Carbon Fluxes in a Managed Pine Forest Under Ambient and Elevated CO_2

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Objectives: The primary objective of this study is to estimate CO_2 fluxes (F_{CO2}) under ambient and elevated atmospheric CO_2, and varying environmental conditions. Additional objectives are to: (2) quantify canopy conductance and evaluate the hypothesis that canopy conductance will not be altered by elevated atmospheric CO_2 because reduction in leaf conductance is compensated by increased leaf area index, and (3) quantify the effect of elevated CO_2 on aboveground production and *apparent* allocation of carbon belowground. In order to achieve the primary objective, we propose a modification to a methodology proposed earlier which emphasized leaf level measurements. These modifications stem from analysis of measurements performed in 1995-1996 that demonstrate (i) high variability in CO_2 assimilation (A) - internal concentration (C_i) relations (A-C_i curves) in each level in the canopy for given photosynthetically active radiation (PAR) and soil moisture content (θ) conditions, (ii) the relative independence of the ratio of C_i to atmospheric CO_2 concentration (C_i/C_a) from C_a (different levels within canopy for a wide range of moisture content conditions), (iii) similarity in CO_2 and water vapor flux co-spectra which permits estimation of CO_2 conductances from water vapor conductances for canopy trees, and (iv) the good correlation (r=0.94) between scaled 15-tree stem flux measurements and eddy correlation water vapor flux on a daily time step.

Products: The expected products from this project include: (1) Evaluation of a new method to predict the assimilation rate of CO_2 from a simplified physiological relationship between internal and external CO_2 concentration, climatic variables, sap flux measurements, and similarity in canopy conductances to CO_2 and water vapor, (2) Based on the proposed method, a quantified effect of elevated CO_2 on canopy conductance and net CO_2 flux, including interactions with hydrologic and climatic variables, (3) Evaluation of the differential response of co-occurring species to elevated CO_2 in-terms of total conductance, and (4) Quantified effect of elevated atmospheric CO_2 on aboveground production and on soil respiration, the latter measured during FACE downtime.

Approach: Eddy-covariance based CO_2 and H_2O fluxes were estimated at the Duke Forest AmeriFlux site (15-year-old loblolly Pine forest) from August 1997-June 1998 for an ambient ring (Ring 1) within the FACE project together with meteorological, soil moisture, and xylem sapflux measurements. The data was processed till April of 1998 and preliminary results are shown below.

Results to Date: The project results to date are:

1. Canopy conductance to water vapor for ambient and elevated C_a were calculated. The values indicate that, during the first year of exposure to elevated CO_2, conductance decreased such that the stand within the FACE plot transpired approximately 25% less water when compared to a reference stand. However, during the second year of exposure, lowered canopy conductance was apparent only at low vapor pressure deficit (VPD) conditions. Combined with a greater increase in LAI in the FACE plot, transpiration in the second year was only 10% less than in the reference plot. By the third year, differences between the FACE and reference plots were undetectable.

2. Preliminary comparison of biomass production (based on measured diameter at breast height and biomass equations) indicates large response to CO_2 enrichment. Production at the FACE prototype during the second year of fumigation was about 50% higher than in the adjacent reference stand; during the first 13 years of the forest's life, growth was slightly greater in the reference stand. By the third year, stemwood production in the prototype plot was only *ca.* 20% greater than in the reference plot, and was less than that in the reference by the end of the fourth year. We are currently investigating the possibility that nutrient limitation is responsible for the recent decrease in growth in the prototype plot.

3. A new closure model for estimating multilevel CO_2 sources, sinks, and fluxes was developed and field -tested. The model requires mean velocity, leaf area density, foliage drag, and CO_2 concentration profiles inside and above the canopy. Good agreement between CO_2 eddy covariance measured and predicted fluxes was obtained (r^2=0.71) at 9 m above the ground surface (canopy height is 14 m).

4. Leaf-level measurements (A-C_i curves) over a range of environmental conditions suggest that elevated atmospheric CO_2 did not alter the functional relationship between A and C_i. The measurements also demonstrated that high variability occurs amongst curves generated under similar environmental conditions; hence, integrating leaf-level A-C_i curves parameter to stand level introduces large uncertainties to CO_2 budget calculations. However, the same measurements demonstrate that the ratio C_i/C_a is insensitive to variability in C_a for both ambient and FACE operating conditions (*ca*. 300-600 ppm).

5. From the AmeriFlux eddy-covariance measurements, from August 1997-

April 1998, latent heat flux, day time net ecosystem CO_2 uptake, nighttime respiration, and net monthly ecosystem CO_2 uptake were computed. In December and January, CO_2 fluxes frequent frost and stable atmospheric conditions resulted in too few runs to obtain a reliable average for these two months for CO_2. Figure 1 shows the preliminary monthly water and CO_2 budgets.

Students: Nathan Phillips (Ph.D - Spring 1997) has been hired for the summer of 1997 to complete the analyses of sapflux data, and link it to soil and atmospheric variables. Cheng-I Hsieh (Ph.D. - Spring 1998) performed eddy covariance measurements and data analyses. Diane E. Pataki (part time, Ph.D. - Spring 1998) continued sapflux measurements and performed canopy conductance calculations.

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Figure 1: Carbon Dioxide Fluxes and Evapotranspiration at the Duke Forest AmeriFlux *Pinus taeda* site.