

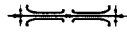
****The following content is intended solely for the educational use of the individual user.****

These digital images may not be copied, retained, printed, shared, modified or otherwise used without the copyright holder's express written permission, except as permitted for educational use.

Chapter 1

INTRODUCTION: WHAT ARE ECOSYSTEM SERVICES?

Gretchen C. Daily



In the space of a single human lifetime, society finds itself suddenly confronted with a daunting complex of trade-offs between some of its most important activities and ideals. Recent trends raise disturbing questions about the extent to which today's people may be living at the expense of their descendants, casting doubt upon the cherished goal that each successive generation will have greater prosperity. Technological innovation may temporarily mask a reduction in earth's potential to sustain human activities; in the long run, however, it is unlikely to compensate for a massive depletion of such fundamental resources as productive land, fisheries, old-growth forests, and biodiversity.

On a global scale, different groups of people are now living at one another's expense, as is readily apparent in the disruption and overexploitation of earth's open-access resources and waste sinks. For example, whereas the levels of disruption caused by energy use were once small, local, and reversible, they have now reached global proportions and carry irreversible consequences. In fueling their industrialization historically and pursuing their activities today, the developed nations appear to have largely used up the atmosphere's capacity to absorb CO₂ and other greenhouse gases without risk of inducing climate change. In the process, they have foreclosed the option of safely using fossil fuels to sustain comparable levels of industrial activity by developing nations.

And, at the local scale, the tradeoffs between competing activities, and between individual and societal interests, are becoming ever more evident. In

virtually any community, allocation of land or water to various activities often involves a zero sum game, as is apparent in the widespread loss of farmland and water to urban and industrial purposes. Thus, constraints on the scale of the human enterprise typically manifest themselves most tangibly not as absolute limits to a particular activity, but rather as tradeoffs, whose resolution is fraught with increasingly difficult practical and ethical considerations.

This book features contributions from a diverse group of natural and social scientists with expertise in different aspects of these issues, reflecting their own technical training, personal interests, and life experiences. Yet, as a whole, the contributors are oriented around a common set of fundamental premises. First, they share a conviction that, while civilization is presently careening along on a dangerous course, its fate is not sealed. The close of the twentieth century represents a period in history that demands not just a carefully tuned focus on crises of the moment, but also a long-term perspective on challenges to the human future. Second, by different paths they have reached the conclusion that society is poorly equipped to evaluate environmental tradeoffs, and that their continued resolution on the sole basis of the social, economic, and political forces prevailing today threatens environmental, economic, and political security. The chapter authors thus share a sense of urgency for developing analytical and institutional frameworks for the informed and wise resolution of these tradeoffs. Third, such decision-making frameworks must ensure the protection of humanity's most fundamental source of well-being: earth's life-support systems. A tremendous amount is known about the importance and value of the natural systems that underpin the human economy, but this information has neither been synthesized nor effectively conveyed to decision makers or to the general public.

The purpose of this book is to characterize the ways in which earth's natural ecosystems confer benefits on humanity, to make a preliminary assessment of their value, and to report this in a manner widely accessible to an educated audience. An ecosystem is the set of organisms living in an area, their physical environment, and the interactions between them. Although the distinction between "natural" and "human-dominated" ecosystems is becoming increasingly blurred, our focus is on the natural end of the spectrum, for three related reasons. First, the goods and services flowing from natural ecosystems are greatly undervalued by society. For the most part, the benefits those ecosystems provide are not traded in formal markets and do not send price signals of changes in their supply or condition. This is a major factor driving their conversion to human-dominated systems (e.g., agricultural lands), whose economic value is expressed, at least in part, in standard currency. Second, anthropogenic disruptions of natural ecosystems—such as alteration of the gaseous composition of the atmosphere, introduction and establishment of exotic species, and extinction of native species—are

difficult or impossible to reverse on any time scale of relevance to society. Finally, if current trends continue, humanity will dramatically alter or destroy virtually all of earth's remaining natural ecosystems within a few decades.

What Are Ecosystem Services?

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of *ecosystem goods*, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors. The harvest and trade of these goods represent an important and familiar part of the human economy. In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well.

One way to appreciate the nature and value of ecosystem services (originally suggested by John Holdren) is to imagine trying to set up a happy, day-to-day life on the moon. Assume for the sake of argument that the moon miraculously already had some of the basic conditions for supporting human life, such as an atmosphere and climate similar to those on earth. After inviting your best friends and packing your prized possessions, a BBQ grill, and some do-it-yourself books, the big question would be, Which of earth's millions of species do you need to take with you?

Tackling the problem systematically, you could first choose from among all the species exploited directly for food, drink, spice, fiber and timber, pharmaceuticals, industrial products (such as waxes, lac, rubber, and oils), and so on. Even being selective, this list could amount to hundreds or even several thousand species. The space ship would be filling up before you'd even begun adding the species crucial to *supporting* those at the top of your list. Which are these unsung heroes? No one knows which—nor even approximately how many—species are required to sustain human life. This means that rather than listing species directly, you would have to list instead the life-support functions required by your lunar colony; then you could guess at the types and numbers of species required to perform each. At a bare minimum, the spaceship would have to carry species capable of supplying a whole suite of ecosystem services that earthlings take for granted. These services include:

- purification of air and water
- mitigation of floods and droughts
- detoxification and decomposition of wastes

- generation and renewal of soil and soil fertility
- pollination of crops and natural vegetation
- control of the vast majority of potential agricultural pests
- dispersal of seeds and translocation of nutrients
- maintenance of biodiversity, from which humanity has derived key elements of its agricultural, medicinal, and industrial enterprise
- protection from the sun's harmful ultraviolet rays
- partial stabilization of climate
- moderation of temperature extremes and the force of winds and waves
- support of diverse human cultures
- providing of aesthetic beauty and intellectual stimulation that lift the human spirit.

Armed with this preliminary list of services, you could begin to determine which types and numbers of species are required to perform each. This is no simple task! Let's take the soil fertility case as an example. Soil organisms play important and often unique roles in the circulation of matter in every ecosystem on earth; they are crucial to the chemical conversion and physical transfer of essential nutrients to higher plants, and all larger organisms, including humans, depend on them (Heywood 1995). The abundance of soil organisms is absolutely staggering: under a square yard of pasture in Denmark, for instance, the soil was found to be inhabited by roughly 50,000 small earthworms and their relatives, 50,000 insects and mites, and nearly 12 million roundworms. And that is not all. A single gram (a pinch) of soil has yielded an estimated 30,000 protozoa, 50,000 algae, 400,000 fungi, and billions of individual bacteria (Ehrlich et al. 1977; Overgaard-Nielsen 1955). Which to bring to the moon? Most of these species have never been subjected to even cursory inspection. Yet the sobering fact of the matter is, as Ed Wilson put it: they don't need us, but we need them.

Ecosystem services are generated by a complex of natural cycles, driven by solar energy, that constitute the workings of the biosphere—the thin layer near earth's surface that contains all known life. The cycles operate on very different scales. Biogeochemical cycles, such as the movement of the element carbon through the living and physical environment, are truly global and reach from the top of the atmosphere to deep into soils and ocean-bottom sediments. Life cycles of bacteria, in contrast, may be completed in an area much smaller than the period at the end of this sentence. The cycles also operate at very different rates. The biogeochemical cycling of carbon, for instance, occurs at orders of magnitude faster than that of phosphorus, just as the life cycles of microorganisms may be orders of magnitude faster than those of trees.

All of these cycles are ancient, the product of billions of years of evolution, and have existed in forms very similar to those seen today for at least hundreds of millions of years. They are absolutely pervasive, but unnoticed by most human beings going about their daily lives. Who, for example, gives a thought to the part of the carbon cycle that connects him or her to the plants in the garden outside, to plankton in the Indian Ocean, or to Julius Caesar? Noticed or not, human beings depend utterly on the continuation of natural cycles for their very existence. If the life cycles of predators that naturally control most potential pests of crops were interrupted, it is unlikely that pesticides could satisfactorily take their place. If the life cycles of pollinators of plants of economic importance ceased, society would face serious social and economic consequences. If the carbon cycle were badly disrupted, rapid climatic change could threaten the existence of civilization. In general, human beings lack both the knowledge and the ability to substitute for the functions performed by these and other cycles (Ehrlich and Mooney 1983).

For millennia, humanity has drawn benefits from these cycles without causing global disruption. Yet, today, human influence can be discerned in the most remote reaches of the biosphere: deep below earth's surface in ancient aquifers, far out to sea on tiny tropical islands, and up in the cold, thin air high above Antarctica. Virtually no place remains untouched—chemically, physically, or biologically—by the curious and determined hand of humanity. Although much more by accident than by design, humanity now controls conditions over the entire biosphere.

Interestingly, the nature and value of Earth's life-support systems have been illuminated primarily through their disruption and loss. Thus, for instance, deforestation has revealed the critical role of forests in the hydrological cycle—in particular, in mitigating flood, drought, and the forces of wind and rain that cause erosion. Release of toxic substances, whether accidental or deliberate, has revealed the nature and value of physical and chemical processes, governed in part by a diversity of microorganisms, that disperse and break down hazardous materials. Thinning of the stratospheric ozone layer sharpened awareness of the value of its service in screening out harmful ultraviolet radiation.

A cognizance of ecosystem services, expressed in terms of their loss, dates back at least to Plato and probably much earlier:

What now remains of the formerly rich land is like the skeleton of a sick man with all the fat and soft earth having wasted away and only the bare framework remaining. Formerly, many of the mountains were arable. The plains that were full of rich soil are now marshes. Hills that were once covered with forests and produced abundant pasture now produce only food for bees. Once

the land was enriched by yearly rains, which were not lost, as they are now, by flowing from the bare land into the sea. The soil was deep, it absorbed and kept the water . . . , and the water that soaked into the hills fed springs and running streams everywhere. Now the abandoned shrines at spots where formerly there were springs attest that our description of the land is true.

—Plato (quoted in Hillel, p. 104)

Ecosystem services have also gained recognition and appreciation through efforts to substitute technology for them. The overuse of pesticides, for example, leading to the decimation of natural pest enemies and concomitant promotion of formerly benign species to pest status, has made apparent agriculture's dependence upon natural pest control services. The technical problems and cost of hydroponic systems—often prohibitive even for growing high-priced, specialty produce—underscore human dependence upon ecosystem services supplied by soil. Society is likely to value more highly the services listed above, and to discover (or rediscover) an array of services not listed, as human impacts on the environment intensify and the costs and limits of technological substitution become more apparent.

Nature's Services

SOCIETAL DEPENDENCE ON
NATURAL ECOSYSTEMS

EDITED BY GRETCHEN C. DAILY

ISLAND PRESS

Washington, D.C. • Covelo, California

Copyright © 1997 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.

No copyright claim is made in "Water Quality Improvement: Evaluation of an Ecosystem Service," work written by an employee of the U.S. government.

Library of Congress Cataloging-in-Publication Data

Nature's services: societal dependence on natural ecosystems/edited
by Gretchen C. Daily.

p. cm.

Includes bibliographical references and index.

ISBN 1-55963-475-8. — ISBN 1-55963-476-6 (pbk.)

1. Nature—Effect of human beings on. 2. Human ecology—Economic aspects. 2. Biotic communities—Economic aspects. 4. Ecosystem management. I. Daily, Gretchen C.

GF75.N37 1997

304.2—dc21

96-40401

CIP

Printed on recycled, acid-free paper ♻️

Manufactured in the United States of America

10 9 8 7 6 5 4 3 2 1