Overview

Amongst the most important environmental changes experienced by terrestrial vegetation over the last century has been the increase in ambient carbon dioxide (CO₂) concentrations, with a projected doubling in CO₂ from pre-industrial levels by the middle of this century. Accurate prediction of land-atmosphere exchange of mass, energy, and momentum requires the consideration of plant biochemical, ecologicalphysiological and structural acclimation to modifications of the ambient environment. Here we present work that utilizes a detailed, vertically resolved canopy-atmosphere exchange model (MLCan), to examine the responses of central US soybean and maize canopies to elevated CO₂.

Free Air Carbon Enrichment (FACE) technology has provided significant insight into the functioning of vegetation in natural conditions under elevated CO₂. Observations from the SoyFACE experimental facility (Savoy, Illinois, USA) guide this work by providing estimates of changes in leaf states and fluxes under elevated CO₂ (550 ppm) for both soybean and maize. SoyFACE observations are routinely made for canopy-top foliage, leaving open the question of how vegetation responses scale to the canopy. We address this question here.

Observations at SoyFACE indicate a 10% increase in leaf area (Structural acclimation, SA), a 9% reduction in Rubisco carboxylation capacity (biochemical acclimation, BA), and a variable reduction of stomatal conductance for soybean (C₃) due to elevated CO₂ (Ecophysiological acclimation, EA). Maize (C₄) has been shown to only experience ecophysiological acclimation.

A set of simulations are conducted to untangle the influences of observed chemical, structural and ecophysiological acclimations

Impacts of Structural and Ecophysiological Acclimation

Top Panel: Soybean LAI augmentation results in mean noon-time increases in shortwave absorption of 15 [W m⁻²] concentrated in the upper canopy. This results in shading of lower canopy, where foliage can more efficiently utilize radiation.

Bottom Panel: Structural acclimation also results in a reduced energy flux into the soil, with implications for soil biogeochemical reactions.

Within-Canopy and Canopy-Integrated Flux Impacts

Increases in \( \text{A} \) and reductions in \( \text{LE} \) for soybean are localized around the LAI maximum under elevated CO₂. \( \text{A} \) increase through maize canopy is negligible (note difference in scales for soy and maize plots), with \( \text{LE} \) reduction under elevated CO₂ much larger and more uniformly distributed. Increase in \( \text{A} \) for soy due to CO₂ fertilization partially offsets reduction in \( \text{LE} \) due to stomatal closure.

For soy (C₃), CO₂ fertilization and acclimations accounted for mean 30% increase in CO₂ uptake and 7% reduction in transpiration. Impact of greater LAI was to reduce net CO₂ uptake due to greater respiration losses. Maize (C₄) had a negligible increase in CO₂ uptake, but a 15% net reduction in transpiration, with implications for interactions with daytime boundary layer and climate.

Summary

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References


