DOE Project: Synthesis of scrub-oak responses to elevated CO_2
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Final Report

Summary

A decade of chronic exposure to elevated CO_2 altered the carbon cycle but did not significantly increase ecosystem carbon storage. The increase in plant carbon content was offset by soil carbon declines. Therefore, microbial responses to elevated CO_2 are just as important as responses of plants in modulating ecosystem carbon balance. Earth System Models that do not represent microbial responses to altered carbon inputs at elevated CO_2 are likely to overestimate future carbon uptake by the terrestrial biosphere.

The stimulation of net primary production by elevated CO_2 was most pronounced immediately after ecological disturbance, either by fire or by hurricane. The stimulation of productivity was apparent aboveground and belowground, but was strongest belowground. This stimulation declined with time after disturbance. The mechanisms causing this declining response could involve nutrient cycling feedbacks where disturbance creates a short-lived pulse of nutrient availability, and effects of plant life histories, where plants are programmed to grow after disturbance. Regardless of the mechanism, the result points to the need to incorporate ecological disturbance into Earth System Models.

Elevated CO_2 altered element cycles in this experiment, causing more rapid rates of element transfer from soils to plants. For nitrogen, elevated CO_2 increased N losses via leaching, a result inferred from the coupling of reduced tracer ^{15}N recovery over time and increased ^{15}N distribution at depth. If increased N losses are a general response to elevated CO_2, N limitation will become exacerbated over time, reducing productivity responses of ecosystems to elevated CO_2.

Elevated CO_2 reduced foliar nitrogen concentrations, in turn reducing herbivory on all plant species. Despite reducing herbivory, elevated CO_2 did not alter the abundance of the predators or parasitoids of insect herbivores, indicating that the trophic effects of elevated CO_2 did not propagate up the food web. After cessation of the CO_2 treatment, there were no apparent legacy effects of prior CO_2 exposure, whether for root biomass and root growth, or herbivory and insect abundance. At least for these responses, the effects of elevated CO_2 do not appear likely to accumulate over cycles of disturbance and recovery.

Data archival

Twelve datafiles have been permanently archived at the CDIAC ftp server as part of the "FACE collection": ftp://cdiac.ornl.gov/pub/FACE/kscdata/Hungate/
General site information and the contents of each datafile are described in a summary file (SICO2_Datafiles_Overview), which is also posted at the site. Each datafile also contains metadata. The data files are listed below, and the titles capture the content:

SICO2_FL_Aboveground C, N, and ^{15}N

SICO2_FL_Aboveground_Diameter_Density_Biomass
SICO2_FL_Belowground_biomass_C_N_15N
SICO2_FL_C_N_concentration_13C_15N_soil_plant
SICO2_FL_L_layer_C_N_13C_15N
SICO2_FL_NPP
SICO2_FL_NPP_and_N
SICO2_FL_Soil_Bulk_Density
SICO2_FL_Soil_C_N_15N_mineral_CPOM_density_fractions
SICO2_FL_root_depth_distribution
SICO2_FL_soil_lab_incubations
SICO2_FL_soil_water

Publications

The following six papers were published in the peer-reviewed literature as a result of this work. All of the data from these papers is archived at the CDIAC website.

1) Hungate BA, Dijkstra P, Wu Z, Duval BD, Day FP, Johnson DW, Megonigal JP, Brown ALP, Garland JL, 2013. Cumulative response of ecosystem carbon and nitrogen stocks to chronic CO_2 exposure in a subtropical oak woodland. *New Phytologist* 200:753-766. DOI: 10.1111/nph.12333
2) Hungate BA, Day FP, Dijkstra P, Duval BD, Hinkle CR, Langley JA, Megonigal JP, Stiling P, Johnson DW, Drake BG, 2013. Fire, hurricane and carbon dioxide: effects on net primary production of a subtropical woodland. *New Phytologist* 200: 767-777. DOI: 10.1111/nph.12409
3) Day FP, Schroeder RE, Stover DB, Brown ALP, Butnor JR, Dilustro J, Hungate BA, Dijkstra P, Duval BD, Seiler TJ, Drake BG, Hinkle CR, 2013. The effects of 11 years of CO_2 enrichment on roots in a Florida scrub-oak ecosystem. *New Phytologist,* 200:778-787 DOI: 10.1111/nph.12246
4) Duval B, Dijkstra P, Drake BG, Johnson DW, Ketterer ME, Megonigal JP, Hungate BA, 2013. Element pool changes within a scrub-oak ecosystem after 11 years of exposure to elevated CO_2. *PLOS ONE* 8: e64386 DOI: 10.1371/journal.pone.0064386
5) Stiling P, Moon D, Rossi A, Forkner R, Hungate BA, Day FP, Schroeder RE, Drake B, 2013. The effects and legacy effects of long-term elevated CO_2 on fine root growth and plant-insect interactions. *New Phytologist,* 200:788-795 DOI: 10.1111/nph.12295
6) Hungate BA, Duval BD, Dijkstra P, Johnson DW, Ketterer ME, Stiling P, Cheng W, Millman J, Hartley A, Stover DB, 2014. Nitrogen inputs and losses in response to chronic CO_2 exposure in a sub-tropical oak woodland. *Biogeosciences Discussion* 11:61-106

Summary of Findings

Figure 1. Increased plant carbon and nitrogen content, but no effect on total ecosystem carbon or nitrogen content. (Ref 1)

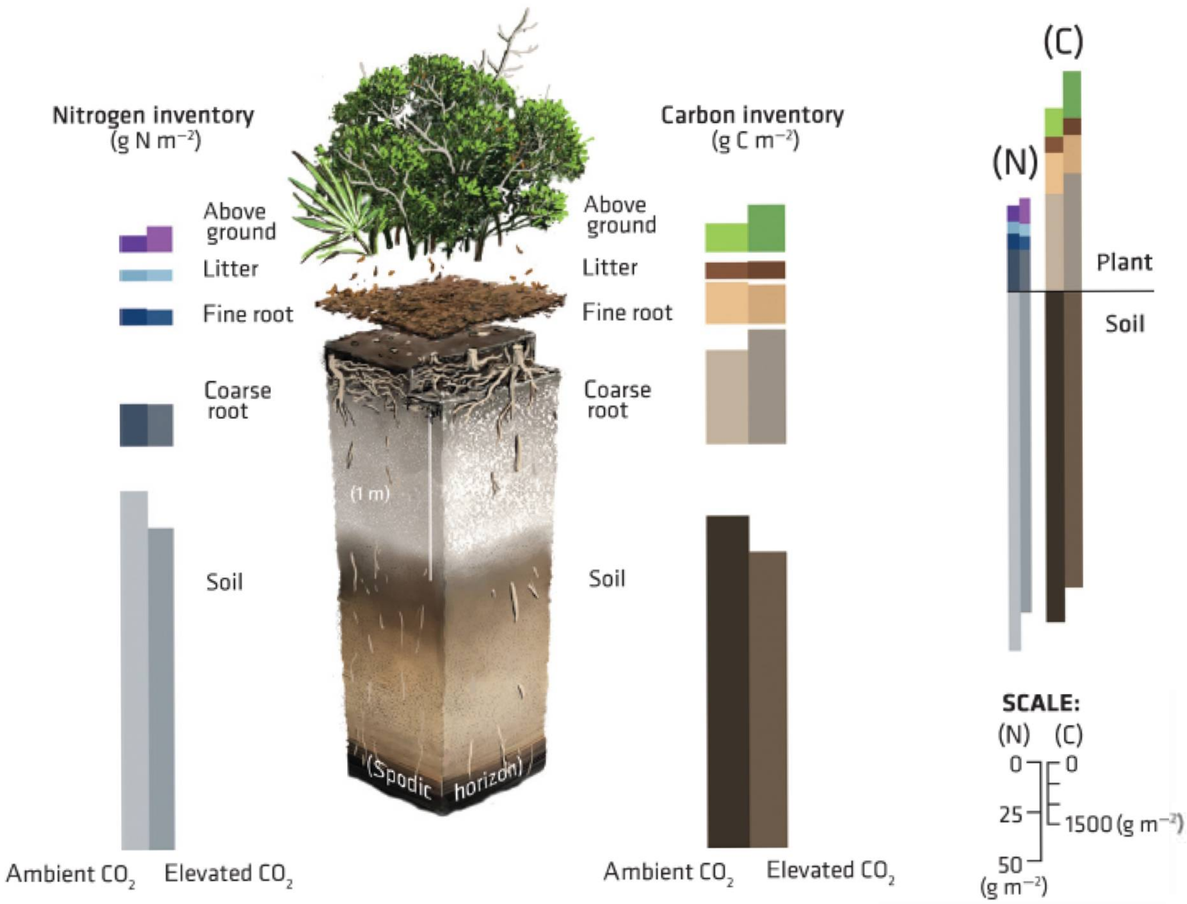

Figure 2. The effect of elevated CO_2 on NPP declines with time since disturbance (Ref 2)

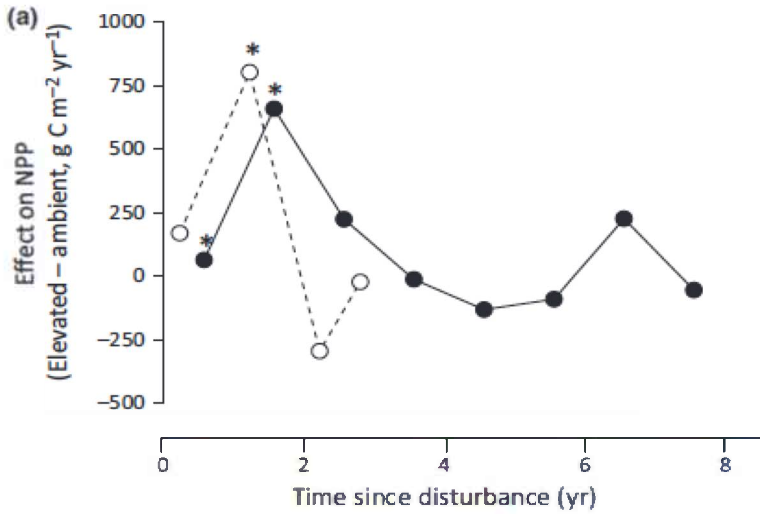

Figure 3. Root biomass responds more strongly to elevated CO_2 immediately after disturbance by fire and hurricane. (Ref 3)

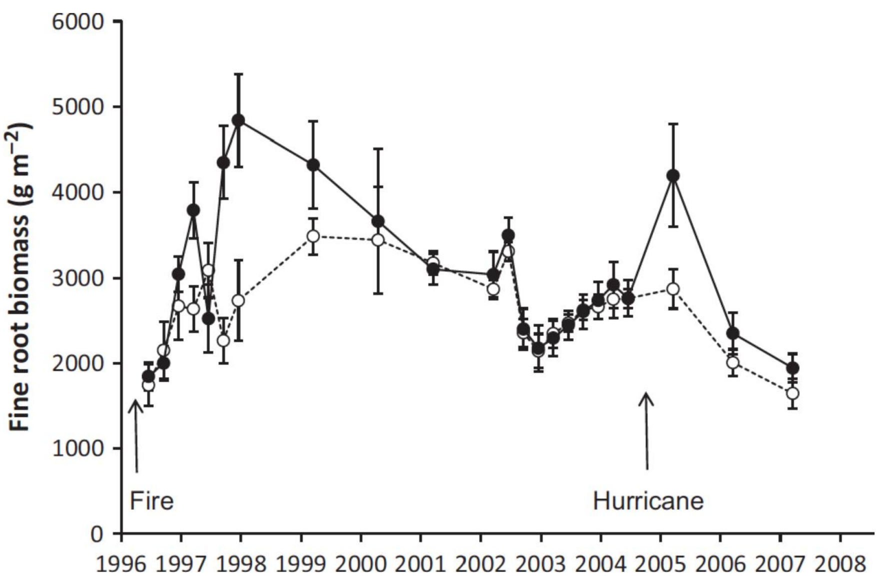

Figure 4. Typical patterns of reduced insect herbivory observed in response to elevated CO_2 for the two most abundant oak species. Elevated CO_2 treatment is shown in black bars, ambient CO_2 in white bars. (Ref 4)

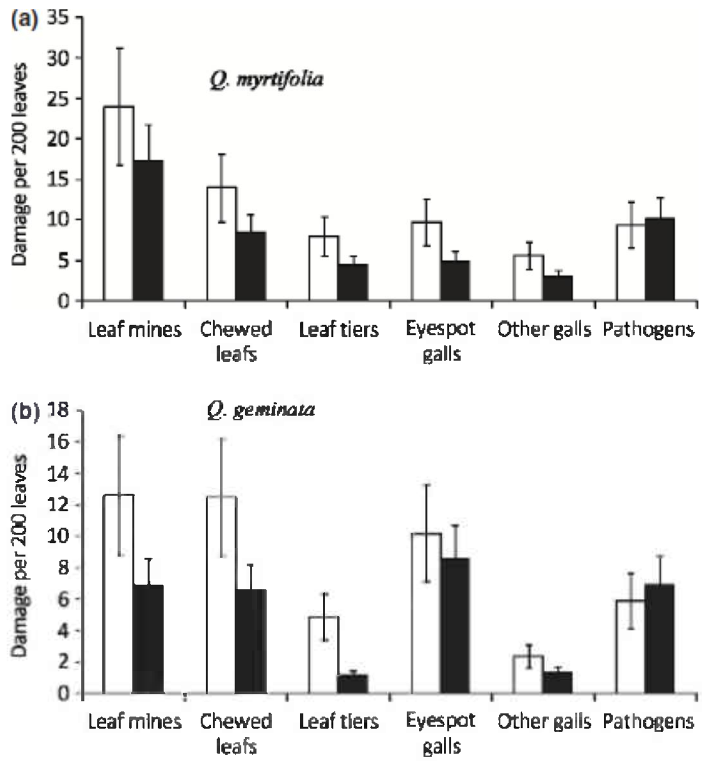

Figure 5. Recover of added tracer ^{15}N as a function of its depth distribution. Higher β values indicate relatively more ^{15}N in deeper soil layers, whereas low β values indicate concentration of ^{15}N at the soil surface.
β describes the depth distribution of ^{15}N where $p = 1-\beta^d$, and p is the cumulative proportion of ^{15}N encountered from the surface to depth d (in cm). Ref 6)

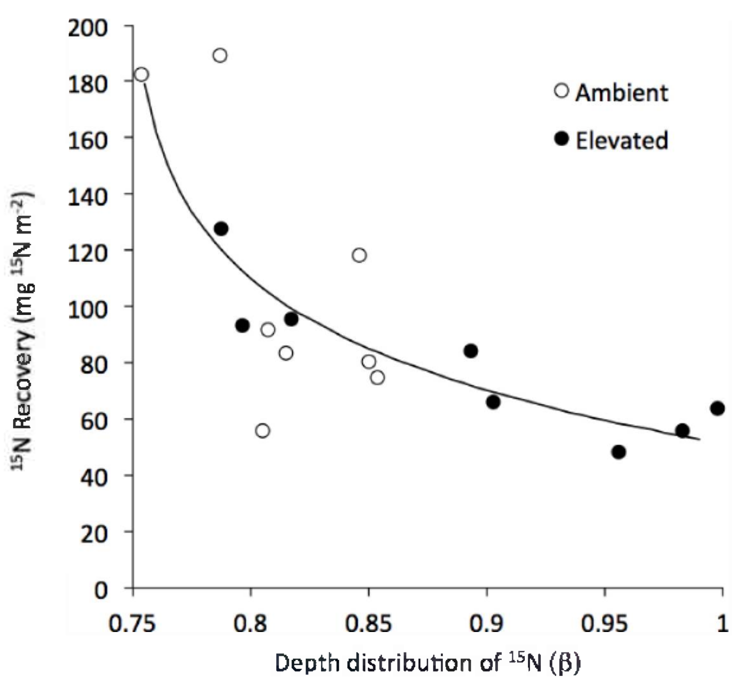

Figure 6. Response of nitrogen fixation to 11 years of exposure to elevated CO_2. Top panel shows rates of nitrogen fixation in the elevated and ambient CO_2 treatments. Bottom panel shows the response to elevated CO_2 as a function of time since disturbance.