



## Foreword

The papers in this special issue grew out of a workshop held in Termás de Chillán, Chile, in December of 1996. This was the fourth of a series of workshops that comprise the core activities of the International SCOPE Project on Nitrogen Transport and Transformations: A Regional and Global Analysis; the first of these workshops also resulted in a special issue of this journal (*Biogeochemistry* 35(1): 1996). The Chilean workshop's central purposes were to compare nitrogen cycling in the relatively pristine temperate South Americas with the generally more polluted temperate North Americas, and to compare both with nitrogen cycling in the tropical Americas. More than 40 scientists from 12 different countries helped make this meeting a success, and their enthusiasm for the ideas generated during the meeting carried over into the production of the twelve manuscripts included in this volume. It is my belief that these manuscripts are rich in exciting new ideas and theory; I hope the readers of *Biogeochemistry* share this opinion.

The first contribution in this issue is by Jorge Corredor; he provides a brief but enlightening and appropriate history of the word nitrogen. As he points out, many of us use nitrogen and related words on a near-daily basis, yet few of us know their etymology. The next paper is by Elisabeth Holland and colleagues; they synthesize data on N deposition and N emissions as well as use a global model of tropospheric chemistry and transport (MOGUNTIA) to provide an updated view of reactive N exchanges between the terrestrial biosphere and the atmosphere.

The next nine papers can be thought of as three somewhat distinct sections of this volume. The first three of these nine all focus on N cycling in terrestrial ecosystems, with an emphasis on the moist tropics. Luiz Martinelli et al. present data on  $^{15}\text{N}$  values of both foliage and soils from a variety of tropical and temperate forests, including forests along a soil age gradient in the Hawaiian Islands. They show substantial differences in  $^{15}\text{N}$  patterns between temperate and tropical systems, and argue that these isotopic data provide time-integrated evidence that N cycles in relative excess in many tropical forests. Pamela Matson and colleagues then present a theoretical analysis of

how moist tropical forests may respond to increasing N deposition in the next few decades; they contend that the naturally N-rich state of these systems will lead to substantially different responses to increasing N additions than has been seen in the temperate zone. Finally, Tamara Chestnut and co-authors present a nitrogen budget for hillslope tabonuco forest stands in Puerto Rico; such budgets for tropical systems are both rare and sorely needed.

The next three papers address N cycling in aquatic ecosystems, again with a focus on the tropics. John Downing and the other members of the aquatic working group from Chillán examine how land use and land cover changes in the tropics may affect N cycling in both freshwater and coastal marine ecosystems. They conclude their analyses with the hypothesis that alterations to the nitrogen cycle will affect tropical aquatic systems to an even greater extent than what has already been seen in the temperate zone. Bill Lewis and co-authors then summarize N export from thirty-one relatively pristine watersheds, thereby providing valuable information on the baseline conditions against which we can assess anthropogenic effects on the N cycle. They focus on the tropics, but present data from a few temperate watersheds as well, and show that N yields and concentrations in the tropical systems are much greater than those seen in the temperate watersheds. Jorge Corredor et al. conclude this group of papers with a look at nutrient limitation and its response to human activities in tropical marine systems, with a focus on the Caribbean.

The next three papers all tackle an enduring paradox in ecosystem ecology: the question of why N limitation remains so widespread despite the occurrence of organisms that can fix atmospheric nitrogen. Eight years ago in this journal, Peter Vitousek and Bob Howarth published a widely read and influential analysis of this issue. Both scientists (along with co-authors) revisit the question here. Vitousek and Chris Field present a new simulation model of N fixation in terrestrial systems, one in which costs of fixation, N losses, light availability, P limitation and grazing are all addressed. They use this model to explore the potential constraints on fixation in the terrestrial biosphere, as well as how both N fixation and limitation may respond to elevated CO<sub>2</sub>. Howarth et al. also describe a new model of N fixation, this time one designed for cyanobacteria in estuaries. Their conclusions, namely that a combination of biotic (especially grazing) and biogeochemical (notably Mo availability) constraints can interact to keep rates of N fixation low to absent in estuarine systems, have striking parallels to the Vitousek and Field paper, and suggest that more general, unifying models of N fixation may be possible. Finally, Tim Crews concludes this section with an alternative view on the patterns in symbiotic N fixation that occur in the terrestrial biosphere. Crews argues that

the presence or absence of N-fixing plant symbioses should first be viewed in an evolutionary context, with a focus on the radiation of the family *Fabaceae*.

David Hooper and Loretta Johnson conclude the issue with an investigation of the interactions between nitrogen limitation and water availability in dryland ecosystems. They survey published data on responses to fertilizer across a broad-scale gradient in annual precipitation, and conclude that there is not a shift in primary limitation from water to N across this gradient, but that co-limitation better explains the data.

The Termás de Chillán workshop was sponsored by the Mellon Foundation and the Inter-American Institute for Global Change (IAI). The Mellon Foundation also supports the SCOPE Nitrogen Project. Bob Howarth and I served as co-chairs for the meeting; other members of the steering committee included Peter Vitousek, Doris Soto, Juan Armesto and Osvaldo Sala. Juan Armesto was the local host and suggested the wonderful location in which the workshop was held. The boundless energy and enthusiasm shown by participants both during and after the meeting were instrumental to the success of this volume; my sincere thanks to all of you.

Alan R. Townsend, Editor  
*University of Colorado, U.S.A.*