Soil Heterotrophic Respiration in Southern Pine Plantations: Seasonality, Microbial Communities, and Models.

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ABSTRACT

In order to determine the effectiveness of southern pine plantations in sequestering atmospheric carbon, we must know the amount of fixed CO_2 that is subsequently lost due to heterotrophic microbial activity in the soil. Furthermore, this heterotrophic proportion of total soil respiration must be quantified as it changes between different operational treatments, ecoregions, and seasons. These proportions are necessary to accurately determine net ecosystem productivity from net primary productivity, thus helping to estimate the amount of carbon accumulated by the ecosystem. The research aims to quantify heterotrophic contributions to total soil respiration in the Piedmont and Upper Coastal Plain ecoregions under control, fertilizer, and herbicide treatments over an annual cycle. Heterotrophic respiration (R_h) is separated in the field from autotrophic root respiration (R_a) by using metal root-excluding collars and CO_2 efflux measurements are made monthly over 90 days. Following final measurements, roots are excised to 30 cm below each point, dried, and weighed to account for differences in rooting mass. A soil sample of the top 10 cm at each point is also taken and measured for microbial biomass.

Collars are re-installed to begin the next 90-day seasonal rotation. Soil respiration is also being modeled at these sites to predict heterotrophic respiration. Preliminary results in Piedmont and Upper Coastal Plain ecoregions indicate R_h of 78 and 82% during winter with little effect of fertilization but a large decrease in herbicide plots. Microbial biomass did not vary among treatments or between exclusion collars relative to control collars, but did differ between ecoregions. Finally, initial modeling efforts in a generic pine plantation estimate seasonal R_h of 20 to 90%, values that exceed empirical measures. These preliminary efforts suggest R_h is a substantial pathway of CO_2 return to the atmosphere in a range of pine ecosystems.

DESIGN & METHODS

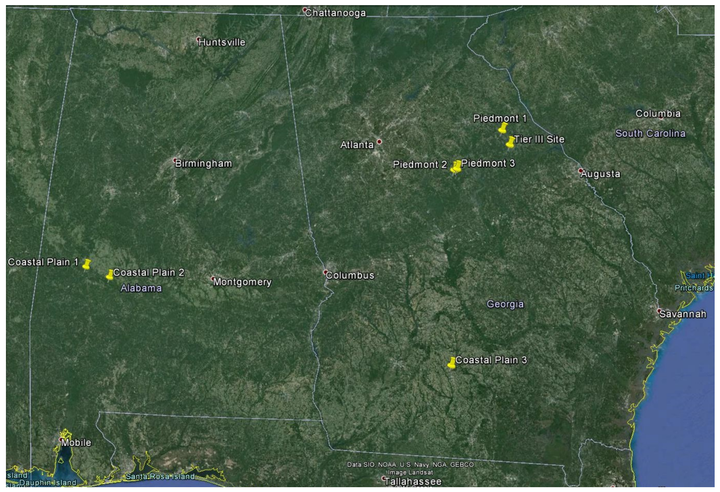


Figure 1. Study site locations.

Efflux measurements were taken monthly at three Piedmont and three Upper Coastal Plain sites. Each site included one control and one fertilize treatment, while Piedmont 2, 3, and Coastal Plain 3 also included an herbicide treatment.

Each treatment contained three subplots composed of a control collar inserted just enough to remain in place, and a root excluding collar inserted 33 cm. At least two efflux cycles were measured using a Licor 6400 in each collar and averaged.

Figure 2. A subsample location including control (PVC) and exclusion (steel) collar. Three subsample pairs are included in each plot.

Exclusion collar measurements made 90 days after installation represented Rh only, while control collars continuously represented Rs. The ratio of Rh:Rs at 90-day measurement efforts represented the proportion of total respiration that was Rh for that season.

Additional data collected included:

- Soil moisture and temperature recorded within each plot every 30 minutes using dataloggers
- Soil moisture and temperature adjacent to each subplot during measurements and moisture within exclusion collars after 90-day measurements
- Sample upper 10 cm of soil at each measurement point for microbial biomass
- Sample upper 30 cm of soil at each measurement point for rooting mass

Microbial biomass was obtained using the fumigation-extraction method and analyzed on a Shimadzu Total Organic Carbon analyzer.

RESULTS

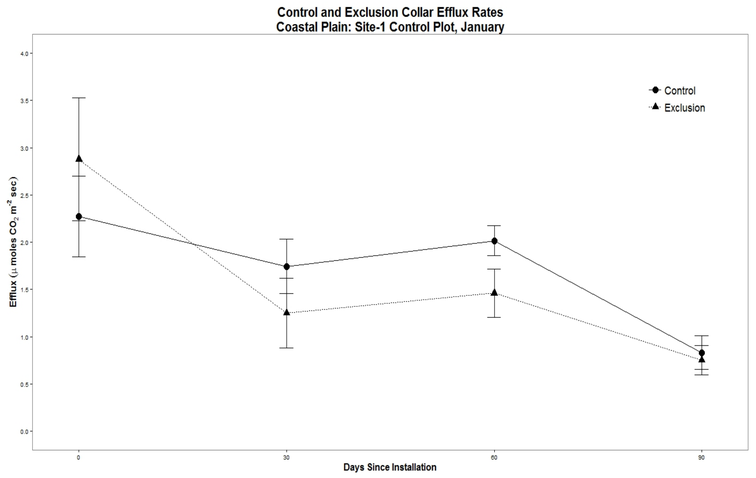


Figure 3. Average monthly collar efflux measurements (± S.E.) from control plot of Coastal Plain 1 for winter rotation. Values at day-90 used for calculating R_h proportion. Points represent averaged value for all subplots for each corresponding collar type (n=3)

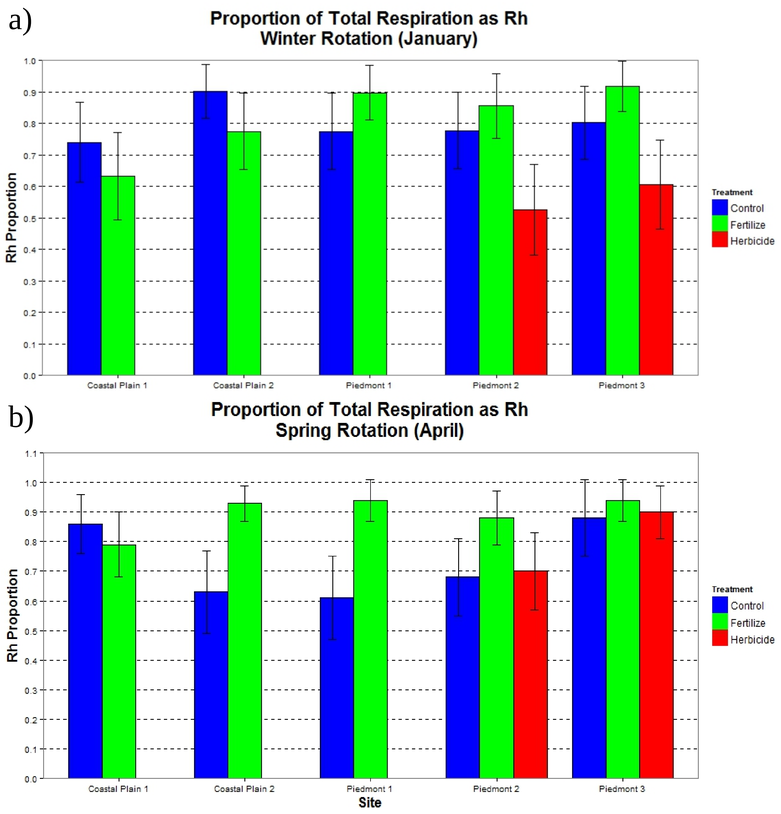


Figure 4. Proportion of total respiration (R_s) as R_h (± S.E.) between treatments and regions for winter rotation (a) and spring rotation (b).

- **Winter Rotation:**
  - Average R_h proportion of 78 and 82% for Piedmont and Upper Coastal Plain
  - No significant difference between regions, control and fertilize plots, however, herbicide was significantly lower fertilize treatment ($\alpha = 0.05$)
- **Spring Rotation:**
  - Average R_h proportion of 82 and 80% for Piedmont and Upper Coastal Plain
  - No significant differences between ecoregions or treatments
- No significant difference between winter and spring proportions

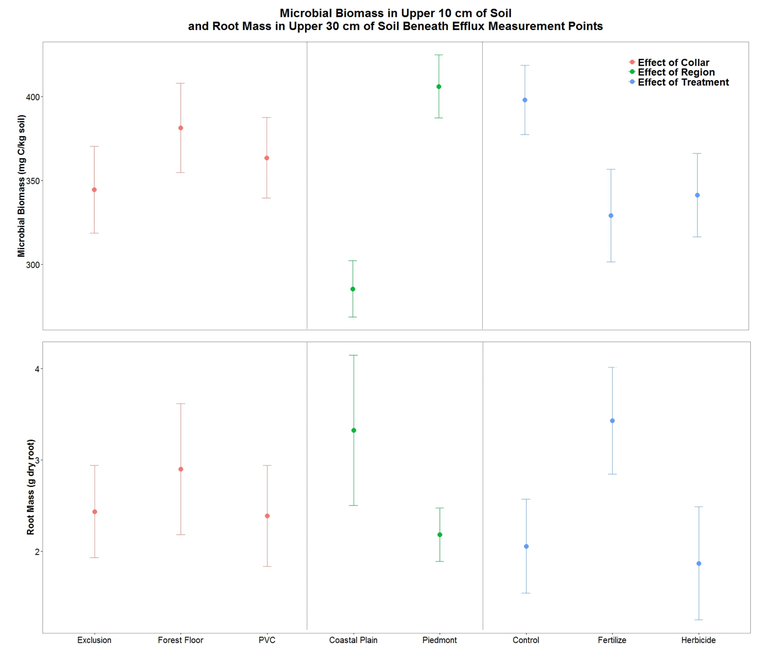
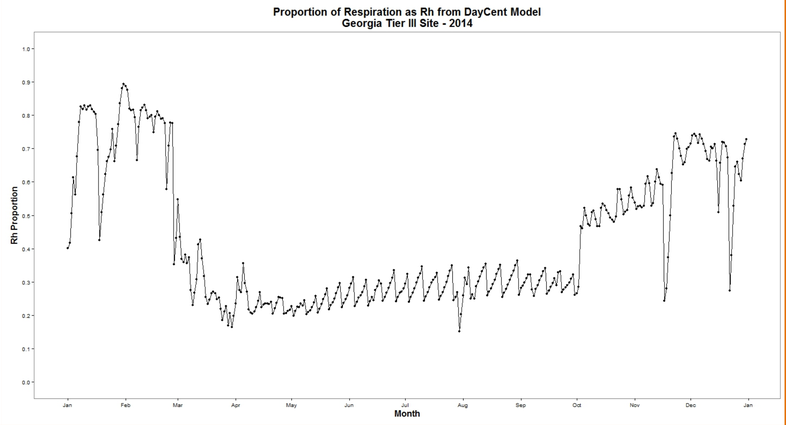


Figure 5. Average microbial biomass in upper 10 cm and average root mass in upper 30 cm of soil (± S.E.) beneath efflux measurement points for winter rotation. Comparisons made between measurement collars and undisturbed forest floor, ecoregions, and treatments.

- Microbial biomass for winter rotation show a significant difference between Piedmont and Upper Coastal Plain, no difference between treatments or measurement collars ($\alpha = 0.05$)
- .No significant differences in rooting mass for winter rotation

MODELLING

- Site soils data, site history, and long-term climate data were used from the Georgia Tier III PINEMAP study site to model R_s and R_h using the Daycent biogeochemical model.
- Plot-level soil sampling from 0-100 cm for model parameterization included:
  - Total carbon
  - Total nitrogen
  - Macronutrients
  - Texture
  - pH
  - CEC



DISCUSSION & FUTURE WORK

- R_h a significant contributor to total respiration during winter and spring
- No apparent difference between control and fertilize treatments, while herbicide appears to reduce R_h contribution
- Exclusion collar method does not have a significant impact on microbial communities, at least during winter
- DayCent model may underestimate R_h contribution to total respiration during spring and summer
- **Future Work:**
  - Continue efflux measurements, root samples, and microbial biomass samples for summer and fall
  - Use continuous datalogger data to develop a regression model to estimate R_h proportion using soil moisture and temperature
  - Process soil samples from Piedmont and Coastal Plain sites in order to parameterize DayCent model for each location
  - Obtain respiration data for Tier III site to validate DayCent model

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