

Contents

<i>Preface</i>	<i>page</i> ix
<i>List of Symbols</i>	xi
<i>Acknowledgments</i>	xiii
1 A Brief History of Leaf Color	1
2 Leaf Biophysics	12
2.1 Leaf Anatomy	14
2.2 Leaf Shape and Venation	21
2.3 Leaf Biochemical Composition	22
2.4 Dry Matter	38
2.5 Natural Range and Relationships of Leaf Constituents	40
2.6 Developmental Evolution of Leaf Constituents	43
3 Spectroscopy of Leaf Molecules	48
3.1 Theory	48
3.2 Pigment-Specific Absorption Coefficients	54
3.3 Water-Specific Absorption Coefficients	60
3.4 Cell Wall Constituent-Specific Absorption Coefficients	63
3.5 Other Minor Constituent-Specific Absorption Coefficients	68
3.6 Refractive Index of Leaf Constituents	70
4 Measurement of Leaf Optical Properties	74
4.1 Terminology	74
4.2 What to Measure?	84
4.3 Measurement of Leaf Color	88
4.4 Measurement of Leaf BRDF/BTDF	94
4.5 Measurement of Leaf DHRF/DHTF	106
4.6 Portable Photometers and Other Probes	113
4.7 Measurement of Leaf Absorption Profiles	118
4.8 Measurement of Leaf Surface Temperature	120
4.9 Measurement of Leaf Electrical Properties	121

5	Leaf Optical Properties in Different Wavelength Domains	124
5.1	Surface Scattering	124
5.2	Volume Scattering of the Entire Leaf	136
5.3	Leaf Color	161
5.4	Light Gradients	162
5.5	Near-Infrared and Fourier Transform Infrared Spectroscopy	167
6	Variation Due to Leaf Structural, Chemical, and Physiological Traits	170
6.1	Structural Sources	170
6.2	Chemical Sources	179
6.3	Physiological Sources	185
6.4	Intraspecific Variation	189
6.5	Interspecific Diversity	190
6.6	Climate Change	194
7	Variations Due to Leaf Abiotic and Biotic Factors	195
7.1	Abiotic Factors	195
7.2	Biotic Factors	214
8	Comprehensive Reviews of Leaf Optical Properties Models	229
8.1	Different Approaches for Leaf Diffuse Optical Properties	230
8.2	Different Approaches for Leaf Fluorescence	246
8.3	Different Approaches for Leaf Surface Reflectance Properties	251
8.4	Terahertz, Microwaves, and Radio Waves Scattering Models	262
9	Modeling Leaf Optical Properties: PROSPECT	265
9.1	The PROSPECT Model	265
9.2	Direct Mode: Sensitivity Analysis	271
9.3	Model Inversion	283
9.4	Link of PROSPECT with a Leaf BRDF Model	286
10	Modeling Three-Dimensional Leaf Optical Properties: RAYTRAN	292
10.1	Three-Dimensional Structure of Plant Leaves	292
10.2	Construction of a Three-Dimensional Leaf Model	302
10.3	The RAYTRAN Model	307
10.4	Radiative Transfer Simulations	308
10.5	Coupling RAYTRAN with a Photosynthesis Model	316
11	Extraction of Leaf Traits	320
11.1	Combinations of Narrow Bands	320
11.2	Absorption Band Depth	328
11.3	Spectral Shifts	332
11.4	Statistical Approach	340
11.5	Wavelet Transform	349
11.6	Spectral Mixture Analysis	351

	<i>Contents</i>	vii
11.7	Artificial Neural Networks	352
11.8	Model Inversion	354
12	Applications of Leaf Optics	357
12.1	Leaf Energy Budget	357
12.2	Photosynthesis – Leaf Carbon Budget	364
12.3	Proximal Sensing	366
12.4	Vegetation Remote Sensing	374
12.5	Color Perception by Animals	381
12.6	Autotrophic Endosymbiosis: Animals That Photosynthesize	385
12.7	Camouflage	387
12.8	Astrobiology	393
12.9	Image Synthesis	397
12.10	Science and Art	401
	Conclusion	404
	<i>Appendix A Glossary and Acronym List</i>	406
	<i>Appendix B Leaf Molecules</i>	423
	<i>Appendix C Planck's Law</i>	435
	<i>Appendix D Radiometry</i>	439
	<i>Appendix E Fresnel's Equations</i>	442
	<i>Appendix F Beer–Lambert Law</i>	452
	<i>Appendix G Kubelka–Munk Theory</i>	455
	<i>Appendix H Global Sensitivity Analysis</i>	462
	<i>Appendix I Leaf Three-Dimensional Reconstruction</i>	464
	<i>Appendix J Leaf Online Databases and Models</i>	469
	References	473
	Index	544
	<i>Color plate section can be found between pages 210 and 211</i>	