

# Contents

## Part I Introduction

<b>1</b>	<b>Environmental Monitoring and Management.</b>	<b>3</b>
1.1	Why Monitor the Environment?	3
1.2	Challenges and Practice of Environmental Monitoring	5
1.3	Geoinformatics and Environmental Monitoring.	7
1.4	Geoinformatics and Environmental Management	12
1.5	Objectives and Aims of the Book.	13
	References	14
<b>2</b>	<b>Geodata and Geoinformatics.</b>	<b>17</b>
2.1	Dimensions of Space, Time and Scale.	17
2.2	Geodata	21
2.3	Digital Earth Concept	22
2.4	Fundamentals of Geoinformatics.	24
2.5	Concluding Remarks	25
	References	26

## Part II Environmental Geodesy

<b>3</b>	<b>Fundamentals of Surveying and Geodesy.</b>	<b>31</b>
3.1	Environmental Geodesy.	31
3.2	Definitions: Plane and Geodetic Surveying	32
3.3	Types of Measurements.	33
3.3.1	Plane Surveying Measurements and Instruments.	34
3.3.2	Geodetic Measuring Techniques	36
3.3.3	Basic Measuring Principles and Error Management.	37

3.4	Measuring Techniques . . . . .	38
3.4.1	Linear Measurements . . . . .	38
3.4.2	Traversing . . . . .	39
3.4.3	Very Long Baseline Interferometry (VLBI) . . . . .	40
3.4.4	Laser Ranging Techniques . . . . .	41
3.5	Concluding Remarks . . . . .	44
	References . . . . .	45
<b>4</b>	<b>Modernization of GNSS . . . . .</b>	<b>47</b>
4.1	Introductory Remarks . . . . .	47
4.2	The GNSS Family . . . . .	49
4.3	Future Missions . . . . .	50
4.4	Environmental Benefits of the Expanded GNSS Family . . . . .	51
4.5	Concluding Remarks . . . . .	53
	References . . . . .	54
<b>5</b>	<b>The Global Positioning System . . . . .</b>	<b>55</b>
5.1	Introductory Remarks . . . . .	55
5.2	GPS Design and Operation . . . . .	56
5.2.1	Space Segment . . . . .	56
5.2.2	Control Segment . . . . .	57
5.2.3	User Segment . . . . .	58
5.3	GPS Observation Principles . . . . .	59
5.3.1	GPS Signals . . . . .	59
5.3.2	Measuring Principle . . . . .	61
5.4	Errors in GPS Measurements . . . . .	64
5.4.1	Ephemeris Errors . . . . .	65
5.4.2	Clock Errors . . . . .	65
5.4.3	Atmospheric Errors . . . . .	66
5.4.4	Multipath . . . . .	69
5.4.5	Satellite Constellation “Geometry” . . . . .	70
5.4.6	Other Sources of Errors . . . . .	70
5.5	Concluding Remarks . . . . .	70
	References . . . . .	71
<b>6</b>	<b>Environmental Surveying and Surveillance . . . . .</b>	<b>73</b>
6.1	Environmental Monitoring Parameters . . . . .	73
6.2	Design of GNSS Monitoring Survey . . . . .	74
6.3	Mission Planning and Reconnaissance . . . . .	75
6.4	GNSS Field Procedures . . . . .	80
6.4.1	Single Point Positioning . . . . .	81
6.4.2	Static Relative Positioning . . . . .	83
6.4.3	Real-Time GNSS (RTGNSS) . . . . .	85
6.4.4	Differential and Augmented GNSS . . . . .	86

6.4.5	Rapid Positioning Methods . . . . .	88
6.4.6	Real-Time Kinematic (RTK) . . . . .	91
6.5	Environmental Surveillance: CORS Monitoring . . . . .	93
6.6	Coordinate Reference System. . . . .	98
6.6.1	Datum . . . . .	100
6.6.2	Coordinate Systems and Transformations. . . . .	102
6.6.3	Map Projection . . . . .	104
6.7	Concluding Remarks . . . . .	104
	References . . . . .	106

### **Part III Remote Sensing and Photogrammetry**

<b>7</b>	<b>Fundamentals of Remote Sensing . . . . .</b>	<b>111</b>
7.1	Basic Concept . . . . .	111
7.2	Principles of Electromagnetic Radiation . . . . .	113
7.2.1	Electromagnetic Spectrum . . . . .	113
7.2.2	Interaction with the Atmosphere and Targets . . . . .	115
7.3	Passive Versus Active Remote Sensing . . . . .	117
7.4	Concluding Remarks . . . . .	117
	References . . . . .	118
<b>8</b>	<b>Optical Remote Sensing . . . . .</b>	<b>119</b>
8.1	Data Acquisition—Sensors and Systems . . . . .	119
8.2	Characteristics of Optical Remote Sensing Data . . . . .	121
8.3	High Spatial Resolution Imagery . . . . .	124
8.3.1	Development and Characteristics of HSRI . . . . .	124
8.3.2	Potential of HSRI . . . . .	125
8.4	Light Detection and Ranging . . . . .	127
8.5	Concluding Remarks . . . . .	129
	References . . . . .	130
<b>9</b>	<b>Microwave Remote Sensing . . . . .</b>	<b>133</b>
9.1	Principles of Microwave Remote Sensing . . . . .	133
9.1.1	Basic Concept . . . . .	133
9.1.2	Radar Backscattering. . . . .	135
9.1.3	Attenuation of Microwave Signals . . . . .	136
9.2	Structure of Microwave Systems. . . . .	137
9.2.1	Microwave Antenna . . . . .	137
9.2.2	Microwave Sensors . . . . .	138
9.3	Radar Imaging and Geometry of SAR. . . . .	139
9.4	Image Reconstruction of SAR Data. . . . .	140
9.5	Interferometric SAR . . . . .	141

9.6	SAR Polarimetry . . . . .	142
9.7	Concluding Remarks . . . . .	143
	References . . . . .	143
<b>10</b>	<b>Image Interpretation and Analysis . . . . .</b>	<b>145</b>
10.1	Introductory Remarks . . . . .	145
10.2	Visual Image Interpretation . . . . .	146
10.3	Digital Image Processing . . . . .	148
	10.3.1 Image Reconstruction/Correction . . . . .	149
	10.3.2 Image Transformation/Conversion. . . . .	151
	10.3.3 Image Classification . . . . .	152
10.4	Concluding Remarks . . . . .	154
	References . . . . .	154
<b>11</b>	<b>Fundamentals of Photogrammetry . . . . .</b>	<b>157</b>
11.1	Definition and Scope. . . . .	157
11.2	Geometry of Aerial Photography . . . . .	159
	11.2.1 Central Perspective Projection . . . . .	159
	11.2.2 Photographic Scale . . . . .	160
	11.2.3 Classification of Aerial Photographs . . . . .	160
11.3	Photogrammetric Procedures . . . . .	162
	11.3.1 Data Acquisition. . . . .	162
	11.3.2 Photogrammetric Restitution . . . . .	167
	11.3.3 Photogrammetric Output . . . . .	172
11.4	Concluding Remarks . . . . .	173
	References . . . . .	174
<b>12</b>	<b>Digital Photogrammetry . . . . .</b>	<b>175</b>
12.1	Introduction . . . . .	175
12.2	Sensor Models . . . . .	176
12.3	Digital Photogrammetric Workstations . . . . .	177
	12.3.1 Basic Hardware Requirements . . . . .	177
	12.3.2 Basic Software Requirements . . . . .	178
12.4	Image Matching . . . . .	179
12.5	Automated Photogrammetric Mapping. . . . .	181
	12.5.1 Interior Orientation . . . . .	181
	12.5.2 Relative Orientation . . . . .	182
	12.5.3 Aerial Triangulation . . . . .	183
12.6	Generating DEMs and Orthoimages . . . . .	184
	12.6.1 Automated Generation of DEMs. . . . .	184
	12.6.2 Automated Orthoimage Generation . . . . .	184
12.7	Automated Feature Extraction . . . . .	185
12.8	Concluding Remarks . . . . .	185
	References . . . . .	186

## Part IV Geographic Information Systems

<b>13</b>	<b>Fundamentals of GIS</b>	191
13.1	Basic Concept	191
13.2	Key Components	193
13.3	Basic Functions and Applications	195
13.4	Reasons for Success or Failure	197
13.5	Concluding Remarks	199
	References	200
<b>14</b>	<b>Data Models and Structure</b>	201
14.1	Introductory Remarks	201
14.2	Vector and Raster Models	202
14.3	GIS Topology	203
14.4	Concluding Remarks	204
	References	205
<b>15</b>	<b>Input of GIS Data</b>	207
15.1	Data Sources for GIS	207
15.2	Data Capture and Editing	208
15.2.1	Vector Data Input	210
15.2.2	Raster Data Input	211
15.3	Rasterization and Vectorization	212
15.4	Concluding Remarks	213
	References	213
<b>16</b>	<b>GIS Database</b>	215
16.1	Basic Concept	215
16.2	Design Considerations	216
16.3	Database Management System	216
16.4	Design Procedure	221
16.5	Concluding Remarks	222
	References	223
<b>17</b>	<b>Spatial Analysis</b>	225
17.1	Introductory Remarks	225
17.2	Methods and Techniques	226
17.2.1	Spatial Exploration	226
17.2.2	Measurements	226
17.2.3	Reclassification	227
17.2.4	Coverage Rebuilding	227
17.2.5	Overlay	228
17.2.6	Connectivity Analysis	229

17.3	Concluding Remarks . . . . .	235
	References . . . . .	235
<b>18</b>	<b>Web GIS and Mapping. . . . .</b>	<b>237</b>
18.1	The Web and its Influence. . . . .	237
18.2	Concept and Applications of Web GIS . . . . .	238
18.3	The Development of Web Mapping . . . . .	240
18.4	Web Services . . . . .	242
18.5	Mobile and cloud-based GIS . . . . .	245
18.6	Concluding Remarks . . . . .	248
	References . . . . .	249
 <b>Part V Applications to Environmental Monitoring and Management</b>		
<b>19</b>	<b>Maps in Environmental Monitoring . . . . .</b>	<b>253</b>
19.1	Introductory Remarks . . . . .	253
19.2	Types of Maps . . . . .	254
	19.2.1 Thematic Maps. . . . .	255
	19.2.2 Topographic Maps . . . . .	255
19.3	Maps and their Environmental Applications. . . . .	255
	19.3.1 GNSS-Derived Topographic Maps . . . . .	257
19.4	Concluding Remarks . . . . .	264
	References . . . . .	266
<b>20</b>	<b>Satellite Environmental Sensing . . . . .</b>	<b>269</b>
20.1	Introductory Remarks . . . . .	269
20.2	Sensing the Atmosphere Using GNSS . . . . .	270
	20.2.1 Background to GNSS Meteorology . . . . .	271
	20.2.2 GNSS-Derived Atmospheric Parameters . . . . .	273
	20.2.3 GNSS Remote Sensing Techniques . . . . .	280
20.3	Remote Sensing of Gravity Variations. . . . .	289
	20.3.1 Mass Variation and Gravity . . . . .	290
	20.3.2 High and Low Earth Orbiting Satellites. . . . .	291
	20.3.3 Gravity Recovery and Climate Experiment . . . . .	292
20.4	Satellite Altimetry. . . . .	296
	20.4.1 Environmental Sensing Using Satellite Altimetry . . . . .	296
	20.4.2 Satellite Altimetry Missions . . . . .	296
20.5	Sensing Using GNSS Reflected Signals. . . . .	298
20.6	Concluding Remarks . . . . .	300
	References . . . . .	300

<b>21</b>	<b>Weather, Climate and Global Warming</b>	305
21.1	Introductory Remarks	305
21.2	Impacts of Weather and the Changing Climate	307
21.2.1	Weather Related Impacts	307
21.2.2	Climate Related Impacts	308
21.3	Water Vapour	310
21.3.1	Significance	310
21.3.2	Numerical Weather Prediction	311
21.4	Carbon Sequestration and Estimation of Vegetation	
	Carbon Stocks	314
21.5	Environmental Monitoring Applications	316
21.5.1	Weather Monitoring Applications	316
21.5.2	Climate Change Monitoring Applications	318
21.5.3	Monitoring of Global Warming	321
21.5.4	Sensing Cryospheric Changes	326
21.5.5	Geoinformatics Support of International Environmental Agreements	328
21.6	Concluding Remarks	333
	References	334
<b>22</b>	<b>Water Resources</b>	341
22.1	Status and Impact of Diminishing Fresh Water Resources	341
22.2	Monitoring Variation in Fresh Water Resources	343
22.3	Gravity Field and Changes in Stored Water	346
22.3.1	Gravity Field Changes and the Hydrological Processes	346
22.3.2	Sensing Changes in Stored Water Using Temporal Gravity Field	346
22.4	Examples of Geoinformatics-Based Monitoring of Changes in Stored Water	349
22.4.1	The Nile Basin	349
22.4.2	Understanding the Decline of Lake Naivasha, Kenya	362
22.4.3	Water, a Critical Dwindling Australian Resource	368
22.5	Concluding Remarks	374
	References	375
<b>23</b>	<b>Land Management</b>	381
23.1	Introductory Remarks	381
23.2	Reconnaissance and Validation	381
23.3	Monitoring of Land Conditions	383
23.3.1	Soil Landscape Mapping	383
23.3.2	Provision of Point Data	383
23.3.3	Provision of Polygon Data	384

23.4	Monitoring of Land Degradation. . . . .	385
23.4.1	Soil Erosion Monitoring . . . . .	385
23.4.2	Salinity Monitoring: The Catchment Approach. . . . .	386
23.5	Role of Geoinformatics in Precision Farming. . . . .	391
23.5.1	Precise Farming . . . . .	391
23.5.2	Farm Topographic Maps . . . . .	392
23.6	Concluding Remarks . . . . .	395
	References . . . . .	395
<b>24</b>	<b>Marine and Coastal Resources . . . . .</b>	<b>397</b>
24.1	Marine Habitat . . . . .	397
24.1.1	Background . . . . .	397
24.1.2	Geoinformatics-Based Monitoring of Marine Habitats . . . . .	398
24.2	Shoreline Monitoring and Prediction . . . . .	400
24.2.1	Definition and Scope. . . . .	400
24.2.2	Monitoring. . . . .	403
24.2.3	Prediction . . . . .	404
24.3	Concluding Remarks . . . . .	410
	References . . . . .	412
<b>25</b>	<b>Protection and Conservation of Animals and Vegetation . . . . .</b>	<b>415</b>
25.1	Introductory Remarks . . . . .	415
25.2	GNSS Animal Telemetry. . . . .	416
25.2.1	Background and Benefits. . . . .	416
25.2.2	Observation and Data Management Techniques . . . . .	419
25.2.3	Applications. . . . .	420
25.3	Vegetation . . . . .	427
25.3.1	Forests. . . . .	427
25.3.2	Wetlands . . . . .	429
25.4	Concluding Remarks . . . . .	432
	References . . . . .	433
<b>26</b>	<b>Disaster Monitoring and Management. . . . .</b>	<b>437</b>
26.1	Introductory Remarks . . . . .	437
26.2	Definition and Scope. . . . .	438
26.3	Geosensor Networks in Disaster Monitoring. . . . .	440
26.4	Floods . . . . .	444
26.4.1	Flood Risk Zone Mapping . . . . .	445
26.4.2	Flood Monitoring and Forecasting . . . . .	445
26.4.3	Flood Response and Mitigation . . . . .	446
26.4.4	Geoinformatics Support of Flood Management. . . . .	447
26.4.5	Monitoring of ENSO and IOD . . . . .	450



26.5	Droughts . . . . .	452
26.5.1	Early Warning of Drought . . . . .	454
26.5.2	Drought Monitoring and Assessment. . . . .	454
26.5.3	Combating Drought. . . . .	455
26.6	Vector-Borne Diseases and Outbreak . . . . .	456
26.7	Earthquakes . . . . .	458
26.8	Changing Sea Levels. . . . .	465
26.8.1	Impacts of Rise in Sea Level . . . . .	466
26.8.2	Tide Gauge Monitoring . . . . .	467
26.8.3	GNSS Monitoring . . . . .	468
26.9	Tsunami Early Warning System . . . . .	470
26.10	Land Subsidence and Landslides. . . . .	473
26.11	Concluding Remarks . . . . .	476
	References . . . . .	477
<b>27</b>	<b>Environmental Pollution . . . . .</b>	<b>483</b>
27.1	Concept of Pollution and Role of Geoinformatics. . . . .	483
27.2	Water Pollution . . . . .	484
27.2.1	Point and Non-point Sources . . . . .	484
27.2.2	Eutrophication of Lakes. . . . .	486
27.3	Air Pollution . . . . .	488
27.3.1	Background . . . . .	488
27.3.2	Pollution from Transportation Sector. . . . .	489
27.4	Land Pollution . . . . .	491
27.4.1	Solid Waste Collection and Management. . . . .	491
27.4.2	Role of Geoinformatics in Solid Waste Management. . . . .	492
27.4.3	Solid Waste from Transportation Sector . . . . .	494
27.4.4	Acid Mine Deposit Sites . . . . .	497
27.5	Concluding Remarks . . . . .	498
	References . . . . .	498
<b>28</b>	<b>Environmental Impact Assessment . . . . .</b>	<b>501</b>
28.1	Role of Geoinformatics in EIA, SEA, and SA . . . . .	501
28.1.1	Impact Assessments and the Need for Monitoring. . . . .	501
28.1.2	Applications of Geoinformatics . . . . .	502
28.2	Impact Monitoring to Detect Change. . . . .	504
28.3	Project EIA . . . . .	505
28.3.1	Geoinformatics in Support of EIA Process. . . . .	505
28.3.2	Geoinformatics and Multi-Criteria Analysis (MCA) . . . . .	508
28.3.3	Example of Gngara Mound Groundwater Resources . . . . .	515

28.4	Strategic Environmental Assessment . . . . .	523
28.4.1	Geoinformatics and Cumulative Impacts Assessments . . . . .	524
28.4.2	Example of Marillana Creek (Yandi) Mine . . . . .	525
28.5	Sustainability Assessment . . . . .	527
28.6	Concluding Remarks . . . . .	528
	References . . . . .	528
<b>Index</b>	. . . . .	<b>533</b>

Environmental Geoinformatics

Monitoring and Management

Awange, J.; Kyalo Kiema, J.B.

2013, XX, 541 p. 214 illus., 202 illus. in color.,

Hardcover

ISBN: 978-3-642-34084-0