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Modeling forest C and N allocation responses to free-air CO_2 enrichment

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Vegetation allocation patterns and soil-vegetation partitioning of C and N are predicted to change in response to rising atmospheric concentrations of CO_2. These allocation responses to rising CO_2 have been examined at the ecosystem level through through free-air CO_2 enrichment (FACE) experiments, and their global implications for the timing of progressive N limitation (PNL) and C sequestration have been predicted for $\sim$100 years using a variety of ecosystem models. However, recent FACE model-data syntheses studies [1,2,3] have indicated that ecosystem models do not capture the 5-10 year site-level ecosystem allocation responses to elevated CO_2. This may be due in part to the missing representation of the rhizosphere interactions between plants and soil biota in models.

Ecosystem allocation of C and N is altered by interactions between soil and vegetation through the priming effect: as plant N availability diminishes, plants respond physiologically by altering their tissue allocation strategies so as to increase rates of root growth and rhizodeposition. In response, either soil organic material begins to accumulate, which hastens the onset of PNL, or soil microbes start to decompose C more rapidly, resulting in increased N availability for plant uptake, which delays PNL.

In this study, a straightforward approach for representing rhizosphere interactions in ecosystem models was developed through which C and N allocation to roots and rhizodeposition responds dynamically to elevated CO_2 conditions, modifying soil decomposition rates without pre-specification of the direction in which soil C and N accumulation should shift in response to elevated CO_2. This approach was implemented in a variety of ecosystem models ranging from stand (G'DAY), to land surface (CLM 4.5, O-CN), to dynamic global vegetation (LPJ-GUESS) models.

Comparisons against data from three forest FACE sites (Duke, Oak Ridge & Rhinelander) indicated that representing rhizosphere interactions allowed models to more reliably capture responses of ecosystem C and N allocation to free-air CO_2 enrichment because they were able to simulate the priming effect. Insights were therefore gained into between-site differences observed in forest FACE experiments, and the underlying physiological and biogeochemical mechanisms determining ecosystem C and N allocation responses to elevated CO_2.

References

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