# Contents

1 Introduction ........................................ 1
   1.1 Overview of Plant Litter Decomposition ............... 1
   1.2 A Short Retrospective .................................. 2
   1.3 The Ecological Significance of Litter Decomposition and the Formation of Humus ...................... 3
   1.4 Factors Influencing Decay and Humus Formation ........ 4
   1.5 Accumulation of Humus and Nutrients ................... 5
   1.6 The Contents and Organization of the Book .............. 6
   1.7 Motives for the Present Synthesis ...................... 9
   1.8 New Developments Included in the Third Edition ........ 10

2 Decomposition as a Process: Some Main Features .......... 11
   2.1 Litter Decomposition: A Set of Different Processes Including Synthesis ................................ 11
   2.2 Definition of Litter Decomposition ...................... 14
   2.3 Ash Dynamics .............................................. 16
   2.4 Degradation of the Main Groups of Organic Compounds in Litter ........................................ 16
      2.4.1 Degradation and Leaching of Soluble Organic Substances ........................................ 17
      2.4.2 Degradation of Non-Lignified Organic Substances ........ 18
      2.4.3 A Pattern of Degradation of the Main Organic Compounds in Pine Needle Litter ............... 19
      2.4.4 Pattern for Main Organic Compounds Based on AUR: Gravimetric Analyses of Lignin .......... 21
      2.4.5 $^{13}$C-NMR Analysis Applied onto Decomposing Foliar Litter .................................... 22
   2.5 Factors Regulating Degradation of Lignin/AUR ............ 24
      2.5.1 Potential Effects and Possible Interactions on Lignin/AUR Degradation ....................... 24
      2.5.2 Effects of Litter Mn Concentration on Lignin/AUR Degradation and Litter Mass Loss ........... 25
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5.3</td>
<td>Effect of N on Lignin/AUR and Late-Stage Litter Degradation</td>
<td>26</td>
</tr>
<tr>
<td>2.6</td>
<td>Proposed Model for Decomposition from Newly Shed Litter to the Humus Stage</td>
<td>28</td>
</tr>
<tr>
<td>2.6.1</td>
<td>The Early Stage</td>
<td>30</td>
</tr>
<tr>
<td>2.6.2</td>
<td>The Late Stage May Have Substages</td>
<td>30</td>
</tr>
<tr>
<td>2.6.3</td>
<td>The Humus-Near or Limit-Value Stage</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>Decomposer Organisms</td>
<td>35</td>
</tr>
<tr>
<td>3.1</td>
<td>Introduction</td>
<td>35</td>
</tr>
<tr>
<td>3.2</td>
<td>General Properties of a Given Microbial Population</td>
<td>36</td>
</tr>
<tr>
<td>3.3</td>
<td>The Degradation of the Main Polymers in Litter</td>
<td>38</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Degradation of Cellulose</td>
<td>38</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Degradation of Hemicelluloses</td>
<td>41</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Degradation of Lignin</td>
<td>41</td>
</tr>
<tr>
<td>3.4</td>
<td>Degradation of Fibers</td>
<td>48</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Bacteria</td>
<td>48</td>
</tr>
<tr>
<td>3.4.2</td>
<td>Soft Rot</td>
<td>48</td>
</tr>
<tr>
<td>3.4.3</td>
<td>Brown Rot</td>
<td>49</td>
</tr>
<tr>
<td>3.4.4</td>
<td>White Rot</td>
<td>49</td>
</tr>
<tr>
<td>3.5</td>
<td>Mycorrhizae</td>
<td>50</td>
</tr>
<tr>
<td>3.6</td>
<td>Ecological Aspects</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Initial Litter Chemical Composition</td>
<td>53</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>53</td>
</tr>
<tr>
<td>4.2</td>
<td>Organic-Chemical Components of Plant Litter and Fiber Structure</td>
<td>55</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Organic-Chemical Components</td>
<td>55</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Fiber Structure</td>
<td>59</td>
</tr>
<tr>
<td>4.3</td>
<td>Nutrient and Heavy Metals’ Concentrations in Newly Shed Litter</td>
<td>61</td>
</tr>
<tr>
<td>4.3.1</td>
<td>General Features</td>
<td>61</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Nutrient Resorption and Withdrawal Efficiency</td>
<td>62</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Nutrient Concentration Change; Green Foliage versus Brown Litter</td>
<td>62</td>
</tr>
<tr>
<td>4.4</td>
<td>Factors Influencing Litter Chemical Composition</td>
<td>64</td>
</tr>
<tr>
<td>4.4.1</td>
<td>General Factors</td>
<td>64</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Nutrients, Heavy Metals and AUR in Needle Litter of Two Conifers, Pine and Spruce spp: Two Case Studies in Climate Gradients</td>
<td>66</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Influence of Soil Properties</td>
<td>73</td>
</tr>
<tr>
<td>4.5</td>
<td>Several Deciduous and Coniferous Leaf Litter Species</td>
<td>74</td>
</tr>
<tr>
<td>4.5.1</td>
<td>Variation in a Eurasian to Global Gradient—Focus on Nitrogen</td>
<td>74</td>
</tr>
</tbody>
</table>
4.5.2 Coniferous versus Deciduous Genera/Species and Influence of Species: An Old Concept ............ 75
4.5.3 General (Global) Relationships .................. 78
4.6 Wood and Fine Root Litter .............................. 79
4.7 Anthropogenic Influences on Initial Litter Composition ...... 79
4.7.1 N-fertilized Scots Pine and Norway Spruce Monocultures ........................................... 79
4.7.2 Heavy Metal Pollution and Initial Litter Chemical Composition ........................................ 82

5 Changes in Substrate Composition during Decomposition .......... 85
5.1 Introductory Comments ..................................... 85
5.2 Organic-Chemical Changes during Litter Decomposition ......... 86
5.2.1 Traditional Analytical Fractions .......................... 86
5.2.2 Relationships Between Holocellulose and AUR ............ 91
5.2.3 13C-NMR Technique ..................................... 92
5.3 Nutrient and Heavy Metal Concentrations during Decay ........... 94
5.3.1 Changes in Concentrations of Elements in Decomposing Litter ...................................... 94
5.4 Special Studies on Mn and N Dynamics ......................... 99
5.4.1 Mn Dynamics ............................................. 99
5.4.2 Nitrogen Concentration Dynamics Over a Climatic Gradient ........................................ 102

6 Chemical Constituents as Rate Regulating: Initial Variation and Changes during Decomposition. New and Traditional Analytical Techniques ............................................. 109
6.1 Introduction .................................................. 109
6.2 New Finding, Possible to Relate to a Phase-Based Model .......... 110
6.3 A Three-Phase Model Applied to Different Litter Species of Different Chemical Composition .................... 111
6.3.1 Early Decomposition Stage: Dominated by Cellulose and Hemicelluloses .............................. 114
6.3.2 Decomposition in the Late Stage: Lignin-Regulated Phase .............................................. 123
6.4 Litter at Humus-Near or Limit-Value Stage ....................... 136
6.4.1 General Comments ........................................ 136
6.4.2 General Relationships .................................... 136
6.4.3 Do Limit Values Indicate a Stable Fraction? ............... 140
6.5 Does Chemical Composition Influence Leaching of Compounds from Humus? .......................... 141
9.4 Type of Model and Some Dominant Influencing Factors .... 195
9.4.1 Some Aspects of Litter Chemical Composition .... 195
9.4.2 Extent and Quality of the Dataset ...... 199

10 Some Possible Influences on Decomposition Pattern, Regression Model, Stable Fraction, and C Sequestration .............. 201
10.1 Introduction ............ 201
10.1.1 Background ............ 201
10.1.2 Potential Influence ............ 203
10.2 Two Main Patterns and Two Main Models? ............ 204
10.3 Specific Factors that May Determine a Pattern: and a Model? ............ 204
10.3.1 Litter Type versus Litter Chemistry Revealing a Pattern ............ 204
10.3.2 Litter Chemical Properties: Specific Factors for Foliar Litter ............ 206
10.3.3 Environmental Factors ............ 208
10.4 What is the Relevance of a Limit Value or a Complete Decomposition? Long-Term Stability at the Limit Value and in Humus: Low or No Decomposition? ............ 210
10.4.1 Can We Use Limit Values to Estimate Organic Matter or Carbon Budgets? ............ 210
10.4.2 Humus in Scots Pine and Norway Spruce Stands, Stability versus Humus N Concentration ............ 212

11.1 Introduction ............ 215
11.2 Amounts of Humus and Increase in Organic Layers. Is There a Steady State? ............ 217
11.3 Accumulation of Stabilized Humus/Carbon in Organic Layers of Boreal and Temperate Forests ............ 219
11.3.1 Accumulation with Stand Age ............ 219
11.4 Variation in Carbon Sequestration Rates among Tree Species and Soil Properties: Data for Northern Europe ............ 222
11.4.1 Large-Scale Comparisons among Species Over Northern Europe ............ 222
11.4.2 Accumulation of SOM-C with Climate: Coniferous Forests in Gradients ............ 225
11.5 Some Factors Related to Mineral Soil may Influence Organic Layer C Sequestration ............ 226
11.5.1 Soil Texture and Mineral Soil Nutrients ............ 227
11.5.2 Organic Layers’ Natural Nutrient Availability ............ 227
11.6 Humus Layer Stability versus its Turnover ............................... 230
11.7 Carbon in the Mineral Soil .................................................. 230
11.7.1 Does the Amount of Organic Matter in the Mineral Soil Change? .................. 230
11.7.2 Organic Matter Mixed into the Mineral Soil ............... 231
11.7.3 Is There any Effect of Disturbance? .................. 232

12 Estimating Carbon Sequestration Rates on a Regional Scale .... 235
12.1 Long-Term Accumulation of Carbon in Organic Layers
(O Horizon): General Comments ................................. 235
12.2 Influences on Carbon Sequestration Rates in Forested Land: Regional Level ........................................ 237
12.2.1 Undisturbed Sites and Anthropogenic Influence ........ 237
12.2.2 General Consideration as Regards a Database for Regional Modeling ......................... 238
12.3 Two Case Studies .......................................................... 239
12.4 Case Study for a Region: Direct Measurements of Humus Depth ................................. 240
12.4.1 Background ............................................................. 240
12.4.2 General Design of the Humus Inventory .......................... 240
12.4.3 Scaling up from Field Measurements on Humus Depth in Plots to C Sequestered on Country Level: Overview ............................................. 241
12.4.4 Changes in Organic Layer Thickness Over Time ........ 243
12.4.5 Calculations of Carbon Bulk Density in the Humus Layer ............................................. 250
12.4.6 Calculated Carbon Sequestration Rates and Some Patterns ............................................. 250
12.4.7 Possible Sources of Error in Estimates of C Sequestration Rates .................................. 252
12.5 Carbon Sequestration in Mineral Soil. Observations on a Regional Scale ............................................. 253
12.5.1 Different Sequestration Patterns? .............................. 253
12.6 Remaining Stable Fraction: A Theory and a Possible Regional Approach .............................. 256
12.6.1 Short Background .......................................................... 256
12.6.2 Geographical Database ................................................. 256
12.6.3 Expanding to a Regional Scale ....................................... 258
12.6.4 Calculation of the Buildup of Humus and Carbon ........ 259
12.6.5 Potential Carbon Sequestration Rates ....................... 259
12.6.6 The Effect of Tree Species on Carbon Sequestration Rates in the Humus Layer .................. 260
Plant Litter
Decomposition, Humus Formation, Carbon Sequestration
Berg, B.; McLaugherty, C.
2014, XVII, 315 p. 92 illus., Hardcover
ISBN: 978-3-642-38820-0