

Contents

Contributors xxiv

Foreword xxvii

Preface xxix

Part one Physiography and history

1 Evolution of landscapes T.C. Partridge 5

1.1 **Introduction** 5

1.2 **Early history: Gondwanaland and its fragmentation** 5

1.3 **Erosion and recession of the Great Escarpment during the Cretaceous** 7

1.4 **The African planation surface and its distribution** 8

1.5 **Mid-Tertiary disturbances and incision of the African surface** 12

1.6 **Late Neogene tectonism and the rise of the southeastern hinterland** 14

1.7 **Soils** 16

1.7.1 High ground above the African surface 16

1.7.2 African surface 16

1.7.3 Post-African planation and dissection 17

1.7.4 The Kalahari Basin 17

1.8 **Conclusion** 18

1.9 **References** 18

2 Climate R.E. Schulze 21

2.1 **Introduction: the climate-vegetation link** 21

2.2 **Information sources, approaches to climate analysis and mapping techniques** 22

2.3 **Light (solar radiation)** 22

2.3.1 The seasonal distribution of solar radiation over southern Africa 23

2.3.2 The influence of topography on solar radiation 23

2.4 **Temperature** 25

x / Contents

- 2.4.1 Distributions of means, maxima, minima and ranges of temperature over southern Africa 25
- 2.4.2 Frost 28
- 2.5 **Precipitation** 28
 - 2.5.1 The importance of precipitation and moisture in vegetation studies 28
 - 2.5.2 Mean annual precipitation patterns over southern Africa 30
 - 2.5.3 Variability of annual precipitation over southern Africa 31
 - 2.5.4 Concentration and seasonality indices of precipitation over southern Africa 31
 - 2.5.5 Precipitation interception by vegetation 33
 - 2.5.6 Fog 33
 - 2.5.7 Snow 34
 - 2.5.8 Lightning 34
- 2.6 **Potential evaporation** 35
 - 2.6.1 The importance of evaporation in vegetation studies 35
 - 2.6.2 Reference potential evaporation and its estimation in southern Africa 35
 - 2.6.3 Annual and seasonal distributions of reference potential evaporation over southern Africa 37
- 2.7 **Moisture availability to plants** 37
 - 2.7.1 The importance of the soil-water budget in vegetation studies 37
 - 2.7.2 Soil moisture stress patterns over southern Africa 39
- 2.8 **Primary production** 39
 - 2.8.1 Concepts 39
 - 2.8.2 Estimation of net above-ground primary production in southern Africa 39
 - 2.8.3 Distributions of mean annual net above-ground primary production and its inter-annual variability over southern Africa 39
- 2.9 **Conclusions** 41
- 2.10 **Acknowledgements** 41
- 2.11 **References** 41

3 **Phytogeography, flora and endemism** R.M. Cowling and C. Hilton-Taylor 43

- 3.1 **Introduction** 43
- 3.2 **Phytogeographical division** 43
 - 3.2.1 Zambezian Region 44
 - 3.2.2 Kalahari-Highveld Region 44
 - 3.2.3 Karoo-Namib Region 45
 - 3.2.4 Tongaland-Pondoland Region 45
 - 3.2.5 Afromontane Region 45
 - 3.2.6 Cape Region 46
 - 3.2.7 Controversies in phytogeographical delimitation 46
- 3.3 **Flora** 47
 - 3.3.1 Size 47
 - 3.3.2 Composition and endemism 49
 - 3.3.3 Affinities 49
- 3.4 **Patterns and correlates of species endemism** 51
 - 3.4.1 Patterns 51
 - 3.4.2 Correlates 52
 - 3.4.2.1 *Habitat aspects* 52

3.4.2.2	Phylogenetic aspects	53
3.4.2.3	Biological aspects	53
3.4.2.4	Age	57
3.5	Concluding discussion	57
3.6	References	58

4 Vegetation history L. Scott, H.M. Anderson and J.M. Anderson 62

4.1	Introduction	62
4.2	The Pangaeic phase	62
4.2.1	The fossil record	62
4.2.2	The early vascular plants (c. 390–360 Myr)	64
4.2.3	The coal-forming Glossopterid forests (c. 280 Myr)	65
4.2.4	A clear biodiversity peak (c. 210 Myr)	65
4.2.5	The Bennettitalean heyday (140–120 Myr)	65
4.3	The spread of flowering plants	66
4.3.1	The mid-Cretaceous to early Tertiary environment (c. 120–60 Myr)	66
4.3.2	Macrofossils	66
4.3.3	Pollen and spores	67
4.4	Origin of modern plant communities	68
4.4.1	The Neogene fossil record and environmental change (c. 20–2 Myr)	68
4.4.2	West coast, Namaqualand and Karoo	68
4.4.3	Southern and southwestern coasts	69
4.4.4	Interior plateau	69
4.5	Quaternary vegetation changes	69
4.5.1	Cyclic change during the Quaternary (c. 1.8 Myr)	69
4.5.2	Desert biome	70
4.5.3	Succulent karoo biome	70
4.5.4	Nama-karoo biome	71
4.5.5	Fynbos biome	72
4.5.6	Grassland biome	73
4.5.7	Savanna biome	76
4.5.8	Forest biome	77
4.6	Evolution of vegetation and global palaeoclimate	78
4.7	Acknowledgements	79
4.8	References	79

Part two Biomes

5	Categorization of biomes	M.C. Rutherford 91
5.1	Introduction	91
5.2	The biome units	92
5.3	Nomenclature	92

5.4	Important outliers 94
5.5	Typification limits 94
5.6	The status of gradual transitions 94
5.7	Biome determinants 95
5.8	Floristic relationships 97
5.9	Conclusions 97
5.10	Acknowledgements 97
5.11	References 97
6	Fynbos R.M. Cowling, D.M. Richardson and P.J. Mustart 99
6.1	Introduction 99
6.2	The fynbos biome in perspective 99
6.3	Determinants of pattern 104
6.3.1	Biome-scale 104
6.3.2	Landscape-scale 105
6.3.2.1	<i>Fynbos/forest boundary</i> 105
6.3.2.2	<i>Fynbos/karroid and renosterveld boundary</i> 106
6.3.2.3	<i>Fynbos/grassland boundary</i> 107
6.3.3	Community-scale 107
6.3.3.1	<i>Structurally characterized communities</i> 107
6.3.3.2	<i>Floristically characterized communities</i> 108
6.4	Plant structure and function 110
6.4.1	Plant types 110
6.4.2	Reproductive ecology 111
6.4.2.1	<i>Flowering phenology and pollination</i> 111
6.4.2.2	<i>Seed ecology</i> 112
6.4.2.3	<i>Germination</i> 114
6.4.2.4	<i>Seedling establishment</i> 114
6.4.3	Physiological traits and processes 115
6.5	Community structure and dynamics 116
6.5.1	Fire and succession 116
6.5.2	Diversity 117
6.5.2.1	<i>Patterns</i> 117
6.5.2.2	<i>Determinants</i> 117
6.5.2.3	<i>Competition and coexistence</i> 118
6.6	Ecosystem processes 119
6.6.1	Biomass 119
6.6.2	Hydrology 120
6.6.3	Nutrient cycling 120
6.7	Conservation and management 121
6.7.1	Fragmentation 121
6.7.2	Alien plants 121
6.7.3	Plant harvesting 122
6.8	Conclusions 123
6.9	References 123

7 Succulent karoo S.J. Milton, R.I. Yeaton, W.R.J. Dean and J.H.J. Vlok 131

- 7.1 **Introduction** 131
- 7.2 **Boundaries at the biome, landscape and community scales** 131
 - 7.2.1 Biome-scale boundaries 131
 - 7.2.2 Landscape-scale boundaries 136
 - 7.2.3 Community-scale boundaries 136
- 7.3 **Organisms** 139
 - 7.3.1 Morphology 139
 - 7.3.2 Phenology 140
 - 7.3.3 Reproductive biology 148
 - 7.3.3.1 *Floral displays and pollination* 148
 - 7.3.3.2 *Dispersal mechanisms and establishment sites* 148
 - 7.3.3.3 *Seed bank dynamics and germination* 149
 - 7.3.3.4 *Seedling establishment* 151
 - 7.3.3.5 *Population structure and turnover* 151
 - 7.3.4 Water, heat, mineral and carbon budgets 152
- 7.4 **Community structure and dynamics** 153
 - 7.4.1 Diversity 153
 - 7.4.2 Dynamics 154
 - 7.4.2.1 *Competition, facilitation and cyclic succession* 154
 - 7.4.2.2 *Disturbance and drought* 156
 - 7.4.2.3 *Grazing and browsing* 157
- 7.5 **Ecosystem function** 158
 - 7.5.1 Biomass, productivity and energy flow 158
 - 7.5.2 Decomposition and redistribution of nutrients 159
- 7.6 **Conservation and management** 159
 - 7.6.1 Agriculture 159
 - 7.6.2 Mining 160
 - 7.6.3 Ecotourism 160
 - 7.6.4 Conservation implications 160
- 7.7 **Conclusions** 161
- 7.8 **References** 161

8 Nama-karoo A.R. Palmer and M.T. Hoffman 167

- 8.1 **Introduction** 167
- 8.2 **Environmental gradients** 167
 - 8.2.1 Topography 167
 - 8.2.2 Precipitation 168
 - 8.2.3 Temperature 168
 - 8.2.4 Geology and soils 168
- 8.3 **Boundaries** 170
 - 8.3.1 Biome-scale 170
 - 8.3.2 Regional- and landscape-scale 170
 - 8.3.2.1 *Griqualand West and Bushmanland* 171
 - 8.3.2.2 *Great Karoo and Central Lower Karoo* 172
 - 8.3.2.3 *Upper Karoo and Eastern Cape Midlands* 174

8.3.3	Community-scale	176
8.3.3.1	<i>Griqualand West and Bushmanland</i>	176
8.3.3.2	<i>Great Karoo and Central Lower Karoo</i>	176
8.3.3.3	<i>Upper Karoo and Eastern Cape Midlands</i>	179
8.4	Plant structure and function	179
8.4.1	Plant types	179
8.4.2	Reproductive ecology	180
8.4.3	Physiological traits and processes	180
8.5	Community structure and dynamics	181
8.5.1	Growth-form mix	181
8.5.2	Succession and dynamics	183
8.6	Land use and management	185
8.7	Conclusions	185
8.8	References	186
9	Desert N. Jürgens, A. Burke, M.K. Seely and K.M. Jacobson	189
9.1	Introduction	189
9.2	Environmental gradients	189
9.2.1	Coast–inland gradients	192
9.2.2	Geomorphological and edaphic features	192
9.3	Boundaries and patterns	194
9.3.1	Biome-scale	194
9.3.2	Regional- and landscape-scale	195
9.3.3	Community-scale	195
9.3.3.1	<i>Plains</i>	195
9.3.3.2	<i>Mountains</i>	200
9.3.3.3	<i>Inselbergs</i>	200
9.3.3.4	<i>Dunes</i>	202
9.3.3.5	<i>Rivers</i>	203
9.3.3.6	<i>Special features, occurring in several community types</i>	203
9.4	Plant types	204
9.4.1	Annuals and ephemerals	204
9.4.2	Facultative perennials	204
9.4.3	Geophytes	204
9.4.4	Phreatophytes	204
9.4.5	Succulents	205
9.4.6	Psammophorous plants	205
9.5	Ecophysiology	206
9.5.1	Modes of carbon dioxide fixation	206
9.5.2	Water uptake	206
9.6	Community structure and dynamics	206
9.6.1	Phenology	206
9.6.2	Seed biology and germination	206
9.6.3	Population dynamics	207
9.6.4	Species interactions	209
9.7	Ecosystem function	209

9.8 **Management and human use** 210

9.8.1 Desertification 210

9.8.2 Tourism 210

9.9 **Conclusions** 210

9.10 **Acknowledgements** 211

9.11 **References** 211

10 Grassland T.G. O'Connor and G.J. Bredenkamp 215

10.1 **Introduction** 215

10.2 **Boundaries** 215

10.2.1 Dynamics of biome boundaries 215

10.2.2 Satellite grasslands 217

10.2.3 Absence of a woody component 217

10.2.4 Summary: determinants of grassland 218

10.3 **Community types** 218

10.3.1 Central inland plateau (A) 224

10.3.2 Dry western areas (B) 224

10.3.3 Northern areas (C) 225

10.3.4 Eastern inland plateau (D) 225

10.3.5 Eastern mountains and escarpment (E) 226

10.3.6 Eastern lowlands (F) 227

10.4 **Organisms** 227

10.4.1 Biome patterns 227

10.4.2 Within-community patterns 229

10.5 **Populations** 232

10.6 **Community dynamics** 234

10.6.1 Secondary succession 234

10.6.2 Effects of rainfall, grazing and fire 236

10.6.3 Patch effects 238

10.7 **Ecosystem functioning** 238

10.8 **Conservation** 244

10.9 **Conclusion** 244

10.10 **References** 245

11 Savanna R.J. Scholes 258

11.1 **Introduction** 258

11.2 **Boundaries** 259

11.2.1 Biome-level 259

11.2.2 Landscape-level 259

11.2.3 Community-level 261

11.3 **Organisms** 262

11.3.1 Functional types 262

11.3.2 Reproductive biology 263

xvi / Contents

- 11.3.3 Ecophysiological adaptations 267
- 11.4 **Populations** 269
 - 11.4.1 Population dynamics of grasses 269
 - 11.4.2 Population dynamics of trees 270
 - 11.4.3 Population dynamics of forbs 270
- 11.5 **Community structure and dynamics** 270
 - 11.5.1 Tree-grass interactions 270
 - 11.5.2 Disturbance and succession 271
 - 11.5.3 Patterns of diversity 272
- 11.6 **Ecosystem function** 272
 - 11.6.1 Primary production 272
 - 11.6.2 Herbivory 272
 - 11.6.3 Hydrology 273
 - 11.6.4 Nutrient cycling 273
- 11.7 **Management and use** 273
 - 11.7.1 Pastoralism 273
 - 11.7.2 Conservation, wildlife and ecotourism 273
 - 11.7.3 Wood harvesting 273
- 11.8 **Conclusions** 274
- 11.9 **References** 274

12 Forest J.J. Midgley, R.M. Cowling, A.H.W. Seydack and G.F. van Wyk 278

- 12.1 **Introduction** 278
- 12.2 **Characterization** 278
 - 12.2.1 Floristics and phytochorology 278
 - 12.2.2 Structure 285
- 12.3 **Boundaries** 285
 - 12.3.1 Climate 285
 - 12.3.2 Fire and fire-responses 285
 - 12.3.3 Forest invasion into other biomes 286
- 12.4 **Plant structure and function** 287
 - 12.4.1 Reproductive ecology 287
 - 12.4.2 Seed dispersal 287
 - 12.4.3 Seed germination 287
 - 12.4.4 Seed banks 288
 - 12.4.5 Growth forms 288
- 12.5 **Richness, diversity and endemism** 288
 - 12.5.1 Rarity and endemism 288
 - 12.5.2 Regional richness 288
 - 12.5.3 Diversity 289
 - 12.5.4 Species-area relationships 290
- 12.6 **Dynamics** 290
 - 12.6.1 Populations 290
 - 12.6.2 Succession and dynamics 291
- 12.7 **Conservation and management** 293
 - 12.7.1 Fragmentation 293

12.7.2 Utilization 293

12.8 **Conclusions** 295

12.9 **Acknowledgements** 295

12.10 **References** 296

13 Coastal vegetation R.A. Lubke, A.M. Avis, T.D. Steinke and C. Boucher 300

13.1 **Introduction** 300

13.2 **Coastal regions** 300

13.3 **Dry coastal communities** 303

13.3.1 Pioneer communities 303

13.3.2 Dune slack communities 308

13.3.3 Rocky substrata 309

13.4 **Wet coastal communities** 309

13.4.1 Saltmarshes 309

13.4.2 Mangroves 311

13.5 **Plant form and function** 313

13.5.1 Dry coastal plants 313

13.5.2 Wet coastal plants 314

13.6 **Community structure and dynamics** 315

13.6.1 Dry coastal communities 315

13.7 **Ecosystem function** 316

13.7.1 Dry coastal systems 316

13.7.2 Wet coastal systems 318

13.8 **Conservation and management** 318

13.9 **References** 319

14 Freshwater wetlands K.H. Rogers 322

14.1 **Introduction** 322

14.2 **Wetland classification and distribution** 323

14.2.1 Limnological regions 323

14.2.1.1 Subtropical coastal peneplain 323

14.2.1.2 Elevated plateau and southeastern coastal plain 323

14.2.1.3 Australomontane 323

14.2.1.4 Temperate acid waters of the Western Cape 323

14.2.1.5 Arid west 326

14.2.2 Classification of South African wetlands 326

14.3 **Autecology** 327

14.4 **Plant community structure and dynamics** 330

14.4.1 Community structure 331

14.4.2 Community dynamics 331

14.4.2.1 Highveld pans 332

14.4.2.2 Riparian vegetation of semi-arid regions 332

14.4.2.3 Highveld vleis 333

14.4.2.4 The Okavango Delta 334

- 14.5 **A conceptual framework of wetland vegetation processes** 337
 - 14.5.1 The Van der Valk model 337
 - 14.5.2 The Mitsch and Gosselink model 339
 - 14.5.3 The Breen *et al.* model 340
 - 14.5.4 Towards a new predictive model 340
- 14.6 **Ecosystem functioning** 341
 - 14.6.1 Primary production and nutrient cycling 341
 - 14.6.2 Decomposition 342
 - 14.6.3 Grazing 342
- 14.7 **Future research and management** 343
- 14.8 **Acknowledgements** 344
- 14.9 **References** 344

15 Marine vegetation J.J. Bolton and R.J. Anderson 348

- 15.1 **Introduction** 348
- 15.2 **Boundaries of marine provinces** 348
 - 15.2.1 Tropical West Africa Marine Province 349
 - 15.2.2 Benguela Marine Province 349
 - 15.2.3 Agulhas Marine Province 350
 - 15.2.4 Indo-West Pacific Marine Province 350
 - 15.2.5 Community gradients on a biogeographic scale 351
- 15.3 **The seaweed flora of southern Africa** 351
 - 15.3.1 Diversity 351
 - 15.3.2 Endemism 352
 - 15.3.3 Affinities and evolutionary biogeography 352
- 15.4 **Community types** 353
 - 15.4.1 Intertidal 353
 - 15.4.2 Subtidal 354
- 15.5 **Population biology** 356
- 15.6 **Community structure and dynamics** 357
 - 15.6.1 Physical factors 357
 - 15.6.2 Grazing 358
 - 15.6.3 Competition 359
 - 15.6.4 Life forms 360
- 15.7 **Ecosystem function** 360
 - 15.7.1 Intertidal 360
 - 15.7.2 Subtidal 362
 - 15.7.3 Sandy beaches 362
- 15.8 **Economic use and resource management** 362
 - 15.8.1 Agarophytes, carrageenophytes and alginophytes 363
 - 15.8.2 Management 364
 - 15.8.3 Conservation 365
- 15.9 **Conclusions** 365
- 15.10 **Acknowledgements** 365
- 15.11 **References** 365

Part three Ecological themes

16 Plant form and function W.D. Stock, N. Allsopp, F. van der Heyden and E.T.F. Witkowski 376

- 16.1 **Introduction** 376
- 16.2 **Sclerophyll leaves** 377
- 16.3 **Succulents** 380
 - 16.3.1 Succulents and temperature 382
 - 16.3.2 Succulents and rainfall 384
- 16.4 **Graminoid-woody plant interactions** 385
 - 16.4.1 Fynbos graminoid-woody plant interactions 385
 - 16.4.2 Nama-karoo graminoid-woody plant interactions 386
 - 16.4.3 Savanna graminoid-woody plant interactions 386
 - 16.4.4 Grassland graminoid-woody plant interactions 387
- 16.5 **Below-ground acquisition of resources** 388
 - 16.5.1 Mycorrhizal relationships 388
 - 16.5.2 Cluster roots and root sheaths 390
- 16.6 **Conclusions** 390
- 16.7 **References** 391

17 Herbivory N. Owen-Smith and J.E. Danckwerts 397

- 17.1 **Introduction** 397
- 17.2 **Herbivore abundance and distribution** 397
 - 17.2.1 Indigenous large mammals 397
 - 17.2.2 Domestic livestock 399
 - 17.2.3 Small vertebrates 401
 - 17.2.4 Insects and other invertebrates 401
- 17.3 **Consumption of leaves and plant structural tissues** 401
 - 17.3.1 Grazing 402
 - 17.3.2 Browsing 405
 - 17.3.3 Nibbling and gnawing 408
 - 17.3.4 Invertebrates 409
- 17.4 **Granivory and frugivory** 410
 - 17.4.1 Granivory and seed predation 410
 - 17.4.2 Frugivory and seed dispersal 411
 - 17.4.3 Consumption of flowers and inflorescences 412
- 17.5 **Anti-herbivore defences** 412
 - 17.5.1 Plant morphology 412
 - 17.5.2 Secondary chemical contents 413
- 17.6 **Summary and conclusions** 413
- 17.7 **Acknowledgements** 415
- 17.8 **References** 415

18 Fire W.J. Bond 421

- 18.1 **Introduction 421**
- 18.2 **Distribution and abundance of fire in southern African landscapes 421**
- 18.3 **Determinants of fire 423**
 - 18.3.1 Fuel characteristics 423
 - 18.3.2 Climate 424
 - 18.3.3 Ignition 424
- 18.4 **Fire regimes 424**
 - 18.4.1 Fire frequency 424
 - 18.4.2 Fire type 426
 - 18.4.3 Fire intensity 426
- 18.5 **The natural history of plant responses to burning 428**
 - 18.5.1 Fire and persistence 428
 - 18.5.2 Fire and reproduction 429
 - 18.5.2.1 Fire-stimulated flowering 429
 - 18.5.2.2 Fire-stimulated seed release 430
 - 18.5.2.3 Fire-stimulated seed germination 430
 - 18.5.3 Fire life histories 431
- 18.6 **Fire and vegetation dynamics 431**
 - 18.6.1 Fynbos 433
 - 18.6.2 Grasslands 434
 - 18.6.3 Savannas 435
- 18.7 **Fire and biome distribution 436**
- 18.8 **Fire and evolution of flora 437**
- 18.9 **Fire in management 438**
 - 18.9.1 The development of fire research 438
 - 18.9.2 Management objectives 438
 - 18.9.3 Fynbos 439
 - 18.9.4 Grasslands 439
 - 18.9.5 Savannas 439
 - 18.9.6 Fire and conservation 440
- 18.10 **Conclusions 441**
- 18.11 **References 442**

19 Species diversity at the regional scale R.M. Cowling, D.M. Richardson, R.E. Schulze, M.T. Hoffman, J.J. Midgley and C. Hilton-Taylor 447

- 19.1 **Introduction 447**
- 19.2 **Theory 447**
 - 19.2.1 Area 448
 - 19.2.2 Heterogeneity 448
 - 19.2.3 Favourableness 449
 - 19.2.4 Energy 449
 - 19.2.5 Seasonality and irregularity 449
 - 19.2.6 Dispersal 449
 - 19.2.7 Speciation history 450
 - 19.2.8 Effect of local processes 450

19.2.9	Convergence of regional richness	450
19.3	Approach and methods	450
19.3.1	Data	450
19.3.2	Model development	452
19.4	Evaluation of theories	453
19.4.1	Area	453
19.4.2	Heterogeneity	454
19.4.3	Favourableness	458
19.4.4	Energy	458
19.4.5	Seasonality and irregularity	461
19.4.6	Dispersal	462
19.4.7	Speciation history	463
19.4.8	Local and regional patterns and processes	464
19.4.9	Global comparisons	464
19.5	General discussion and conclusions	466
19.5.1	Patterns of regional richness	466
19.5.2	Models and explanations	467
19.5.3	Ecology versus history	467
19.6	Acknowledgements	467
19.7	References	470

20 Human use of plants A.B. Cunningham and G.W. Davis 474

20.1	Introduction	474
20.2	People and plants in the cradle of humankind	475
20.3	Plants, culture and change	476
20.3.1	Wild plants: nature and culture	476
20.4	Patterns of plant use across southern Africa	477
20.4.1	African crops and introduced staples	477
20.4.2	Wild plants for food	477
20.4.3	Plants for fencing, housing and fuel	482
20.4.4	Plants in domestic use	484
20.4.5	Plants for medicine	485
20.4.6	Plants as symbols	487
20.5	Back to the future: the neglected harvest	489
20.5.1	The colonial interest in plant resources	489
20.5.2	The hidden economy	491
20.5.3	Developing new crops from wild plants	492
20.6	Plant use, land use and harvesting impacts	494
20.6.1	Leaf, flower and fruit harvesting	495
20.6.2	Harvesting bulbs, bark, roots, timber or whole plants	498
20.7	What are wild plants worth?	499
20.8	Conclusions	501
20.9	Acknowledgements	501
20.10	References	501

21 Human impacts on vegetation M.T. Hoffman 507

- 21.1 **Introduction** 507
- 21.2 **Humans in southern Africa: a general chronology** 507
- 21.3 **Population growth and land degradation** 511
- 21.4 **Human impacts on the biomes of southern Africa** 512
 - 21.4.1 Displacement, new crops and aliens in the fynbos biome 512
 - 21.4.2 Desertification in the arid zone 515
 - 21.4.3 Agricultural history and impacts in the grassland and savanna biomes 519
 - 21.4.3.1 *The impact of the Iron Age* 519
 - 21.4.3.2 *Megaherbivores and the 'bush encroachment' problem* 522
 - 21.4.3.3 Overgrazing 522
 - 21.4.3.4 Cultivation 523
 - 21.4.3.5 Afforestation 526
 - 21.4.3.6 Industrialization and urbanization 528
 - 21.4.4 Deforestation and the forest biome 528
- 21.5 **Conclusions** 530
- 21.6 **Acknowledgments** 531
- 21.7 **References** 531

22 Alien plant invasions D.M. Richardson, I.A.W. Macdonald, J.H. Hoffmann and L. Henderson 535

- 22.1 **Introduction** 535
- 22.2 **The history of plant invasions in southern Africa** 536
 - 22.2.1 Pre-colonial introductions 536
 - 22.2.2 The urge to alter, tame or improve: the impact of colonialism 537
 - 22.2.3 Appreciation of the problem 538
- 22.3 **Which species have invaded?** 539
 - 22.3.1 Major invaders in southern African biomes 540
 - 22.3.1.1 *The fynbos biome* 540
 - 22.3.1.2 *The grassland biome* 540
 - 22.3.1.3 *The forest biome* 541
 - 22.3.1.4 *The savanna biome* 541
 - 22.3.1.5 *The karoo biomes* 541
 - 22.3.1.6 *The desert biome* 542
 - 22.3.1.7 *Aquatic ecosystems* 543
 - 22.3.2 Characteristics of invasive alien species 543
 - 22.3.3 Differences between biomes 548
- 22.4 **The extent of invasions** 549
 - 22.4.1 What proportion of each biome is invaded? 549
 - 22.4.1.1 *The fynbos biome* 549
 - 22.4.1.2 *The grassland biome* 552
 - 22.4.1.3 *The forest biome* 552
 - 22.4.1.4 *The savanna biome* 553
 - 22.4.1.5 *The karoo biomes* 553
 - 22.4.1.6 *The desert biome* 553
 - 22.5 **Patterns and processes of invasion** 554
 - 22.5.1 Invaders of riparian habitats 554

22.5.2 Serotinous trees and shrubs in fynbos and grassland 554

22.5.3 *Acacia* species in fynbos 554

22.5.4 The role of disturbance: *Pinus* as a case study 555

22.6 Consequences of plant invasions 556

22.6.1 Negative economic impacts 556

22.6.2 Positive economic impacts 556

22.7 Control 557

22.7.1 Biological control 558

22.7.2 Integrated control 560

22.8 The future 561

22.8.1 Dealing with current invaders 561

22.8.2 New invaders 562

22.9 Acknowledgements 563

22.10 References 567

23 Conservation A.G. Rebelo 571

23.1 **Introduction 571**

23.2 **A brief history of conservation planning 571**

23.3 **The conservation estate 573**

23.4 Problems with assessing conservation requirements 576

23.4.1 Scale and representativeness 576

23.4.2 Representativeness and parochial interests 579

23.4.3 Biases and responsibilities in reporting 579

23.5 Designing an efficient conservation network 580

23.5.1 Evaluation of a levels approach 580

23.5.2 How much should be conserved? 581

23.5.2.1 *Ecosystem approaches* 582

23.5.2.2 *Species approaches* 583

23.5.3 What are the conservation priorities? 585

23.5.4 Conservation research needs 586

23.6 The future 587

23.7 Acknowledgements 587

23.8 References 587

Glossary 591

Subject index 596

Index of biota and taxa 602