4. Forest Carbon Sequestration: Big Changes Underfoot

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Carbon (C) in terrestrial ecosystems is one of the main reservoirs in the global C cycle. Within these terrestrial ecosystems, soil C in the form of organic matter and plant biomass are the two largest pools of C. Further, the processes of photosynthesis and respiration that occur in these systems are the two largest fluxes of C globally. Given their size, even small changes in these pools and fluxes can significantly impact atmospheric CO_2 concentrations. Forest ecosystem management can influence global C dynamics by manipulating these pools and fluxes. Afforestation, in general, and forest management (silviculture), specifically, can increase terrestrial ecosystem C in soils and biomass. In the southern United States, intensive management of loblolly pine forests has resulted in appreciable increases in productivity since the widespread establishment of pine plantations in the 1950s. Understanding the interacting effects of management (e.g., fertilization) and climate variability (e.g., drought) will be critical in guiding the adaptation of these forest ecosystems for the mitigation of negative climate impacts.

To quantify the effects of management and climate change, a measure of C storage is necessary. One such measure that forest scientists use is net ecosystem productivity (NEP), a measure of the net C accumulated by an ecosystem. For a loblolly pine ecosystem, it represents the C captured by photosynthesis minus the losses due to plant and soil respiration. Unfortunately, a direct measurement of NEP is difficult over large geographic areas. Ecosystem C models have the capacity to predict NEP with one modification of their present configuration—there is a need to understand the relative contributions of soil heterotrophic, microbial respiration (R_H) and autotrophic, root respiration

Figure 4.1. This picture shows a root exclusion core being excavated after a 90-day installation so that roots can be collected for analysis. Photo by Brett Heim.

(R_A) to the overall belowground soil respiration (R_S). Present estimates suggest R_A and R_H are roughly evenly split, but deviations from this even split could have significant impacts on the estimates of C storage in managed forest ecosystems. In short, a higher proportion of R_H would result in lower measures of NEP; whereas, a lower proportion of R_H would indicate greater estimates of ecosystem C storage.

In order to partition R_S into its R_H and R_A components, R_S needs to be measured in a root free environment, and such conditions hardly exist in nature. On small scales, however, these conditions can be artificially created by severing the roots from their supply of plant carbohydrates (i.e., photosynthesis). Over time, the roots run out of carbohydrates for respiration

Figure 4.2. PINEMAP M.S. student Brett Heim uses a LI-COR 6200 to measure soil respiration underneath a throughfall exclusion structure at the Virginia Tier III site. Photo by John Seiler.

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and R_A falls to zero. At this point, a measure of R_S is equal to R_H. Practically, this is achieved by driving a 10 cm wide core 35 cm into the ground to sever tree roots and waiting for the exhaustion of R_A (Figure 4.1). Then, comparing measures of R_S inside (now simply R_H) and outside ($R_S = R_H + R_A$), the core provides the information necessary to allow current ecosystem C models to more accurately predict NEP in order to determine if managed southern pine ecosystems can meet the objective of increased C storage.

During the 2012 field season, we tested this coring method at the PINEMAP Tier III site in Virginia. This nine-year-old loblolly pine stand is located in the Appomattox-Buckingham State Forest in the Piedmont region of Virginia. This location represents the northernmost range of climatic conditions where loblolly pine is intensively managed in the southeastern U.S. (see Figure 1.3 on page 7).

Respiration measurements were taken approximately every two weeks both adjacent to and on top of each root severing core to measure the decline in R_A over the course of a three month period (Figure 4.2). Soil temperature (at 10 cm) and moisture measurements (at 0 to 12 cm) were also taken adjacent to the collar during each measurement.

Respiration initially increased inside the cores due to the disturbance of installation. After a period of equilibration, however, the respiration inside the core began to decrease relative to outside the core before stabilizing after approximately 65 days (Figure 4.3). At the point of stabilization, the respiration measured inside the root severing cores was about 25% lower than respiration measured adjacent to the cores. This suggests that the assumed partitioning of R_S into equal proportions of R_H and R_A may underestimate the amount of C stored in these systems.

Based on these initial results, PINEMAP researchers will be deploying this method at the other Tier III installations as well as in a broader regional context at some of the Tier II sites to estimate loblolly pine NEP across the range of the species.

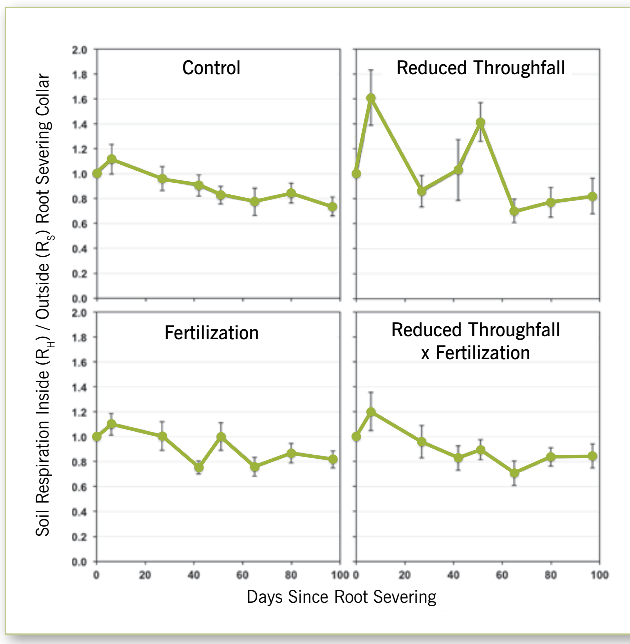

Figure 4.3. A time series showing the ratio of soil respiration measurements inside to soil respiration measurements outside root severing cores relative to time of core installation. Values below 1.0 indicate lower rates of soil respiration inside root severing cores. Once the response has stabilized (~65 days), the value is used to estimate the heterotrophic (R_H) contribution to total soil respiration (R_S).