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A novel plant-mycorrhiza interaction model improves representation of plant responses to elevated CO_2

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Rising atmospheric CO_2 concentrations may lead to a higher carbon (C) uptake by plants and thus enhanced plant growth but the extent to which such growth is limited by nutrient availability is still uncertain. Most current global vegetation models are able to reproduce short-term NPP responses, but fail to predict long-term biomass development, because of a poor representation of nutrient dynamics. Mycorrhiza-plant interactions are essential for plant nitrogen (N) nutrition in many ecosystems. However, their role in predictions of biomass responses to elevated CO_2 is still highly uncertain.

We present a new framework to simulate plant-mycorrhiza interactions in a land-surface model that focusses on capturing the important processes responses rather than characterisation of responses per mycorrhizal type or morphology. The framework includes a representation of the effects of mycorrhizae on inorganic N uptake, uptake of organic forms of N, as well as the potential of mycorrhizae to increase the decomposition of soil organic material. The model further simulates the trade-off between plants' C allocation to mycorrhizae and N export from mycorrhizae to plants. These two aspects allow elucidating the implications of increased plant N demand under elevated CO_2 for the role of mycorrhizae in the rhizosphere dynamics and plant growth. We show that the inclusion of mycorrhizae generally improves plants' nutrition status and that including different N uptake processes affects vegetation growth under similar soil N availability.

We evaluate this new model with observations from two FACE sites, the Duke and Oak Ridge (ORNL) forest experiments. We show that the inclusion of mycorrhizal processes can better represent the observed increase N uptake compared to a model that only accounts for plant root nutrient uptake. We conclude that a land-surface model that includes plant-mycorrhiza processes can provide better predictions of plant growth under nutrient limitation and highlight the need for further observations to constrain essential parameters in this new model to improve our understanding of future vegetation responses under climate change and elevated CO_2.