Digging deeper: fine-root responses to rising atmospheric CO_2 concentration in forested ecosystems

Colleen M. Iversen, Oak Ridge National Laboratory

Introduction

- The distribution of fine (< 2 mm diameter) tree roots throughout the soil profile affects important ecosystem processes such as root longevity and decomposition rates, as well as soil nutrient cycling.

Methods

- I surveyed the literature to determine whether elevated [CO_2] may lead to deeper rooting distributions in forested ecosystems. I focused on forests exposed to elevated [CO_2] in relatively intact soil systems (i.e. free-air CO_2 enrichment , FACE, experiments and open- and closed-top chambers).
- I examined the potential mechanisms for, and consequences of, deeper rooting distributions under elevated [CO_2] as they relate to ecosystem carbon (C) and nitrogen (N) cycling.

Results

- CO_2-enrichment resulted in deeper rooting distributions in three-quarters of FACE and chamber experiments across a diverse set of forested ecosystems (Fig. 1).
- Rooting depth responses were dynamic through time, and differed among studies (Fig. 1). The methodology used to examine root depth distribution, as well as the depth examined, also differed among studies.

Discussion

Potential causes and consequences of deeper roots

- Deeper rooting distributions in CO_2-enriched forests are probably a result of three interacting factors (Fig. 2): (a) increased resource demand by trees, (b) greater C available for allocation belowground, and (c) increased competition from microbes or other roots for scarce resources in shallower soil.
- The depth at which fine roots are produced may influence root chemistry, physiological function, and mycorrhizal infection, leading to slower root turnover and altered N uptake rates (Fig. 2).
- Soil processes such as microbial decomposition are slowed at depth in the soil, potentially affecting the rate at which root detritus becomes incorporated into soil organic matter (Fig. 2).
- Novel analyses may be required to determine the consequences of increased root proliferation at deeper soil depths under elevated [CO_2] for ecosystem C and N cycling.

Incorporating rooting depth into model projections

- Models do not currently incorporate information on root turnover and soil carbon and nitrogen cycling at depth in the soil (Fig. 3). Modification is necessary to accurately represent processes associated with altered rooting depth distributions.
- Progress in understanding and modeling the interface between deeper rooting distributions and soil processes will be critical in projecting the sustainability of forest responses to rising atmospheric [CO_2].

Acknowledgements

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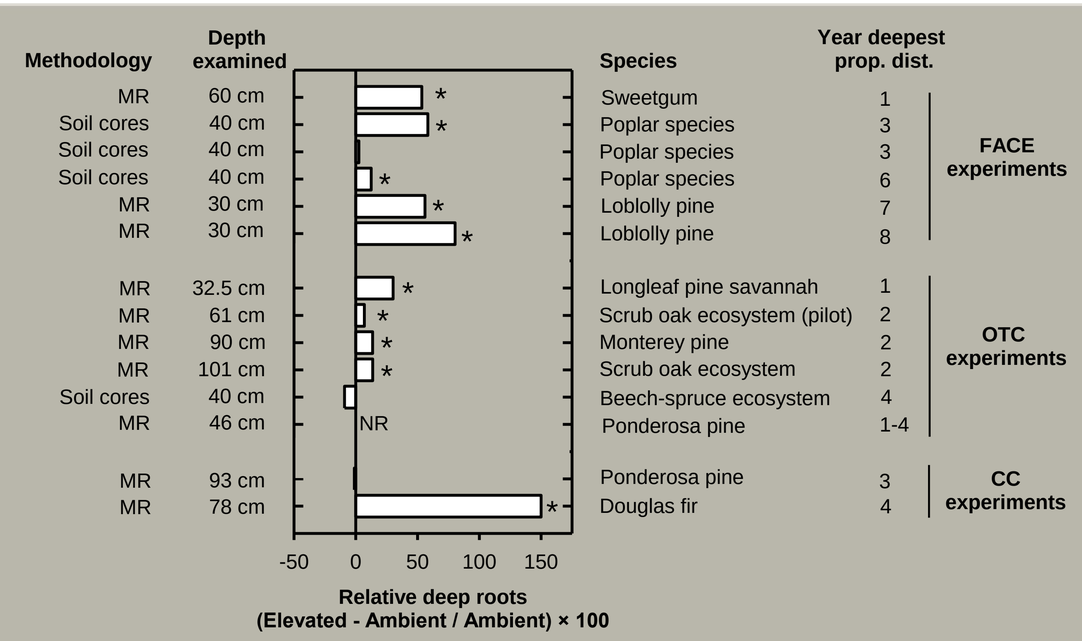

Fig. 1 Where rooting depth was reported, ¾ of CO_2-enrichment experiments in forests observed deeper rooting distributions. However, rooting depth distribution was reported in only 14 out of 31 studies. MR, minirhizotron; OTC, open-top chamber; CC, closed chamber.

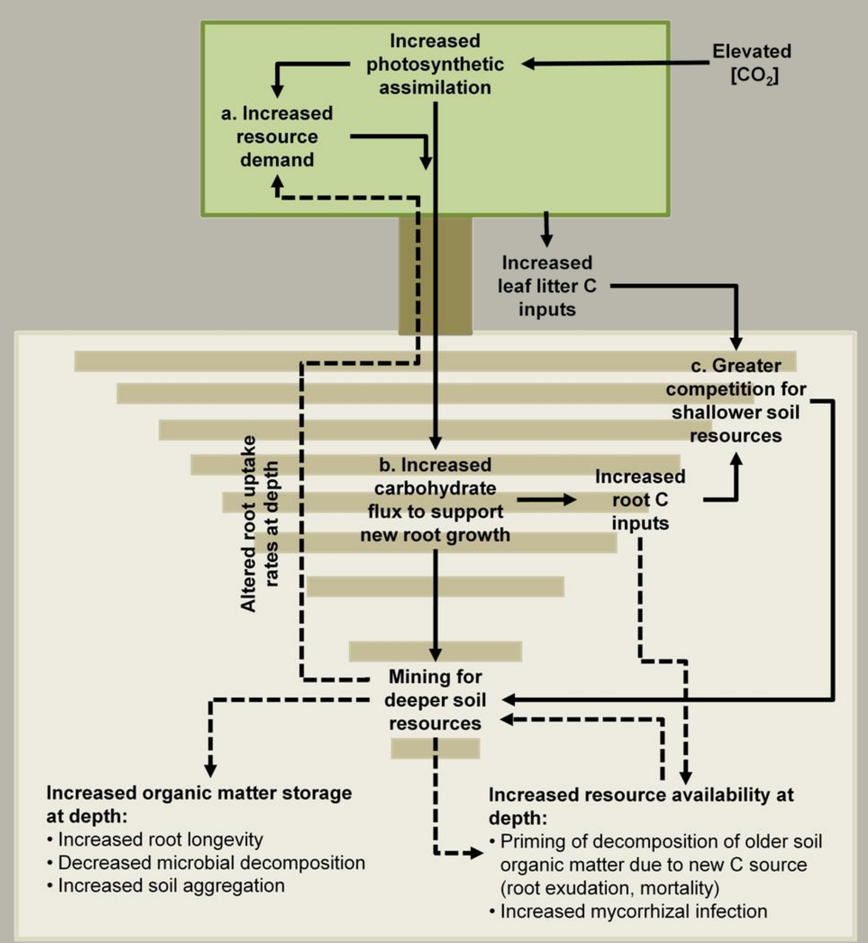

Fig. 2 A conceptual model of the processes leading to deeper rooting distributions under elevated [CO_2] (solid lines), and potential ecosystem feedbacks from the production of deeper roots (dashed lines).

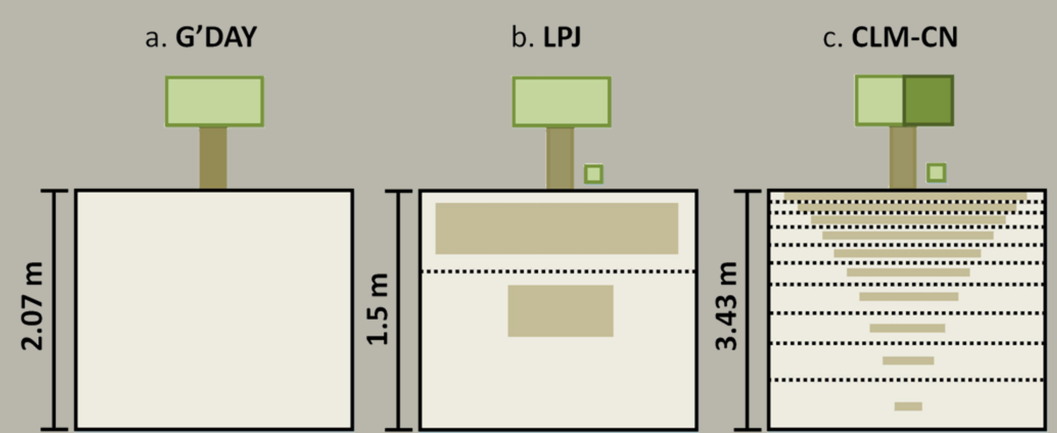

Fig. 3 A small subsample of ecosystem and land surface models, represented by schematic diagrams. The diagrams are separated into canopy, stem, roots, and the soil system. Belowground, dotted lines indicate soil layers. Thus far, the soil layers are used solely to model water distribution and transpiration dynamics; soil C and N dynamics are modeled as one 'depth' (dark outline) in all three models. Total soil depth is indicated on the left of each diagram.

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