

Remote Sensing, GIS and GPS: Principles and Applications

Remote Sensing, GIS and GPS: Principles and Applications is a comprehensive textbook that introduces the foundations, techniques, and real-world applications of geospatial technologies. Designed for students, researchers, and professionals, the book explains how remote sensing, global positioning systems (GPS), and geographic information systems (GIS) are revolutionizing Earth observation, resource management, and decision-making across disciplines.

Beginning with the principles of remote sensing, the text explores the physics of electromagnetic radiation, sensor technologies, data acquisition, image processing, and classification techniques. It then introduces GPS fundamentals, including positioning, navigation, accuracy, and error correction. The coverage of GIS provides insights into spatial and non-spatial data, map projections, data models, thematic mapping, and advanced analysis methods.

The book emphasizes the integration of Remote Sensing, GPS, and GIS, demonstrating their combined potential in solving global and regional challenges from precision agriculture, forestry, and water resource management to urban planning, disaster monitoring, and environmental sustainability.

Key Features of the Book:

1. Clear explanation of principles, sensors, and data acquisition.
2. Step-by-step guide to image processing, classification, and accuracy assessment.
3. Practical insights into GPS applications for navigation, mapping, and fieldwork.
4. Detailed coverage of GIS concepts, spatial analysis, and geostatistics.
5. Richly illustrated with figures, diagrams, and examples.

An essential resource for students and professionals in engineering, environmental science, geography, agriculture, and urban studies, bridging theory with practice.



Scan this
QR Code
& visit us:

Published by:

The Institute for Innovations in
Engineering and Technology (IET)
www.theiiet.com
contact@theiiet.com

ISBN: 978-81-981763-7-0



978-81-981763-7-0

REMOTE SENSING, GIS AND GPS : PRINCIPLES AND APPLICATIONS

REMOTE SENSING GIS AND GPS: PRINCIPLES AND APPLICATIONS

1st Edition, 2025

Author(s):

Dr. K. Nooka Ratnam
Dr. V.Hema Sailaja
Mr. Mudigandla Rajesh
Mr. K. Anil
Mr. S. Ashok Kumar
Dr. K.Sundara Kumar



www.theiiet.com
contact@theiiet.com

**The Institute for Innovations in
Engineering and Technology (IET)**

ISBN: 978-81-981763-7-0

REMOTE SENSING GIS AND GPS: PRINCIPLES AND APPLICATIONS

**Edition-1
September-2025**

Author (s)

Dr. K. Nooka Ratnam

Associate Professor
Department of Civil Engineering
AdiKavi Nannaya University
Rajamahendravaram, Andhra Pradesh

Dr. V. Hema Sailaja

IOCL Chair Professor
Department of Environmental Sciences
Andhra University, Visakhapatnam

Mr. Mudigandla Rajesh

Research Scholar
Department of Geo-Engineering and
Resource Development Technology
Andhra University College of
Engineering, Visakhapatnam
Andhra Pradesh, India

Mr. Anil Kodimela

Assistant Professor
Department of Civil Engineering,
Bapatla Engineering College (BEC)
Bapatla, Andhra Pradesh

Mr. S. Ashok Kumar

Associate Professor and Deputy HOD
Civil Engineering Department
DVR & Dr. HS MIC College of
Technology (Autonomous) (MIC)
Kanchikacherla

Dr. Kusuma Sundara Kumar

Professor & HoD
Department of Civil Engineering
Ramachandra College of Engineering (A)
Eluru, Andhra Pradesh, India

Publisher:

The Institute for Innovations in
Engineering and Technology
1-102, GP Street, Gurazada,
Pamidimukkala Mandal, Krishna (Dt.),
AP-521256, Website: www.theijet.com
E-Mail: contact@theijet.com



ISBN: 978-81-981763-7-0



978-81-981763-7-0

Author(s)Details:



Dr. Nooka Ratnam Kinthada: Associate Professor at AdiKavi Nannaya University, Rajamahendravaram. With a Ph.D. in Water Resource Management and 24 years of experience, she specializes in geospatial information technology, water resources, and civil engineering. She has received prestigious awards including the CSIR-SRF and has served in key academic and administrative roles.



Dr. V. Hema Sailaja: IOCL Chair Professor, Department of Environmental Sciences, College of Science and Technology Andhra University, Visakhapatnam. She holds a Ph.D. in Environmental Science and Technology (JNTUH) and has over 15 years of experience in teaching and research. Her expertise lies in environmental monitoring, urban development, disaster risk assessment, and geospatial data analytics.



Mudigandla Rajesh: Research Scholar at Andhra University College of Engineering (A), Visakhapatnam. His work focuses on environmental and hydrological studies, including rainfall–runoff modeling, land use/land cover dynamics, landfill leachate treatment, and watershed management using geospatial tools. He has received prestigious award including NET JRF and Assistant Professorship.



Mr. Anil Kodimela: Assistant Professor in Civil Engineering at Bapatla Engineering College (BEC), Andhra Pradesh. He holds an M. Tech in Geo-Engineering from Andhra University and specializes in integrating geospatial technologies with civil engineering practices. He is active in teaching and applied research.



Mr. S. Ashok Kumar: Associate Professor and Deputy HOD of Civil Engineering at DVR & Dr. HS MIC College of Technology, Andhra Pradesh. With over 23 years of experience in teaching, research, and industry, his expertise spans water resources, wastewater treatment, solid waste management, IoT in civil engineering, and GIS applications. He has published more than 40 papers and holds two patents.



Dr. K. Sundara Kumar: Professor of Civil Engineering with over 25 years of experience in academics, research, and industry. He holds a B. Tech from JNTUK, M. Tech from IIT Madras, and Ph.D. in Environmental Remote Sensing from JNTUK. He has published 60+ research papers, holds one granted patent with six more published, and completed a DST-funded project with another from SERB under progress. A recipient of multiple “Best Teacher” awards, he is a life member of ISTE, IE(I), and EPS.



THE INSTITUTE FOR INNOVATIONS IN ENGINEERING AND TECHNOLOGY

Published by **The Institute for Innovations in Engineering and Technology**

1-102, GP Street, Gurazada, Pamidimukkala Mandal, Krishna (Dt.), Andhra Pradesh-521256.

Title of the Book: **Remote Sensing, GIS and GPS: Principles and Applications; Edition-1,**
September Copyright © 2025, with Authors.

Authors:

Dr. K. Nooka Ratnam, Associate Professor, Department of Civil Engineering, AdiKavi Nannaya University, Rajamahendravaram, Andhra Pradesh.

Dr. V. Hema Sailaja, IOCL Chair Professor, Department of Environmental Sciences, Andhra University, Visakhapatnam.

Mr. Mudigandla Rajesh, Research Scholar, Department of Geo-Engineering and Resource Development Technology, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh, India.

Mr. K. Anil, Assistant Professor, Department of Civil Engineering, Bapatla Engineering College (BEC), Bapatla, Andhra Pradesh.

Mr. S. Ashok Kumar, Associate Professor and Deputy HOD, Civil Engineering Department, DVR & Dr. HS MIC College of Technology (Autonomous) (MIC), Kanchikacherla.

Dr. Kusuma Sundara Kumar, Professor & HoD, Department of Civil Engineering, Ramachandra College of Engineering (A), Eluru, Andhra Pradesh, India

No part of this publication may be reproduced or distributed in any form or by any means, electronic, mechanical, photocopying, recording or otherwise or stored in a database or retrieval system without the prior written permission of the publisher or editors. The program listings (if any) may be entered, stored and executed in a computer system, but they may not be reproduced for publication.

This edition can be exported from India only by the publishers,

The Institute for Innovations in Engineering and Technology

Information contained in this work has been obtained by The Institute for Innovations in Engineering and Technology, from sources believed to be reliable. However, neither The Institute for Innovations in Engineering and Technology nor its authors guarantee the accuracy or completeness of any information published herein, and neither The Institute for Innovations in Engineering and Technology (India) nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that The Institute for Innovations in Engineering and Technology and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

Price: MRP Rs. 650/-



Typeset at the IIET, D: 1-102, GP Street, Vijayawada-521256. Printed and bounded in India at Flash Photostat, Vijayawada-520007, Visit us at: www.theiiet.com ; Phone: 91-9533111789;

Write to us at: contact@theiiet.com

PREFACE

The fields of Remote Sensing, Global Positioning System (GPS), and Geographic Information Systems (GIS) have witnessed remarkable growth in recent decades, establishing themselves as essential technologies for scientific research, environmental management, infrastructure development, and sustainable planning. Their ability to provide accurate, reliable, and timely spatial information has made them indispensable in addressing challenges such as climate change, urbanization, natural hazards, and resource management.

This textbook, *Remote Sensing, GPS and GIS: Principles and Applications*, has been prepared with the objective of presenting the fundamental principles and practical applications of geospatial technologies in a clear and systematic manner. The contents of the book are structured to cover the physics of remote sensing, sensor platforms, data acquisition methods, digital image processing, GPS fundamentals, and GIS concepts including spatial analysis, data integration, and modeling. The integration of these three domains is highlighted through case studies and applications in agriculture, forestry, hydrology, disaster management, and urban planning.

The book is intended to serve as a comprehensive resource for undergraduate and postgraduate students in engineering, environmental sciences, geography, and allied disciplines. It is also expected to benefit researchers, academicians, and practitioners seeking to apply geospatial technologies in their respective fields. To facilitate learning, the text is supported by illustrations and diagrams that bridge theoretical concepts with real-world practice.

The authors wish to express their deep sense of gratitude to all those who have contributed directly or indirectly to the successful completion of this book. We are indebted to our colleagues, mentors, and research collaborators for their valuable insights and encouragement throughout the preparation of this work.

We extend our heartfelt appreciation to our institutions for providing the academic environment and resources that supported this endeavor. Special thanks are due to Dr. Raffi Mohammed, Professor of Mechanical Engineering, Ramachandra College of Engineering, Eluru, for his constant encouragement, insightful suggestions, and continuous support in shaping the content and direction of this book.

We also acknowledge our families for their patience, understanding, and unwavering motivation, which made this work possible.

The Authors

CONTENTS

PAGES

SECTION 1: PRINCIPLES OF REMOTE SENSING

Chapter 1: The Physics of Remote Sensing	3
1.1 Sources of Energy	4
1.2 Active and Passive Radiation	7
1.3 Electromagnetic Radiation	7
1.4 Reflectance	9
1.5 Transmission	10
1.6 Absorption	10
1.7 Thermal Emissions	11
1.8 Interaction with Atmosphere	11
1.9 Atmospheric Windows	13
1.10 Spectral Reflectance of Earth's Surface Features	13
1.11 The Multi-Concept of Remote Sensing	15
Chapter 2: Platforms and Sensors	16
2.1 Various Types of Platforms	16
2.2 IRS Satellite Sensors	17
2.3 LANDSAT	18
2.4 SPOT	19
2.5 IKONOS	20
2.6 QUICK BIRD	22
2.7 GEOEYE	23
2.8 KOMPSAT	24
2.9 Worldview II & III	25
2.10 Microwave	26
2.11 ALOS (Advanced Land Observing Satellite)	26
2.12 Planet Data	27
2.13 SENTINEL	28
2.14 SMAP (Soil Moisture Active Passive)	29
2.15 MODIS (Moderate Resolution Imaging Spectroradiometer)	30
Chapter 3: Data Acquisition Systems	31
3.1 Optical	31
3.2 Thermal and Microwave	32
3.3 Digital Images in Remote sensing	32
3.4 Composition of a digital satellite image	33
3.5 Structure of a Digital Image	34
3.6 Types of Digital Images	35
3.7 Colour composites	36
3.8 Resolutions of a Satellite Image	37
3.9 Spatial Resolution	37
3.10 Spectral Resolution	38
3.11 Radiometric Resolution	40
3.12 Temporal Resolution	41

3.13	Signal-to-Noise Ratio (SNR)	41
3.14	LiDAR Data Acquisition and Processing	41
Chapter 4: Applications		43
4.1	Agriculture and Forestry Applications of Remote Sensing	43
4.2	Geology and Soil Applications of Remote Sensing	44
4.3	Water Resources and Hydrology Applications of Remote Sensing	44
4.4	Oceanography and Coastal Studies Applications of Remote Sensing	45
4.5	Environment and Ecology Applications of Remote Sensing	46
4.6	Urban and Regional Planning Applications of Remote Sensing	46
4.7	Disaster Management Applications of Remote Sensing	47
4.8	Defence and Security Applications of Remote Sensing	48
SECTION 2: SATELLITE IMAGE PROCESSING		
Chapter- 5 Data Products and Image Pre-processing		50
5.1	Data Products and Their Characteristics	51
5.2	Digital Image Formation	52
5.3	Digital Image Display Mechanism	52
5.4	Image Histograms	52
5.5	Look-Up Table Data	53
5.6	Pre-processing – Atmospheric	53
5.7	Pre-processing – Radiometric	54
5.8	Pre-processing – Geometric Corrections	54
5.9	Basic Principles of Visual Interpretation	55
5.10	Ground Truth	56
5.11	Orthorectification	57
Chapter- 6 Image Enhancements		58
6.1	Linear and Non-linear Contrast Enhancement Techniques	58
6.2	Density Slicing	60
6.3	Pseudo Colour Images	61
6.4	Spatial Enhancement Techniques (Convolution Filtering)	61
6.5	Image Algebra	62
6.6	Principal Component Analysis (PCA)	62
6.7	Data Fusion Techniques	63
Chapter- 7: Image Classification Techniques		64
7.1	Supervised Classification	64
7.2	Training Set	65
7.3	Statistical Computation	66
7.4	Understanding Feature Space & Scatter Plots	66
7.5	Signature Purity & Separability	66
7.6	Bayes' Decision Rule	67
7.7	Non-Parametric & Parametric Classification Techniques	67
7.8	Minimum Distance Rule	68
7.9	Parallelepiped Algorithm	68
7.10	Maximum Likelihood Method	68
7.11	Unsupervised and Hybrid Classification Techniques	69
7.12	Classification Analysis	70
7.13	Confusion Matrix	71

7.14	Error Analysis & Kappa Coefficient	72
7.15	Analysis of Multi-Temporal Series and Change Detection	73
Chapter- 8: Advanced Classification Techniques		74
8.1	Learning Methods	74
8.2	Object, Texture	75
8.3	Object-Based Fuzzy	75
8.4	ANN and SVM Classification Techniques	75
8.5	Sub-Pixel Mixture Analysis	78
8.6	Object-Oriented Image Classification	78
8.7	Image Processing	78
8.8	Segmentation	79
8.9	Methods of Segmentation	79
8.10	MDL (Minimum Description Length)	80
8.11	Watershed	80
8.12	Mean-Shift	81
8.13	Edge Detection	81
8.14	Spectral Indices	82
8.15	Vegetation Indices	82
8.16	Water-Related Indices	83
8.17	Indices Related to Cloud Properties	83
8.18	Google Earth Engine Platform for Satellite Data Processing	84
SECTION 3: THERMAL, MICROWAVE, AND HYPERSPPECTRAL REMOTE SENSING		
Chapter- 9: Thermal Remote Sensing		86
9.1	Thermal Sensors and Characteristics	86
9.2	Interpretation of Thermal Images	87
9.3	Emissivity Conservation	88
9.4	Thermal Inertia Considerations	89
9.5	Factors Affecting Analysis of Thermal Images	89
9.6	Estimation of Land Surface Temperature (LST)	90
9.7	Applications of Thermal Remote Sensing for Geological Studies	91
9.8	Evapotranspiration (ET) and Thermal Remote Sensing	92
Chapter- 10: Microwave Remote Sensing		93
10.1	Microwave Remote Sensing and Its Advantages	93
10.2	Active and Passive Systems	94
10.3	Platforms and Sensors	94
10.4	Polarimetry – A Complementary Technique	95
10.5	Hybrid Systems	96
10.6	Basic Principles of Radar	97
10.7	Radar Equation	97
10.8	Resolution and Range	98
10.9	Phase and Angular Measurements	99
10.10	Microwave Scattering and Its Measurement	99
10.11	Relationships Between Scene and Sensor Parameters	100
10.12	Imaging Systems	100

10.13	Imagery – Their Characteristics and Interpretation	101
10.14	Applications in Various Fields	101
10.15	Land Use / Land Cover	102
10.16	Soil / Rock	103
10.17	Hydrology and Flood Disaster Applications	103
Chapter- 11: Hyperspectral Remote Sensing		104
11.1	Types of Hyperspectral Remote Sensing Systems	104
11.2	Methods of Hyperspectral Remote Sensing	106
11.3	Applications of Hyperspectral Remote Sensing	107
11.4	Geology and Mineral Exploration Applications of Hyperspectral Remote Sensing	107
11.5	Environmental Monitoring Applications of Hyperspectral Remote Sensing	108
11.6	Urban and Land Use Planning Applications of Hyperspectral Remote Sensing	109
11.7	Disaster Management Applications of Hyperspectral Remote Sensing	109
11.8	Defence and Security Applications of Hyperspectral Remote Sensing	110
11.9	Public Health and Food Security Applications of Hyperspectral Remote Sensing	111
11.10	Principles of Hyperspectral Remote Sensing	112
11.11	Spectral Cube	113
11.12	Airborne and Spaceborne Hyperspectral Sensors	113
11.13	Data Correction – Atmospheric	114
11.14	Radiometric and Geometric Correction	114
11.15	Data Visualization	115
11.16	Animation	116
11.17	Multiple Colour Composites	116
11.18	Observing Signatures of Various Features and Comparing with Spectral Libraries	117
11.19	Comparison of PCA	117
11.20	MNF (Minimum Noise Fraction)	118
11.21	ICA Derived Products	118
11.22	Spectral Mapping Methods	119
11.23	Spectral Angle Mapper (SAM)	119
11.24	Spectral Correlation Mapper (SCM)	120
11.25	Spectral Feature Fitting (SFF)	120
11.26	Linear Spectral Unmixing (LSU)	121
Chapter- 12: SAR Interferometry for DEM Generation		122
12.1	Differential SAR Interferometry for Surface Displacement Studies	123
12.2	Applications in Land Subsidence	123
12.3	Landslide Movements	123
12.4	Glacier Movements	124
12.5	Polarimetry in Radar Remote Sensing	124
12.6	Basic Equations, Propagation of Waves, and Wave Polarization (HH, VV, HV, VH)	125

SECTION 4: GEOGRAPHICAL INFORMATION SYSTEMS

Chapter- 13: Introduction	126
13.1 Functions of GIS	127
13.2 Map	131
13.3 Mapping Concepts	132
13.4 Analysis with Paper-Based Maps	133
13.5 Limitations	134
13.6 Computer-Automated Cartography	134
13.7 History and Developments	135
13.8 GIS – Definition	135
13.9 Advantages of Digital Maps	136
13.10 Projections and Coordinate Systems	137
Chapter- 14: Fundamentals of GIS	138
14.1 Information Systems	138
14.2 Modelling Real-World Features Data	139
14.3 Data Models	140
14.4 Spatial and Non-Spatial Data	140
14.5 Components	141
14.6 Data Collection and Input	142
14.7 Data Conversion and Metadata	142
Chapter- 15: Database Management	144
15.1 Database Structures	144
15.2 Files	145
15.3 Standard Data Formats	145
15.4 Compression Techniques	146
15.5 Hardware and Software	147
Chapter- 16: Topology	149
16.1 Types of Errors	150
16.2 Editing and Error Rectification	150
16.3 Types of Topology	151
16.4 Modelling Topological Relationships	152
16.5 Tolerances	153
Chapter- 17: Spatial Analysis	154
17.1 Proximity Analysis	154
17.2 Overlay Analysis	155
17.3 Buffer Analysis	156
17.4 Network Analysis	157
17.5 Route Alignment	157
17.6 Canal Alignment	158
17.7 Digital Elevation Models	158
17.8 Map Composition	159
17.9 Preparation of Qualitative and Quantitative Maps	159
17.10 Levels of Maps	160
17.11 Map Elements and Map Scales	160
17.12 3D Analyst	161
Chapter 18: GIS Project Planning and Implementation	163

18.1 Understanding the Requirements	164
18.2 Phases of Planning	164
18.3 Specifications	165
18.4 Procedure for Analysis Projects	166
18.5 Design Projects	167

SECTION 5: GEOSPATIAL DATA PROCESSING AND MODELLING

Chapter- 19: Interpolation	168
19.1 Local and Global Methods of Interpolation	169
19.2 Kriging Methods	170
19.3 Geostatistical Methods	171
Chapter- 20 Digital Elevation Models	173
20.1 Slope and Aspect	174
20.2 Site Selection Studies	175
20.3 Viewshed and Watershed Analysis	175
20.4 Working with Open Source DEMs	177
Chapter-21: GIS Models	179
21.1 Modelling Process	179
21.2 Classification	180
21.3 Model Builder Tools	181
Chapter-22: Programming Tools	184
22.1 Python	184
22.2 R Programming and MATLAB Concepts for Geo-processing Tools	184
22.3 Free and Open-Source GIS Components	185
22.4 Data Sources	187
22.5 Free and Open-Source GIS Software and Applications	188

SECTION 6: GLOBAL POSITIONING SYSTEM (GPS)

Chapter-23: Types of GPS	189
23.1 Aided GPS (A-GPS)	190
23.2 Assisted Navigation GPS (Standalone GPS)	191
23.3 Differential GPS (DGPS)	192
23.4 Real-Time Kinematic GPS (RTK-GPS)	192
23.5 Simultaneous Multi-GNSS GPS	193
23.6 Military GPS (P(Y) Code GPS)	194
Chapter-24: Segments of GPS	195
24.1 Space Segment	195
24.2 Control Segment	197
24.3 User Segment	197
Chapter-25: Working Principles of GPS	199
25.1 Trilateration in GPS	199
25.2 Working Principle of DGPS	200
25.3 Difference between GPS and DGPS	200
Chapter-26: Applications of GPS (Global Positioning System)	203
26.1 Navigation and Routing	204
26.2 Surveying and Mapping	204
26.3 Agriculture (Precision Farming)	205

26.4 Disaster Management	205
26.5 Military and Défense	205
26.6 Aviation and Marine Applications	206
26.7 Transportation and Logistics	206
26.8 Personal and Recreational Uses	207
26.9 Telecommunication and Networking	207
26.10 Scientific Research	207
26.11 Urban Planning and Infrastructure	208
26.12 Law Enforcement and Public Safety	208
26.13 GPS Devices	208