Change is an omnipresent aspect of the environment, so that the practical problem of predicting how terrestrial ecosystems might respond in the future to large-scale human-generated changes is a major challenge for ecologists. In *Terrestrial Ecosystems in Changing Environments*, Hank Shugart describes the fundamental ecological concepts, theoretical developments and quantitative analyses involved in understanding the responses of natural systems to change.

The key ecological concepts described include the ecosystem paradigm, niche theory, vegetation–climate relationships, landscape ecology and ecological modelling. A variety of ecological models are presented, and their applications in predicting responses to change are considered. The challenge of producing ecological models capable of predicting long-term and large-area ecosystem dynamics is reviewed and several examples are provided. Finally, a review of some of the exciting new findings regarding terrestrial landscapes and their feedback with their climatic setting are discussed in the context of human land-use and global change.

Terrestrial ecosystems in changing environments

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Terrestrial ecosystems in changing environments

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Contents

Preface

For the past decade or more, I have had the opportunity to be involved with one of the most exciting research areas in ecology and the geosciences: the efforts to understand the interactions of the major Earth systems of atmosphere, oceans and the terrestrial surface. This research area is sometimes referred to as 'global change biology' or 'global change ecology'. For research scientists, interest in this area has been stirred by the actions of international scientific co-ordinating committees (notably the IPCC (the Intergovernmental Panel on Climate Change) and the IGBP (the International Geosphere–Biosphere Programme)) and by public concerns as to the eventual effects of human alterations of the composition of the atmosphere, ocean and land. My own work in this area has focused mostly on the application of ecological models in an attempt to project the possible consequences of changes in climate and other conditions on forests and other terrestrial ecosystems.

A few years ago, it occurred to me that the opportunity for today's students to gain background for studies in global change ecology was rather limited. The scientists with whom I collaborated had arrived at their interest in studying global change by different and often circuitous routes. Some were palaeontologists or palaeoecologists interested in past ecosystems. The Earth has been highly variable climatically during its recent geological history and palaeoecological research leads naturally to wanting to understand better ocean–climate–vegetation interactions. Others have been drawn into global ecology by a desire to comprehend better the patterns of plants, animals and habitats over large areas. These scientists often applied a diverse array of technologies that are unique to our times: notably, the computational power to statistically interweave larger ecological and climatological data sets, the satellite technology to allow large surveys of the Earth's surface from space, instruments to measure fluxes of water, carbon dioxide, heat, chemicals to and from ecological systems, etc.

Still others with an interest in conservation of unusual plants and animals saw the destruction and damage of essential habitat for these organisms by a wide variety of large-scale causes (climate change, human land-use, human alteration of the environment) as the motivation to understand better Earth systems function. Even with these and other diverse avenues for becoming interested in global change, the availability of a text that could provide necessary background for a student potentially interested in the area seemed to me to be lacking.

There are a large number of excellent books that are technical compendia on the subject of global change. They often feature chapters written by particular experts on topics in global change and whole Earth system dynamics. These represent a rich source of information for the advanced scholar with some background in the area, but there was still a need for a text that would provide access to the field for students with a basic background in ecology and sciences. During a sabbatical leave from the University of Virginia in the 1993–4 academic year, I had the good fortune to serve as a Visiting Scientist with Australia's Commonwealth Scientific and Industrial Research Organisation, Division of Wildlife and Ecology and, at the same time, to be a Visiting Fellow with the Research School of Biological Sciences, Environmental Biology Department, Australian National University. These two outstanding Australian institutions are among the world leaders in the ecological aspects of global change. Among old friends, I set about writing this book.

During the time in Australia and additional time working at the University of Virginia in the summer of 1994, I produced a first draft of this book. Several colleagues and students were dragooned into reading all or part of the text. I taught a course to about 50 students per year in the Department of Environmental Sciences at the University of Virginia beginning in the fall of 1994. This course ('Issues in Global Change' EVSC 493/795) was taught to third- and fourth-year undergraduate/introductory graduate student level and has been taught every fall since. I used the draft as a photocopied text-book for this class and revised sections according to student comments. Eventually, I produced the book that follows.

This book is not solely intended to be a textbook (although it has worked as a text in my own teaching and could serve this purpose for others) and it is to some degree idiosyncratic. My own research career has moved from ornithology to plant ecology and now to global ecology. Having already mentioned that there are several rather different routes taken by research professionals to arrive at an interest in global ecology, it

seems appropriate to outline the path most familiar to me – which I have done. Any lecturer using this book as a text would indubitably draw heavily from his or her own experience in developing a course syllabus. There are some larger, pedagogical points that I hoped to demonstrate in developing this text. I wanted to stress the changing, non-equilibrium nature of the biosphere. I hoped to show that global ecological studies were not a new invention, rather they derived naturally from basic ecological constructs (niche theory, plant geography, the mosaic nature of landscapes). I wanted to use ecological models as examples in a discursive manner and to discuss model formulation and model results generally. With respect to this latter point, I have included a discussion on the history and basics of ecological modelling that is strongly derived from a course taught by Professor B. C. Patten at the University of Georgia (Athens) when I was a student there. Some may find even this rather gentle taste of mathematics daunting, but modelling is an essential part of prediction of the consequences of past or future environmental changes. I also wanted to provide some of the many results that reflect the potential impact of the changes that humankind has wrought on the Earth. These are found mostly in the later chapters of the book.

Funding from grants from US Federal Agencies, particularly the National Science Foundation (DEB-90202041: *Coupling of Ecosystem Process and Vegetation Pattern Across Environmental Gradients*), NASA (NAG 5-2295: *Multidiscipline Integrative Models of Forest Ecosystem Dynamics for the Boreal Forest Biome*; NAG 5-1018: *Forest Ecosystem Dynamics*) and the Environmental Protection Agency (CR-81627-01: *Implications of Climate Change on Forests: the Development of Forest Simulation Models for Evaluating Climate Change in Global Forest Ecosystems*), supported major parts of the research work of my students and I over the years. Substantial parts of the later chapters of the book draw on this work as examples. A pair of Academic Enhancement grants from the Board of Visitors of the University of Virginia (*Global Systems Analysis Program* and *Global Environmental Change Program*) were invaluable in the development of this project and most appreciated. Travel to Australia was supported, in part, by a travel grant from the Australian CSIRO Division of Wildlife and Ecology. I have many friends and colleagues to thank for their help and patience during the development of this project. M. P. Austin, H. J. B. Birks, R. B. Carlson, F. Daria, T. E. Dennis, W. R. Emanuel, L. Gu, B. P. Hayden, B. M. McIntyre, M. W. Palace, B. R. Rizzo, G. Shao, W. L. Steffen, L. Von Schill, B. H. Walker, J. A. Wiens and F. I. Woodward read all or part of the book and provided helpful comments and encouragement. Two

classes at the University of Virginia in 'Ecological Issues in Global Change' used earlier drafts of the book as a reference text. In particular and along with several others, A. W. Farmer, K. K. Caylor, W. J. Faubert, A. J. Hill, N. D. Kaufman, J. M. Owens, S. U. Seddon-Brown, R. R. Shah, P. C. Shahani, A. M. Thomson and K. E. Winterson from these classes were kind enough to provide frank advice from a student's perspective. Part of the draft text was also used in a training course on 'Modelling Land-use and Forest Dynamics' at the BIOTROP-GCTE Southeast Asian Impacts Centre, Bogor, Indonesia. Thanks to Louis Lebel, Daniel Murdiyarso, Habiba Gitay, Ian Noble and Ian Davies, who were involved with me in developing part of this and an earlier workshop. M. L. Merriam and J. R. Montambault, both undergraduate students at the University of Virginia, read an early draft for clarity. R. L. Smith, Jr drafted illustrations and Jane Ward of Cambridge University Press provided much-appreciated text editing. Finally and certainly not least, I would like to express my gratitude to my wife, Ramona Jeanne Kozel Shugart, to whom this book is dedicated.

H. H. Shugart
March 1997