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Deep soil carbon: A dynamic, unmeasured pool in terrestrial ecosystems

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ABSTRACT: Carbon calculations indicate that soils are more important than plants as reservoirs of C but rarely receive adequate attention. When soil pools are quantified they are typically sampled to relatively shallow depths to reduce study costs. This study assessed the potential of soil sampling to estimate carbon in the soil profile. Soil pits at twenty-two locations in Washington and Oregon were dug. Sites were selected from University of Washington Stand Management Cooperative (SMC) Type V long term site productivity plots (LTSPs) and then classified. All sites are intensively managed Douglas-fir (*Pseudotsuga menziesii*) plantations. Results showed that where soils were sampled to at least 80 cm or more depth 27–77% of mineral soil C was found **>** 20 cm in depth. To quantify soil C pools is recommended to sample soil profiles as deeply as possible and not assume that deeper soil horizons are not a critical part of adequate ecosystem analysis.

Index terms: forest soils, soil C stock.

INTRODUCTION

Most of the carbon (C) in terrestrial ecosystems is found in the soil. Although C calculations indicate that soils are more important than plants as reservoirs of C, soil rarely receives the attention given aboveground ecosystem components when C budgets are calculated.

When soil pools are quantified they are typically sampled to relatively shallow depths to reduce study costs. Shallow soil sampling in research includes studies that estimate C and nutrient pools and studies assessing the response of terrestrial ecosystems (i.e., forests, grasslands, and agricultural fields) to management treatments.

Although many soils have sola that are substantially deeper than 20 cm and C accumulates well below these depths in many soils, the majority of studies of soil C sample to depths of 20 cm or less, generally because of the difficulty and cost of sampling the soil profile deeper. Shallow soil sampling is often justified by assuming that deeper soil horizons are stable and will not change over time, although some medium- and long-term studies do not support this assumption.

Shallow soil sampling can result in both a major underestimate of soil C present in the soil profile and an inability to adequately measure the impacts of both treatments for specific goals (i.e., tillage, fertilization, and vegetation management) or other changes (i.e., global change and atmospheric inputs) over time in whole-ecosystem studies.

We assessed the potential of shallow soil sampling to underestimate carbon in the soil profile as well as to change the conclusions of studies of management treatments on soil C.

MATERIAL AND METHODS

Soil pits at twenty-two locations in Washington and Oregon were dug using an excavator to 250 or 300 cm. Sites were selected from University of Washington Stand Management Cooperative (SMC) Type V long term site productivity plots (LTSPs), and classified using data from the US Department of Agriculture Natural Resources Conservation Service soil surveys **(Figure 1)**. All sites are intensively managed Douglas-fir (*Pseudotsuga menziesii*) plantations.

Bulk density samples were taken using a soil corer of a known volume at depth intervals of 10, 50, 100, 150, 200, 250 and 300 cm (when possible). Major horizons were identified and recorded, along with horizon thickness and profile depth. In all cases, soil pits extended into the C horizon, often extensively. Additionally, forest floor samples were gathered from randomly placed 30 cm x 30 cm quadrats.

Samples were sealed in plastic bags and immediately returned to the lab, where they were refrigerated at 3°C until analysis. Samples were analyzed for C concentration using a LECO automated carbon analyzer. The total carbon (C_{tot}) and total nitrogen (N_{tot}) for each sample layer was calculated from: the layer height (H) between the sample depth and the depth of the sample immediately above it or the surface; the bulk density (D_b) of the <4.75 mm fraction; and the C or N concentration (C_{con} or N_{con}), using the equations

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$$C_{tot} = H * D_b * C_{con} \quad (1)$$
$$N_{tot} = H * D_b * N_{con} \quad (2)$$

The results of this calculation were then converted from g cm^{-2} to Mg C ha^{-1} and kg N ha^{-1} using dimensional analysis.

RESULTS AND DISCUSSION

Results showed that where soils were sampled to at least 80 cm or more depth 27–77% of mineral soil C was found **>** 20 cm in depth **(Figure 2)**.

In addition, analysis of results for 105 different studies of N fertilization in forests and N fertilization or conversion to switchgrass in agricultural studies shows that deeper sampling can actually change the conclusions of results of some research studies of net C accumulation or loss.

Research in 20 Pacific Northwest forest indicated that there were substantial quantities of carbon at depths up to 4 m, the limit of sampling in the study. Sampling to 3 m more than tripled the carbon estimates of the soil profile compared to sampling to 20 cm (202 vs. 59 Mg C ha^{-1}, respectively), the current national sampling depth of the primary US forest soil monitoring effort, the Forest Inventory and Analysis.

CONCLUSIONS

Researchers wishing to either quantify soil C pools or measure changes of soil C over time are cautioned to sample soil profiles as deeply as possible and not assume that deeper soil horizons are not a critical part of adequate ecosystem analysis.

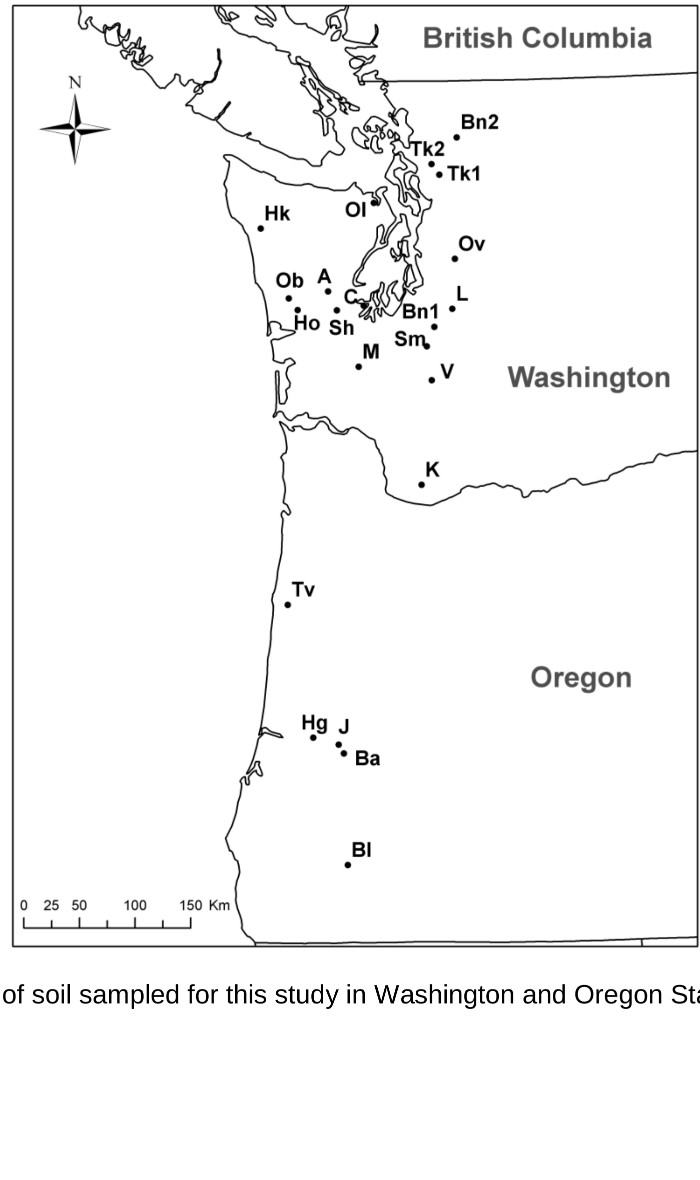

Figure 1 – Locations of soil sampled for this study in Washington and Oregon State, USA.

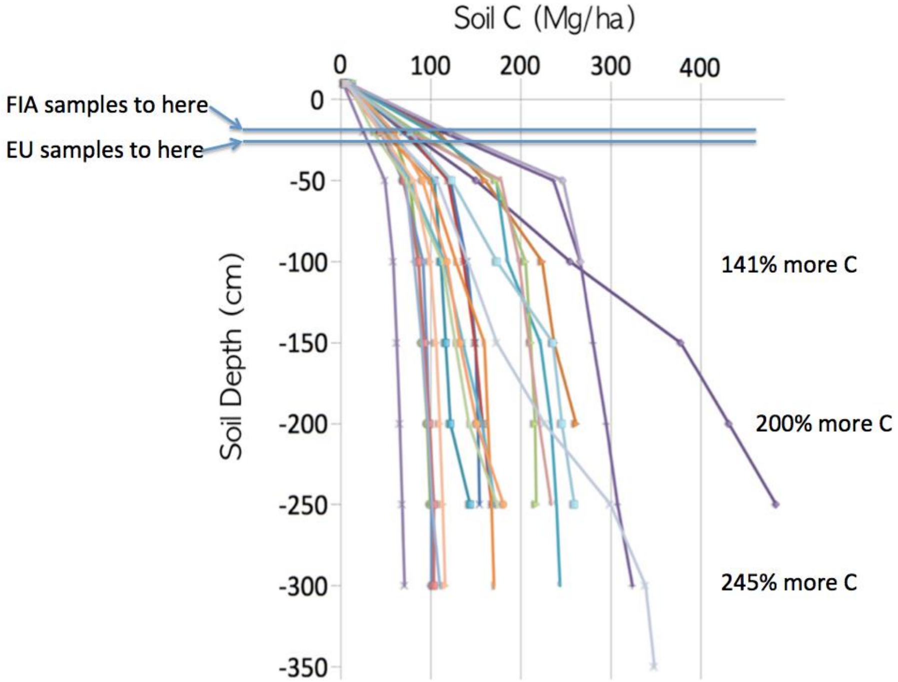

Figure 2 – Cumulative carbon content (Mg C ha^{-1}) vs. depth for the soils sampled in this study.