

Invited Feature

Belowground Processes and Global Change¹

The evidence for global change is increasingly apparent. Population growth and increased resource consumption are altering atmospheric composition and transforming landscapes. While many aboveground changes are obvious, there are important belowground changes that are less visible yet equally relevant. This Invited Feature examines interactions between belowground processes and global change, highlighting feedbacks between them. It also emphasizes the importance of belowground processes in successfully predicting the ecological effects of global change. The goals for the feature are to help provide frameworks for such predictions, to present evidence from recent experiments, and to examine the use of models for predicting the extent and consequences of global change.

Two aspects of the ecological effects of global change most closely link the six papers in the feature: soil carbon dynamics and vegetation change. Trumbore begins the feature by discussing the importance of soil organic matter for the global carbon cycle. She highlights the use of radiocarbon data to estimate the proportion of soil organic matter that is relatively young (decades or less), the turnover time of that carbon, and the extent to which relatively young soil organic carbon contributes to soil respiration. Such questions are important for a basic understanding of soil processes, but they have practical relevance for the Kyoto accord and for global carbon sequestration. Insight into soil and ecosystem carbon fluxes is also the theme of Ehleringer et al., but using stable isotopes rather than radioisotopes. They discuss ecosystem and global patterns of respiration, including an analysis of how to partition fluxes into heterotrophic and autotrophic components. General patterns of soil organic carbon, climate, and vegetation are the subject of the Jobbágy and Jackson contribution. Their analysis, using data from several thousand soil cores in three global soil databases, shows that climate is a predictably dominant control of the amount and vertical distribution of soil carbon, but that vegetation type modifies the observed patterns significantly. Consequently, changes in plant life forms (e.g., grasses, shrubs, and trees) with vegetation change may have important consequences for organic carbon distributions and longer-term carbon storage at different depths in the soil, particularly relatively deep layers.

The second group of papers builds upon the first group to examine experimental and simulated responses to global change. Allen et al. describe results from the first Free Air CO₂ Enrichment (FACE) experiment in a forest ecosystem. They examine changes in belowground properties, including root and microbial biomass, litterfall, net N mineralization, and CO₂ flux from the soil. They also use isotopic tools, as discussed in Trumbore and Ehleringer et al., to estimate inputs of new carbon to the soil. Climate change (and its interaction with soil and vegetation) is the subject of the paper by Daly et al. They describe a new dynamic vegetation model that simulates vegetation distributions and carbon and nutrient fluxes in response to climate scenarios. It combines aspects of two widely used models (MAPSS and CENTURY as biogeography and ecosystem biogeochemistry models, respectively) to address how changes in belowground attributes affect vegetation type, productivity, and trace gas emissions. A fire module stresses interactions among plant functional types at the landscape scale. For the final paper, Jackson et al. examine the belowground consequences of vegetation change. Deforestation, afforestation, and woody plant encroachment typically alter the relative abundance of grasses, shrubs, and trees. These changes in plant life forms, in turn, can change ecosystem properties, including soil nutrient distributions, the water balance, and plant primary productivity. Since models are an increasingly important tool for predicting the effects of vegetation change, the paper discusses ways current models differ in their treatment of belowground processes and how these differences affect model outputs.

¹ Reprints of the 87-page Invited Feature are available for \$13.00 each. Prepayment is required. Order reprints from the Ecological Society of America, Attention: Reprint Department, 1707 H Street, N.W., Suite 400, Washington, DC 20006.

Several activities contributed to the ideas presented in this feature. These include workshops at the National Center for Ecological Analysis and Synthesis, the Dahlem Conference “Integrating Hydrology, Ecosystem Dynamics, and Biogeochemistry in Complex Landscapes,” and the joint Global Change and Terrestrial Ecosystems (GCTE)/Land Use and Cover Change (LUCC) open science conference in Barcelona, Spain. The papers presented here contribute to the efforts of GCTE and BAHC (Biospheric Aspects of the Hydrological Cycle), core projects of the International Geosphere Biosphere Programme (IGBP). GCTE’s twin goals are (1) to predict the effects of changes in climate, atmospheric composition, and land use on terrestrial ecosystems and (2) to determine how these effects lead to feedbacks with the atmosphere and climate. BAHC’s central focus is the interaction of vegetation with the physical processes of the hydrological cycle.

Ultimately what we seek as ecologists is a better understanding of ecology as an integrated science. Dichotomies of “plant and animal” or “belowground and aboveground” are conveniences, allowing processes to be broken down conceptually. Reassembling the parts is eventually necessary. The challenges of global change research have made that reassembly especially important, blurring traditional distinctions among ecology, biogeochemistry, hydrology, atmospheric science, and other disciplines. That blurring is productive and essential for solving today’s global problems and for the continued growth of the diverse science of ecology.

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Key words: belowground processes; climate change; elevated CO₂; global carbon sequestration; nitrogen; respiration; roots; soil organic matter; stable isotopes; vegetation change; vegetation model; water fluxes.

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