E., Footen, P., Harrison, R., Terry, T., & Holub, S. (2014). Competing Vegetation Effects on Soil Carbon and Nitrogen in a Douglas-fir Plantation. *Soil Science Society of America Journal*, *78*, S146–S151.

Steinbrenner, E. C. (1979). Forest Soil Productivity Relationships. In P. Heilman, H. Anderson, & D. Barmgartner (Eds.), *Forest Soils of the Douglas-fir Region* (pp. 199–229). Pullman, WA: Extension Service, Washington State University.

Strahm, B. D., & Harrison, R. B. (2007). Mineral and Organic Matter Controls on the Sorption of Macronutrient Anions in Variable-Charge Soils. *Soil Science Society of America Journal*, *71*(6), 1926.

James, J., Devine, W., Harrison, R., Terry, T., 2014. Deep Soil Carbon: Quantification and Modeling in Subsurface Layers. Soil Science Society of America Journal 78, S1-S10.

NARA
Northwest Advanced Renewables Alliance

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.