

Soil Degradation, Conservation and Remediation

Khan Towhid Osman

Soil Degradation, Conservation and Remediation

 Springer

Khan Towhid Osman
Department of Soil Science
University of Chittagong
Chittagong, Bangladesh

ISBN 978-94-007-7589-3 ISBN 978-94-007-7590-9 (eBook)
DOI 10.1007/978-94-007-7590-9
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2013950937

© Springer Science+Business Media Dordrecht 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

*Md. Bazlul Karim Khan and Rowshan
Ara Begum
Who would have been the proudest
of their son's work*

Preface

Recently, I wrote a book entitled *Soils: Principles, Properties and Management* which Springer published in December 2012. The original manuscript had a long chapter of more than 75 normally typed pages on soil resources and degradation. While writing the chapter, I collected more than adequate literatures on the levels and impacts of soil degradation worldwide. I figured it would be a good idea to extend it with necessary details, examples, tables, and figures into a full-fledged book on soil degradation, conservation, and remediation should an opportunity ever present itself. I did so eventually, and while writing, I endeavored to give lucid accounts of the principal processes of soil degradation, its effects on soil quality, plant production and human health, and methods of improvement of degraded soils.

The decline in soil quality due to human interventions in soil, water, and environment is called human-induced soil degradation. H. Eswaran et al.'s observation on the looming significance of soil degradation studies is noteworthy: "Soil degradation has been a major global issue during the 20th century and will remain high on the international agenda in the 21st century. The importance of soil degradation among global issues is enhanced because of its impact on world food security and quality of the environment" (<http://soils.usda.gov/use/worldsoils/papers/land-degradation-overview.html>). Deforestation of fragile lands, overexploitation of vegetation and biomass resources, shifting cultivation, overgrazing, unbalanced fertilizer use, non-adoption of soil conservation management practices, use of ground water in excess of the capacity for recharge, inappropriate irrigation system, and indiscriminate disposal of wastes are some of the factors responsible for soil degradation. Physical deterioration of soil including surface sealing, hardsetting and compaction, water and wind erosion, and chemical soil degradation including nutrient depletion, acidification, salinization, and soil pollution are the chief processes of soil degradation. Decline in soil productivity and fall in crop quality are the measurable impacts of soil degradation. The productivity of some lands has declined by as much as 50 % due to soil erosion and desertification. Mean yield reduction due to erosion in Africa is 8.2 %. Annual loss in productivity due to water erosion is estimated at 36 million tons of cereal equivalent to US\$5,400 million and due to wind erosion to US\$1,800 million in South Asia. It is estimated that the total annual cost

of erosion from agriculture in the USA is about US\$44 billion per year. On a global scale, the annual loss of 75 billion tons of soil costs the world about US\$400 billion per year.

Soil Degradation, Conservation, and Remediation is intended for undergraduate and graduate students of Soil Science, Agricultural Sciences, Forestry, Ecology, Geography, and Environmental Sciences. The processes and impacts of soil degradation have been dealt with in this book in sufficient details. Chapter 1 describes global soil resources, land capability and soil quality classes, soil orders, global arable land, causes and types of soil degradation, and laws of sustainable management of soil. Chapter 2 deals with factors and processes of physical deterioration of soil, including surface sealing, surface crusting, hardsetting, compaction, effects of crusting and compaction, and decrusting and decompaction of soil. Chapter 3 narrates the causes, factors, and processes of water erosion. Methods of soil conservation including amendments, conservation farming, cover crops, no tillage, minimum tillage, mulching, contour cropping, strip cropping, contour-strip cropping, SALT, terracing, and grassed waterways have been explored with examples and data. In Chap. 4, causes, effects, and processes of wind erosion are described. Measures to control wind erosion and dune stabilization are shown with a good number of illustrations. Chapter 5 emphasizes chemical degradation of soil including nutrient depletion, acidification, and salinization (but not soil pollution which is narrated in detail in Chap. 6).

My colleagues Dr. Abul Kashem, Mr. Jajar Afsar, and Md. Enamul Haque of the Department of Soil Science, University of Chittagong, have indebted me with inspiration and useful suggestions on the manuscript. Thanks to them are due.

University of Chittagong
Chittagong, Bangladesh

Khan Towhid Osman

Contents

1	Soil Resources and Soil Degradation.....	1
1.1	Soil as a Resource	1
1.2	Need for Management and Protection of Soil	3
1.3	Land Capability and Land Capability Classification	3
1.4	Soil Fertility, Soil Productivity, Soil Quality, and Soil Health	5
1.4.1	Soil Fertility	5
1.4.2	Soil Productivity	6
1.4.3	Soil Health	6
1.4.4	Soil Quality	6
1.5	Global Arable Land.....	9
1.6	Classification of World Soils.....	10
1.6.1	Alfisols	11
1.6.2	Andisols	12
1.6.3	Aridisols.....	13
1.6.4	Entisols	15
1.6.5	Gelisols	16
1.6.6	Histosols	16
1.6.7	Inceptisols	18
1.6.8	Mollisols	19
1.6.9	Oxisols	20
1.6.10	Spodosols.....	21
1.6.11	Ultisols.....	22
1.6.12	Vertisols.....	23
1.7	Soil Degradation	24
1.7.1	Causes of Soil Degradation.....	25
1.7.2	Institutional Initiatives for Assessment of Land/Soil Degradation.....	34
1.7.3	Types of Soil Degradation	35
1.7.4	Extent of Soil Degradation	37

1.8	Laws of Sustainable Soil Management.....	37
	References.....	39
2	Physical Deterioration of Soil	45
2.1	Processes and Types of Physical Deterioration of Soil.....	45
2.2	Surface Sealing, Crusting, Hardsetting, and Compaction (Pc)	46
2.2.1	Surface Sealing	46
2.2.2	Surface Crusting	48
2.2.3	Soil Compaction	52
2.3	Waterlogging.....	57
2.3.1	Causes of Waterlogging	58
2.3.2	Effect of Waterlogging.....	59
2.3.3	Control of Waterlogging	59
2.4	Lowering of Groundwater Table	59
2.5	Subsidence of Organic Soils	60
2.6	Desertification	61
2.6.1	Natural Versus Human-Induced Desertification	62
2.6.2	Convention to Combat Desertification.....	63
2.6.3	Mechanism of Human-Induced Desertification.....	63
	References.....	65
3	Soil Erosion by Water	69
3.1	Geological and Accelerated Erosion.....	69
3.2	Causes of Water Erosion	70
3.3	Types of Water Erosion	70
3.3.1	Splash Erosion	71
3.3.2	Sheet Erosion	72
3.3.3	Rill Erosion.....	74
3.3.4	Gully Erosion.....	75
3.3.5	Tillage Erosion.....	77
3.3.6	Landslide/Landslip/Mudflow.....	77
3.3.7	Riverbank/Stream Bank Erosion.....	77
3.3.8	Effects of Water Erosion	78
3.3.9	Soil Loss Equations (USLE and RUSLE)	80
3.3.10	Soil Loss Tolerance Value (T Value).....	83
3.4	Control of Water Erosion	83
3.4.1	Amendments	84
3.4.2	Cover Crops	84
3.4.3	Conservation Tillage.....	86
3.4.4	Mulching.....	88
3.4.5	Contour Cropping	89
3.4.6	Strip Cropping	90
3.4.7	Contour Strip Cropping	90
3.4.8	Sloping Agricultural Land Technology (SALT)	91
3.4.9	Agroforestry	93

3.4.10	Alley Cropping.....	93
3.4.11	Buffer Strips.....	94
3.4.12	Grassed Waterways.....	95
3.4.13	Terracing.....	96
	References.....	99
4	Wind Erosion.....	103
4.1	Causes of Wind Erosion.....	103
4.2	Effects of Wind Erosion.....	104
4.3	Processes of Wind Erosion.....	105
4.3.1	Saltation.....	105
4.3.2	Suspension.....	106
4.3.3	Surface Creep.....	106
4.3.4	Abrasion.....	107
4.3.5	Sorting.....	107
4.4	Factors Affecting Wind Erosion.....	107
4.4.1	Soil.....	108
4.4.2	Climate.....	109
4.4.3	Field Width and Slope.....	110
4.4.4	Vegetation.....	110
4.5	Principles of Wind Erosion Control.....	111
4.6	Wind Erosion Control Measures.....	112
4.6.1	Stabilization of Soil.....	112
4.6.2	Cover Crops.....	112
4.6.3	Ridging and Surface Roughening.....	113
4.6.4	Residue Management.....	114
4.6.5	Wind Barrier.....	116
4.6.6	Strip Cropping.....	117
4.7	Stabilization of Dunes.....	118
	References.....	120
5	Chemical Soil Degradation.....	125
5.1	Chemical Degradation of Soil and Its Extent.....	125
5.2	Loss of Nutrients and/or Organic Matter.....	126
5.2.1	Leaching of Nutrients.....	127
5.2.2	Nutrient Loss due to Residue Burning.....	128
5.2.3	Nutrient Losses due to Erosion.....	129
5.2.4	Crop Removal of Nutrients.....	129
5.3	Acidification.....	129
5.3.1	Causes of Soil Acidification.....	130
5.3.2	Effects of Soil Acidity.....	133
5.3.3	Management of Acidic Soils.....	136
5.3.4	Acid Sulfate Soils.....	141
5.4	Soil Salinization.....	142
5.4.1	Management of Saline Soils.....	143
5.5	Salt-Tolerant Crops.....	144
	References.....	146

6	Soil Pollution.....	149
6.1	Pollution and Soil Pollution	149
6.2	Sources of Soil Pollutants	150
6.2.1	Municipal Waste	150
6.2.2	Sewage Sludge	156
6.2.3	Contaminants in Garden Composts	158
6.2.4	Hospital Wastes.....	159
6.2.5	Industrial Wastes	160
6.2.6	Agrochemicals	160
6.2.7	Atmospheric Deposition	170
6.2.8	Mining.....	172
6.2.9	Traffic.....	174
6.2.10	Radionuclides in Soil	175
6.2.11	Organic Pollutants in Soil	176
6.2.12	Heavy Metal Pollution of Soils.....	190
	References.....	216
	Index.....	227

Abbreviations

AMD	Acid Mine Drainage
ASSOD	Assessment of human-induced soil degradation for South and Southeast Asia
BTEX	Benzene, toluene, ethylbenzene, xylene
DCE	Dichloroethylene
DCPA	Dichloro propanilic acid
DDT	Dichlorodiphenyltrichloroethane
EDC	Endocrine disrupting chemicals
FAO	Food and Agriculture Organization of the United Nations
GLADA	Global assessment of land degradation in arid lands
GLASOD	Global assessment of human-induced soil degradation
ISRIC	International Soil Reference and Information Centre
LADA	Land Degradation Assessment for Dryland Areas
NPE	Nonylphenol ethoxylates
NRCS	Nature Resource Conservation Service
PAE	Phthalate esters
PAHs	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxin
PCDF	Polychlorinated dibenzofurans
PCE	Polychloroethylene
PCN	Polychlorinated naphthalenes
POP	Persistent organic pollutant
RUSLE	Revised Universal Soil Loss Equation
SALT	Sloping Agricultural Land Technology
SOTER	Soil and Terrain Digital Database
TCDD	Tetrachloro- <i>p</i> -dibenzodioxin
TCE	Trichloroethylene
TEPP	Tetraethyl pyrophosphate
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environmental Program

UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
VC	Vinyl chloride
WHO	World Health Organization
WRB	World Reference Base