

Contents

Preface xi

1 Introduction 1

- 1.1 History of forest soil studies 1
- 1.2 Soil formation 3
- 1.3 Trees and soil environment 8

2 Soil properties 10

- 2.1 Physical properties 10
 - 2.1.1 Texture 10
 - 2.1.2 Soil structure 13
 - 2.1.3 Water 17
- 2.2 Chemical properties 20
 - 2.2.1 Acidity and alkalinity 20
 - 2.2.2 Cation exchange capacity and nutrient availability 22
 - 2.2.3 Salinity 24
- 2.3 Soil organic matter 25
 - 2.3.1 Litter 25
 - 2.3.2 Humus: inherited and humified organic substances 27
 - 2.3.3 Organo-mineral complexes 28
- 2.4 Soil fertility 30

3 Forest soil development and classification 32

- 3.1 Soil development 33
 - 3.1.1 Soil formation processes 33
- 3.2 Soil profile 37
 - 3.2.1 Soil horizons 38
 - 3.2.2 Soil depth 40
 - 3.2.3 Time 41

viii Contents

- 3.3 Soil classification 42
 - 3.3.1 History and principles of soil classification 42
 - 3.3.2 USDA classification 43
 - 3.3.3 FAO classification 47
- 3.4 Examples of typical temperate and boreal forest soils 50
 - 3.4.1 Leptosols 52
 - 3.4.2 Luvisols 53
 - 3.4.3 Cambisols 53
 - 3.4.4 Podzols 54
 - 3.4.5 Gleysols 55
 - 3.4.6 Histosols 56
- 4 Soil fungi 57**
 - 4.1 Mycorrhizas 57
 - 4.1.1 Emanating hyphae and rhizomorphs 60
 - 4.1.2 Identification of mycorrhizas 62
 - 4.1.3 Determination of the extraradical and extramatrical mycelium 64
 - 4.2 Community structure 66
 - 4.2.1 Common mycelial networks 76
 - 4.2.2 Relating ectomycorrhizal community structure to ecosystem function 76
- 5 Soil water 78**
 - 5.1 Introduction and background 78
 - 5.1.1 Water-binding forces in soils 78
 - 5.1.2 Water potential 79
 - 5.1.3 Soil moisture heterogeneity 80
 - 5.2 Water acquisition by roots and mycorrhizas 82
 - 5.3 Hydraulic redistribution 86
 - 5.4 Waterlogging 90
 - 5.5 Drought 93
- 6 Forest carbon cycle 94**
 - 6.1 The global carbon cycle 95
 - 6.2 Formation of organic matter 96
 - 6.3 Belowground carbon cycles 98
 - 6.3.1 Belowground biomass pool and fluxes 99
 - 6.3.2 Consumption: soil fauna 108
 - 6.3.3 Final stages of organic matter breakdown 109
 - 6.4 Soil humus 112
 - 6.4.1 Mor and mull humus 113
 - 6.4.2 Chemical composition of humus 115
 - 6.4.3 Peat formation 116

7	Nutrient cycling	118
7.1	Nutrient supply and uptake	119
7.2	Nitrogen	124
7.2.1	N cycling	124
7.2.2	Importance of C:N ratios	128
7.2.3	Climate change and the N cycle	130
7.3	Phosphorus	133
7.4	Potassium, calcium and magnesium	137
7.5	Forest nutrient cycle and climate change	138
8	Northern forests in a high-CO₂ world	143
8.1	Atmospheric CO ₂ enrichment technology	143
8.2	Increased forest production	146
8.3	Soil C dynamics	148
8.4	Soil CO ₂ efflux	155
8.5	High CO ₂ and soil N cycle	156
8.6	Diversity of soil biota	158
9	Soil acidity and heavy metal pollution	161
9.1	Emission, transport and deposition of pollutants	161
9.2	Inputs of acidity	164
9.2.1	Soil acidification: nutrient loss, Al release, Al in soil solutions	165
9.2.2	Soil solution speciation of Al	170
9.3	Heavy metals in forest soils	171
9.3.1	Soil solution speciation of heavy metals	174
9.4	Loss of base cations	174
9.5	Aluminium accumulation and toxicity	179
9.5.1	Aluminium activity and speciation	182
9.5.2	Base cations	182
9.6	Heavy metal effects on trees	183
9.7	Soil acidity effects on forest ecosystems	184
9.7.1	Effects of soil acidity on roots, rooting depth and root growth	184
9.7.2	Chronology of soil acidification	189
9.7.3	Soil acidity and mycorrhizas	191
9.7.4	Recovery from acidification	194
10	Nitrogen	195
10.1	Nitrogen cycle	195
10.2	Tree growth and biomass allocation	199
10.3	Changes in ground vegetation	205
10.4	Changes in ectomycorrhizal community structure and function	207
10.5	Increased susceptibility to pathogens and insects	209
10.6	Export of NO ₃ with seepage water	210

x Contents

11 Soil functioning and climate change 213

- 11.1 Effects of climate change 214
 - 11.1.1 Increasing temperature 216
 - 11.1.2 Changing rainfall 220
 - 11.1.3 Nitrogen deposition 223
- 11.2 Feedback effects of forests 226
 - 11.2.1 Contribution of northern forests to the global C cycle 227
 - 11.2.2 Forest expansion and the water cycle 229
- 11.3 Environmental benefits and ecosystem services of forest soils 232
 - 11.3.1 Carbon sequestration 233
 - 11.3.2 Water cycle 235
 - 11.3.3 Biodiversity 236

References 238

Index 253

The color plate section can be found between pages 148 and 149.