8. Partitioning Soil Respiration to Quantify Carbon Sequestration: A Regional Synthesis of Fertilization and Throughfall Reduction

***Brian Strahm*[1,6] • *John Seiler*[2,6] • *Brett Heim*[3,6] • *Rodney Will*[4,7] • *Casey Ausmus*[3,7]**
***Jason Vogel*[1,8] • *Geoffrey Lokuta*[5,9] • *Eric Jokela*[4,9]**

[1]Assistant Professor • [2]Alumni Distinguished Professor • [3]M.S. Student • [4]Professor • [5]Research Associate
[6]Department of Forest Resources and Environmental Conservation, Virginia Tech • [7]Department of Natural Resource Ecology and Management, Oklahoma State University
[8]Department of Ecosystem Science and Management, Texas A&M University • [9]School of Forest Resources and Conservation, University of Florida

The amount of carbon metabolized by soil organisms (heterotrophic respiration) is a key component of the forest carbon cycle and links total ecosystem productivity to net carbon sequestration. By quantifying how heterotrophic respiration responds to silviculture and environmental factors, this research will improve our understanding of carbon sequestration impacts from silvicultural and genetic enhancement of productivity, efficiency of fertilizer use, and resilience to climate variability and disturbance.

Forests are strong terrestrial carbon sinks, but our knowledge of the impact of management activities on carbon (C) sequestered by planted pine systems is limited by our lack of information on below ground carbon dynamics. Forest trees allocate photosynthetically fixed atmospheric carbon dioxide (CO_2) both aboveground (e.g., stems and leaves) and belowground (e.g., roots and soil), where at least some portion of that C is respired (metabolized by plant cells and soil organisms) and passed back into the atmosphere as CO_2. The challenge is to quantify the balance between C fixation and respiration at stand and ecosystem scales. Models (e.g., Physiological Principles in Predicting Growth [3-PG], Landsberg and Waring 1997) are commonly used to estimate C fixation and respiration for the trees themselves, but require further refinement in order to account for C that passes through or resides in the soil.

This refinement requires the separation of total soil respiration (R_S) into components of heterotrophic, microbial respiration (R_H) and autotrophic, root respiration (R_A). With these numbers in hand, net ecosystem production (NEP), or the measure of C accumulated by the ecosystem, can be derived by subtracting R_H from model estimates of net primary production (NPP), a measure of ecosystem biomass production. Based on current PINEMAP efforts to model regional NPP across the range of loblolly pine and previous work partitioning soil respiration at a single site (see PINEMAP Year 2 Report), we present a synthesis of efforts to quantify the R_H proportion of soil respiration in response to fertilization and throughfall reduction at three contrasting sites at the edges of the loblolly pine range.

NPP: **Net primary production, ecosystem biomass production**
NEP: **Net ecosystem production, net increment of carbon; carbon accumulated by the ecosystem**
R_H: **Heterotrophic, microbial respiration**
R_A: **Autotrophic, root respiration**
R_S: **Total soil respiration (R_H + R_A)**

Over the past two years, researchers at the Tier III throughfall reduction x fertilization sites in Oklahoma, Florida, and Virginia have installed a series of root-

Figure 8.1. Right: Root-severing core installed at the Virginia Tier III site. Left: Root-severing core being excavated. Photos by Brett Heim.

PINEMAP field researcher Geoffrey Lokuta uses a LI-COR LI-8100A instrument to measure soil respiration at the PINEMAP Tier III throughfall reduction x fertilization site in Taylor County, Florida. Photo by Jessica Ireland.

Our field measurements suggest that the R_H fraction of respiration is much higher than originally thought, and that more of the photosynthetically fixed C that is allocated belowground passes through the soil and back to the atmosphere rather than being sequestered in the system.

severing cores intended to eliminate root respiration (i.e., R_A) and allow direct estimation of the microbial (i.e., R_H) contribution to soil respiration (Figure 8.1). Despite the diversity of soil types, stand ages, seasons, and treatments (fertilization and throughfall reduction), the proportion of soil respiration from R_H was remarkably consistent (Figure 8.2). Statistical analysis of the possible treatment combinations confirmed this consistency. We evaluated soil respiration from R_H for all season-by-site combinations and across seasons and sites. When evaluating each season-by-site combination independently, there were very few significant ($p < 0.05$) interactions (July 2013, Oklahoma) or main effects of fertilization or throughfall reduction. Further, when analyzed collectively, there were no significant differences in R_H contributions to soil respiration across sites or seasons.

Perhaps the most surprising result was the estimated R_H proportion itself. Given the general lack of observed differences across sites, seasons, and treatments, a single regional estimate of 0.840 ± 0.026 emerges as the R_H proportion of soil respiration. The robustness of this estimate will greatly aid the modeling of NEP across the range of managed loblolly pine, because the models will not need to account for site, season, or treatment effects. Without the need to account for site- or stand-specific characteristics to estimate R_H, modeling efforts can focus on improving NPP estimates alone.

An implication of these field results is that soil C sequestration in managed southern pine forests may be smaller than some previous estimates. Most efforts to use NPP to model NEP assume that soil respiration is evenly partitioned between R_H and R_A. Our field measurements suggest that the R_H fraction of respiration is much higher than originally thought, and that more of the photosynthetically fixed C that is allocated belowground passes through the soil and back to the atmosphere rather than being sequestered in the system. Incorporation of these results into models like 3-PG will allow PINEMAP to more accurately quantify the C sequestration potential of planted pine in the region.

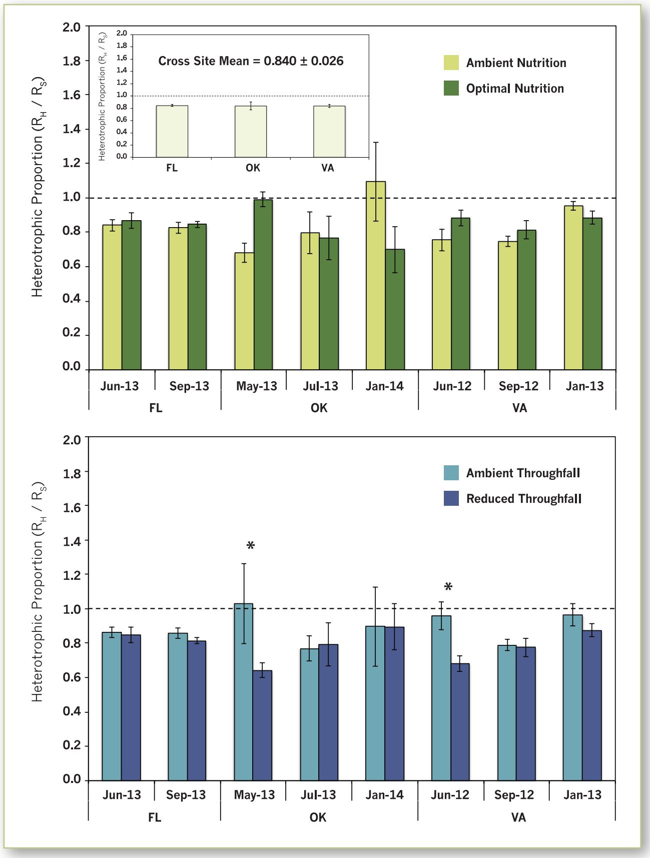

Figure 8.2. Proportion of total soil respiration (R_S) from heterotrophic, microbial respiration (R_H) at the PINEMAP Tier III sites in Florida (FL), Oklahoma (OK), and Virginia (VA) at multiple points in time. Upper panel shows main effect of fertilization; lower panel shows main effect of throughfall reduction. Inset provides site and regional means. Asterisks represent significant main effect differences ($p < 0.05$).