

Summary

A decade of chronic exposure to elevated CO₂ 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 CO₂ 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 CO₂ are likely to overestimate future carbon uptake by the terrestrial biosphere.

The stimulation of net primary production by elevated CO₂ 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 CO₂ altered element cycles in this experiment, causing more rapid rates of element transfer from soils to plants. For nitrogen, elevated CO₂ increased N losses via leaching, a result inferred from the coupling of reduced tracer ¹⁵N recovery over time and increased ¹⁵N distribution at depth. If increased N losses are a general response to elevated CO₂, N limitation will become exacerbated over time, reducing productivity responses of ecosystems to elevated CO₂.

Elevated CO₂ reduced foliar nitrogen concentrations, in turn reducing herbivory on all plant species. Despite reducing herbivory, elevated CO₂ did not alter the abundance of the predators or parasitoids of insect herbivores, indicating that the trophic effects of elevated CO₂ did not propagate up the food web. After cessation of the CO₂ treatment, there were no apparent legacy effects of prior CO₂ exposure, whether for root biomass and root growth, or herbivory and insect abundance. At least for these responses, the effects of elevated CO₂ 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 ¹⁵N

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 CO₂ 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 CO₂ 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 CO₂. *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 CO₂ 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 CO₂ 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)

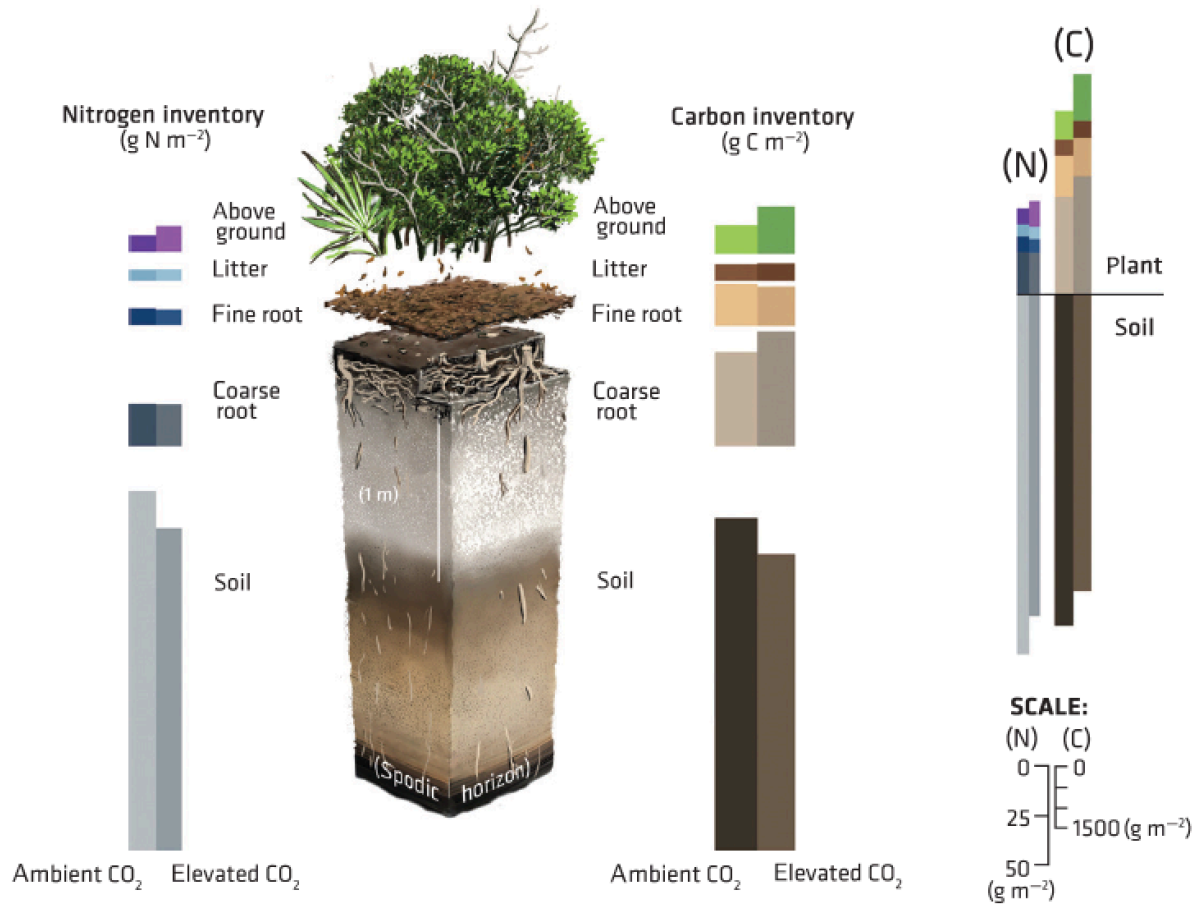


Figure 2. The effect of elevated CO₂ on NPP declines with time since disturbance (Ref 2)

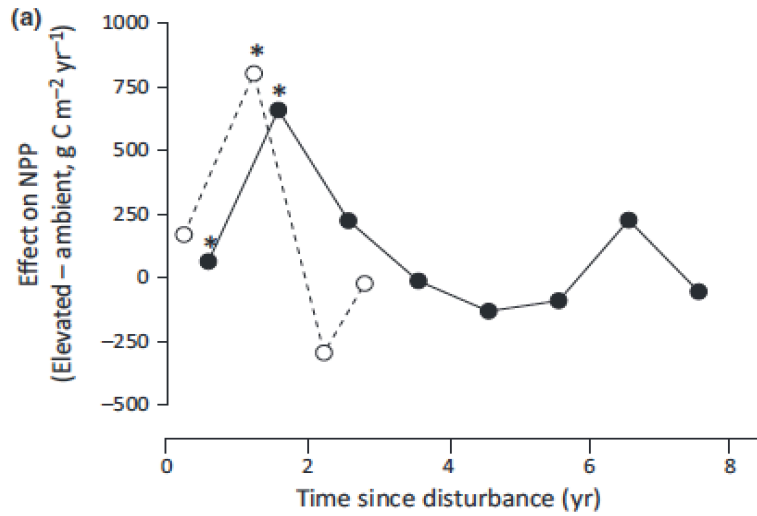


Figure 3. Root biomass responds more strongly to elevated CO₂ immediately after disturbance by fire and hurricane. (Ref 3)

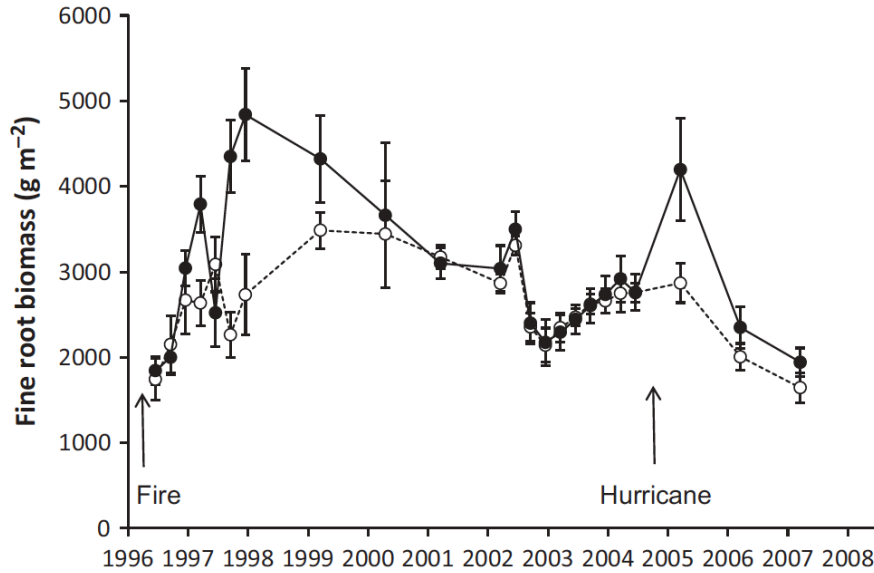


Figure 4. Typical patterns of reduced insect herbivory observed in response to elevated CO₂ for the two most abundant oak species. Elevated CO₂ treatment is shown in black bars, ambient CO₂ in white bars. (Ref 4)

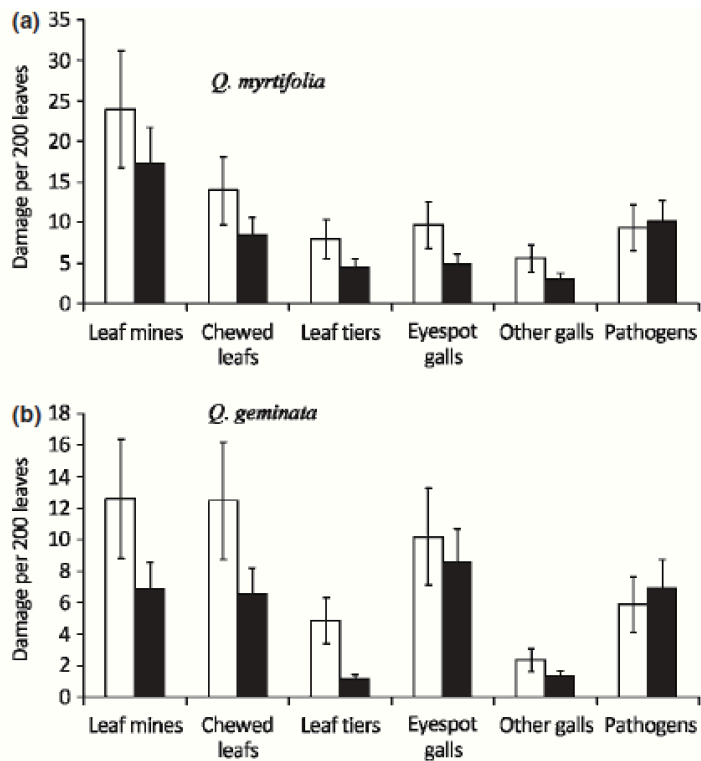


Figure 5. Recover of added tracer ¹⁵N as a function of its depth distribution. Higher β values indicate relatively more ¹⁵N in deeper soil layers, whereas low β values indicate concentration of ¹⁵N at the soil surface. β describes the depth distribution of ¹⁵N where $p = 1 - \beta^d$, and p is the cumulative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

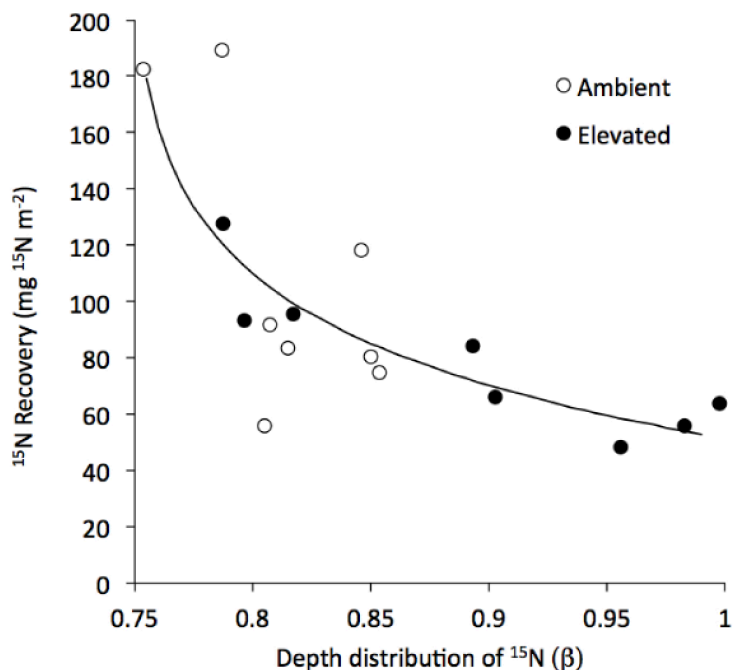


Figure 6. Response of nitrogen fixation to 11 years of exposure to elevated CO_2 . Top panel shows rates of nitrogen fixation in the elevated and ambient CO_2 treatments. Bottom panel shows the response to elevated CO_2 as a function of time since disturbance.

