Seeing the Forest for the Trees

Forests, Climate Change, and Our Future

Gordon Bonan
National Center for Atmospheric Research (NCAR)

CAMBRIDGE
UNIVERSITY PRESS

Contents

Preface *page* xi

Part I Historical Perspective 1

1 The Forest–Climate Question 3

2 Tempering the Climate, c. 1600–1840 12
The Quandary of America 12
Forest–Climate Processes 15
The Debate Heightens 18
Divergent Science 21

3 Destroying the Rains, c. 1500–1830 26
Forests and Rainfall 26
Discovery of Oxygen 31
A Precipitation–Evapotranspiration Feedback 32
The Problem of Streamflow 33
Protecting Forests for Climate 35

4 Planting Trees for Rain, c. 1840–1900 39
India 39
Australia and New Zealand 41
South Africa 43
Russia 44
The United States 45
Rain Follows the Plow 49

5 Making a Science: Forest Meteorology, c. 1850–1880 52
France and Her Forests 52
Climates and the Influence of Wooded Soils 54
The Physical Effects of Forests on Air and Soil 57
Forests, Climate, and Water 60
CO_2, Water Vapor, and the Greenhouse Effect 64

6 American Meteorologists Speak Out, c. 1850–1910 67
Rational Climatology 67
Fernow's Forest Influences 70
The Disagreement Deepens 72

Disciplinary Splintering 74
A Renewed Science 77

7 Views of Forests 82
In the Beginning, There Were Trees 82
What Is a Forest? 83
Visual Art 86
Literature 91
The Forest for Trees 95

Part II The Scientific Basis 99

8 Global Physical Climatology 101
Earth's Energy Balance 101
Atmospheric General Circulation 102
Ocean Circulation 104
The Hydrologic Cycle 105
Climate Zones 105
Climate Variability 106
Mechanisms of Climate Change 108
Anthropogenic Climate Change 110

9 Forest Biometeorology 114
Principles of Environmental Physics 114
Leaf Temperature 117
Forest Canopies 120

10 Scientific Tools 127
Chamber Measurements 127
Eddy Covariance Flux Towers 128
Inventory Measurements 131
Ecosystem Experiments 132
Watershed Studies 132
Satellite Remote Sensing 134
Global Climate Models 136

11 Forest Microclimates 139
Foliage 139
Solar Radiation 142
Wind 143
Air Temperature 143
The Air above Forests 146

12 Water Yield 149
The Economy of Forest Water 149
The Hydrologic Cycle on Land 150
Paired Watershed Experiments 153
Eddy Covariance Studies 155

13 Carbon Sequestration 157
Ecosystem Carbon Fluxes 157
The Global Carbon Budget 161
The Land Carbon Sink 163
The Water Cost of Carbon Uptake 165
Forests and Oxygen 166

14 Forest Macroclimates 168
A Desert World 168
Forest–Climate Processes 170
The Climate Influences of Forests 173
The Spatial Scale Problem 175
Atmospheric Circulations 177
Droughts and Heat Waves 179
The Physiological Forcing of Climate 180
Atmospheric CO_2 180
Atmospheric Chemistry 181

15 Case Studies 184
Amazonian Rain Forest 185
Boreal Forests 189
Temperate Forests 193
Northern Africa 196

16 Climate-Smart Forests 201
Nature-Based Climate Solutions 201
Reforesting the Planet 203
Biogeophysical Climate Influences 205
What Is a Climate-Smart Forest? 207
European Forests: Case Studies 210

17 Forests of the Future 214
Biogeography and Climate 214
Past Forests 216
Forest Succession 221
Threats to Forests 222

18 The Forests before Us 224
Bridging Two Worlds 224
On Narrow-Mindedness 225
Beyond the Utilitarian Forest 227
Natural Laws 228
Why We Plant Trees 229

Notes 232
References 256
Index 308