
CONTENTS

CHAPTER 1	
INTRODUCTION	1
<i>Ghassem Asrar</i>	
I Introduction	1
II Sensors	1
III Absolute Radiometric Calibration	3
IV Methods of Data Analysis	8
V Outline of the Following Chapters	9
References	13
CHAPTER 2	
FIELD MEASUREMENTS OF BIDIRECTIONAL REFLECTANCE	14
<i>Donald W. Deering</i>	
I Introduction	14
II Fundamental Considerations	18
III Field Instruments	26
IV Field-Measurement Principles and Considerations	59
References	61
CHAPTER 3	
SOIL REFLECTANCE	66
<i>James R. Irons, Richard A. Weismiller, and Gary W. Petersen</i>	
I Introduction	66
II The Composition and Physical Properties of Soils	67

X	CONTENTS	
III	The Interaction of Solar Energy with Soil	78
IV	Models of Soil Reflectance	82
V	Observations of Soil Reflectance	88
VI	Remote-Sensing Applications to Pedology	97
VII	Concluding Remarks	100
	References	101
CHAPTER 4		
SOIL INFLUENCES IN REMOTELY SENSED VEGETATION-CANOPY SPECTRA		107
<i>Alfredo R. Huete</i>		
I	Introduction	107
II	Soil Spectral Characteristics	110
III	Soil Influences on Vegetation Spectra	112
IV	Soil Influences on Vegetation Spectral Indices	119
V	Modeling Soil-Vegetation Spectral Interactions	129
VI	Summary and Conclusions	136
	References	138
CHAPTER 5		
THE THEORY OF PHOTON TRANSPORT IN LEAF CANOPIES		142
<i>Ranga B. Myneni, Ghassem Asrar, and Edward T. Kanemasu</i>		
I	Introduction	142
II	The Transport Equation for Leaf Canopies	143
III	Optical Models for a Leaf Canopy	150
IV	Analytical Methods for Solving the Transport Equation	156
V	Numerical Methods for Solving the Transport Equation	164
VI	Approximate Methods for Solving the Transport Equation	194
VII	In Retrospect	197
	List of Principal Symbols	199
	References	200
CHAPTER 6		
INVERSION OF CANOPY REFLECTANCE MODELS FOR ESTIMATION OF BIOPHYSICAL PARAMETERS FROM REFLECTANCE DATA		205
<i>Narendra S. Goel</i>		
I	Introduction	205
II	Conceptual Basis for Understanding Canopy Reflectance	208
III	Inversion Techniques for Canopy Parameters Estimation	214
IV	Concluding Remarks	241

List of Principal Symbols	246
Appendix: Sensitivity Analysis of a Canopy Reflectance Model	245
References	248

CHAPTER 7**ESTIMATION OF PLANT-CANOPY ATTRIBUTES FROM
SPECTRAL REFLECTANCE MEASUREMENTS****252***Ghassem Asrar, Ranga B. Myneni, and Edward T. Kanemasu*

I Introduction	252
II Estimation of Absorbed PAR	253
III Estimation of Plant-Canopy Structural Variables	263
IV Estimation of Above-Ground Phytomass	282
V The Canopy Hot Spot	286
VI In Retrospect	288
VII Future Directions	289
List of Principal Symbols	290
References	292

CHAPTER 8**VEGETATION-CANOPY SPECTRAL REFLECTANCE AND
BIOPHYSICAL PROCESSES****297***Piers J. Sellers*

I Introduction	297
II Canopy Radiative Transfer, Photosynthesis, and Transpiration Models	299
III Applications	324
IV Summary and Conclusions	328
List of Symbols	331
References	333

CHAPTER 9**THE ATMOSPHERIC EFFECT ON REMOTE SENSING AND
ITS CORRECTIONS****336***Yoram J. Kaufman*

I Introduction	336
II Atmospheric Constituents	339
III Atmospheric Optics	346
IV Atmospheric Effects	353
V Measurements of the Atmospheric Effect	389
VI Atmospheric Corrections	401
VII Conclusions	419
List of Symbols	421
References	424

CHAPTER 10		
APPLICATIONS IN FOREST SCIENCE AND MANAGEMENT		429
<i>David L. Peterson and Steven W. Running</i>		
I Introduction		429
II Unique Biophysical Problems in Remote Sensing of Forests		430
III Theoretical Modeling and Leaf Spectral Properties		431
IV Remote Sensing of Forest-Canopy Characteristics		435
V Spatial Characterization of Forest Attributes		447
VI Geographic Aggregations and Estimation		452
VII Integration of Satellite Imagery with Geographic Information Systems		455
VIII Coupling Satellite Data and Forest Ecosystem Models		459
References		465
CHAPTER 11		
APPLICATIONS TO COASTAL WETLANDS VEGETATION		474
<i>Michael F. Gross, Michael A. Hardisky, and Vytautas Klemas</i>		
I Introduction		474
II Mapping Coastal Wetlands Vegetation		475
III Spectral Estimation of Macrophytic Biomass and Productivity		477
IV Future Research Areas		486
V Summary		487
References		487
CHAPTER 12		
SPECTRAL REMOTE SENSING IN GEOLOGY		491
<i>Alexander F. H. Goetz</i>		
I Introduction		491
II Historical Perspective		491
III Spectral Properties of Minerals		493
IV Electronic Transitions		494
V Color Centers		498
VI Electronic Effects of Iron		498
VII Vibrational Processes		498
VIII Silicates		504
IX Sensors		506
X Data-Analysis Techniques		512
XI Applications		518
XII Future Directions		522
References		523

CHAPTER 13**REMOTE SENSING OF SNOW IN VISIBLE AND NEAR-INFRARED WAVELENGTHS** **527***Jeff Dozier*

I	Introduction	527
II	Remote Sensing of Snow Properties for Hydrology and Climatology	528
III	Optical Properties of Ice	529
IV	A Model for the Reflectance of Snow	530
V	Spectral Characteristics of the Reflectance of Snow	535
VI	Measurement of Snow Properties by Remote Sensing	539
VII	Summary	545
	References	545

CHAPTER 14**KNOWLEDGE-BASED SPECTRAL CLASSIFICATION OF REMOTELY SENSED IMAGE DATA** **548***Stephen W. Wharton*

I	Introduction	548
II	Background	549
III	Spectral Expert System Case Study	555
IV	Conclusions	571
	References	574

CHAPTER 15**QUANTITATIVE ASPECTS OF REMOTE SENSING IN THE THERMAL INFRARED** **578***John C. Price*

I	Introduction	578
II	Relationships among Radiation, Temperature, and Surface Emissivity	580
III	The Heat-Flow Equation	584
IV	The Inverse Problem	587
V	The Initial-Value Problem and the Laplace Transform	590
VI	Micrometeorology and the Surface-Energy Balance	592
VII	The Force-Restore Approximation	595
VIII	Correcting Thermal-Infrared Observations for Atmospheric Effects	595
IX	Sea Surface Temperature	597
X	Emissivity in the Thermal Infrared	598
XI	Summary	599
	List of Symbols	601
	References	602

CHAPTER 16	
ESTIMATING SURFACE ENERGY-BALANCE	
COMPONENTS FROM REMOTELY SENSED DATA	604
<i>William P. Kustas, Ray D. Jackson, and Ghassem Asrar</i>	
I Introduction	604
II Surface Energy-Balance	605
III Net Radiation	606
IV Soil Heat Flux	613
V Sensible Heat Flux	614
VI Latent Heat Flux	616
VII Future Directions	622
List of Symbols	622
References	623
CHAPTER 17	
ESTIMATING EVAPORATION AND CARBON	
ASSIMILATION USING INFRARED TEMPERATURE DATA:	
VISTAS IN MODELING	628
<i>Bhaskar J. Choudhury</i>	
I Introduction	628
II Evaporation and Surface Temperature	629
III Carbon Assimilation	665
IV Spatial Variability	674
V Conclusion	682
List of Important Symbols	682
References	684
CHAPTER 18	
FUTURE DIRECTIONS FOR REMOTE SENSING IN	
TERRESTRIAL ECOLOGICAL RESEARCH	691
<i>Diane E. Wickland</i>	
I Introduction	691
II Plans for Future Research	692
III Plans for Future Technology: Expected Advances for Ecological Research	709
IV The Eos Era and Beyond	718
References	719
INDEX	725