A Biogeoscience Approach to Ecosystems

Biogeoscience is a rapidly growing interdisciplinary field that aims to bring biological and geophysical processes together. This book builds an enhanced understanding of ecosystems by focusing on the integrative connections between ecological processes and the geosphere, hydrosphere, and atmosphere.
Each chapter provides studies by researchers who have contributed to the biogeoscience synthesis, presenting the latest research on the relationships between ecological processes, such as conservation laws and heat and transport processes, and geophysical processes, such as hillslope, fluvial and aeolian geomorphology, and hydrology. Highlighting the value of biogeoscience as an approach to understand ecosystems, this is an ideal resource for researchers and students in both ecology and the physical sciences.

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Preface

We are not students of some subject matter but students of problems. And problems may cut right across the boundaries of our subject matter and disciplines.

– Karl Popper, 1963. **Conjectures and Refutations: Growth of Scientific Knowledge**.

This is not an ecosystem textbook in the usual sense in being primarily about biology but rather it is a collateral book that introduces the physical environment into ecosystems using a biogeoscience approach. Why do this? A biogeoscience approach uses: 1) process- or mechanistic-based approaches and 2) formal (mathematical) models of governing equations that involve transport processes and continuity or conservation equations. Ecology has, in general, viewed the physical environment as a black box, using simple arrows to indicate the connections between the physical environment and ecological systems, but with minimal or no consideration of the operation of these physical environmental processes. The reasons for this are varied, but may be attributed partly to different approaches of problem solving in biological vs. geophysical sciences and to both disciplines not always understanding how the other could be connected in more than a descriptive or correlational manner.

The purpose of this book is to take advantage of progress in the geosciences (including geomorphology, soil science, hydrology, and meteorology/climatology) to advance the understanding of ecosystem science. The goal is to present these geoscience developments in a manner such that ecologists who have had limited exposure to these ideas and methods can gain an introduction and understanding of how these couplings can be used in ecosystem science. We intend the book not to be a *hopeful* discussion of what we should or could be doing to tie the disciplines together, but rather to be a set of chapters providing examples of explicit approaches and procedures of how such research has coupled successfully the fields of ecology and geoscience.

A quick look at the research areas of biogeoscience (Table 1.1) will note large and very active topics (e.g., geomicrobiology) that are not considered in this book. It is easy to think of topics that we could (should) have included in this book. However, this book cannot be definitive but reflects our and our chapter authors' choices of ecological-geoscience connections that illustrate a mechanistic and process-based approach. We have chosen topics that we feel would best cover some traditional areas of ecological interest. The chapters are assembled to follow a logical development of topics but can still be read independently.

This book could be used as an advanced undergraduate or graduate textbook in ecosystem processes with a strong emphasis on environmental coupling or as a supplementary text to standard ecosystem texts (e.g., Aber and Melillo, 1991; Waring and Running, 1998; Chapin *et al.*, 2002). Note that some of these ecosystem texts are intended for *one-term introductory* courses in ecology. For the adoption of this book into undergraduate courses we are thinking of senior level courses. It is possible that instructors of geoscience courses may also be interested in this textbook if they want to introduce ecosystem content and adopt a biogeoscience approach to the material.

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Table 1.1 Classification of research areas in biogeoscience[a] modified from Martin and Johnson, 2012.

Branch	Most Relevant Spheres	Comments
BIOGEOPHYSICS dominant (some biogeochemistry may be involved)		
Ecohydrology[b] Ecohydraulics	Biosphere, Hydrosphere Secondary: Lithosphere, Atmosphere	• Interactions between microorganisms/plants/animals and components of hydrologic cycle
Biogeomorphology[b] (sometimes called Ecogeomorphology)	Biosphere, Lithosphere Secondary: Hydrosphere, Atmosphere	• Interactions between microorganisms/plants/animals and geomorphic forms and processes
Biometeorology Bioclimatology	Biosphere, Atmosphere Secondary: Hydrosphere, Lithosphere	• Interactions between biosphere and atmosphere • Main difference is biometeorology involves time scales of order seasons or shorter, while bioclimatology involves time scales of order seasons or longer
Biophysical ecology	Biosphere, Hydrosphere, Lithosphere, Atmosphere	• Interactions between plants/animals and physical environment; may consider individuals and/or groups and physiological and/or behavioral responses
BIOGEOCHEMISTRY dominant (some biogeophysics may be involved)		
Elemental cycles	Biosphere, Hydrosphere, Lithosphere, Atmosphere	• May consider entire elemental cycle or aspects, such as: weathering, soil formation, biomineralization, rock-forming processes
Geomicrobiology (important in Palaeobiology, Astrobiology and Bio-Oceanography)	Biosphere, Lithosphere, Hydrosphere, Atmosphere	• Role of microbes and microbial processes in geological and geochemical processes and vice versa
COMBINED BIOGEOPHYSICS AND BIOGEOCHEMISTRY		
Ecopedology (Edaphology)	Biosphere, Lithosphere, Hydrosphere, Atmosphere	• Interactions between biology and regolith/soil
Bio-Oceanography	Biosphere, Hydrosphere, Atmosphere, Lithosphere	• Considers biological components of oceans (marine organisms and ecosystems) in relation to physical and chemical aspects of oceans
Palaeobiology Palaeoecology	Biosphere, Hydrosphere, Lithosphere, Atmosphere	• This grouping is defined on the basis of a unifying temporal scale (as per descriptor *palaeo*) • Often, stratigraphic record provides means to date and unravel past environments
Astrobiology	Spheres of other planets (comparisons made to Earth)	• Origin, evolution, distribution, and future of life in universe • Search for evidence of prebiotic chemistry, research into origins and early evolution of life on Earth http://en.wikipedia.org/wiki/Astrobiology-cite_note-about-1#cite_note-about-1

[a] Some disciplines use the terms “eco” or “ecology” as part of the descriptor, while other disciplines use the terms “bio” or “biology.” In such cases, we have attempted to follow what appears to be main convention in the literature for that discipline. In addition, some disciplines may place two relevant sub-disciplines in a particular order; for example ecohydrology vs. hydroecology. There may be significance in that the first term is seen as a descriptor for the primary second term. We have attempted to follow what appears to be the primary convention for that discipline, but for simplicity, we have not included all possibilities.
[b] To simplify our categorization, we have not included names of disciplines that have several sub-disciplines in their terminology, such as eco-hydrogeomorphology or eco-hydropedology. The classification quickly becomes cumbersome if all possibilities are included. However, the reader should be aware that such terms do exist in the research literature.