

# Contents

Preface .....	v
---------------	---

## **Part I Context**

### Chapter 1

#### The Ecosystem Concept

Introduction .....	3
Overview of Ecosystem Ecology .....	3
History of Ecosystem Ecology .....	7
Ecosystem Structure .....	10
Controls over Ecosystem Processes .....	11
Human-Caused Changes in Earth's Ecosystems .....	13
Summary .....	16
Review Questions .....	17
Additional Reading .....	17

### Chapter 2

#### Earth's Climate System

Introduction .....	18
Earth's Energy Budget .....	18
The Atmospheric System .....	21
Atmospheric Composition and Chemistry .....	21
Atmospheric Structure .....	22
Atmospheric Circulation .....	24
The Oceans .....	28
Ocean Structure .....	28
Ocean Circulation .....	29
Landform Effects on Climate .....	31
Vegetation Influences on Climate .....	32
Temporal Variability in Climate .....	34
Long-Term Changes .....	34
Interannual Climate Variability .....	38
Seasonal and Daily Variations .....	40

Relationship of Climate to Ecosystem Distribution and Structure .....	41
Summary .....	44
Review Questions .....	44
Additional Reading .....	45

### Chapter 3 Geology and Soils

Introduction .....	46
Controls over Soil Formation .....	46
Parent Material .....	47
Climate .....	48
Topography .....	48
Time .....	49
Potential Biota .....	50
Human Activities .....	50
Controls over Soil Loss .....	50
Development of Soil Profiles .....	53
Additions to Soils .....	54
Soil Transformations .....	54
Soil Transfers .....	56
Losses from Soils .....	57
Soil Horizons and Soil Classification .....	58
Soil Properties and Ecosystem Functioning .....	61
Summary .....	66
Review Questions .....	67
Additional Reading .....	67

## **Part II Mechanisms**

### Chapter 4 Terrestrial Water and Energy Balance

Introduction .....	71
Surface Energy Balance .....	73
Solar Radiation Budget .....	73
Ecosystem Radiation Budget .....	74
Energy Partitioning .....	75
Seasonal Energy Exchange .....	77
Water Inputs to Ecosystems .....	77
Water Movements Within Ecosystems .....	78
Basic Principles of Water Movement .....	78
Water Movement from the Canopy to the Soil .....	79
Water Movement Within the Soil .....	80
Water Movement from Soil to Roots .....	81
Water Movement Through Plants .....	83
Water Losses from Ecosystems .....	89
Evaporation from Wet Canopies .....	89
Evapotranspiration from Dry Canopies .....	90

Changes in Storage .....	92
Runoff .....	93
Summary .....	95
Review Questions .....	96
Additional Reading .....	96

Chapter 5

Carbon Input to Terrestrial Ecosystems

Introduction .....	97
Overview .....	97
Photosynthetic Pathways .....	98
C <sub>3</sub> Photosynthesis .....	98
C <sub>4</sub> Photosynthesis .....	102
Crassulacean Acid Metabolism Photosynthesis .....	103
Net Photosynthesis by Individual Leaves .....	105
Basic Principle of Environmental Control .....	105
Light Limitation .....	105
CO <sub>2</sub> Limitation .....	109
Nitrogen Limitation and Photosynthetic Capacity .....	110
Water Limitation .....	113
Temperature Effects .....	114
Pollutants .....	115
Gross Primary Production .....	115
Canopy Processes .....	115
Satellite Estimates of GPP .....	117
Controls over GPP .....	119
Summary .....	121
Review Questions .....	121
Additional Reading .....	122

Chapter 6

Terrestrial Production Processes

Introduction .....	123
Overview .....	123
Plant Respiration .....	125
Physiological Basis of Respiration .....	125
Net Primary Production .....	127
What Is NPP? .....	127
Physiological Controls over NPP .....	128
Environmental Controls over NPP .....	129
Allocation .....	132
Allocation of NPP .....	132
Allocation Response to Multiple Resources .....	133
Diurnal and Seasonal Cycles of Allocation .....	134
Tissue Turnover .....	136
Global Distribution of Biomass and NPP .....	137
Biome Differences in Biomass .....	137
Biome Differences in NPP .....	138
Net Ecosystem Production .....	140

Ecosystem Carbon Storage .....	140
Leaching .....	141
Lateral Transfers .....	145
Disturbance .....	145
Controls over Net Ecosystem Production .....	145
Net Ecosystem Exchange .....	146
Global Patterns of NEE .....	147
Summary .....	148
Review Questions .....	149
Additional Reading .....	149

## Chapter 7

### Terrestrial Decomposition

Introduction .....	151
Overview .....	151
Leaching of Litter .....	152
Litter Fragmentation .....	152
Chemical Alteration .....	153
Fungi .....	153
Bacteria .....	154
Soil Animals .....	155
Temporal and Spatial Heterogeneity of Decomposition ..	157
Temporal Pattern .....	157
Spatial Pattern .....	158
Factors Controlling Decomposition .....	159
The Physical Environment .....	159
Substrate Quality and Quantity .....	163
Microbial Community Composition and Enzymatic Capacity .....	168
Long-Term Storage of Soil Organic Matter .....	169
Decomposition at the Ecosystem Scale .....	170
Aerobic Heterotrophic Respiration .....	170
Anaerobic Heterotrophic Respiration .....	173
Summary .....	174
Review Questions .....	174
Additional Reading .....	175

## Chapter 8

### Terrestrial Plant Nutrient Use

Introduction .....	176
Overview .....	176
Nutrient Movement to the Root .....	177
Diffusion .....	178
Mass Flow .....	178
Root Interception .....	180
Nutrient Uptake .....	180
Nutrient Supply .....	180
Development of Root Length .....	181
Mycorrhizae .....	182

Root Uptake Properties . . . . .	184
Nutrient Use . . . . .	189
Nutrient Loss from Plants . . . . .	191
Senescence . . . . .	192
Leaching Loss from Plants . . . . .	193
Herbivory . . . . .	193
Other Avenues of Nutrient Loss from Plants . . . . .	194
Summary . . . . .	194
Review Questions . . . . .	195
Additional Reading . . . . .	195

Chapter 9

Terrestrial Nutrient Cycling

Introduction . . . . .	197
Overview . . . . .	197
Nitrogen Inputs to Ecosystems . . . . .	198
Biological Nitrogen Fixation . . . . .	198
Nitrogen Deposition . . . . .	201
Internal Cycling of Nitrogen . . . . .	202
Overview of Mineralization . . . . .	202
Production and Fate of Dissolved Organic Nitrogen . . . . .	203
Production and Fate of Ammonium . . . . .	204
Production and Fate of Nitrate . . . . .	207
Temporal and Spatial Variability . . . . .	210
Pathways of Nitrogen Loss . . . . .	211
Gaseous Losses of Nitrogen . . . . .	211
Ecological Controls . . . . .	211
Solution Losses . . . . .	214
Erosional Losses . . . . .	215
Other Element Cycles . . . . .	215
Phosphorus . . . . .	215
Sulfur . . . . .	219
Essential Cations . . . . .	219
Nonessential Elements . . . . .	220
Interactions Among Element Cycles . . . . .	220
Summary . . . . .	222
Review Questions . . . . .	222
Additional Reading . . . . .	223

Chapter 10

Aquatic Carbon and Nutrient Cycling

Introduction . . . . .	224
Ecosystem Properties . . . . .	224
Oceans . . . . .	228
Carbon and Light Availability . . . . .	228
Nutrient Availability . . . . .	231
Carbon and Nutrient Cycling . . . . .	233
Lakes . . . . .	236
Controls over NPP . . . . .	236

Carbon and Nutrient Cycling . . . . .	238
Streams and Rivers . . . . .	238
Carbon and Nutrient Cycling . . . . .	240
Summary . . . . .	242
Review Questions . . . . .	242
Additional Reading . . . . .	243

Chapter 11

Trophic Dynamics

Introduction . . . . .	244
Overview . . . . .	244
Plant-Based Trophic Systems . . . . .	246
Controls over Energy Flow Through Ecosystems . . . . .	246
Ecological Efficiencies . . . . .	250
Food Chain Length and Trophic Cascades . . . . .	257
Seasonal Patterns . . . . .	258
Nutrient Transfers . . . . .	259
Detritus-Based Trophic Systems . . . . .	261
Integrated Food Webs . . . . .	261
Mixing of Plant-Based and Detritus-Based Food	
Chains . . . . .	261
Food Web Complexities . . . . .	263
Summary . . . . .	263
Review Questions . . . . .	263
Additional Reading . . . . .	264

Chapter 12

Community Effects on Ecosystem Processes

Introduction . . . . .	265
Overview . . . . .	266
Species Effects on Ecosystem Processes . . . . .	268
Species Effects on Resources . . . . .	268
Species Effects on Climate . . . . .	271
Species Effects on Disturbance Regime . . . . .	272
Species Interactions and Ecosystem Processes . . . . .	273
Diversity Effects on Ecosystem Processes . . . . .	274
Summary . . . . .	277
Review Questions . . . . .	277
Additional Reading . . . . .	278

**Part III Patterns**

Chapter 13

Temporal Dynamics

Introduction . . . . .	281
Fluctuations in Ecosystem Processes . . . . .	281
Interannual Variability . . . . .	281
Long-Term Change . . . . .	283

Disturbance . . . . .	285
Conceptual Framework . . . . .	285
Disturbance Properties . . . . .	285
Succession . . . . .	288
Ecosystem Structure and Composition . . . . .	288
Carbon Balance . . . . .	292
Nutrient Cycling . . . . .	296
Trophic Dynamics . . . . .	298
Water and Energy Exchange . . . . .	299
Temporal Scaling of Ecological Processes . . . . .	301
Summary . . . . .	303
Review Questions . . . . .	303
Additional Reading . . . . .	304

Chapter 14

Landscape Heterogeneity and Ecosystem Dynamics

Introduction . . . . .	305
Concepts of Landscape Heterogeneity . . . . .	305
Causes of Spatial Heterogeneity . . . . .	307
State Factors and Interactive Controls . . . . .	307
Community Processes and Legacies . . . . .	307
Disturbance . . . . .	309
Interactions Among Sources of Heterogeneity . . . . .	311
Patch Interactions on the Landscape . . . . .	314
Topographic and Land-Water Interactions . . . . .	314
Atmospheric Transfers . . . . .	317
Movement of Plants and Animals on the Landscape . . . . .	320
Disturbance Spread . . . . .	320
Human Land Use Change and Landscape Heterogeneity . . . . .	321
Extensification . . . . .	321
Intensification . . . . .	323
Spatial Heterogeneity and Scaling . . . . .	325
Summary . . . . .	330
Review Questions . . . . .	330
Additional Reading . . . . .	331

**Part IV Integration**

Chapter 15

Global Biogeochemical Cycles

Introduction . . . . .	335
The Global Carbon Cycle . . . . .	335
Long-Term Change in Atmospheric CO <sub>2</sub> . . . . .	337
Anthropogenic Changes in the Carbon Cycle . . . . .	339
Terrestrial Sinks for CO <sub>2</sub> . . . . .	340
The Global Methane Budget . . . . .	342

The Global Nitrogen Cycle .....	343
Anthropogenic Changes in the Nitrogen Cycle .....	344
The Global Phosphorus Cycle .....	347
Anthropogenic Changes in the Phosphorus Cycle .....	347
The Global Sulfur Cycle .....	348
The Global Water Cycle .....	350
Anthropogenic Changes in the Water Cycle .....	351
Consequences of Changes in the Water Cycle .....	352
Summary .....	354
Review Questions .....	354
Additional Reading .....	355

## Chapter 16

### Managing and Sustaining Ecosystems

Introduction .....	356
Ecosystem Concepts in Management .....	357
Natural Variability .....	357
Resilience and Stability .....	357
State Factors and Interactive Controls .....	358
Application of Ecosystem Knowledge in Management ..	359
Forest Management .....	359
Fisheries Management .....	359
Ecosystem Restoration .....	360
Management for Endangered Species .....	360
Integrative Approaches to Ecosystem Management .....	362
Ecosystem Management .....	362
Integrated Conservation and Development Projects .....	365
Valuation of Ecosystem Goods and Services .....	366
Summary .....	368
Review Questions .....	369
Additional Reading .....	369

Abbreviations .....	371
---------------------	-----

Glossary .....	375
----------------	-----

References .....	393
------------------	-----

Index .....	423
-------------	-----