

# Contents

---

## SECTION A Soil Physics

Introduction	<i>A.W. Warrick</i>	A-1
1	Physical Properties of Primary Particles <i>Joseph M. Skopp</i>	A-3
1.1	Particle Density	A-3
1.2	Particle Shape	A-4
1.3	Particle Size Distribution	A-6
1.4	Specific Surface Area	A-12
1.5	Bulk Density and Porosity	A-13
1.6	References	A-16
2	Dynamic Properties of Soils <i>Rainer Horn and Thomas Baumgartl</i>	A-19
2.1	Introduction	A-19
2.2	Processes in Aggregate Formation	A-20
2.3	Determination of Mechanical Parameters	A-20
2.4	Effect of Soil Structure and Dynamics on Strength and Stress/Strain Processes	A-33
2.5	Further Dynamic Aspects in Soils	A-40
2.6	Modeling Dynamic Coupled Processes	A-43
2.7	Conclusions	A-45
2.8	References	A-46
3	Soil Water Content and Water Potential Relationships <i>Dani Or and Jon M. Wraith</i>	A-53
3.1	Introduction	A-53
3.2	Soil Water Content	A-54
3.3	Soil Water Energy	A-65
3.4	Soil Water Content-Energy Relationships	A-76
3.5	Resources	A-81
3.6	References	A-83
4	Soil Water Movement <i>David E. Radcliffe and Todd C. Rasmussen</i>	A-87
4.1	Introduction	A-87
4.2	Flow in Saturated Soil	A-88
4.3	Flow in Unsaturated Soil	A-96
4.4	Measurement of Hydraulic Parameters	A-113
4.5	Numerical Models of Water Flow	A-119
4.6	Concluding Remarks	A-123
4.7	References	A-123

5	Energy and Water Balances at Soil-Plant-Atmosphere Interfaces	
	<i>S.R. Evett</i>	A-129
5.1	Introduction	A-129
5.2	Energy Balance Equation	A-129
5.3	Water Balance Equation	A-167
5.4	References	A-178
6	Solute Transport	<i>Feike J. Leij and Martinus Th. van Genuchten</i>
		A-183
6.1	Introduction	A-183
6.2	The Advection-Dispersion Equation	A-184
6.3	Solutions of the Advection-Dispersion Equation	A-200
6.4	Stream Tube Models	A-218
6.5	References	A-224
7	Soil Structure	<i>B.D. Kay and D.A. Angers</i>
		A-229
7.1	Characteristics, Significance, and Measurement of Soil Structure	A-229
7.2	Soil Factors Influencing Structure	A-237
7.3	Other Factors Influencing Soil Structure	A-254
7.4	Interpreting Data on Soil Structure	A-258
7.5	References	A-264
8	Soil Gas Movement in Unsaturated Systems	
	<i>B.R. Scanlon, J.P. Nicot and J.M. Massmann</i>	A-277
8.1	General Concepts Related to Gas Movement	A-277
8.2	Transport of a Homogeneous Gas	A-286
8.3	Multicomponent Gas Transport	A-292
8.4	Methods	A-296
8.5	Applied Numerical Modeling	A-303
8.6	Applications of Gas Transport Theory	A-305
8.7	Derivation of Equations	A-311
8.8	References	A-314
9	Soil Spatial Variability	<i>D.J. Mulla and A.B. McBratney</i>
		A-321
9.1	Variability in Soil Properties from Soil Classification	A-321
9.2	Classical Measures of Variability	A-322
9.3	Geostatistics	A-325
9.4	Sampling Design	A-342
9.5	References	A-349

## SECTION B Soil Chemistry

	Introduction	<i>P.M. Huang</i>	B-1
1	The Chemical Composition of Soils	<i>Philip A. Helmke</i>	B-3
1.1	Introduction		B-3
1.2	Origin and Abundance of Elements		B-4
1.3	General Abundances of Elements in the Earth's Crust and Soils		B-8
1.4	Concentration of Elements in Soils		B-9
1.5	Composition of the Soil Solution		B-22
1.6	References		B-24

2	<b>Soil Organic Matter</b> <i>J.A. Baldock and P.N. Nelson</i>	B-25
2.1	Introduction and Definitions	B-25
2.2	Functions of Soil Organic Matter	B-28
2.3	Quantifying Soil Organic Matter Contents	B-36
2.4	Factors Determining Soil Organic C Levels	B-37
2.5	Chemical Structure of Soil Organic Matter	B-49
2.6	Conclusions	B-71
2.7	References	B-71
3	<b>The Soil Solution</b> <i>A.P. Schwab</i>	B-85
3.1	Basic Concepts	B-85
3.2	Sampling the Soil Solution	B-87
3.3	Thermodynamics of the Soil Solution	B-91
3.4	Interactions of Gases with the Soil Solution	B-101
3.5	Acid/Base Reactions in the Soil Solution	B-104
3.6	Formation of Soluble Complexes	B-108
3.7	Application of Thermodynamic and Equilibrium Concepts to Soil Solutions	B-111
3.8	Current Status and Future Research Directions	B-119
3.9	References	B-120
4	<b>Kinetics and Mechanisms of Soil Chemical Reactions</b> <i>Donald L. Sparks</i>	B-123
4.1	Introduction	B-123
4.2	Time Scales of Soil Chemical Processes	B-124
4.3	Application of Chemical Kinetics to Heterogeneous Surfaces	B-125
4.4	Kinetic Models	B-130
4.5	Kinetics of Important Reactions on Soils and Soil Components	B-140
4.6	Conclusions	B-161
4.7	References	B-162
5	<b>Redox Phenomena</b> <i>Bruce R. James and Richmond J. Bartlett</i>	B-169
5.1	Concepts, Principles, and Theories	B-169
5.2	Methods and Procedures	B-176
5.3	Other Sources on Redox Phenomena and Databases	B-191
5.4	References	B-191
6	<b>Soil Colloidal Behavior</b> <i>Sabine Goldberg, Inmaculata Lebron, and D.L. Suarez</i>	B-195
6.1	Nature of Soil Colloids	B-195
6.2	Interparticle Forces	B-217
6.3	Colloidal Stability	B-221
6.4	Colloid Transport	B-231
6.5	References	B-235
7	<b>Ion Exchange Phenomena</b> <i>Garrison Sposito</i>	B-241
7.1	Origin of Surface Charge	B-241
7.2	Points of Zero Charge	B-245
7.3	Ion Exchange Phenomenology	B-250

7.4	Ion Exchange Models	B-253
7.5	Ion Exchange Kinetics and Thermodynamics	B-257
7.6	References	B-261
8	<b>Chemisorption and Precipitation Reactions</b> <i>M.B. McBride</i>	B-265
8.1	Introduction	B-265
8.2	Surface Functional Groups	B-265
8.3	Surface Complexes	B-268
8.4	Precipitation and Coprecipitation of Inorganic Ions	B-272
8.5	Adsorption Versus Precipitation	B-273
8.6	Adsorption Isotherms	B-277
8.7	Adsorption Kinetics and Equilibria	B-280
8.8	Sorption of Cations	B-282
8.9	Sorption of Anions	B-285
8.10	Coprecipitation of Trace Elements in Solid Solutions	B-293
8.11	Aging Effects During Sorption	B-297
8.12	References	B-299
9	<b>Abiotic Catalysis</b> <i>P.M. Huang</i>	B-303
9.1	Introduction	B-303
9.2	Fundamentals of Catalysis	B-304
9.3	Abiotic Catalysis of Natural and Anthropogenic Organic Compounds	B-306
9.4	Abiotic Catalysis of Metals, Metalloids, and Other Inorganics	B-321
9.5	Conclusions	B-326
9.6	References	B-327
10	<b>Soil pH and pH Buffering</b> <i>Paul R. Bloom</i>	B-333
10.1	Introduction	B-333
10.2	Definition and Determination of Soil pH	B-333
10.3	Acids and Bases in Soil Solutions	B-335
10.4	Overview of Reactions with Soil Solids Controlling pH and pH Buffering	B-337
10.5	Buffering by Soil Organic Matter	B-338
10.6	Proton and Al Exchange in Silicate Clays	B-340
10.7	Variable Charge Buffering by Mineral Components	B-342
10.8	Buffering by Dissolution and Precipitation of Carbonates	B-344
10.9	Proton Consumption by Irreversible Weathering of Aluminous Minerals	B-346
10.10	Determination of Buffer Capacities	B-347
10.11	Soil Acidification	B-349
10.12	References	B-350

## **SECTION C Soil Biology and Biochemistry**

	<b>Introduction</b> <i>E.A. Paul</i>	C-1
1	<b>Microbiota</b>	C-11
1.1	Viruses <i>J.S. Angle</i>	C-11
1.2	Bacteria <i>J.S. Angle</i>	C-14
1.3	Soil Fungi <i>R. Greg Thom</i>	C-22
1.4	Mycorrhizae <i>John Klironomos</i>	C-37

2	Soil Fauna	<i>Paul F. Hendrix</i>	C-45
2.1	Protozoa	<i>Stuart S. Bamforth</i>	C-45
2.2	Nematodes	<i>Robert McSorley</i>	C-52
2.3	Microarthropods	<i>D.A. Crossley, Jr. and David C. Coleman</i>	C-59
2.4	Macroarthropods	<i>D.A. Crossley, Jr. and David C. Coleman</i>	C-65
2.5	Enchytraeids	<i>P.C.J. van Vliet</i>	C-70
2.6	Earthworms	<i>Paul F. Hendrix</i>	C-77
2.7	References		C-85
3	Microbially Mediated Processes		C-95
3.1	Phosphorus, Sulfur and Metal Transformations	<i>J.J. Germida and S.D. Siciliano</i>	C-95
3.2	Decomposition	<i>E.G. Gregorich and H.H. Janzen</i>	C-107
3.3	Anaerobic Microbially Mediated Processes	<i>Zhengping Wang and Wm. H. Patrick, Jr.</i>	C-120
3.4	Soil Enzymes	<i>Paolo Nannipieri and Loretta Landi</i>	C-129
4	Nitrogen Transformations		C-139
4.1	Dinitrogen Fixation	<i>Peter H. Graham</i>	C-139
4.2	Nitrogen Mineralization Immobilization Turnover	<i>Jeanette M. Norton</i>	C-148
4.3	Nitrification	<i>Jeanette M. Norton</i>	C-160
4.4	Denitrification	<i>G.P. Robertson</i>	C-181
4.5	Nitrogen in the Environment	<i>Peter M. Groffman</i>	C-190

## SECTION D Soil Fertility and Plant Nutrition

	Introduction	<i>Eugene J. Kamprath</i>	D-1
1	Bioavailability of Major Essential Nutrients		D-3
1.1	Introduction		D-3
1.2	Bioavailability of Nitrogen	<i>Alfred M. Blackmer</i>	D-3
1.3	Phosphorus Availability	<i>Andrew Sharpley</i>	D-18
1.4	Bioavailability of Soil Potassium	<i>Donald L. Sparks</i>	D-38
1.5	Bioavailability of Calcium, Magnesium, and Sulfur	<i>J.J. Camberato and W.L. Pan</i>	D-53
2	Bioavailability of Micronutrients	<i>John J. Mortvedt</i>	D-71
2.1	Introduction		D-71
2.2	Iron, Manganese, Copper, and Zinc		D-71
2.3	Boron, Molybdenum, and Chloride		D-81
2.4	References		D-86
3	Nutrient Interactions in Soil and Plant Nutrition		
		<i>S.R. Wilkinson, D.L. Grunes, and Malcolm E. Sumner</i>	D-89
3.1	Introduction		D-89
3.2	What are Interactions?		D-89
3.3	Nutrient Interactions Involving Nitrogen		D-91
3.4	Interactions Primarily Involving Potassium		D-98
3.5	Interactions Involving Phosphorus		D-100
3.6	Soil Acidity and Related Interactions		D-103
3.7	Other Interactions		D-104

3.8	Contributing Factors in Plant Nutrient Interactions	D-106
3.9	References	D-108
4	Soil Fertility Evaluation <i>J. Thomas Sims</i>	D-113
4.1	Introduction	D-113
4.2	Soil Testing	D-115
4.3	Plant Testing	D-144
4.4	Soil Fertility Evaluation: The Future	D-147
4.5	References	D-149
5	Fundamentals of Fertilizer Application <i>David Mengel and George Rehm</i>	D-155
5.1	Introduction	D-155
5.2	Application of Mobile Nutrients	D-156
5.3	Application of Immobile Nutrients	D-161
5.4	Placement of P and K Fertilizers	D-163
5.5	Calcium and Magnesium	D-166
5.6	Micronutrients	D-167
5.7	References	D-169
6	Nutrient and Water Use Efficiency <i>Robert Westerman, William R Raun, and Gordon V. Johnson</i>	D-175
6.1	Introduction	D-175
6.2	Nutrient Use Efficiency	D-176
6.3	Water Use Efficiency	D-183
6.4	Concluding Remarks	D-186
6.5	References	D-186

## SECTION E Pedology

	Introduction <i>Larry P. Wilding</i>	E-1
1	Geomorphology of Soil Landscapes <i>Douglas A. Wysocki, Philip J. Schoeneberger and Hannan E. LaGarry</i>	E-5
1.1	Introduction	E-5
1.2	Key Terminology	E-6
1.3	Soil as a Landscape Unit or Body	E-6
1.4	Models of Soil Formation	E-7
1.5	Soil Landscape Models	E-8
1.6	Soil Hydrology	E-14
1.7	Geomorphic Description of Landscapes	E-19
1.8	Geomorphic Components	E-22
1.9	Landscapes, Landforms, Microfeatures, and Anthropogenic Features	E-27
1.10	Age Assessment of Soil Landscapes	E-28
1.11	Paleosols, Geosols, and Climate Interpretation	E-33
1.12	References	E-36
2	Pedogenic Processes <i>Oliver A. Chadwick and Robert C. Graham</i>	E-41
2.1	Introduction	E-41
2.2	Environmental Factors that Drive Pedogenesis	E-41

2.3	Pedogenic Processes	E-45
2.4	From Property to Process	E-72
2.5	References	E-72

## Pedological Modeling

*Marcel R. Hoosbeek, Ronald G. Amundson and Ray B. Bryant* E-77

3.1	Introduction	E-77
3.2	Basics of Modeling	E-80
3.3	Pedological Models	E-86
3.4	Research Chains	E-110
3.5	Model Selection and Application	E-111
3.6	References	E-111

**Soil Taxonomy** *Robert J. Ahrens and Richard W. Arnold* E-117

4.1	Conditions Favoring the Development of <i>Soil Taxonomy</i>	E-117
4.2	Recognition of Guiding Principles for a Soil Classification System	E-118
4.3	Science and Classification	E-119
4.4	Definitions of Categories of <i>Soil Taxonomy</i>	E-121
4.5	Differentiating Characteristics	E-122
4.6	Categories of <i>Soil Taxonomy</i>	E-127
4.7	Recognition of the Categories	E-128
4.8	Forming Names	E-133
4.9	References	E-135

**Other Systems of Soil Classification** *Otto C. Spaargaren* E-137

5.1	Introduction	E-137
5.2	The FAO-UNESCO Legend of the Soil Map of the World	E-137
5.3	The Revised Legend of the FAO-UNESCO Soil Map of the World	E-141
5.4	The World Reference Base for Soil Resources	E-143
5.5	The French Systems of Soil Classification	E-150
5.6	The Soil Classification System of the Former USSR	E-156
5.7	The Chinese Soil Taxonomic Classification	E-161
5.8	The Australian Soil Classification	E-166
5.9	Classification Systems of Brazil, Canada, England and Wales, New Zealand and South Africa	E-170
5.10	References	E-173

**Classification of Soils** E-175

6.1	Introduction: General Characteristics of Soil Orders and Global Distributions <i>Larry P. Wilding</i>	E-175
6.2	Histosols <i>Martin C. Rabenhorst and David Swanson</i>	E-183
6.3	Andisols <i>J.M. Kimble, C.L. Ping, Malcolm E. Sumner and Larry P. Wilding</i>	E-209
6.4	Entisols <i>L.C. Nordt, M.E. Collins, D.S. Fanning and H.C. Monger</i>	E-224
6.5	Inceptisols <i>Wayne H. Hudnall, Lois M. West, Ellis C. Benham and Larry P. Wilding</i>	E-242
6.6	Gelisols <i>J.G. Bockheim and C. Tarnocai</i>	E-256
6.7	Vertisols <i>Clement E. Coulombe, Larry P. Wilding and Joe B. Dixon</i>	E-269
6.8	Mollisols <i>J.C. Bell and P.A. McDaniel</i>	E-286
6.9	Spodosols <i>Delbert L. Mokma and Christine V. Evans</i>	E-307

6.10	Aridisols	<i>Randal J. Southard</i>	E-321
6.11	Alfisols	<i>C.T. Hallmark and D.P. Franzmeier</i>	E-338
6.12	Ultisols	<i>Larry T. West and Friedrich H. Beinroth</i>	E-358
6.13	Oxisols	<i>Friedrich H. Beinroth, Hari Eswaran, Goro Uehara and Paul F. Reich</i>	E-373
7	Land Evaluation for Landscape Units	<i>J. Bouma</i>	E-393
7.1	Introduction		E-393
7.2	Developments in Land Evaluation		E-393
7.3	Beyond Classical Land Evaluation		E-396
7.4	What is the Question?		E-396
7.5	What is the Proper Procedure?		E-397
7.6	What is the Role of the Land?		E-400
7.7	Interaction with Stakeholders in the Information Age		E-401
7.8	Case Studies on Field and Farm Scale		E-401
7.9	References		E-411

## SECTION F Soil Mineralogy

Introduction	<i>Joseph W. Stucki</i>	F-1	
1	The Alteration and Formation of Soil Minerals by Weathering		
	<i>G.J. Churchman</i>	F-3	
1.1	Introduction	F-3	
1.2	Weathering	F-4	
1.3	Driving Forces in Mineral Alteration	F-6	
1.4	Processes and Products of Mineral Weathering	F-9	
1.5	Occurrence of Clay Minerals in Relation to Soil Types	F-40	
1.6	Effect of Environmental Factors on the Formation of Clay Minerals	F-42	
1.7	Explanations and Predictions of Mineral Development from Bulk Solution Compositions	F-46	
1.8	Processes of Mineral Alteration and Formation by Weathering	F-53	
1.9	References	F-59	
2	Phyllosilicates	<i>C.G. Olson, M.L. Thompson and M.A. Wilson</i>	F-77
2.1	Introduction	F-77	
2.2	Characteristics of Phyllosilicate Clays	F-80	
2.3	Instrumental Techniques for Characterization of Phyllosilicates in Soil	F-96	
2.4	Clay Minerals and Properties of Soils	F-112	
2.5	Engineering Properties	F-118	
2.6	References	F-119	
3	Oxide Minerals	<i>Nestor Kämpf, Andreas C Scheinost and Darrell G. Schulze</i>	F-125
3.1	Introduction	F-125	
3.2	Iron Oxides	F-125	
3.3	Manganese Oxides	F-137	
3.4	Aluminum Oxides	F-143	
3.5	Silicon Oxides	F-148	
3.6	Titanium and Zirconium Minerals	F-154	
3.7	References	F-157	



4	Poorly Crystalline Aluminosilicate Clays	<i>James Harsh</i>	F-169
4.1	Poorly Crystalline Materials		F-169
4.2	Allophane and Imogolite: Nature and Occurrence in Soils		F-170
4.3	Surface Charge Characteristics of Noncrystalline Aluminosilicates and Variable Charge Soils		F-176
4.4	Interactions of Allophane and Imogolite with Other Soil Constituents		F-178
4.5	Conclusion		F-180
4.6	References		F-180

## SECTION G Interdisciplinary Aspects of Soil Science

	Introduction	<i>Isaac Shainberg</i>	G-1
1	Salinity	<i>R. Keren</i>	G-3
1.1	Origin and Distribution of Saline Soils		G-3
1.2	Water Quality Criteria for Irrigation		G-5
1.3	Effect of Salinity on Soil Physical Properties		G-10
1.4	Effects of Salinity on Plants		G-11
1.5	Reclamation of Saline and Boron-Affected		G-16
1.6	References		G-21
2	Sodicity	<i>G.J. Levy</i>	G-27
2.1	Introduction		G-27
2.2	Sodic Soils: Definition and Distribution		G-28
2.3	Processes Characterizing the Behavior of Sodic Soils		G-32
2.4	Aggregate Stability and Organic Matter in Sodic Soils		G-35
2.5	Hydraulic Properties of Sodic Soils		G-37
2.6	Crop Responses to Sodic Conditions		G-46
2.7	Reclamation of Sodic Soils		G-48
2.8	Management of Sodic Soils		G-51
2.9	Environmental Aspects of Sodic Soils		G-53
2.10	Concluding Comments		G-55
2.11	References		G-55
3	Hardsetting Soils	<i>Chris E. Mullins</i>	G-65
3.1	Identification and Definition of Hardsetting Soils		G-65
3.2	Distribution of Hardsetting Soils		G-67
3.3	Processes Involved in Hardsetting		G-69
3.4	Methodologies for Assessing Hardsetting Soils		G-75
3.5	Effects of Hardsetting on Plant Growth		G-78
3.6	Management of Hardsetting Soils		G-79
3.7	References		G-83
4	Biogeochemistry of Wetlands	<i>K.R. Reddy, E.M. D'Angelo and W.G. Harris</i>	G-89
4.1	Introduction		G-89
4.2	Definitions		G-89
4.3	Wetland Soils		G-90
4.4	Redox Gradients		G-97

4.5	Carbon	G-99
4.6	Nitrogen	G-103
4.7	Phosphorus	G-106
4.8	Metals	G-109
4.9	Toxic Organics	G-110
4.10	References	G-114
5	<b>Acid Sulfate Soils</b> <i>C.J. Ritsema, M.E.F. van Mensvoort, D.L. Dent, Y. Tan, H. van den Bosch and A.L.M van Wijk</i>	G-121
5.1	Introduction	G-121
5.2	Characteristics, Occurrence and Environmental Problems	G-122
5.3	Role of Pyrite	G-128
5.4	Modeling Soil Physical and Chemical Processes in Acid Sulfate Soils	G-130
5.4	Use, Management and Evaluation of Acid Sulfate Land	G-144
5.6	References	G-150
6	<b>Soils and Environmental Quality</b> <i>Terry J. Logan</i>	G-155
6.1	Introduction	G-155
6.2	Nutrients	G-156
6.3	Pesticides and Other Xenobiotics	G-160
6.4	Trace Elements	G-162
6.5	Other Chemicals	G-165
6.6	Chemical Speciation, Bioavailability, and Risk Assessment	G-165
6.7	Concept and Use of Bioavailability in Environmental Soil Assessment	G-167
6.8	Soil Exposure Assessment in Environmental Risk Assessment	G-167
6.9	Remediation of Chemically Degraded Soil	G-168
6.10	References	G-168
7	<b>Water Erosion</b> <i>Dino Torri and Lorenzo Borselli</i>	G-171
7.1	Introduction	G-171
7.2	Wetting of the Soil	G-171
7.3	Drop Impact	G-172
7.4	Overland Flow Erosion	G-175
7.5	Pipe Erosion	G-179
7.6	Shallow Mass Movement	G-181
7.7	Gully Erosion	G-183
7.8	Vegetation, Land Leveling and Wildfires	G-185
7.9	Soil Erosion Models	G-187
7.10	Soil Characteristics and Erosion	G-188
7.11	Conclusions	G-191
7.12	References	G-192
8	<b>Wind Erosion</b> <i>D.W. Fryrear</i>	G-195
8.1	Introduction	G-195
8.2	Mechanics of Wind Erosion Processes	G-196
8.3	Modeling the Wind Erosion Process	G-203
8.4	Wind Erosion Measuring Systems: Field Instrumentation	G-208
8.5	Major Control Systems	G-210

8.6	Conclusions	G-212
8.7	References	G-213
9	<b>Land Application of Wastes</b> <i>D.M. Miller and W.P. Miller</i>	G-217
9.1	A Brief History and Overview of Land Application	G-217
9.2	Properties of Common Land-Applied Byproducts	G-220
9.3	Soil Fertility Considerations in Land Application	G-229
9.4	Effects of Land Application on Soil Properties	G-231
9.5	Environmental Aspects of Byproduct Applications	G-234
9.6	Recommendations	G-241
9.7	References	G-241
10	<b>Conservation Tillage</b> <i>J.M. Bradford and G.A. Peterson</i>	G-247
10.1	Introduction	G-247
10.2	Definitions	G-248
10.3	Carbon Cycle and No-Till	G-248
10.4	Residue Management and Decomposition	G-250
10.5	Biological Activity	G-252
10.6	Soil Fertility and Nutrition	G-254
10.7	Water and Wind Erosion	G-256
10.8	Surface Sealing, Crusting, and Seedling Emergence	G-258
10.9	Compaction	G-259
10.10	Cover Crops	G-261
10.11	Water Conservation	G-261
10.12	Soil by Climate Interactions	G-263
10.13	Conclusions	G-266
10.14	References	G-266
11	<b>Soil Quality</b> <i>Michael J. Singer and Stephanie Ewing</i>	G-271
11.1	Introduction	G-271
11.2	Definitions of Soil Quality	G-276
11.3	Measuring Soil Quality	G-277
11.4	Indices of Soil Quality	G-287
11.5	Conclusions	G-293
11.6	References	G-293

## SECTION H     Soil Databases

	<b>Introduction</b> <i>Marion F. Baumgardner</i>	H-1
1	<b>From the Soil Map of the World to the Digital Global Soil and Terrain Database: 1960-2002</b> <i>F.O. Nachtergaele</i>	H-5
1.1	Introduction	H-5
1.2	The Soil Map(s) of the World	H-5
1.3	Information Contained in the Soil Map of the World	H-7
1.4	Advantages and Disadvantages of the Soil Map of the World	H-8
1.5	The World Soils and Terrain Database	H-9
1.6	Soil Profile Databases	H-11

1.7	Conclusions	H-12
1.8	References	H-12
2	<b>SOTER: The World Soils and Terrain Database</b>	
	<i>W.P. van Engelen</i>	H-19
2.1	Introduction	H-19
2.2	Background and Objectives	H-19
2.3	The SOTER Approach	H-21
2.4	Status	H-23
2.5	Discussion and Conclusions	H-26
2.6	References	H-27
3	<b>Development of a 0.5° by 0.5° Resolution Global Database</b>	
	<i>N.H. Batjes</i>	H-29
3.1	Introduction	H-29
3.2	Background and Rationale	H-30
3.3	Database Development	H-30
3.4	Applications	H-34
3.5	Discussion and Conclusions	H-36
3.6	References	H-38
4	<b>The Canadian Soil Database</b> <i>D.R. Coote and K.B. MacDonald</i>	H-41
4.1	Canadian Soil Database	H-41
4.2	The National Soil Database (NSDB)	H-41
4.3	Soil Map of Canada/Land Potential Database (LPDB)	H-42
4.4	Soil Landscapes of Canada (SLC)	H-43
4.5	Detailed Soil Surveys	H-45
4.6	National Ecological Framework	H-48
4.7	Provincial Soil Databases	H-48
4.8	Non-GIS Databases	H-49
4.9	References	H-51
5	<b>United States Soil Survey Database</b> <i>D.J. Lytle</i>	H-53
5.1	Introduction	H-53
5.2	Description of Soil Survey Databases	H-53
5.3	The Evolution of Soil Survey Map Unit Databases	H-60
5.4	Standards for Soil Survey Data	H-64
5.5	Research and Development Opportunities	H-66
5.6	References	H-67
6	<b>The Use of Soil Databases in Resource Assessments and Land Use Planning</b> <i>G.W. Petersen, Egide Nizeyimana, D.A. Miller and B.M. Evans</i>	H-69
6.1	Introduction	H-69
6.2	Land Use Planning	H-70
6.3	Conservation Planning and Nutrient Management	H-76
6.4	Environmental Resource Assessments and Modeling	H-77
6.5	Resource Assessments and Planning at Regional and Global Scales	H-80
6.6	Future Trends and Considerations	H-88
6.7	References	H-89