RAPID N$_2$ FIXATION IN PINES, ALDER, AND LOCUST: EVIDENCE FROM THE SANDBOX ECOSYSTEM STUDY

BERNARD T. BORMANN
USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon 97331 USA

F. HERBERT BORMANN
School of Forestry and Environmental Studies, Yale University, New Haven, Connecticut 06511 USA

WILLIAM B. BOWDEN
School of Forestry, University of New Hampshire, Durham, New Hampshire 03824 USA

ROBERT S. PIERCE
USDA Forest Service, Northeastern Forest Research Station, Durham, New Hampshire 03824 USA

STEVE P. HAMBURG
Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66405 USA

DEANE WANG AND MICHAEL C. SNYDER
School of Natural Resources, University of Vermont, Burlington, Vermont 05405 USA

C. Y. LI
USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon 97331 USA

RICK C. INGERSOLL
Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado 80309 USA

Abstract. Not all nitrogen (N) inputs have been accounted for in forested ecosystems. We sought to account for N$_2$ fixation and dry deposition using a lysimeter mass–balance approach. Large sand-filled, field lysimeters were used to construct 5-yr nitrogen budgets for two N$_2$-fixing trees, two pines, and a nonvegetated control soil. This approach is a promising and straightforward technique for quantifying otherwise difficult-to-measure fluxes. Accurate assessment of changes in N storage combined with direct measurement of N inputs in precipitation and losses from leaching allowed us to estimate fluxes. Gains of N in pine systems were greatest in vegetation and litter, overshadowing combined losses from mineral soil and leaching by about threefold. Rapid acetylene reduction in pine rhizospheres and in cultures from washed roots suggests that unexplained gains are due to associative N$_2$ fixation. These results provide strong evidence for N$_2$ fixation in pine systems of ≈50 kg·ha$^{-1}$·yr$^{-1}$ N. The symbiotic N$_2$-fixing trees black locust and black alder fixed 2 and 5 times more N$_2$, respectively, than did pines. In all systems, input in precipitation and dry deposition were relatively unimportant to the N budget. Unexplained losses of N from the nonvegetated control suggest that denitrification is an important flux. Mineral soil organic matter declined sharply and significantly in pines (20%) and even more so in the nonvegetated control (40%). Symbiotic N$_2$-fixing trees caused a small, nonsignificant increase in mineral soil organic matter and large, significant increases in litter layer organic matter. Bulk density (0–20 cm) declined by 5% under symbiotic N$_2$-fixing trees and increased by 5% in one pine sandbox. Correction for soil expansion or collapse did not greatly alter estimates of unexplained N or N$_2$ fixation. Pines with rhizospheres that fix N$_2$ at the rates we observed might be used to restore degraded land and to create silvicultural systems that are N self-sufficient. We first need to better understand the microbiology, tree genetics, and soil conditions that lead to rapid N$_2$ fixation in pine ecosystems.

Key words: acetylene reduction; associative nitrogen fixation; dry deposition; Hubbard Brook; land restoration; mass–balance; nitrogen volatilization; organic matter losses; rhizosphere; soil expansion; sustainable forestry; unexplained nitrogen.