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Towards the integration of mycorrhizal processes into assessments of ecosystem carbon-nitrogen dynamics in forest ecosystems under elevated CO_2

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Mycorrhizal interactions between plants and soil are essential for plants‘ nitrogen (N) nutrition. Especially in N limited conditions, mycorrhizal fungi can enhance plants' growth by supporting their N acquisition. However, mycorrhizae do not only provide N for plants, but also affect carbon (C) flows in ecosystems as plant C investment into mycorrhizal fungi shifts C allocation from vegetation to soils and contributes to a stronger release of C to the atmosphere through an increased turnover of soil organic matter (SOM). Despite their importance, mycorrhizal fungi are rarely included into current global land-surface models due to a lack of knowledge about important processes within these interactions. This omission may have important consequences for their ability to capture the response of terrestrial vegetation to elevated atmospheric CO_2 concentrations.

We developed a new modelling framework within the terrestrial biosphere model QUINCY (QUantifying Interactions between terrestrial Nutrient CYcles and the climate system) to simulate the role of mycorrhiza associated processes on plant C allocation and plant-soil interactions. Owing to the lack of available data to parameterise mycorrhizae in detail, we characterise mycorrhizal types based on their functionalities within the ecosystem instead of their morphology: uptake of mineral N by mycorrhizae, mycorrhizal N uptake from organic material, and mycorrhizal effects on the speed of SOM decomposition. The model tracks the investment of C into mycorrhizae, the subsequent effects on plant C and N economy, as well as the effect on SOM dynamics, and therefore predicts changes not only in the C allocation, but also in the C storage potential of the entire ecosystem.

At the example of the Duke Free-Air CO_2 Enrichment (FACE) experiment, we show that the interaction of mycorrhizal fungi with SOM is important to understand observations from ambient as well as from elevated CO_2 treatments. We explore the robustness of these predictions by a systematic parameter uncertainty study and highlight crucial data gaps. This result emphasizes the importance of the inclusion of mycorrhizal fungi into land-surface models in order to improve model predictions with respect to changing climate conditions and rising atmospheric CO_2 concentrations.