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Informal Report

FREE-AIR CO₂ ENRICHMENT FOR FORESTS: PROTOTYPE DEVELOPMENT

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SGCP Project Title

Free-Air CO₂ Enrichment for Forests: Prototype Development

Principal Investigators:

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1. Research Hypothesis and Findings:

A. H₀: It is not possible to maintain [CO₂]_{atm} in a forest plot experiment encompassing trees nearing canopy closure at a concentration similar to that anticipated for the mid twenty-first century without any type of enclosure.

- * USFS/SGCP is cooperating with the U.S. Department of Energy, Office of Health and Environmental Research (primary sponsor of the work) and the National Council for Air and Stream Improvement of the Paper Industry (NCASI) in the development of a prototype free-air carbon dioxide enrichment (FACE) facility for application to forests. The Brookhaven National Laboratory (BNL) Forest FACE Prototype (FFP) facility is located in the Duke Forest of Duke University, Durham, NC. The site is a 12 year old plantation of loblolly pine 8m tall and just approaching canopy closure.

- * Engineering tests were conducted in 1993 and design modifications have been made that should improve system performance to be tested in 1994.

- * Average hourly wind speeds during the period 13-17 September 1993 measured 12 m above the forest floor at the FFP varied from calm to above 2.5 m/s (Figure 1). The 1-minute average of [CO₂]_{atm} at their control point (7 m in the center of the FFP) was within 10% of the set point for 71% of the time and within 20% of the set point for 94% of the time (Figure 2).

- * Mean [CO₂]_{atm} at the control point was very close to the set point of 550 μmol mol⁻¹ (Figure 3) but the mode is slightly lower. CO₂ use was determined primarily by wind speed (Figure 4) and vertical turbulence (not shown) which is closely related to total insolation.

B. H₀: Elevated, relatively stable [CO₂]_{atm} can not be maintained from ground-level to tree crown within a plot of at least 25m diameter using FACE technology.

- * Average [CO₂]_{atm} measured at 68 points throughout the FFP from ground to crown were in the range 500 to 675 μmol mol⁻¹ corresponding to a range of -9% to +22% of the target value, 550 μmol mol⁻¹.

* The performance data presented here demonstrate that the FFP in its current configuration nearly meets the minimal operational criterion: to maintain $[\text{CO}_2]_{\text{atm}}$ within $\pm 20\%$ of the set point at least 80% of the time throughout the experimental volume for extended operation under normal weather conditions.

* The FFP will be modified based on 1993 engineering data and tests will resume in early 1994.

2. Tables and figures:

Fig.1. Hourly average windspeed at 12 m above ground in the FFP 13-17 Sept. 1993.

--- +/- 10% of set point (includes 70.7% of data)
 +/- 20% of set point (includes 94.2% of data)

Fig. 2. One minute average $[CO_2]_{atm}$ at 7 m elevation at the FFP control point 13-17 Sept. 1993.

Fig. 3. Frequency of 1-min. average $[CO_2]_{atm}$ at the FFP control point 13-17 Sept. 1993 (all fumigation data at control point, day and night).

Fig. 4. CO_2 use (—) and windspeed (---) at the FFP 13-17 Sept. 1993.

Fig. 5. Isolines of $[\text{CO}_2]_{\text{atm}}$ at 1 m above ground in the FFP 13-17 Sept. 1993 (0700-1700h).

Fig. 6. Isolines of $[\text{CO}_2]_{\text{atm}}$ at 3 m above ground in the FFP 13-17 Sept. 1993 (0700-1700h).

Fig. 7. Isolines of $[\text{CO}_2]_{\text{atm}}$ at 6 m above ground in the FFP 13-17 Sept. 1993 (0700-1700h).

Fig. 8. Isolines of $[\text{CO}_2]_{\text{atm}}$ at 9 m above ground in the FFP 13-17 Sept. 1993 (0700-1700h).

3. SGCP Policy and Scientific Questions

A. Policy Question 1: Is there a problem?

Science Question 1:

What process in the southern forest ecosystems are sensitive to physical and chemical changes in the environment? (A co-lateral question is: How can we measure the changes in a realistic way?)

- * Most growth and biomass variables are observed to change under increased $[\text{CO}_2]_{\text{atm}}$ experiments in growth chambers of various types.
- * Complications associated with chamber studies necessitate finding a better approach to conducting realistic field experiments on intact forests at the ecosystem level.
- * Advantage of FACE systems are: 1) there are no significant changes in environmental conditions other than $[\text{CO}_2]_{\text{atm}}$; 2) perhaps the only means for conducting $[\text{CO}_2]_{\text{atm}}$ enrichment studies on intact forest ecosystems; 3) similar BNL FACE experiments in agricultural settings have proven to become user facilities, within which dozens of scientists from many funding organizations from the U.S. and abroad collaborate in integrated research.
- * The current project will provide a technology for realistic experiments on CO_2 enrichment in which biological and biogeochemical processes can be measured at the cell, organ, stand and ecosystem levels (as appropriate):

B. Policy Question 2: How serious is the problem?

Science Question 2:

How will atmospheric changes influence the structure, function and productivity of southern forests and related ecosystems?

- * Changes in forest structure, growth rate, standing biomass, nutrient recycling are all thought to be sensitive to changes in $[\text{CO}_2]_{\text{atm}}$
- * Fumigation experiments are required to investigate the nature of forest responses to elevated $[\text{CO}_2]_{\text{atm}}$ under realistic field conditions.

C. Policy Question 3. What can be done about the problem?

Science Question 3:

How must forest management activities be altered to sustain southern forest productivity, health and diversity?

- * Prudent long-term management of forests includes consideration of successional or production changes that may occur slowly over decades as $[\text{CO}_2]_{\text{atm}}$ continues to increase.
- * Experiments using FACE systems in forests can examine the primary responses to CO_2 enrichment and nutrient-forest growth relationship with increased $[\text{CO}_2]_{\text{atm}}$ and provide data for development, calibration and validation of models of forest physiology, growth or community dynamics. These data can be obtained in FACE experiments without confounding changes in microclimate variables.