## Contents

List of Contributors		xi
	oduction na H. Wall	1
Sec	tion 1—The Living Soil and Ecosystem Services	
	Introduction Karl Ritz and Wim H. van der Putten	5
1.1	Soil as a Habitat Patrick Lavelle	7
	<ul> <li>1.1.1 Introduction</li> <li>1.1.2 Conditions in soils</li> <li>1.1.3 Adaptive strategies of soil organisms</li> <li>1.1.4 Self-organization and the spatial organization of soils</li> <li>1.1.5 Discrete scales in soil function</li> <li>1.1.6 The challenge of an eco-efficient use of soils</li> <li>1.1.7 Approaches to soil ecological research</li> <li>1.1.8 Conclusions</li> </ul>	7 7 12 15 16 18 21 21
1.2	Soil Biodiversity and Functions Susanne Wurst, Gerlinde B. De Deyn, and Kate Orwin	28
	<ul> <li>1.2.1 Soil biodiversity</li> <li>1.2.2 How to investigate soil communities</li> <li>1.2.3 Diversity-function relationships</li> <li>1.2.4 Taking a holistic view to soil diversity-ecosystem functioning</li> <li>1.2.5 Conclusions</li> </ul>	28 34 37 39 41
1.3	Ecosystem Services Provided by the Soil Biota Lijbert Brussaard	45
	<ul> <li>1.3.1 Introduction</li> <li>1.3.2 Understanding ecosystem functioning</li> <li>1.3.3 Understanding ecosystem structure: revisiting the functional group concept</li> <li>1.3.4 Understanding effects of environmental drivers and land management on ecosystem functioning and services</li> <li>1.3.5 Working with nature</li> </ul>	45 46 49 51 52

v

	1.3.6 Landscape context	54
	1.3.7 Conclusions	55
	Synthesis	59
	Karl Ritz and Wim H. van der Putten	
Sec	tion 2—From Genes to Ecosystem Services	
	Introduction	63
	Wim H. van der Putten and Karl Ritz	
2.1	From Single Genes to Microbial Networks	65
	Evelyn Hackl, Michael Schloter, Ute Szukics, Levente Bodrossy, and Angela Sessitsch	
	2.1.1 Introduction	65
	2.1.2 Analyzing microbial genes to understand ecosystem functioning 2.1.3 Methodological approaches to the gene-based study	66
	of microbial communities and networks	68
	2.1.4 Genes in microbial networks of organic matter decomposition	
	and biodegradation of pollutants	69
	2.1.5 Microbial genes in nitrogen turnover cascades	71
	2.1.6 Genes underlying microbial communication	72
	2.1.7 Microbial genes for interacting in the plant environment	73
	2.1.8 From genes to microbial networks: future prospects	75
2.2	From Genes to Ecosystems: Plant Genetics as a Link between	
	Above- and Belowground Processes	82
	Jennifer A. Schweitzer, Michael D. Madritch, Emmi Felker-Quinn, and Joseph K. Bailey	
	2.2.1 Introduction	82
	2.2.2 The role of plant functional traits in bridging species interactions	
	with soil community dynamics	84
	2.2.3 The role of plant genetic variation on soil communities	85
	2.2.4 The role of plant genetic variation on ecosystem processes	87
	2.2.5 The evolutionary implications of plant–soil linkages	89
	2.2.6 Conclusions and future directions	92
2.3	Delivery of Soil Ecosystem Services: From Gaia to Genes	98
	Katarina Hedlund and Jim Harris	
	2.3.1 Introduction	98
	2,3.2 Ecosystem services delivery and Gaia theory	99
	2.3.3 At what biological levels are soil ecosystem services produced?	101
	2.3.4 At what spatial scales can we describe and quantify soil ecosystem services?	102
	2.3.5 Use of soil ecosystem services in a policy context	103
	2.3.6 Conclusions	105
	Synthesis	111
	Wim H. van der Putten and Karl Ritz	

Sec	tion 3—Community Structure and Biotic Assemblages	
	Introduction Donald R. Strong and Valerie Behan-Pelletier	115
		447
3.1	Succession, Resource Processing, and Diversity in Detrital Food Webs Justin Bastow	117
	3.1.1 The surprising diversity of soil communities	117
	3.1.2 From litter and carrion to soil organic matter: detrital succession in soils	118
	3.1.3 Mechanisms and models for detrital succession	121
	<ul><li>3.1.4 Can successional specialization explain coexistence and the diversity in soils?</li><li>3.1.5 Latitudinal gradients in soil diversity: detrital food webs thwart ecology's</li></ul>	126
	oldest pattern	128
	3.1.6 Future directions in understanding detrital succession	130
3.2	<b>Patterns of Biodiversity at Fine and Small Spatial Scales</b> Matty P. Berg	136
	3.2.1 The riddle of soil biodiversity	136
	3.2.2 It is all a matter of scale	137
	3.2.3 Spatial distribution of soil functions	147
	3.2.4 Spatial scales are nested	149
3.3	Linking Soil Biodiversity and Human Health: Do Arbuscular Mycorrhizal Fungi	
	Contribute to Food Nutrition?	153
	Pedro M. Antunes, Philipp Franken, Dietmar Schwarz, Matthias C. Rillig, Marco Cosme, Martha Scott, and Miranda M. Hart	
	3.3.1 Soil health is linked to human health and global food security	153
	3.3.2 Traditional ways of boosting crop nutrients	154
	3.3.3 A critical role for soil microbes	155
	3.3.4 Using rhizosphere microbes to create healthier food	157
	3.3.5 Negative effects of microbes on food quality	162
	3.3.6 The full potential of soil microbes to improve human health	163
	3.3.7 Conclusion	164
3.4	Ecosystem Influences of Fungus-Growing Termites in the Dry Paleotropics	173
	Gregor W. Schuurman	173
	3.4.1 Introduction	173
	3.4.2 Fungus-growers	174
	3.4.3 Fungus-grower influences on ecosystem processes	177
	3.4.4 Fungus-growers as ecosystem engineers 3.4.5 Synthesis	183
	3.4.6 Take-home messages	185
	3.4.7 Future directions	185
3.5	The Biogeography of Microbial Communities and Ecosystem Processes:	
-1-	Implications for Soil and Ecosystem Models	189
	Mark A. Bradford and Noah Fierer	
	3.5.1 Predicting environmental responses of soil processes	189
	· · · · ·	

	3.5.2 Misplaced physics envy in soil models	190
	3.5.3 Functional redundancy, similarity, equivalence, and biogeography	192
	3.5.4 Experimental tests of functional equivalence	192
	-	195
	3.5.5 Putting ecology into soil models	
	3.5.6 Revisiting the functional paradigm in soil ecology	198
3.6	Biogeography and Phylogenetic Community Structure of Soil Invertebrate Ecosystem	
	Engineers: Global to Local Patterns, Implications for Ecosystem Functioning and	
	Services and Global Environmental Change Impacts	201
	Lijbert Brussaard, Duur K. Aanen, Maria J.I. Briones, Thibaud Decaëns, Gerlinde B. De Deyn,	
	Tom M. Fayle, Samuel W. James, and Tânia Nobre	
	3.6.1 Introduction	201
	3.6.2 Macroecological patterns in soil invertebrate communities	203
	3.6.3 Termite biogeography and phylogenetic community structure	206
	3.6.4 Ant biogeography and phylogenetic community structure	211
	3.6.5 Earthworms	214
	3.6.6 Enchytraeids	218
	3.6.7 Trait-based ecology of soil invertebrate ecosystem engineers with a view to the	
	possible effects on global environmental change and ecosystem	
	functioning and services	222
	0	
	Synthesis	233
	Donald R. Strong and Valerie Behan-Pelletier	
Soc	tion 4—Global Changes	
Sec	tion 4—Giobal Changes	
	Introduction	239
	Richard D. Bardgett and T. Hefin Jones	
4.1	Climate Change and Soil Biotic Carbon Cycling	241
	Nicholas J. Ostle and Susan E. Ward	
	4.1.1 Introduction	241
	4.1.2 Climate change and plant-soil interactions	242
	4.1.3 Direct effects	243
	4.1.4 Indirect effects	245
	4.1.5 Making predictions	248
	4.1.6 Conclusions	249
4.2	The Impact of Nitrogen Enrichment on Ecosystems and Their Services	256
	Peter Manning	
	4.2.1 Nitrogen—the Earth's most limiting resource?	256
	4.2.2 Direct impacts of nitrogen enrichment on soil chemistry	200
	and plant and microbial metabolism	258
	4.2.3 Effects of nitrogen enrichment on plants and the soil biota	259
	4.2.4 Net effects on ecosystem services	265
	4.2.5 Conclusion and future directions	265
	Tiery Southandrout and internetions	207

4.3	Urbanization, Soils, and Ecosystem Services	270
	Mitchell A. Pavao-Zuckerman	250
	4.3.1 Introduction to urbanization and soils in cities	270 270
	4.3.2 Urbanization effects on soils	270
	4.3.3 Examples of ecosystem services in cities	275
	<ul><li>4.3.4 Management for urban ecosystem services</li><li>4.3.5 Summary</li></ul>	278
4.4	Management of Grassland Systems, Soil, and Ecosystem Services	282
	Phil Murray, Felicity Crotty, and Nick van Eekeren	
	4.4.1 Introduction	282
	4.4.2 Plant–soil interactions	283
	4.4.3 Ecosystem services provided by the soil biota	284
	4.4.4 Impact of management intensity of grassland systems	288
	4.4.5 Trade-offs between ecosystem services	288
	4.4.6 Conclusions	290
	Synthesis	295
	Richard D. Bardgett and T. Hefin Jones	200
	Renard D. Durugen und I. Hejin jones	
Sec	tion 5—Sustainable Soils	
	Introduction	299
	Johan Six and Jeffrey E. Herrick	
5.1	Soil Productivity and Erosion	301
5.1	Kristof Van Oost and Martha M. Bakker	
	5.1.1 Introduction	301
	5.1.2 Soil gain versus soil loss, and accelerated versus natural erosion	301
	5.1.2 Son gain versus son loss, and accelerated versus natural crosson 5.1.3 Erosion's effect on agricultural productivity	305
	5.1.3 The importance of erosion-induced productivity losses for agriculture	309
	5.1.5 Summary	312
		245
5.2	Agroforestry and Soil Health: Linking Trees, Soil Biota, and Ecosystem Services Edmundo Barrios, Gudeta W. Sileshi, Keith Shepherd, and Fergus Sinclair	315
	5.2.1 Introduction	315
	5.2.2 How trees influence soil properties and biota	316
	5.2.3 Agroforestry systems increase abundance of soil biota	318
	5.2.4 Soil biological processes and soil-based ecosystem services	319
	5.2.5 Tree–soil biota interactions foster the provision of soil-based ecosystem services	320
	5.2.6 Soil health monitoring systems	324
	5.2.7 Conclusions and recommendations	327
5.3	Soil Health: The Concept, Its Role, and Strategies for Monitoring	331
	Douglas L. Karlen	331
	5.3.1 The concept of soil health	001

CONTENTS

ix

х	CONTENTS
---	----------

	5.3.2 The evolution of soil health	333
	5.3.3 Monitoring soil health	334
	5.3.4 Summary and conclusions	335
5.4	Managing Soil Biodiversity and Ecosystem Services	337
	Michel A. Cavigelli, Jude E. Maul, and Katalin Szlavecz	
	5.4.1 Introduction	337
	5.4.2 Edible crop diversity	338
	5.4.3 Plant selection impacts on ecosystem services	338
	5.4.4 Plant selection impacts on soil biodiversity	340
	5.4.5 Managing plant diversity	341
	5.4.6 Tillage impacts on ecosystem services	342
	5.4.7 Tillage impacts on soil biodiversity	343
	5.4.8 Chemical application impacts on ecosystem services	344
	5.4.9 Chemical application impacts on soil biodiversity	345
	5.4.10 Organic material application impacts on ecosystem services	346
	5.4.11 Organic material application impacts on soil biodiversity	346
	5.4.12 Organic cropping system impacts on ecosystem services	347
	5.4.13 Organic cropping system impacts on soil biodiversity	348
	5.4.14 Conclusions	350
5.5	Soil Ecosystem Resilience and Recovery	357
	A. Stuart Grandy, Jennifer M. Fraterrigo, and Sharon A. Billings	
	5.5.1 Introduction	357
	5.5.2 Soil disturbance, resilience, and recovery	358
	5.5.3 Resilience and recovery: soil organic matter dynamics	361
	5.5.4 Resilience and recovery: soil nutrient cycling	364
	5.5.5 Future directions	366
5.6	Applying Soil Ecological Knowledge to Restore Ecosystem Services	377
	Sara G. Baer, Liam Heneghan, and Valerie T. Eviner	
	5.6.1 Introduction	377
	5.6.2 Low to high legacy: lessons from restoration of mined land	381
	5.6.3 Moderate legacy: restoration of agricultural systems	382
	5.6.4 High legacy under dynamic change: preventing invasion and	205
	restoring invaded systems	385
	5.6.5 Novel legacy: no analog ecosystems and environmental conditions	387
	5.6.6 Conclusions	389
	Synthesis	395
	Jeffrey E. Herrick and Johan Six	

397

## Index