MODELING the ENVIRONMENT

Second Edition

UYÊN JÊU

ANDREW FORD

Số hóa bởi Trung tâm Học liệu – ĐHTN

http://www.lrc-tnu.edu.vn

About Island Press

Since 1984, the nonprofit Island Press has been stimulating, shaping, and communicating the ideas that are essential for solving environmental problems worldwide. With more than 800 titles in print and some 40 new releases each year, we are the nation's leading publisher on environmental issues. We identify innovative thinkers and emerging trends in the environmental field. We work with world-renowned experts and authors to develop cross-disciplinary solutions to environmental challenges.

Island Press designs and implements coordinated book publication campaigns in order to communicate our critical messages in print, in person, and online using the latest technologies, programs, and the media. Our goal: to reach targeted audiences—scientists, policymakers, environmental advocates, the media, and concerned citizens—who can and will take action to protect the plants and animals that enrich our world, the ecosystems we need to survive, the water we drink, and the air we breathe.

Island Press gratefully acknowledges the support of its work by the Agua Fund, Inc., Annenberg Foundation, The Christensen Fund, The Nathan Cummings Foundation, The Geraldine R. Dodge Foundation, Doris Duke Charitable Foundation, The Educational Foundation of America, Betsy and Jesse Fink Foundation, The William and Flora Hewlett Foundation, The Kendeda Fund, The Andrew W. Mellon Foundation, The Curtis and Edith Munson Foundation, Oak Foundation, The Overbrook Foundation, the David and Lucile Packard Foundation, The Summit Fund of Washington, Trust for Architectural Easements, Wallace Global Fund, The Winslow Foundation, and other generous donors.

The opinions expressed in this book are those of the author(s) and do not necessarily reflect the views of our donors.

Modeling the Environment

Second Edition

Modeling the Environment

Second Edition



Andrew Ford



Washington | Covelo | London

Copyright © 2010 by Island Press

All rights reserved under International and Pan-American Copyright Conventions. No part of this book may be reproduced in any form or by any means without permission in writing from the publisher: Island Press, 1718 Connecticut Avenue, N.W., Suite 300, Washington, DC 20009.

ISLAND PRESS is a trademark of The Center for Resource Economics.

Library of Congress Cataloging-in-Publication Data

Ford, Andrew (Frederick Andrew)

Modeling the environment / Andrew Ford, — 2nd ed. Includes bibliographical references and index. ISBN-13: 978-1-59726-472-3 (doth: alk paper) ISBN-10: 1-59726-472-5 (cloth: alk. paper) ISBN-13: 978-1-59726-473-0 (pbk. : alk. paper)

ISBN-10: 1-59726-473-3 (pbk.: alk. paper) 1. Environmental sciences—Simulation methods. I. Title.

GE45.D37F67 2010 363.7001'1-dc22

2009032257

Printed on recycled, acid-free paper



Manufactured in the United States of America 10987654321

Keywords: Converters, cyclical behavior, Daisyworld, environmental systems, epidemic dynamics, exponential growth, feedback loops, homeostasis, Kaiba, mathematical models, Mono Lake, oscillations, system dynamics, stocks and flows, S-shaped growth, Stella, Vensim

For Amy

Contents

| Acknowledgmen | ats xvii | |
|---------------|--|-----|
| Part I. Intr | oductory Modeling | |
| Chapter 1. | Introduction 3 | |
| Chapter 2. | Software: Getting Started with Stella and Vensim | 17 |
| Chapter 3. | Stocks and Flows: The Building Blocks of System Dynamics Models 31 | |
| Chapter 4. | Accumulating the Flows 39 | |
| Chapter 5. | Water Flows in the Mono Basin 47 | |
| Chapter 6. | Equilibrium Diagrams 65 | |
| Chapter 7. | S-Shaped Growth 77 | |
| Chapter 8. | Epidemic Dynamics 87 | |
| Chapter 9. | Information Feedback and Causal Loop Diagrams | 99 |
| Chapter 10. | Homeostasis 117 | |
| Chapter 11. | Temperature Control on Daisyworld 125 | |
| Chapter 12. | Hitting the Bull's-Eye 139 | |
| Part II. Int | ermediate Modeling | |
| Chapter 13. | The Modeling Process 149 | |
| Chapter 14. | Software: Further Progress with Stella and Vensim | 169 |
| Chapter 15. | The Salmon of the Pacific Northwest 189 | |
| Chapter 16. | Managing a Feebate Program for Cleaner Vehicles | 209 |
| Chapter 17. | Modeling Pitfalls 223 | |
| Chapter 18. | Introduction to Cyclical Behavior 235 | |
| Chapter 19. | Cycles in Real Estate Construction 245 | |
| Chapter 20. | Cycles in Predator and Prey Populations 255 | |
| Chapter 21. | The Overshoot of the Kaibab Deer Population | 267 |

Preface

xi

| Chapter 22. | DDT in the Ocean 289 | |
|-------------|---|----|
| Chapter 23. | CO ₂ in the Atmosphere 295 | |
| Chapter 24. | Concluding Perspective 305 | |
| Appendixes. | Review and Advanced Methods | |
| Appendix A. | Review of Units 317 | |
| Appendix B. | Review of Exponential Growth 323 | |
| Appendix C. | Software Choices and Individual-Based Models 329 | |
| Appendix D. | Sensitivity Analysis and Uncertainty 341 | |
| Appendix E. | Incorporating Other Methods in a System Dynamics Model 349 | |
| Appendix F. | Short-Run and Long-Run Dynamics in a Single Model 35 | 53 |
| Appendix G. | Spatial Dynamics and Spatial Displays 359 | |
| References | 367 | |
| Index 37 | 5 | |