

**The**

# **ENVIRONMENT**

**Science, Issues, and Solutions**



**Mohan K. Wali**  
**Fatih Evrendilek**  
**M. Siobhan Fennessy**



**CRC Press**  
Taylor & Francis Group

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# **The ENVIRONMENT**

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**Science, Issues, and Solutions**

*Dedicated to present and future students  
of all ages who seek environmental literacy*



# Preface

The study of our natural environment in institutions of higher learning, even in secondary schools, has finally found a foothold. Unlike traditional academic disciplines, however, the introductory courses in environment are taught by instructors who are trained in fields ranging from biology, chemistry, geography, and geology to ethics, philosophy, and political science. Thus, a dichotomy between environmental *science* and environmental *studies* that began in the 1970s has also taken hold. The net result has been that introductory courses on the environment present a widely-diverse coverage of natural processes. What is needed, we believe, is a deeper understanding of basic scientific facts and principles interwoven with the social, economic, and political implications of environmental decision-making.

We have taught environmental science topics for many years, and these opportunities have provided us with a first-hand view of both the technical and the human dimensions of environmental subject matter. It was the experience from 18 years of teaching an introductory course that led the first author to take the lead on writing a new text. Fellow ecologists, Drs. F. Evrendilek and S. Fennessy, terrestrial and aquatic specialists, respectively, kindly joined the effort as coauthors. From the beginning, it has been our goal to develop a fully integrated textbook that rigorously explores environmental issues and their possible solutions. To achieve this dual objective we emphasize the basics of ecology, use this foundation to build an understanding of major environmental problems, and explore methods that might mitigate what has been degraded or destroyed. In doing so, we have endeavored to include an in-depth selection of references, examples and data, case studies, and websites. With these tools, students can further explore topics of special interest.

But why a new text? There are several reasons. We want to share our experience with teaching introductory environmental science using an approach that is strongly grounded in science, the scientific method, and evidence. We also noted that students in our classes were not wholly satisfied with the textbooks we used. What we have also noticed over the years was that students are eager to learn about the environment and are actively looking for ways to focus their talents and make a difference. This desire is important to us as teachers, for our students are the world's future scientists and environmental professionals, decision-makers, writers, poets, and artists. We firmly believe that environmental literacy for all is a must. We also recognize that students welcome the challenge to learn, ask thoughtful questions, and generally crave current, in-depth information.

This book, intended for a beginning college-level environmental science course, uses a back-to-the-basics, building-block approach. The subject matter is divided into three major sections. In Section A, we introduce principles of ecology that can be used to understand how ecosystems respond to disturbance. In Section B, we deal with how human population growth, expanded technology, and unprecedented economic development have altered ecosystems and created

serious local, regional, and global environmental problems. The final Section C makes a case for seeking long-term solutions through the prevention and mitigation of environmental problems in their interconnected, interrelated, and thus, interdependent ways.

We have undertaken this project in the belief that students can attain an environmental literacy that “requires a fundamental understanding of the systems of the natural world, the relationships and interactions between the living and non-living environment, and the ability to deal sensibly with problems that involve scientific evidence, uncertainty, and economic, aesthetic, and ethical considerations.”\* Nonetheless, given the speed with which new data and syntheses are becoming available from diverse sources, no textbook on the environment can claim to have covered everything.

Our gauge of success depends on how well this book is received by students and instructors alike. From both, we look forward to receiving comments and suggestions with gratitude.

**Mohan K. Wali**  
**Fatih Evrendilek**  
**M. Siobhan Fennessy**

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\* Environmental Literacy Council, Washington, DC. (<http://www.envroliteracy.org>)



## Acknowledgments

We acknowledge our gratitude to Professor Emeritus Robert P. McIntosh of the University of Notre Dame and Jerry M. Bigham, professor-director, School of Environment and Natural Resources at the Ohio State University (OSU) for their comments on multiple chapters and especially their encouragement. Our gratitude is due as well to the following colleagues who read drafts of chapters (noted in parentheses) and provided many useful comments and materials. They include, from OSU, Virginie Bouchard (5), Craig Davis (9), Don Eckert (4), Earl Epstein (21), Stacey Fineran (1, 2), Robert Gates (8, 24), Dale Gnidovec (14), Randall Heiligmann (13), Fred Hitzhusen (22), Greg Hitzhusen (26), Elizabeth Marschall (8), James Metzger (3), Martin Quigley (8, 9), Amanda Rodewald (8), Allison Snow (8), Brian Slater (12), Brent Sohngen (22), Alan Stam (4, 8), Lonnie Thompson (19), Robert Vertrees (5), and Roger Williams (13); and to Martin Quigley (University of Central Florida) (8, 25), Maharaj Raina (1) (NCERT, New Delhi), Nirander M. Safaya (1, 21) (North Dakota Public Service Commission, Bismarck), and Alan Stam (8, 25) (Capital University, Columbus). We also appreciate the encouragement of L. H. Newcomb and the assistance of Dennis Hull, Jim Pojar, and Paul Rodewald.

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We have tried our best to make sure that the materials used in this book are properly attributed to their appropriate sources. We shall appreciate knowing about any of our lapses which, we want to assure you, are oversights.

Many comments and useful advice were offered from students. These include, at OSU, graduate students Cara Bosco, John Bowzer, Ellen Crivella, Laura Jacobs, Laura Kearns, Sujith Kumar, and Heather Whitman, and undergraduates Joshua Griffin, Rachelle



Howe, Melissa Gray, Kurtis Meyer, and Philip Renner. The “60+ Program” at OSU encourages senior citizens to enroll in courses of their choice, and it was the choice of senior librarian, Susan Logan to take ENR 201: Introduction to Environmental Science, a course for which this book is intended. She was not only meticulous in reading an early draft, but, as a librarian, indispensable in locating books post-haste. At Kenyon College, the Environmental Studies class that met during the spring of 2008 read an early draft of the text and provided many useful comments, as did Sadettin Erdonmez from Abant Izzet Baysal University, Turkey. We were ably assisted correcting the proofs by Philip Renner, John Bowzer, and Laura Kearns. Much office and computer assistance came from Patricia Patterson, Patricia Polczynski, and Anthony Utz (OSU). Our grateful thanks are due to them all.

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We conclude this manifesto of appreciation with deep indebtedness to our respective spouses, Sara, Gülsün, and Ted, with much more than words can say.

# The Authors

MOHAN K. WALI (PhD, U. British Columbia, ecology and soils) is professor in the School of Environment and Natural Resources, and John Glenn School of Public Affairs at the Ohio State University (OSU). At OSU, in addition to other courses, he has taught introductory environmental science for 18 years. He and his colleagues and students have conducted research in the Kashmir Himalayas, the Danish woodlands, Canadian boreal forests, ecosystems of the mid-continent of North America, and the eastern temperate deciduous forest. From his early research in understanding the dynamics of plant communities in relation to their environmental gradients, he and his coworkers have investigated the processes of ecosystem rehabilitation/restoration of drastically disturbed ecosystems to ensure their long-term biological productivity. Along with his graduate students, his most recent work is related to combining restoration of ecosystems with aspects of global climate change. He was a national lecturer of Sigma Xi—the Scientific Research Society for 2 years, and is a Fellow of the American Association for the Advancement of Science.

FATİH EVRENDİLEK received his BSc in landscape architecture from Ege University (Turkey), MA in energy and environmental policy from the University of Delaware, and his PhD in environmental science from the Ohio State University. He is an associate professor of environmental science and vice dean of the faculty of engineering and architecture at Abant İzzet Baysal University in Bolu, Turkey. In 2005, Dr. Evrendilek was a NATO Fellow in the United States. Dr. Evrendilek currently teaches the introductory environmental science course. He and his coworkers and students are active in modeling biogeochemical cycles research and global climate change, environmental and energy policy, and ecosystem restoration. His active research projects include “Modeling Temporal and Spatial Changes in Net Primary Productivity of Terrestrial Ecosystems in Turkey,” and the “GIS-Supported Integrated Water Resources Management System for the Eastern Mediterranean: A Regional Clean Water Action Plan for the Seyhan River.”

M. SIOBHAN FENNESSY received her BS in botany and PhD in environmental science from the Ohio State University. An associate professor of biology and codirector of environmental studies at Kenyon College, she and her students study freshwater wetlands, biological assessment methods, restoration ecology, and the role of temperate wetlands in the global carbon cycle. Earlier, she served on the faculty of the Geography Department of University College, London and held a joint appointment at the Station Biologique du la Tour du Valat investigating the human impact on Mediterranean wetlands. Later, at the Ohio EPA, she founded Ohio's wetland program and wrote the current rules designed to protect wetlands. She is a member of the U.S. EPA's Biological Assessment of Wetlands Workgroup, and currently leads a project to test the use of rapid assessment methods to evaluate the ecological condition of wetlands on a watershed basis. She is coauthor of the best-selling book, *Wetland Plants: Biology and Ecology* (Lewis Publishers, 2001).

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In this book, we use the International System of Units, or SI. These units are the accepted currency of most scientific journals throughout the world. In those cases where the unit conversion from and to those in use in the United States is cumbersome, we provide both units in the text for convenience.

# International System of Units (SI)



To convert Column 1 into Column 2, multiply by	Column 1 SI unit	Column 2 non-SI units	To convert Column 2 into Column 1, multiply by
<b>Length</b>			
0.621	kilometer, km ( $10^3$ m)	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
3.28	meter, m	foot, ft	0.304
1.0	micrometer, $\mu\text{m}$ ( $10^{-6}$ m)	micron, $\mu$	1.0
$3.94 \times 10^{-2}$	millimeter, mm ( $10^{-3}$ m)	inch, in	25.4
10	nanometer, nm ( $10^{-9}$ m)	angstrom, $\text{\AA}$	0.1
<b>Area</b>			
2.47	hectare, ha	acre	0.405
247	square kilometer, $\text{km}^2$ ( $10^3$ m) <sup>2</sup>	acre	$4.05 \times 10^{-3}$
0.386	square kilometer, $\text{km}^2$ ( $10^3$ m) <sup>2</sup>	square mile, $\text{mi}^2$	2.590
$2.47 \times 10^{-4}$	square meter, $\text{m}^2$	acre	$4.05 \times 10^3$
10.76	square meter, $\text{m}^2$	square foot, $\text{ft}^2$	$9.29 \times 10^{-2}$
$1.55 \times 10^{-3}$	square millimeter, $\text{mm}^2$ ( $10^{-3}$ m) <sup>2</sup>	square inch, $\text{in}^2$	645
<b>Volume</b>			
$9.73 \times 10^{-3}$	cubic meter, $\text{m}^3$	acre-inch	102.8
35.3	cubic meter, $\text{m}^3$	cubic foot, $\text{ft}^3$	$2.83 \times 10^{-2}$
$6.10 \times 10^4$	cubic meter, $\text{m}^3$	cubic inch, $\text{in}^3$	$1.64 \times 10^{-5}$
$2.84 \times 10^{-2}$	liter, L ( $10^{-3}$ m <sup>3</sup> )	bushel, bu	35.24
1.057	liter, L ( $10^{-3}$ m <sup>3</sup> )	quart (liquid), qt	0.946
$3.53 \times 10^{-2}$	liter, L ( $10^{-3}$ m <sup>3</sup> )	cubic foot, $\text{ft}^3$	28.3
0.265	liter, L ( $10^{-3}$ m <sup>3</sup> )	gallon	3.78
33.78	liter, L ( $10^{-3}$ m <sup>3</sup> )	ounce (fluid), oz	$2.96 \times 10^{-2}$
2.11	liter, L ( $10^{-3}$ m <sup>3</sup> )	pint (fluid), pt	0.473
<b>Mass</b>			
$2.20 \times 10^{-3}$	gram, g ( $10^{-3}$ kg)	pound, lb	454
$3.52 \times 10^{-2}$	gram, g ( $10^{-3}$ kg)	ounce (avdp), oz	28.4
2.205	kilogram, kg	pound, lb	0.454
0.01	kilogram, kg	quintal (metric), q	100
$1.10 \times 10^{-3}$	kilogram, kg	ton (2000 lb), ton	907
1.102	megagram, Mg (tonne)	ton (U.S.), ton	0.907
1.102	tonne, t	ton (U.S.), ton	0.907
<b>Yield and Rate</b>			
0.893	kilogram per hectare, $\text{kg ha}^{-1}$	pound per acre, $\text{lb acre}^{-1}$	1.12
$7.77 \times 10^{-2}$	kilogram per cubic meter, $\text{kg m}^{-3}$	pound per bushel, $\text{lb bu}^{-1}$	12.87
$1.49 \times 10^{-2}$	kilogram per hectare, $\text{kg ha}^{-1}$	bushel per acre, 60 lb	67.19
$1.59 \times 10^{-2}$	kilogram per hectare, $\text{kg ha}^{-1}$	bushel per acre, 56 lb	62.71
$1.86 \times 10^{-2}$	kilogram per hectare, $\text{kg ha}^{-1}$	bushel per acre, 48 lb	53.75
0.107	liter per hectare, $\text{L ha}^{-1}$	gallon per acre	9.35
893	tonne per hectare, $\text{t ha}^{-1}$	pound per acre, $\text{lb acre}^{-1}$	$1.12 \times 10^{-3}$
893	megagram per hectare, $\text{Mg ha}^{-1}$	pound per acre, $\text{lb acre}^{-1}$	$1.12 \times 10^{-3}$
0.446	megagram per hectare, $\text{Mg ha}^{-1}$	ton (2,000 lb) per acre, $\text{ton acre}^{-1}$	2.24
2.24	meter per second, $\text{m s}^{-1}$	mile per hour	0.447



To convert Column 1 into Column 2, multiply by	Column 1 SI unit	Column 2 non-SI units	To convert Column 2 into Column 1, multiply by
<b>Specific Surface</b>			
10	square meter per kilogram, $\text{m}^2 \text{kg}^{-1}$	square centimeter per gram, $\text{cm}^2 \text{g}^{-1}$	0.1
1000	square meter per kilogram, $\text{m}^2 \text{kg}^{-1}$	square millimeter per gram, $\text{mm}^2 \text{g}^{-1}$	0.001
<b>Pressure</b>			
9.90	megapascal, MPa ( $10^6 \text{ Pa}$ )	atmosphere	0.101
10	megapascal, MPa ( $10^6 \text{ Pa}$ )	bar	0.1
$2.09 \times 10^{-2}$	pascal, Pa	pound per square foot, $\text{lb ft}^{-2}$	47.9
$1.45 \times 10^{-4}$	pascal, Pa	pound per square inch, $\text{lb in}^{-2}$	$6.90 \times 10^3$
<b>Temperature</b>			
1.00 (K – 273)	kelvin, K	Celsius, $^{\circ}\text{C}$	1.00 ( $^{\circ}\text{C} + 273$ )
$(9/5 ^{\circ}\text{C}) + 32$	Celsius, $^{\circ}\text{C}$	Fahrenheit, $^{\circ}\text{F}$	$5/9 (^{\circ}\text{F} - 32)$
<b>Energy, Work, Quantity of Heat</b>			
$9.52 \times 10^{-4}$	joule, J	British thermal unit, Btu	$1.05 \times 10^3$
0.239	joule, J	calorie, cal	4.19
$10^7$	joule, J	erg	$10^{-7}$
0.735	joule, J	foot-pound	1.36
$2.387 \times 10^{-5}$	joule per square meter, $\text{J m}^{-2}$	calorie per square centimeter (langley)	$4.19 \times 10^4$
$10^5$	newton, N	dyne	$10^{-5}$
$1.43 \times 10^{-3}$	watt per square meter, $\text{W m}^{-2}$	calorie per square centimeter minute (irradiance), $\text{cal cm}^{-2} \text{min}^{-1}$	698
<b>Plane Angle</b>			
57.3	radian, rad	degrees (angle), $^{\circ}$	$1.75 \times 10^{-2}$
<b>Electrical Conductivity</b>			
10	siemen per meter, $\text{S m}^{-1}$	millimho per centimeter, $\text{mmho cm}^{-1}$	0.1
<b>Water Measurement</b>			
$9.73 \times 10^{-3}$	cubic meter, $\text{m}^3$	acre-inch, acre-in	102.8
$9.81 \times 10^{-3}$	cubic meter per hour, $\text{m}^3 \text{h}^{-1}$	cubic foot per second, $\text{ft}^3 \text{s}^{-1}$	101.9
4.40	cubic meter per hour, $\text{m}^3 \text{h}^{-1}$	U.S. gallon per minute, $\text{gal min}^{-1}$	0.227
8.11	hectare meter, ha m	acre-foot, acre-ft	0.123
97.28	hectare meter, ha m	acre-inch, acre-in	$1.03 \times 10^{-2}$
$8.1 \times 10^{-2}$	hectare centimeter, ha cm	acre-foot, acre-ft	12.33
<b>Concentrations</b>			
1	centimole per kilogram, $\text{cmol kg}^{-1}$	milliequivalent per 100 grams, $\text{meq } 100 \text{ g}^{-1}$	1
0.1	gram per kilogram, $\text{g kg}^{-1}$	percent, %	10
1	milligram per kilogram, $\text{mg kg}^{-1}$	parts per million, ppm	1
<b>Radioactivity</b>			
$2.7 \times 10^{-11}$	becquerel, Bq	curie, Ci	$3.7 \times 10^{10}$
$2.7 \times 10^{-2}$	becquerel per kilogram, $\text{Bq kg}^{-1}$	picocurie per gram, $\text{pCi g}^{-1}$	37
100	gray, Gy (absorbed dose)	rad, rd	0.01
100	sievert, Sv (equivalent dose)	rem (roentgen equivalent man)	0.01

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