PROJECT INFORMATION

Project title: Effect of temperate and boreal tree traits on soil carbon stocks

Project ID: 7

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PROJECT DESCRIPTION

Scientific background

Tree species and their traits influence forest carbon pools and fluxes and can shape both soil C inputs (through growth rates) and outputs (through decomposition rates). Globally, traits such as tissue nitrogen, phosphorus, calcium, and lignin content shape leaf, wood, and root decomposition rates (Silver and Miya 2001, Cornwell et al. 2008, Weedon et al. 2009). Plant traits, including allocation to and distribution of roots, are also known to influence soil carbon distribution and sequestration (Jobbagy and Jackson 2000, De Deyn et al. 2008). However, specific relationships between tree traits and soil carbon stocks have not been established. I will assess the relationship between tree functional traits and forest soil carbon stocks in temperate and boreal forest ecosystems, and I hope to expand the breadth of this analysis by drawing on data from the extensive ICP Forests network.

Trait influences on litter decomposition rates and species effects on soil carbon stocks (e.g., Schulp et al. 2008) suggest that tree traits shape soil carbon content. Conversely, soil physical processes can protect organic matter from decomposition and may interfere with a direct relationship between soil carbon stocks and the plant traits that shape initial litter decomposition (Schmidt et al. 2011). Because soil carbon may primarily derive from roots (Rasse et al. 2005), root traits may have stronger control over soil carbon dynamics than do aboveground traits. Further, some traits promote quick tree growth and so quick carbon storage in living tree biomass (e.g., high specific leaf area, high tissue nitrogen content, and low lignin content). However, these same traits may promote swift decomposition, presenting a trade-off between carbon stocks in living plant tissues and in soil. These factors suggest three hypotheses:

1. Species vary in their influence on soil carbon stocks due to their functional traits.
2. Root traits such as high rooting depth, belowground allocation, and root tissue chemistry more strongly shape soil carbon stocks than do aboveground traits.
3. Trait values associated with both swift aboveground growth and elevated decomposition rates do not contribute to high soil carbon stocks.

Additional data
The ICP Forests data will be paired with additional data sources for soil carbon stocks with their overlying tree species, as well as species-specific trait data and environmental factors where appropriate.

Soil carbon and tree species composition.
For an analysis across forest systems, the ICP Forests data will be merged with additional datasets of tree community composition and soil carbon stocks. Due to data availability, I am focusing on temperate and boreal ecosystems. I have accessed two large databases compiling soil and ecosystem carbon data In Canadian forests, the Forest Soil Profile Carbon Database includes soil carbon and tree species data at 1300 Canadian forest sites (Siltanen et al. 1997), and the Forest Ecosystem Carbon Database includes soil carbon, biomass, and species data for 706 sites (Shaw et al. 2005). In the United States, data will be drawn from the Forest Inventory and Analysis National Program, with carbon and species data from an estimated >2000 sites. The United States National Soil Carbon Network will provide up to several hundred sites with soil carbon and tree species information, and I may include data from single-point sources such as forest research stations to augment underrepresented regions in the U.S. In this analysis, I plan to analyze shallow horizons and deeper carbon separately to maximize use of available data. Together, these sources will provide a substantial database of forest soil carbon data paired with current dominant tree species. I plan to constrain this analysis to species with available trait data (see below) that are also dominant at multiple sites (e.g., at least 10 sites).

Trait data.
Species-specific values of relevant functional traits will be drawn from the forest databases and estimated from other sources in the literature. Target traits: Tissue nitrogen, phosphorus, calcium, and lignin; annual litterfall; relative growth rate; specific leaf area; rooting depth; and root density (root mass per soil volume). When all soil carbon sources are collated, I will determine a precise species list and will further be able to request access to the global TRY traits database. Sources such as the large-scale ICP datasets of foliar traits, paired with environmental conditions, may allow me to estimate species-specific trait values with varying environmental conditions.

Environmental factors.
Many of these above sources also provide soil chemistry data. When site-specific climate data are not available, climate factors (e.g., actual evapotranspiration) will be estimated based on location.

Statistical analyses
I plan to assess soil carbon stocks as a function of tree traits (e.g., tissue nitrogen, phosphorus, calcium, lignin, rooting depth, specific leaf area, and relative growth rate), tree species, and environmental conditions (e.g., growing season length and actual evapotranspiration rates) using multivariate linear models specific to the hypotheses above. Generalized linear models may be appropriate to accommodate unbalanced species data.

The availability of trait data may require me to address specific hypotheses or the contributions of specific traits with a subset of the overall dataset.

Overview

This broad-scale analysis planned with the ICP data will be paired with a meta-analysis of common-garden tree experiments from the literature to directly control for site-specific effects on soil carbon stocks. Many of the species included in common-garden experiments are economically important species with substantial trait data in the literature (e.g., Crow 2005, Withington et al. 2006). Together, these analyses will form one chapter of my PhD dissertation on the relationship between plant functional traits and soil carbon cycling.

The results of this work may be particularly of interest for two applications: As plant species shift their ranges in response to climate change, ecosystem functions shaped by plants may shift as well; understanding the mechanisms by which species influence ecosystem functions will better help us predict changes in carbon dynamics with such range shifts. Further, understanding species and trait effects on forest soil stocks will help inform forest carbon sequestration projects.