Soil Respiration and the Environment

Yiqi Luo and Xuhui Zhou
Table of Contents

Part I  Context

1. Introduction and Overview 3
   1.1. Definition and introduction 4
   1.2. History of research 7
   1.3. Overview of the book 13

2. Importance and Roles of Soil Respiration 17
   2.1. Soil respiration and ecosystem carbon balance 17
   2.2. Soil respiration and nutrient cycling 21
   2.3. Soil respiration and regional and global carbon cycling 22
   2.4. Soil respiration and climate change 25
   2.5. Soil respiration and carbon storage and trading 28

Part II  Mechanisms 33

3. Processes of CO₂ Production in Soil 35
   3.1. Biochemistry of CO₂ production processes 36
       Tricarboxylic acid (TCA) cycle 36
       Other CO₂ production and consumption processes in soil 39
       Respiratory quotient 40
3.2. Root respiration 42
3.3. Rhizosphere respiration with labile carbon supply 46
3.4. Litter decomposition and soil organisms 49
3.5. Oxidation of soil organic matter (SOM) 55

4. Processes of CO₂ Transport from Soil to the Atmosphere 61
   4.1. CO₂ transport within soil 61
   4.2. CO₂ release at the soil surface 67
   4.3. CO₂ transfer in plant canopy 70
   4.4. CO₂ transport in the planetary boundary layer (PBL) 74

Part III Regulation 77

5. Controlling Factors 79
   5.1. Substrate supply and ecosystem productivity 79
   5.2. Temperature 85
   5.3. Soil moisture 92
   5.4. Soil oxygen 98
   5.5. Nitrogen 99
   5.6. Soil texture 101
   5.7. Soil pH 102
   5.8. Interactions of multiple factors 104

6. Temporal and Spatial Variations in Soil Respiration 107
   6.1. Temporal variation 108
      Diurnal and weekly variation 108
      Seasonal variation 110
      Interannual variability 112
      Decadal and centennial variation 113
   6.2. Spatial patterns 115
      Stand level 115
      Landscape level 117
      Regional scale 118
      Biomes: Forests, grasslands, tundra, savannas/woodlands, deserts, crop fields, and wetlands 120
   6.3. Variation along gradients 128
      Latitudes 128
      Altitudes 129
      Topography 130
# Table of Contents

7. Responses to Disturbances 133
   7.1. Elevated CO₂ concentration 134
   7.2. Climatic warming 138
   7.3. Changes in precipitation frequency and intensity 143
   7.4. Disturbances and manipulations of substrate supply 146
      Fire or burning 146
      Forest harvesting, thinning, and girdling 147
      Grazing, clipping, and shading in grasslands 151
      Litter removal and addition 152
   7.5. Nitrogen deposition and fertilization 152
   7.6. Agricultural cultivation 155
   7.7. Interactive and relative effects of multiple factors 156

Part IV Approaches 159

8. Methods of Measurements and Estimations 161
   8.1. Methodological challenges and classification of measurement methods 162
   8.2. Closed dynamic chamber (CDC) method 163
   8.3. Open dynamic chamber (ODC) method 169
   8.4. Closed static chamber (CSC) methods 170
      Alkali trapping 171
      Soda-lime trapping 172
   8.5. Gas chromatograph (GC) 174
   8.6. Chamber design and deployment 175
      Chamber design 175
      Chamber deployment 176
   8.7. Gas-well (GW) method 178
   8.8. Miscellaneous indirect methods 181
   8.9. Method comparison 183

9. Separation of Source Components of Soil Respiration 187
   9.1. Experimental manipulation methods 189
      Direct component measurements and integration 189
      Root exclusion 190
      Severing substrate supply to the rhizosphere 190
      Litter removal 194
   9.2. Isotope methods 195
      Growing C₃ plants on C₄ soil or C₄ plants on C₃ soil 197
      CO₂ enrichment experiments 199
Bomb $^{14}$C tracer 204
Labeling experiments 207

9.3. Inference and modeling methods 209
Regression extrapolation and modeling analysis 209
Deconvolution analysis 210

9.4. Estimated relative contributions of different source components 212

10. Modeling Synthesis and Analysis 215
10.1. Empirical models 216
Temperature-respiration models 216
Moisture-respiration models 219
Substrate-respiration models 224
Multifactor models 226
10.2. CO$_2$ production models 230
10.3. CO$_2$ production-transport models 239
10.4. Modeling soil respiration at different scales 241
10.5. Model development and evaluation 244

Appendix 247

References 257

Index 307