

Contents

Preface.....	xiii
Author	xv

Chapter 1	Introduction	1
1.1	Definition and Objectives	1
1.2	Historical Background.....	3
1.3	International Space Law	9
1.4	Benefits of Environmental Monitoring from Satellite Sensors	12
1.4.1	Global Coverage	12
1.4.2	Synoptic View	12
1.4.3	Multiscale Observations	13
1.4.4	Observations over the Nonvisible Regions of the Spectrum	15
1.4.5	Repeat Observation	15
1.4.6	Immediate Transmission	16
1.4.7	Digital Format	16
1.5	Sources of Information on RS Data	17
1.6	Review Questions	19
Chapter 2	Physical Principles of Remote Sensing	21
2.1	Fundamentals of Remote Sensing Signals	21
2.2	The Electromagnetic Spectrum	23
2.3	Terms and Units of Measurement.....	25
2.4	Electromagnetic Radiation Laws.....	27
2.5	Spectral Signatures in the Solar Spectrum.....	29
2.5.1	Introduction	29
2.5.2	Vegetation Reflectance	34
2.5.3	Soil Reflectance Properties	37
2.5.4	Water in the Solar Spectrum	39
2.6	The Thermal Infrared Domain.....	43
2.6.1	Characteristics of EM Radiation in the Thermal Infrared.....	43
2.6.2	Thermal Properties of Vegetation	44
2.6.3	Soils in the Thermal Domain	45
2.6.4	Thermal Signature of Water and Snow	46
2.7	The Microwave Region.....	47
2.7.1	Characteristics of Electromagnetic Radiation in the Microwave Region.....	47
2.7.2	Characteristics of Vegetation in the Microwave Region	51
2.7.3	Characteristics of Soil in the Microwave Region	51
2.7.4	Water and Ice in the Microwave Region	52
2.8	Atmospheric Interactions	53
2.8.1	Atmospheric Absorption	54
2.8.2	Atmospheric Scattering	55
2.8.3	Atmospheric Emission	56
2.9	Review Questions	57

Chapter 3	Sensors and Remote Sensing Satellites	59
3.1	Resolution of a Sensor System	59
3.1.1	Spatial Resolution	59
3.1.2	Spectral Resolution	61
3.1.3	Radiometric Resolution	62
3.1.4	Temporal Resolution	63
3.1.5	Angular Resolution	64
3.1.6	Relationship between Different Resolution Types	64
3.2	Passive Sensors	65
3.2.1	Photographic Cameras	65
3.2.2	Across-Track Scanners	68
3.2.3	Along-Track (Push-Broom) Scanners	69
3.2.4	Video Cameras	70
3.2.5	Microwave Radiometers	71
3.3	Active Sensors	72
3.3.1	Radar	72
3.3.2	Lidar	78
3.4	Satellite Remote Sensing Missions	83
3.4.1	Satellite Orbits	83
3.4.2	The Landsat Program	85
3.4.3	The SPOT Satellites	87
3.4.4	The Sentinel-2 Mission	90
3.4.5	Other Medium-Resolution Optical Sensors	91
3.4.6	High-Spatial-Resolution Satellites	93
3.4.7	Geostationary Meteorological Satellites	97
3.4.8	Polar-Orbiting Meteorological Satellites	98
3.4.9	Terra–Aqua	101
3.4.10	Sentinel-3	104
3.4.11	Radar Missions	105
3.4.12	Programs with Hyperspectral Sensors	108
3.5	Commercialization of EO Data	110
3.6	Review Questions	111
Chapter 4	Basis for Analyzing EO Satellite Images	113
4.1	Constraints in Using Remote Sensing Data	113
4.1.1	What can be estimated from the EO Images?	113
4.1.2	Costs of Data Acquisition	114
4.1.3	End-User Requirements	115
4.2	Types of Interpretation	116
4.2.1	Thematic Classification	117
4.2.2	Generation of Biophysical Variables	117
4.2.3	Change Detection	117
4.2.4	Spatial Patterns	117
4.3	Organization of Remote Sensing Project	118
4.3.1	Description of Objectives	118
4.3.2	Scale and Resolution	119
4.3.3	Classification Typology	121
4.3.4	Selection of Imagery	123
4.3.5	Image Formats and Media	124

4.3.6	Selection of Interpretation Method: Visual or Digital Processing?.....	124
4.4	Interpretation Phase.....	125
4.5	Presentation of Study Areas	127
4.6	Review Questions	130
Chapter 5	Visual Interpretation	131
5.1	Characteristics of Photographic Images.....	131
5.2	Feature Identification.....	132
5.3	Criteria for Visual Interpretation.....	132
5.3.1	Brightness.....	134
5.3.2	Color	134
5.3.3	Texture.....	138
5.3.4	Spatial Context	140
5.3.5	Shape and Size	140
5.3.6	Shadows.....	142
5.3.7	Spatial Pattern	142
5.3.8	Stereoscopic View	143
5.3.9	Period of Acquisition.....	144
5.4	Elements of Visual Analysis.....	145
5.4.1	Geometric Characteristics of a Satellite Image.....	145
5.4.2	Effect of Spatial Resolution in Visual Analysis	146
5.4.3	Effect of Spectral Resolution in Visual Analysis	147
5.4.4	Color Composites	147
5.4.5	Multitemporal Approaches.....	147
5.5	Review Questions	150
Chapter 6	Digital Image Processing (I): From Raw to Corrected Data	153
6.1	Structure of a Digital Image.....	153
6.2	Media and Data Organization	155
6.2.1	Data Storage	155
6.2.2	Image File Formats	155
6.3	Digital Image Processing Systems	156
6.4	General File Operations	158
6.4.1	File Management.....	158
6.4.2	Display Utilities.....	159
6.4.3	Image Statistics and Histograms	162
6.5	Visual Enhancements	165
6.5.1	Contrast Enhancement	165
6.5.2	Color Composites	173
6.5.3	Pseudocolor	174
6.5.4	Filters.....	176
6.6	Geometric Corrections	181
6.6.1	Sources of Errors in Satellite Acquisitions	181
6.6.2	Georeferencing from Orbital Models.....	183
6.6.3	Georeferencing from Control Points	187
6.6.4	Georeferencing with Digital Elevation Models.....	196
6.7	Radiometric Corrections	197
6.7.1	Restoration of Missing Lines and Pixels.....	197
6.7.2	Correction of Striping Effects	198

6.8	Generation of Basic Variables	200
6.8.1	Image Calibration	201
6.8.2	Reflectance	203
6.8.3	Temperature	219
6.8.4	Backscatter	224
6.8.5	Height	225
6.9	Review Questions	232
Chapter 7	Digital Image Processing (II): Generation of Derived Variables.....	235
7.1	Generation of Biophysical Variables	235
7.1.1	Inductive and Deductive Models in Remote Sensing.....	235
7.1.2	Principal Component Analysis.....	238
7.1.3	Spectral Vegetation Indices.....	243
7.1.4	Other Spectral Indices.....	256
7.1.5	Extraction of Subpixel Information.....	257
7.2	Digital Image Classification	263
7.2.1	Introduction	263
7.2.2	Training Phase.....	265
7.2.3	Assignment Phase	278
7.2.4	Post-Assignment Generalization	299
7.2.5	Classification Outputs	301
7.3	Techniques for Multitemporal Analysis	303
7.3.1	Interest of the Temporal Dimension.....	303
7.3.2	Prerequisites for Multitemporal Analysis	305
7.3.3	Methods for Seasonal Analysis	308
7.3.4	Change Detection Techniques.....	312
7.4	Analysis of Spatial Properties	323
7.4.1	Remote Sensing and Landscape Ecology.....	323
7.4.2	Spatial Metrics for Interval-Scale Images.....	324
7.4.3	Spatial Metrics for Classified Images	328
7.4.4	Landscape Structural Dynamics	331
7.5	Review Questions	332
Chapter 8	Validation	335
8.1	Relevance of Validating Results	335
8.2	Approaches to Accuracy Assessment.....	336
8.3	Sampling Design	338
8.3.1	Error Characteristics	338
8.3.2	Sampling Unit.....	339
8.3.3	Sampling Strategies.....	339
8.3.4	Sample Size	340
8.4	Collecting Reference Information	342
8.5	Validating Interval-Scale Variables.....	343
8.6	Validating Classified Images	344
8.6.1	Confusion Matrix	344
8.6.2	Global Accuracy	346
8.6.3	User and Producer Accuracy.....	347
8.6.4	Error Bias	348

8.6.5	Validation of Binary Classes	349
8.6.6	Verification in Multitemporal Analysis	350
8.7	Sources of Error	351
8.7.1	Sensor Limitations	352
8.7.2	Method of Analysis	352
8.7.3	Landscape Complexity	353
8.7.4	Verification Process	354
8.8	Review Questions	355
Chapter 9	Earth Observation and Geographic Information Systems	357
9.1	Trends in GIS and EO Development	357
9.2	GIS as Input for Image Interpretation	358
9.3	EO as a Source of Geographic Information	360
9.3.1	Availability of Geographic Information	360
9.3.2	Generation of Input Variables	360
9.3.3	Updating the Information	361
9.4	Integration of Satellite Images and GIS	362
9.5	Review Questions	364
References		367
Appendix		399
	Acronyms Used in This Textbook	399
	Answers to Review Questions	401
Index		403