

# Contents

## Part I Introduction

<b>1</b>	<b>Relating Ecosystem Studies to the Management of Resources in Central Europe: A Problem of Complexity, Scales and Communication . . . . .</b>	<b>3</b>
	J. D. Tenhunen	
1.1	Ecosystem Studies at Plot, Landscape, and Global Scales . . . . .	3
1.1.1	Global Ecology versus Resource Management . . . . .	3
1.1.2	Landscape Ecology and Resource Management . . . . .	4
1.2	Networks of Landscape-Oriented Investigations in Germany . . . . .	7
	References . . . . .	14
<b>2</b>	<b>A Historical Perspective on the Development of Ecosystem and Landscape Research in Germany . . . .</b>	<b>17</b>
	R. Lenz, W. Haber, J. D. Tenhunen	
2.1	Introduction . . . . .	17
2.1.1	The Ecosystem Concept . . . . .	18
2.1.2	The Ecotope Concept . . . . .	20
2.2	Milestones in German Ecosystem Research . . . . .	22
2.2.1	Process Links in Temperate Ecosystems: The Solling IBP Project . . . . .	22
2.2.2	Impact on the Landscape: The “Man and the Biosphere” Project . . . . .	24
2.2.3	Forest Toxicology and the “Dieback” Phenomenon . . . .	27
2.2.4	The German Terrestrial Ecosystem Research Network . .	28

2.3	Ecotope Function in Landscapes and Resource Management . . . . .	30
	References . . . . .	32
<b>Part II</b>	<b>Investigations in a Catchment and Chain of Lakes on the Northern Coastal Plain of Germany</b>	
<b>3</b>	<b>Conceptual Framework of the Bornhöved Lake District Research . . . . .</b>	<b>39</b>
	O. Fränzle, E.-W. Reiche, W. Windhorst	
3.1	Introduction . . . . .	39
3.2	Spatio-temporal Heterogeneity, Emergent Properties, and Hierarchies . . . . .	42
3.3	Approach to Regionalized Hydrological and Chemical Transport Modelling . . . . .	43
3.4	The WASMOD Landscape Function Model . . . . .	44
3.4.1	General Model Structure . . . . .	44
3.4.2	Submodels for Biological Processes . . . . .	45
3.4.3	Vertical Structure and Transport . . . . .	45
3.4.4	Model Summary . . . . .	46
3.5	Conclusions: Key Foci of the Bornhöved Research . . . . .	46
	References . . . . .	47
<b>4</b>	<b>Spatial Heterogeneity in Forest Soils and Understory Communities of the Bornhöved Lake District . . . . .</b>	<b>49</b>
	E.-W. Reiche, F. Müller, I. Dibbern, A. Kerrinnes	
4.1	Introduction . . . . .	49
4.2	Site Description and Sampling Methods . . . . .	52
4.3	Scale Dependency of Observed Heterogeneity in Vegetation and Soil . . . . .	54
4.4	Geostatistical Features of the Spatial Patterns . . . . .	59
4.5	Major Processes Influencing Spatial Differentiation . . . . .	62
4.6	Conclusions . . . . .	69
	References . . . . .	72

<b>5</b>	<b>The Carbon Cycle of Contrasting Landscape Elements of the Bornhöved Lake District . . . . .</b>	<b>75</b>
	W.L. Kutsch, C. Eschenbach, O. Dilly, U. Middelhoff, W. Steinborn, R. Vanselow, K. Weisheit, J. Wötzel, L. Kappen	
5.1	Introduction . . . . .	75
5.2	Database for Comparing Landscape Elements . . . . .	76
5.2.1	Field Study Methods . . . . .	76
5.2.1.1	Measurement of Carbon Pools . . . . .	76
5.2.1.2	Measurement of CO <sub>2</sub> Fluxes . . . . .	77
5.2.1.3	Internal Biomass Fluxes . . . . .	78
5.2.2	Field Study Results . . . . .	78
5.3	Modelling . . . . .	82
5.4	Carbon Pools and Fluxes . . . . .	85
5.5	Conclusions . . . . .	91
	References . . . . .	92
<b>6</b>	<b>Nitrogen Retention and Loss from Ecosystems of the Bornhöved Lake District . . . . .</b>	<b>97</b>
	C. G. Schimming, J. Schrautzer, E.-W. Reiche, J.-C. Munch	
6.1	Introduction . . . . .	97
6.2	Nitrogen Cycling of Ecosystems, Landscapes, and Watersheds . . . . .	98
6.2.1	Anthropogenic Influences on Landscape Nitrogen Balances . . . . .	99
6.2.2	Nitrogen Cycling of an Agro-ecosystem . . . . .	100
6.2.3	Nitrogen Cycling of a Beech Forest Ecosystem . . . . .	103
6.2.4	Imbalance and Terrestrial Input to Groundwater Systems . . . . .	104
6.3	Temporal Variability in Ecosystem Nitrogen Trapping Potentials . . . . .	107
6.4	Conclusions . . . . .	112
	References . . . . .	113

<b>7</b>	<b>Spatial and Temporal Variability of Limnological Processes in the Bornhöved Lake District</b> . . . . .	<b>117</b>
	R. Pöpperl, W. Kluge, G. Schernewski, C.-D. Garbe-Schönberg, W. Nellen	
7.1	Introduction . . . . .	117
7.2	Characteristics of Lake Belau . . . . .	118
7.3	The Catchment Area and Inflows to Lake Belau . . . . .	118
7.3.1	Characteristics of the Main Point Source . . . . .	121
7.3.2	Water Exchange Between Lake Belau and the Surrounding Catchment . . . . .	123
7.3.3	Non-point Inputs of Matter with Groundwater . . . . .	125
7.4	Process Variability Within Lake Ecosystems . . . . .	128
7.4.1	Dynamics of Basic Physical and Chemical Structures . . . . .	129
7.4.2	Spatial and Temporal Variability in the Pelagial . . . . .	130
7.4.2.1	Phytoplankton . . . . .	131
7.4.2.2	Primary Production and Zooplankton Grazing . . . . .	132
7.4.3	Spatial and Temporal Variability in the Littoral . . . . .	137
7.5	Complexity of Interactions and Superimposing of Processes . . . . .	140
7.5.1	Factors Controlling the Development of Diatoms in Spring . . . . .	141
7.5.2	Processes Controlling the Composition of the Lake Belau Sediments . . . . .	143
7.5.3	Changes in Benthic Communities at the Lake Outlet . . . . .	148
7.6	Conclusions . . . . .	152
	References . . . . .	155
<b>8</b>	<b>Sustainable Landscape Management in the Börnhoved Lake District</b> . . . . .	<b>163</b>
	W. Windhorst, O. Fränzle	
8.1	The Relationship Between Ecosystem Research and Sustainable Development . . . . .	163
8.2	Long-term Changes in Ecosystem Dynamics in the Lake Belau Catchment . . . . .	164
8.3	Strategies for Sustainable Management in the Börnhoved Lake District . . . . .	168
	References . . . . .	170

**Part III Investigations in an Agricultural Catchment in the Tertiary Hills of Southern Germany**

**9 Adapting Land Use To Promote Sustainable Agricultural Management: A Model Project at the Scheyern Experimental Farm of FAM . . . . . 175**  
 J. Pfadenhauer, J. Filser

9.1 Development of the European Cultural Landscape . . . . . 175  
 9.2 Integrative Nature Conservation . . . . . 178  
 9.2.1 Functional Integrity . . . . . 178  
 9.2.2 Spatial Balance . . . . . 178  
 9.2.3 Temporal Integration . . . . . 179  
 9.2.4 Socio-economic Justification . . . . . 179  
 9.3 The FAM Concept . . . . . 179  
 References . . . . . 181

**10 The Scheyern Experimental Farm: Research Methods, the Farming System and Definition of the Framework of Site Properties and Characteristics . . . . . 183**  
 K. Auerswald, M. Kainz, A. C. Scheinost, W. Sinowski

10.1 Introduction to the Research Area . . . . . 183  
 10.2 Cropping Practice To Determine Site Potentials . . . . . 187  
 10.3 Spatial Determination of Soil Properties . . . . . 187  
 10.4 Variability of Soil Properties . . . . . 191  
 10.5 Conclusions . . . . . 193  
 References . . . . . 193

**11 Site Effects on the Variability of Crop Growth at the Scheyern Experimental Farm . . . . . 195**  
 K. Auerswald, R. Brunner, M. Demmel, M. Kainz, W. Sinowski, A. C. Scheinost

11.1 Introduction . . . . . 195  
 11.2 Materials and Methods . . . . . 195  
 11.3 Results . . . . . 196  
 11.3.1 Spatial Patterns in Yield . . . . . 196  
 11.3.2 Nutrient Controls on Production . . . . . 199  
 11.3.3 Interactive Effects of Abiotic and Biotic Factors on Yield . . . 200

11.4	Conclusions . . . . .	205
	References . . . . .	206
<b>12</b>	<b>Site Effects on Plant and Animal Distribution at the Scheyern Experimental Farm . . . . .</b>	<b>209</b>
	H. Albrecht, N. Kühn, H. Laußmann, M. Pilgram, J. Filser	
12.1	Introduction . . . . .	209
12.2	Material and Methods . . . . .	210
12.3	Spatial Variability of Organism Communities . . . . .	210
12.3.1	Relationships Between Different Organism Communities . . . . .	215
12.3.2	Effects of Previous Management and Vegetation Structure . . . . .	216
12.3.3	Effects of Soil Type . . . . .	219
12.3.4	Detrended Correspondence Analysis of Weed Distribution . . . . .	220
12.4	Temporal Variability . . . . .	222
12.5	Conclusions . . . . .	222
	References . . . . .	225
<b>13</b>	<b>Site Effects on the Variability of Nitrogen Turnover at the Scheyern Experimental Farm . . . . .</b>	<b>229</b>
	R. Hantschel, R. Stenger	
13.1	Introduction . . . . .	229
13.2	Methods . . . . .	230
13.3	Spatial and Temporal Variability of Dominant Nitrogen Pools . . . . .	231
13.3.1	Total Nitrogen in Soils . . . . .	232
13.3.2	Microbial Nitrogen in Soils . . . . .	233
13.3.3	Mineral Nitrogen in Soils . . . . .	234
13.4	Quantification of Nitrogen Fluxes . . . . .	237
13.4.1	N Fluxes in the Soil-plant System . . . . .	237
13.4.2	N Losses from the Soil-plant System . . . . .	239
13.4.2.1	Emissions of N <sub>2</sub> O . . . . .	239
13.4.2.2	Nitrogen in Groundwater . . . . .	240
13.5	Integration of Data with Models . . . . .	241
13.6	Conclusions . . . . .	244
	References . . . . .	245

**14 Modelling Seasonal Dynamics of Matter Transport and Cycling from Patch to Landscape: Extrapolating from the Scheyern Experimental Farm . . . . . 249**  
 R. Lang, A. Müller, R. Lenz

14.1 The Agricultural Information System (AIS) . . . . . 249

14.2 Spatial Data of the AIS . . . . . 250

14.3 Modelling Methods . . . . . 251

14.3.1 Modelling Concepts at the Level of the Scheyern Farm . . 251

14.3.2 Modelling Concepts at the Landscape Level . . . . . 252

14.4 Model Performance . . . . . 253

14.4.1 Surface Runoff and Factors Influencing Plant Growth . . 253

14.4.2 Effects of Scale on Simulation Results . . . . . 255

14.4.3 Data Quality at the Landscape Level . . . . . 258

14.4.4 Landscape Level Simulation of Soil Loss . . . . . 259

14.4.5 Landscape Level Simulation of Nitrate Leaching . . . . . 261

14.5 Conclusions . . . . . 261

References . . . . . 262

**15 Ecological and Economic Evaluations of Agricultural Land Use – Experiences from the Scheyern Experimental Farm . . . . . 265**  
 K. Auerswald, J. Filser

15.1 Consequences of Spatial Variability in Agro-ecosystems . . 265

15.2 Consequences of Temporal Variability in Agro-ecosystems 266

15.3 Ecological Evaluation of Agro-ecosystems . . . . . 267

References . . . . . 269

**Part IV Investigations in Coastal Lowland Agro-landscapes of Northeast Germany**

**16 Interdisciplinary and Multifunctional Approaches for Ensuring Sustainable Use of Northeast German Agro-landscapes . . . . . 273**  
 H.-P. Piorr, H.-R. Bork, K.-O. Wenkel

16.1 Introduction . . . . . 273

16.2 The Study Areas of the Center for Agricultural Landscape and Land Use Research . . . . . 275

16.3	Development of Models and Indicators for Landscape Assessments . . . . .	276
16.4	The Future of Agro-landscapes in Northeast Germany . .	279
	References . . . . .	279
17	<b>Spatially Distributed Simulation of Evapotranspiration, Soil Water Dynamics, and Groundwater Recharge in Northeast German Agro-landscapes . . . . .</b>	<b>281</b>
	M. Wegehenkel, C. Prietzsch, H. Jochheim	
17.1	Introduction . . . . .	281
17.2	The Water Balance Modelling System MOBOWASI . . . .	281
17.2.1	Model Structure for the Biosphere Reserve Schorfheide-Chorin . . . . .	282
17.2.2	Regional Water Balance Simulations . . . . .	287
17.3	Conclusions . . . . .	288
	References . . . . .	289
18	<b>“Potholes” in Northeast German Agro-landscapes: Functions, Land Use Impacts, and Protection Strategies . . . . .</b>	<b>291</b>
	T. Kalettka, C. Rudat, J. Quast	
18.1	Introduction . . . . .	291
18.2	Genesis and Land Use History of Potholes . . . . .	291
18.3	Functions and Land Use Impacts of Potholes . . . . .	292
18.3.1	Sink Function of Potholes . . . . .	293
18.3.1.1	Hydrological Function . . . . .	293
18.3.1.2	Matter Accumulation . . . . .	294
18.3.1.3	Eutrophication and Water Quality . . . . .	295
18.3.2	Habitat Function of Potholes . . . . .	295
18.3.2.1	Flora . . . . .	295
18.3.2.2	Fauna . . . . .	296
18.4	Conclusions: Protection Strategies for Potholes . . . . .	297
18.4.1	Restoration of Potholes . . . . .	297
18.4.2	Redesign of Catchment Landscapes . . . . .	297
	References . . . . .	298



<b>19</b>	<b>Assessing the Impact of Land Use Intensity and Climate Change on Ontogenesis, Biomass Production, and Yield of Northeast German Agro-landscapes</b> . . . . .	<b>299</b>
	W. Mirschel, A. Schultz, K.-O. Wenkel	
19.1	Introduction to the AGROSIM Model . . . . .	299
19.2	Experimental Basis of AGROSIM . . . . .	300
19.3	Description of Process Linkages in AGROSIM . . . . .	302
19.4	Simulation Results . . . . .	307
19.5	Conclusions . . . . .	311
	References . . . . .	312
<b>20</b>	<b>A Model To Assess the Effects of Land Use Changes on Nitrogen Leaching in Northeast German Agro-landscapes</b> . . . . .	<b>315</b>
	K.C. Kersebaum, W. Mirschel, K.-O. Wenkel	
20.1	Introduction . . . . .	315
20.2	Materials and Methods . . . . .	316
20.2.1	Background Database . . . . .	316
20.2.2	Simulation Model Structure . . . . .	317
20.2.3	Data Management . . . . .	319
20.3	Simulation Results . . . . .	320
20.3.1	Changes in Leaching after German Reunification . . . . .	320
20.3.2	Sensitivity to Input Data . . . . .	321
20.4	Conclusions . . . . .	323
	References . . . . .	323
<b>21</b>	<b>Effects of Patterning on Biodiversity in Northeast German Agro-landscapes</b> . . . . .	<b>325</b>
	J. Hoffmann, H. Kretschmer, H. Pfeffer	
21.1	Introduction . . . . .	325
21.2	Materials and Methods . . . . .	325
21.3	Diversity of Vascular Plants and Landscape Mosaics . . . . .	329
21.3.1	Historical Changes . . . . .	329
21.3.2	Effects of Land Use Intensity on the Occurrence of Indigenous vs. Non-indigenous Plant Species . . . . .	330

21.3.3	Distribution of Oligotrophic Species with Respect to Landscape Structure . . . . .	332
21.4	Effects of Habitat Structure on Species Diversity in Agricultural Areas . . . . .	333
21.5	Conclusions . . . . .	338
	References . . . . .	339
<b>22</b>	<b>Land Use Change and Habitat Quality in Northeast German Agro-landscapes</b> . . . . .	<b>341</b>
	R. Wieland, M. Voss	
22.1	Introduction . . . . .	341
22.2	The “Crane” Prototype Model . . . . .	342
22.2.1	A Fuzzy Approach to Habitat Modelling . . . . .	344
22.2.2	Refinement and Evaluation of the Model . . . . .	344
22.3	Conclusions . . . . .	345
	References . . . . .	346
<b>23</b>	<b>Future Land Use Planning in Northeast German Agro-landscapes</b> . . . . .	<b>347</b>
	H.-P. Piorr, H.-R. Bork, K.-O. Wenkel	
23.1	Integrated Analyses of Rural Development . . . . .	347
23.2	Future Development of Landscape Management Tools . . . . .	350
	References . . . . .	352
<b>Part V</b>	<b>Investigations in a Montane Forest Catchment in Central Germany</b>	
<b>24</b>	<b>Assessing Environmental Influences on Ecological Function of a Spruce Forest Catchment in the Fichtelgebirge</b> . . . . .	<b>357</b>
	J. D. Tenhunen, E. Matzner, B. Heindl, Y. Chiba, B. Manderscheid	
24.1	Introduction . . . . .	357
24.1.1	Recent Impacts on Forest Water, Nutrient, and Carbon Balances . . . . .	357
24.1.2	Sustainable Use of Forest Resources . . . . .	358

24.1.3 Budgets, Catchments, and Landscape Processes . . . . . 360  
 24.2 A Spruce Catchment in the Fichtelgebirge, Germany . . . 362  
 24.2.1 Climate, Geology, and Vegetation History . . . . . 362  
 24.2.2 Lehstenbach Catchment and Experimental Stands . . . . 364  
 24.2.2.1 Tree Overstory . . . . . 364  
 24.2.2.2 Understory Development . . . . . 370  
 24.2.2.3 Soils . . . . . 370  
 24.3 Conclusions . . . . . 372  
 References . . . . . 373

**25 Controls on Evapotranspiration in a Spruce Forest Catchment of the Fichtelgebirge . . . . . 377**  
 B. Köstner, J. D. Tenhunen, M. Alsheimer, M. Wedler,  
 H.-J. Scharfenberg, R. Zimmermann, E. Falge, U. Joss

25.1 Introduction . . . . . 377  
 25.2 Methods of Water Flux Studies . . . . . 378  
 25.2.1 Xylem Sap Flux . . . . . 378  
 25.2.2 Understory Gas Exchange . . . . . 379  
 25.3 Tree Canopy Transpiration . . . . . 380  
 25.4 Understory Structure and Evapotranspiration . . . . . 392  
 25.4.1 Composition, Biomass, and Diversity . . . . . 392  
 25.4.2 Estimated Evapotranspiration . . . . . 397  
 25.5 Forest Evapotranspiration and Atmospheric Coupling . . 403  
 25.5.1 Conductance Definitions, Scaling, and Atmospheric Coupling . . . . . 403  
 25.5.2 Estimates of Conductances and  $\Omega$  in Spruce and Pine Stands . . . . . 405  
 25.6 Conclusions . . . . . 409  
 References . . . . . 410

**26 Modelling of Fluxes in a Spruce Forest Catchment of the Fichtelgebirge . . . . . 417**  
 J. D. Tenhunen, E. Falge, R. Ryel, B. Manderscheid,  
 K. Peters, B. Ostendorf, U. Joss, G. Lischeid

26.1 Hierarchy of Flux Models . . . . . 417  
 26.2 Modelling of Stand Fluxes . . . . . 422  
 26.2.1 Water and CO<sub>2</sub> Exchange . . . . . 422  
 26.2.1.1 Weiden Brunnen Stand Climate . . . . . 422

26.2.1.2	Individual Tree Transpiration . . . . .	422
26.2.1.3	Stand Water Balance . . . . .	424
26.2.1.4	Stand CO <sub>2</sub> Uptake and Water Use Efficiency . . . . .	430
26.2.2	SO <sub>2</sub> Uptake . . . . .	431
26.3	Integrated Fluxes at the Catchment Scale . . . . .	439
26.3.1	Spatial Variation in Ecosystem Properties . . . . .	439
26.3.2	Lehstenbach Catchment Discharge . . . . .	443
26.4	Conclusions . . . . .	447
Appendix A	Model Descriptions . . . . .	448
A.1	Forest Canopy Gas Exchange (STANDFLUX) . . . . .	448
A.1.1	NEEDLES . . . . .	448
A.1.2	CYLICON . . . . .	450
A.1.3	STANDFLUX . . . . .	452
A.2	Soil Water Status and Deep Seepage (SIMULA) . . . . .	452
A.3	Pollutant Deposition (DEPOSITE) . . . . .	454
A.4	Watershed Flux Partitioning (TOPMODEL) . . . . .	457
References	. . . . .	459
27	<b>Biogeochemistry of a Spruce Forest Catchment of the Fichtelgebirge in Response to Changing Atmospheric Deposition . . . . .</b>	<b>463</b>
	E. Matzner, C. Alewell, J. Bittersohl, G. Lischeid, G. Kammerer, B. Manderscheid, G. Matschonat, K. Moritz, J.D. Tenhunen, K. Totsche	
27.1	Introduction and Scope . . . . .	463
27.2	Atmospheric Deposition . . . . .	464
27.3	Soil Solution, Groundwater, and Runoff Chemistry . . . . .	467
27.4	Analysis of Sulfate Dynamics in Runoff with Neural Networks . . . . .	474
27.5	Element Fluxes and Budgets at Different Scales . . . . .	475
27.6	Soil Sulfate Pools and Sulfate Behavior . . . . .	479
27.7	Riparian Zone Influences on Watershed Biogeochemistry . . . . .	483
27.8	Modelling and Predictions of Catchment Biogeochemistry . . . . .	486
27.8.1	Changing Deposition, Chemistry of Soil Solutions, and Cation Exchange Capacity of Soils . . . . .	486
27.8.2	Runoff Chemistry in Response to Changing Sulfate Deposition . . . . .	489

27.8.3 Nitrogen Retention and Release at the Couliissenhieb Site  
as Influenced by Changing Nitrogen Deposition . . . . . 491

27.9 Conclusions . . . . . 493

Appendix A Calibration and Testing of the SIMFONI Model . . . 497

References . . . . . 499

**28 Generalizing from a Spruce Forest Catchment of the  
Fichtelgebirge: Expected Responses of Montane Forests to  
Environmental Change . . . . . 505**  
E. Matzner, J. D. Tenhunen

28.1 Introduction . . . . . 505

28.2 Yield of High Quality Water  
from Forested Catchments . . . . . 506

28.2.1 Acidification of Groundwater . . . . . 506

28.2.2 Eutrophication of Groundwater . . . . . 507

28.2.3 Vegetation and Groundwater Yield . . . . . 509

28.2.4 Effects of Forest Restructuring on Fluxes . . . . . 510

28.3 Environmental Change and Wood Production . . . . . 511

28.4 Conclusions . . . . . 512

References . . . . . 513

**Part VI Temporal Changes in Forest Ecosystem Function**

**29 Changes in Forest Ecosystem Function  
with Succession in the Lüneburger Heide . . . . . 517**  
Ch. Leuschner

29.1 Introduction . . . . . 517

29.2 Heathland to Forest Succession in the Lüneburger Heide,  
Germany . . . . . 518

29.3 Hypotheses and Methodology . . . . . 521

29.4 Humus Accumulation During Succession . . . . . 526

29.4.1 Rates of Humus Accumulation . . . . . 526

29.4.2 Plant Productivity and Humus Accumulation . . . . . 529

29.4.3 Change in Humus Morphology . . . . . 532

29.4.4 Nutrient Pools in the Organic Profile . . . . . 533

29.4.5 Nutrient Concentrations and Element Ratios  
in the Organic Profile . . . . . 539

29.4.6 Nutrient Turnover in the Organic Profile . . . . . 541

29.4.7	Humus Moisture Status . . . . .	544
29.4.8	The Organic Profile as a Rooting Medium . . . . .	550
29.5	Competition-relevant Attributes of Early- and Late-successional Plant Species . . . . .	553
29.5.1	Is Competitive Superiority Linked to Productivity? . . . .	553
29.5.2	Resource-capturing Organs: Leaves and Roots . . . . .	555
29.5.3	The Cost of Canopy Space Occupation . . . . .	557
29.5.4	The Cost of Shade Production . . . . .	558
29.6	Conclusions: Key Mechanisms in Heathland to Forest Succession . . . . .	561
References	. . . . .	563

## Part VII Future Perspectives

<b>30</b>	<b>Future Development of Landscapes in Marginal Agrarian Regions of Central Europe: Long-term Effects of Land Use on the Water Balance . . . . .</b>	<b>571</b>
	H.-R. Bork, C. Dalchow, B. Faust, H.-P. Piorr, V. Toussaint, A. Werner	
30.1	Introduction . . . . .	571
30.2	The Water Budget of Landscapes Related to Past Land Use . . . . .	572
30.3	Future Land Use in Marginal Agrarian Regions and Water Balance . . . . .	576
References	. . . . .	581
<b>31</b>	<b>Remote Sensing, GIS and Modelling: Assessing Spatially Distributed Water, Carbon, and Nutrient Balances in the Ammer River Catchment in Southern Bavaria . . . . .</b>	<b>583</b>
	W. Mauser, J.D. Tenhunen, K. Schneider, R. Ludwig, R. Stolz, R. Geyer, E. Falge	
31.1	Introduction . . . . .	583
31.2	Approaches to Landscape and Regional Modelling . . . .	585
31.3	Remote Sensing and Spatial Data for Landscape Models . . . . .	589
31.4	The Test Site: Landscape Structure and Model Inputs . . .	590
31.4.1	Spatial Information for Microscale Modelling . . . . .	592

Contents	XXI
31.4.2 Spatial Information for Mesoscale Modelling . . . . .	593
31.5 PROMET/PROXEL: A Multiscale Modelling Framework . . . . .	594
31.5.1 PROXEL <sub>ET</sub> . . . . .	595
31.5.1.1 PROXEL <sub>ET</sub> Description . . . . .	595
31.5.1.2 Spatial Patterns in Hydrology and Water Balance . . . . .	596
31.5.1.3 Future Testing of Model Outputs: Temperature, Soil Moisture, and NDVI . . . . .	601
31.5.2 PROXEL <sub>NEE</sub> . . . . .	601
31.5.2.1 PROXEL <sub>NEE</sub> Description . . . . .	601
31.5.2.2 Land Use Effects on Landscape Carbon Balance . . . . .	602
31.5.3 PROXEL <sub>ECOSYS</sub> . . . . .	604
31.5.3.1 PROXEL <sub>ECOSYS</sub> Description . . . . .	604
31.5.3.2 Ecosystem Processes and Management Influences at Landscape Scale . . . . .	606
31.5.3.3 Seasonal Biomass Changes in Meadows . . . . .	609
31.5.3.4 Biomass Production of Crops and Heterogeneities Within Single Fields . . . . .	609
31.5.3.5 Spatial Patterns of Biomass Production . . . . .	611
31.5.3.6 Nitrogen Trapping and Release . . . . .	612
31.6 Conclusions and Future Perspectives . . . . .	613
References . . . . .	615

<b>32 Ecosystem Science Contributions and the Implementation of an Ecologically Based Landscape Management in Central Europe . . . . .</b>	<b>621</b>
J. D. Tenhunen, W. Mauser, R. Lenz	
32.1 Ecosystem Studies and Resource Management . . . . .	621
32.1.1 Upscaling Ecosystem Studies in Spatial and Temporal Dimensions . . . . .	622
32.1.2 Unsolved Problems: Landscape Heterogeneity, Fragmentation, and Biological Diversity . . . . .	628
32.2 Assessments of Landscape Function and Linkages with Socio-economic and Political Dimensions . . . . .	629
32.2.1 A General Methodology for Upscaling Biological, Biogeochemical, and Hydrological Information . . . . .	629
32.2.2 Shortcomings of the Methodology Related to Heterogeneity, Time Lags, and Biogeochemical Equilibria . . . . .	630

32.2.3	Building Communication Between Ecosystem Science and Resource Management . . . . .	632
32.3	Summary and Conclusions . . . . .	634
	References . . . . .	635
	Appendix: Color Illustrations . . . . .	637
	Subject Index . . . . .	647