HEMVATI NANDAN BAHUGUNA GARHWAL UNIVERSITY
(A Central University)

NEP-2020 BASED

Revised Curriculum and Syllabus

of

M.Sc. Remote Sensing & GIS Applications

(w.e.f. 2025-26)

DEPARTMENT OF REMOTE SENSING & GIS APPLICATIONS

SCHOOL OF EARTH SCIENCES

VISION AND MISSION

Vision and Mission of the University

VISION

To achieve excellence by empowering all stakeholders through promotion of innovations in the field of higher education by imparting training and education, and encouraging research for the development of the country with specific attention to the mountain region.

MISSION

- To stimulate the academic environment for promotion of holistic learning and research and contribute to the nation's growth.
- To inculcate values and impart skills for shaping able and responsible individuals committed towards the intellectual, academic and cultural development of society.

Programme Structure in Accordance with National Education Policy - 2020

With Multiple Entry and Multiple Exit Options

M.Sc. in Geoinformatics First Year (NHEQF Level 6)

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester I							
1	Discipline Specific Core	DSC T101	Aerial Photography & Digital Photogrammetry	5	0	0	5
2		DSC T102	Fundamentals of Remote Sensing	5	0	0	5
3		DSC T103	Geographical Information System (GIS)	5	0	0	5
4		DSC P104	Lab Course- I	0	3	0	3
5	Discipline Specific Elective (Any **ONE** within the list)	DSE TP105	Thermal and Microwave Remote Sensing	4	2	0	6
		DSE TP106	Basic Programming Concepts				
		DSE TP107	Environmental Monitoring & Assessment				
	Total Credits (A)			19	5	0	24
Semester II							
6	Discipline Specific Core	DSC T201	Digital Image Processing (DIP)	5	0	0	5
7		DSC T202	Digital Cartography & GPS	5	0	0	5
8		DSC T203	Statistics for Geospatial Studies	5	0	0	5
9		DSC P204	Lab Course- 2	0	3	0	3
10	Discipline Specific Elective (Any **ONE** within the list)	DSE TP205	Internship/Industrial Training** with MOOC*	4	2	0	6
		DSE TP206	Programming for Geospatial Analysis				
		DSE TP207	Research Project-I#			6#	
	Total Credits (B)			19	5		**24**

Structure in Accordance with National Education Policy - 2020

With Multiple Entry and Multiple Exit Options

M.Sc. in Geoinformatics Second Year (NHEQF Level 6.5)

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester III							
11	Discipline Specific Core	DSC T301	Sustainability & Geospatial Technology	5	0	0	5
12		DSC T302	Geospatial Modelling & Decision Support System	5	0	0	5
13		DSC T303	Research Methodology & Academic Writing	5	0	0	5
14		DSC P304	Lab Course- 3	0	3	0	3
15	Discipline Specific Elective (Any **ONE** within the list)	DSE TP305	Application of Geoinformatics in Geoscience	4	2	0	6
		DSE TP306	Application of Geoinformatics in Hydrology & Watershed Management				
		DSE TP307	Application of Geoinformatics in Urban Development & Planning				
		DSE TP308	Application of Geoinformatics in Natural Resource Management				
Total Credits (C)				19	5	0	**24**
Semester IV							
16	Discipline Specific Core	DSC T401	Application of Geoinformatics in Climate Change Studies	5	0	0	5
17		DSC T402	Research Project-II/Dissertation##	0	0	10	10
18		DSC P403	Lab Course- 4	0	3	0	3
19	Discipline Specific Elective (Any **ONE** within the list)	DSE TP404	Application of Geoinformatics in Disaster Management	4	2	0	6
		DSE TP405	Advance Geospatial Data Collection Techniques				
Total Credits (D)				9	5	10	**24**
Total Credits (A+B+C+D)							**96**

Semester I Syllabus

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester I							
1	Discipline Specific Core	DSC T101	Aerial Photography & Digital Photogrammetry	5	0	0	5
2		DSC T102	Fundamentals of Remote Sensing	5	0	0	5
3		DSC T103	Geographical Information System (GIS)	5	0	0	5
4		DSC P104	Lab Course- I	0	3	0	3
5	Discipline Specific Elective (Any **ONE** within the list)	DSE TP105	Thermal and Microwave Remote Sensing	4	2	0	6
		DSE TP106	Basic Programming Concepts				
		DSE TP107	Environmental Monitoring & Assessment				
	Total Credits (A)			19	5	0	24

DSC T101: Aerial Photography & Digital Photogrammetry	**Credits-5**
Objective: To provide students with a comprehensive understanding of aerial remote sensing and photogrammetry, including their historical development, principles, techniques, and applications	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will study aerial photography, including types, planning, and execution. ✓ Will investigate various photogrammetric principles and photographic scales. ✓ Students would be able to understand the concepts of relief displacement, orthorectification, stereoscopic viewing and stereoscopic parallax. ✓ Develop skills of relief and tilt displacements, vertical exaggeration, and slope factors affecting DEM generation from stereo pairs.	
Unit – I	• Evolution and Historical development of Aerial Remote Sensing • Basic Concept and Principles of Aerial Remote Sensing, Acquisition of Aerial Photographs, Flight planning • Aerial Photography: Types and Characteristics of Aerial Photos, Scale, Ground Coverage, Season of photography
Unit – II	• Aerial Cameras, Films- Types, Characteristics, and Applications • Geometry of Aerial photograph • Scale of Aerial photograph and its determination
Unit – III	• Making measurements from aerial photographs, measurement of height from aerial photograph • Principles and fundamentals of Aerial photo interpretation Elements of photo interpretation • Fundamentals of Photogrammetry: Definitions, Terms
Unit – IV	• Introduction to Digital Photogrammetry- Orthophotos- Elements, Digital Orthophotos • Concepts of Stereo-photogrammetry, Stereovision, stereoscopes, stereoscopic exaggeration, Concept of kappa, Omega, and phi • Stereoscopic parallax and parallax equations
Unit – V	• Relief Displacement of vertical features and its determination, Tilt Displacements • Vertical exaggeration and slopes – factor affecting vertical exaggeration and its determination • Application of Digital stereopair- Topographic mapping, Feature extraction • Advantage, Disadvantage, Limitation and Applications of Aerial photography and Photogrammetry

Books Recommended

Gupta, R.P.., 1990: Remote Sensing Geology. Springer Verlag.
Jensen, J.R. 2000: Remote Sensing of the Environment: An Earth Resource Perspective. Prentice Hall.
Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John Wiley.
Miller, V.C., 1961: Photogeology. McGraw Hill.
Moffitt, F.H. and Mikhail, E.M., 1980. Photogrammetry, Harper and Row,
Paine, D.P.,1981: Aerial Photography and Image Interpretation for Resource Management. John Wiley.
Pandey, S.N.,1987: Principles and Applications of Photogeology. Wiley Eastern.
Rampal K.K. 1999: Hand book of Aerial Photography and Interpretation. Concept Publication

DSC T102: Fundamentals of Remote Sensing	**Credits-5**
Objective: Disseminate basic concepts and applications of Electromagnetic Spectrum in Remote Sensing, and learn about remote sensing platforms, sensors and their characteristics as well as visual image interpretation.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will learn the basic concepts and physical principles of remote sensing. ✓ Will understand the basic difference between various kinds of satellites, platforms and sensors. ✓ Apply the principles of thermal, microwave, and hyperspectral remote sensing to real-world scenarios. ✓ Employ advanced techniques of image interpretation, such as multidate, multispectral, and multidisciplinary analysis, supported by the utilization of appropriate instruments for visual interpretation and ground truth collection.	
Unit – I	• Introduction to Remote Sensing – Concept, History & development, Definition, and Principles • EMR – Energy sources and Radiation principles, Energy equation, and Heat budget • EMR & EMS –interaction with Atmosphere and Earth surface • Spectral response pattern – Vegetation, Rocks, Soil, Water bodies – Spectral properties and characteristics
Unit – II	• Platforms – Types and Characteristics, • Orbit, Satellites and their characteristics – Geo-stationery and Sun-synchronous, • Earth resources satellites such as IRS, LANDSAT, Sentinel, SPOT, PlanetScope, IKONOS, MODIS, and other popular series. • Weather/Meteorological satellites Series– INSAT, NOAA, GOES, NIMBUS Applications, Marine observation satellites OCEANSAT
Unit – III	• Scanners & Sensors – Types and their Characteristics • Optical mechanical scanners – MSS, TM, LISS, WiFS, PAN • Concept of resolution – Spatial, Spectral, Temporal, Radiometric • Basic concept and principles of Thermal, Microwave and Hyperspectral Remote Sensing
Unit – IV	• Basic principles, types, and elements of image interpretation • Techniques of visual interpretation and interpretation keys • Multidate, multispectral and multidisciplinary concepts
Unit – V	• Importance of Ground Truthing in Remote Sensing, Ground Truth Radiometer (GTR), • Radiometric Calibration, Digital and Analog Methods, Spectral Response Patterns: Soil, Vegetation, Rocks and Water, • RS Applications in Agriculture, Forestry, Land cover/Land use, RS Applications in Water resources and Earth Science.

Books Recommended

Campbell, J.B.2002: Introduction to Remote Sensing. Taylor Publications
Drury, S.A., 1987: Image Interpretation in Geology. Allen and Unwin Gupta,
R.P.., 1990: Remote Sensing Geology. Springer Verlag
Jensen, J.R. 2000: Remote Sensing of the Environment: An Earth Resource Perspective. Prentice Hall.
Joseph George, 2003: Fundamentals of Remote Sensing. Universities Press
Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John Wiley

DSC T103: Geographical Information System (GIS)	**Credits-5**
Objective: To understand and learn fundamental concepts, becoming familiar with the spatial data, Organisation. Students will gain an understanding on various GIS based approaches and techniques to visualise and solve real time natural, environmental and societal problems	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will understand GIS fundamentals, differentiate between GIS and cartography, distinguish normal versus spatial data, and comprehend the integration of spatial and non-spatial data. ✓ Will understand the mapping on GIS platforms and Database Management Systems. ✓ Apply spatial data integration and modelling techniques in diverse fields such as environmental management, urban planning, and public health	
Unit – I	• Basic principles and concept of Geographical Information System (GIS) • Nature, scope and Historical development of GIS • Components of GIS: Hardware, software, data and users.
Unit – II	• Basics of spatial and non-spatial data, Linking of spatial and non-spatial data • Database management systems (DBMS) in GIS • Data formats and standards: shapefiles, GeoTIFF, KML, GeoJSON.
Unit – III	• Data models in GIS: vector and raster models, Digital Elevation Models: TIN – DEM • Spatial data processing techniques: overlay, buffering, proximity analysis, spatial interpolation. • Introduction to computer Cartography and Classification of maps
Unit – IV	• Coordinate systems and map projections • Digitization: types and errors • GIS software platforms (QGIS, ArcGIS, ArcGIS Pro, Grass, Google Earth, ERDAS Imagine, Geometica etc), Generalization, Symbolization, Map design and Map layout
Unit – V	• Spatial data integration and modeling • Web GIS: Components and Spatial data formats for the web: GeoJSON, KML, TopoJSON, Shapefile conversion Integration with web-friendly formats (CSV, XML) • Applications of GIS in environmental management, urban planning, agriculture, public health, hydrology and natural resource management • Role of GIS in decision-making and problem-solving

Books Recommended

Anji Reddy, M. 2004: Geoinformatics for Environmental Management. B.S. Publications
Chang.T.K. 2002: Geographic Information Systems. Tata McGrawHill
Heywood.I, Cornelius S, CrverSteve. 2003: An Introduction to Geographical Information Systems. Pearson Education
Ram Mohan Rao. 2002: Geographical Information Systems. Rawat Publication.
Skidmore A.2002: Environmental Modeling with GIS and Remote Sensing. Taylor and Francis
Tar Bernhardsen. Geographical Information Systems. John Wiley.
Wise S.2002: GIS Basics. Taylor Publications
ESRI Map book: GIS the Language of Geography by ESRI-USA ESRI-2004

DSC P104: Lab Course- I	**Credits-3**
Objective: To equip students with hands-on expertise in photogrammetric analysis, satellite image interpretation, and geospatial data management using remote sensing and GIS technologies.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will demonstrate proficiency in stereo aerial photograph interpretation, including determination of photo scale and heights using parallax bar. ✓ Will develop skills in visual interpretation of satellite images and aerial photographs, as well as the study of topographic sheets. ✓ Acquire working knowledge of Remote Sensing & GIS software and gain expertise in visual interpretation of satellite images and the identification of features ✓ Perform comprehensive GIS operations, including data digitization, topology editing, spatial querying, overlay and buffer analysis, network modelling, and output map generation using commercial and open-source platforms.	
Unit – I	Stereo test and orientation of aerial photograph; Determination of photo scale; Use of parallax bar, determination of heights; Identification of features on single vertical aerial photographs Visual interpretation of satellite images and aerial photographs; Study of SOI topographic sheets Calculation of map numbering system; Base map preparation
Unit – II	Working knowledge of Remote Sensing & GIS software's File export import/ translation, Conversion of file formats False colour composite and visual identification Image registration / Geo coding, Projection, Creating Region of Interest File sub setting /clipping Mosaic Air photo and Images Feature identification and signature curve generation Image Statistics, Histogram
Unit – III	Visual interpretation of satellite images Interpretation of High, Medium, and Course resolution satellite images at local, regional, national, and global scales. Interpretation of cultural details from high-resolution images provided by IRS and other available satellite series
Unit – IV	Overview of GIS software (Commercial & Open Source); Satellite Data Download from USGS and BHUVAN (ISRO); Data Import and Conversion of Analog to Digital format; Georeferencing (Image to Map & Map to Map Transformation). Data Creation & Topology: Input, Creation of Spatial and Non-Spatial data; Integration of Non-Spatial Data; Topology and Non-Topology Editing Editing the layers (use of snap tolerance, remove over lap, gaps etc.) Create new table, add field to table, add record to table, calculate area and perimeter Data Analysis: Spatial and Non-Spatial Data Query; Overlay; Buffering Network analysis –finding the shortest route between two places, finding the optimum path etc. Output map generation
	Practical Notebook and Viva Voce

DSE TP105: Thermal and Microwave Remote Sensing	**Credits-6**
Objective: The objective of this course is to provide students with a comprehensive understanding of thermal and microwave remote sensing principles, technologies, and applications.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will comprehend the concept, theory, and operation of thermal remote sensing. ✓ Will understand the concept, principle and operation of microwave remote sensing. ✓ Will understand the application of RADAR, LIDAR data in geospatial studies	
Unit – I	• Basic Principles of Thermal remote sensing and Multispectral thermal imagery • Thermal Radiation and Energy Balance: Blackbody radiation, Stefan-Boltzmann law, Wien's displacement law and Energy balance equation • Thermal Sensors and Detectors: Types of thermal sensors, Characteristics and specifications • Platforms for Thermal Remote Sensing: Aerial platforms (aircraft, drones), Satellite platforms (e.g., MODIS, Landsat Thermal Infrared Sensor)
Unit – II	• Principles of thermal emission and absorption • Interaction of thermal radiation with different surface types (e.g., land, water, built-up land and vegetation) • Thermal scanners, interpreting thermal scanner imagery, Geometric characteristics of thermal imagery • Temperature mapping with thermal scanner data, applications of thermal remote sensing
Unit – III	• Principles and basic concepts of microwave remote sensing • Historical development of microwave remote sensing • Interaction of microwaves with Earth's surface and atmosphere • Microwave sensors and their applications, Platforms for Microwave Remote Sensing
Unit – IV	• SLAR and SAR, Geometric characteristics, Spatial resolution and Interpretation of data. • Transmission characteristics of radar signals and other radar image characteristics • RADAR: Working Principle of RADAR, Measurement and Discrimination, System Parameters: Wavelength, Polarization, Resolution, Look Angle, Target Parameters: Back Scattering, Point Target, Volume Scattering, Penetration, Reflection, Physics of RADAR Remote Sensing, Factors affecting Microwave Measurement • LIDAR – components of LIDAR system, type and platforms of LIDAR
	Practical
Unit – V	• Calculation of at satellite radiance and true surface radiance from thermal imagery • Computation of brightness temperature from thermal imagery • Calculation of emissivity fractional vegetation cover; Calculation of land surface temperature • Radar Image Interpretation; Processing of radar image: speckle removal through different filters; Processing of SAR data and applications

Books Recommended

Drury, S.A., 1987: Image Interpretation in Geology. Allen and Unwin
Gupta, R.P.., 1990: Remote Sensing Geology. Springer Verlag.
Jensen, J.R. 2000: Remote Sensing of the Environment: An Earth resource Perspective. Prentice Hall
Joseph George, 2003: Fundamentals of Remote Sensing. Universities Press
Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John .

DSE TP106: Basic Programming Concepts	**Credits-6**
Objective: To introduce the basic knowledge of computers, Programming concepts, database models and design**s**	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will exhibit expertise in computer hardware, software, and programming fundamentals ✓ Will apply basic python/C programme for data processing, analysis, and application in various geospatial intelligence tasks ✓ Understand the principles of database management systems and will be able to manage large sets of data ✓ Develop ability to craft in conceptual data modelling for optimal geodatabase creation in GIS contexts	
Unit – I	• Introduction to Computers - Essential PC hardware, peripherals and software-types, Data, storage and manipulation, Number system, Introduction to Networks, Major types of networks • Introduction to C: keywords, data types, variables, constants, expressions • Operators: Mathematical, Unary, Binary, Relational and Logical operators, Operator precedence and associativity • Conditional Control statements: if statement, if else statement, nested if statement, if else if ladder and Ternary operator, Switch case statement • Looping control Statements: While loop, Do while Loop, For loop, Nested loops
Unit – II	• Introduction to Python, Operators, Expressions and Python Statements, • Sequence of Data Types, The Integer, Floating-Point, and String Data Types, String Concatenation and Replication, Storing Values in Variables • You're First Program, Dissecting Your Program • Flow control, Functions, File Processing
Unit – III	• Introduction to databases, characteristics of the database approach, database users and designers, role of a DBA, RDBMS: Concepts and specific features • Application, Advantages, Disadvantages of DBMS, Advantage of DBMS in context of GIS • Data models, schemas, instances, DBMS architecture (Three-Schema Architecture) • Fundamentals of Geodatabase
Unit – IV	• Conceptual Data Modelling: Phases of database design, entity type, entity set, attributes, keys, value sets • Relationships: relationship types, relationship sets, relationship instances, relationship degree, • Recursive relationships, constraints on relationship types, attributes of relationship types, weak entity types • ER Diagram-entity-keys and design issues, Application
	Practical
	Programming with C and Python Installation in different IDE; Simple C/Python programs demonstrating use of keywords, variables, constants, and expressions. Implement mathematical, relational, and logical operations using operators. Apply conditional control structures and develop nested decision-making algorithms. Use iterative constructs (for, while, do-while) with dry-run tracing and output verification. Programming with Python: Construct basic Python programs using variables, data types, and expressions. Practice string operations including concatenation, slicing, and replication. Perform flow control using conditional and loop structures. Introduce modularity with functions and process text-based data using file operations. Installation, handling library in Python.

Books Recommended

Byron S. Gottfried, Theory and Problems of Programming with C, Tata McGraw Hill Publication

Computer Networks by Andrew S. Tanenbaum

Gottrfriield, B.S.: Programming with C, Tata McGraw Hill Publishing Co. Ltd. Programming in C by Jamwal Shubhnandan, Pearson Publications

E. Balaguruswamy: Programming in ANSIC, Tata McGraw Hill Publishing Co. Ltd.

N.F.Korth and A.Silberschatz, S.Sudarshan, Database Management System Concepts, 4/e, McGraw Hill Inc., New Delhi, 2002.

P. K. Sinha and Priti Sinha, Computer Fundamentals, BPB Publications

R.Elmasri, S.B Navathe, Fundamentals of Database Systems, Addision, Wesley

DSE TP107: Environmental Monitoring & Assessment	**Credits-6**
Objective: To equip students with essential knowledge and analytical tools to evaluate environmental quality, impacts of anthropogenic activities, and methodologies for environmental monitoring and assessment.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will understand environmental quality and its deterioration due to human impact ✓ Comprehend the significance and steps of Environmental Impact Assessment (EIA). ✓ Explore different environmental issues and understand the applications of Geoinformatics in environmental studies.	
Unit – I	**Environmental Monitoring:** What is environmental quality? Quality of environment for life on earth and man; Advantages of Environmental Monitoring, Deterioration of environmental quality with reference to anthropogenic impact; Methods of assessment of environmental quality; Short term studies/ surveys; Rapid assessment; Continuous short and long term monitoring
Unit – II	**Environment & Ecology:** Ecosystems: Introduction, Types, Structure and Functions; Energy resources; Renewable and Non-renewable Energy Sources; Use of Alternative Energy; Impact of Energy Use on Environment; Environmental Management: Concept and Principles.
Unit – III	**Environmental Impact Assessment (EIA):** Need of EIA; Scope and objectives; Types of environmental impacts; Steps involved in conducting the EIA Studies; Environmental Impact Assessment techniques- Ad-hoc method, checklist method, overlay mapping method, network method, simulation and modeling technique, matrix method, and system diagram technique; Merits and Demerits of EIA studies.
Unit – IV	**Thermal pollution, Oil Pollution and Electronic waste (E-waste) :** Definition and sources, Chemical and biological effects of thermal pollution, Effect of thermal pollution; Thermal pollution from power plants and their control. Oil pollution and marine ecology, sources of oil pollution, factors effecting fate of oil after spillage movement, remote sensing in water quality monitoring. Sources and types and constituents of E-wastes and its environmental consequences.
	Practical
Unit – V	**Geoinformatics and its applications in Environmental Monitoring:** Application of Geoinformatics in environmental studies: land use mapping, forest survey, habitat analysis, water management, drought monitoring and flood studies, wetland survey; rainfall estimation, pollution studies, soil conservation, watershed management and vegetation mapping.

Books recommended:

1. Environmental Impact Assessment: Practical Solutions to Recurrent Problems, D. P. Lawrence
2. Environmental Impact Analysis Handbook: J. G. Rau and D. C. Wooten;
3. Environmental Impact Assessment, L. W. Canter,
4. Methods of Environmental Impact Assessment, P. Morris and R. Therivel

Semester II Syllabus

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester II							
6	Discipline Specific Core	DSC T201	Digital Image Processing (DIP)	5	0	0	5
7		DSC T202	Digital Cartography & GPS	5	0	0	5
8		DSC T203	Statistics for Geospatial Studies	5	0	0	5
9		DSC P204	Lab Course- 2	0	3	0	3
10	Discipline Specific Elective (Any **ONE** within the list)	DSE TP205	Internship/Industrial Training** with MOOC*	4	2	0	6
		DSE TP206	Programming for Geospatial Analysis				
		DSE TP207	Research Project-I#			6#	
	Total Credits (B)			19	5		**24**

DSC T201: Digital Image Processing (DIP)	**Credits-5**
Objective: To introduce fundamental concepts and techniques in digital image processing, covering topics such as image enhancement, image restoration, image segmentation and image compression.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will know the fundamental concepts of digital image processing ✓ Will gain proficiency in image rectification, restoration, and interpolation techniques ✓ Will acquire skills in image enhancement and spectral transformations. ✓ Develop skills in image classification and explore advanced techniques for improving classification accuracy.	
Unit – I	• Introduction to digital image processing: definition, scope and applications in various fields • Concept of digital image: types of digital images, data formats, data storage and digital image representation • Digitization of photographic image, converting digital image to visual form
Unit – II	• Digital Image Compression: Lossy and lossless compression techniques, transform coding (Discrete Cosine Transform, Wavelet Transform), JPEG, JPEG2000 and other compression standards • Basic concept of digital image data processing • Concepts of image rectification, image restoration and interpolation
Unit – III	• Principles and Techniques of geometric correction: Polynomial transformation, Orthorectification and Resampling methods. • Radiometric correction: Importance and techniques of radiometric calibration, Atmospheric correction, Sensor calibration, Reflectance transformation and FCC, Noise removal
Unit – IV	• Introduction to Image Enhancement: Definition, Importance and applications • Basics concept of Contrast Enhancement and Techniques for enhancing image contrast: linear and non-linear, Histogram equalization • Spatial feature manipulation: Spatial filtering, Convolution, Edge enhancement. Filtering techniques and Image smoothing, Multi image manipulation • Band rationing, Principal component analysis, Intensity-hue-Saturation transformation.

Unit – V	• Basics concept of Image Classification, multispectral satellite imagery bands, types of image classification and their importance; Spectral Indices: NDVI, NDWI, NDBI, SAVI, NDWI, LAI, NBR and other popular indices. • Supervised classification: Training data preparation, Classifiers-Advantage and Disadvantage; Machine learning models in classification and evaluation of the performance of classification models. • Unsupervised Classification: Methods, Clustering algorithms: K-means, ISODATA and Hierarchical Clustering, Advantage, Disadvantage and Limitations • Accuracy Assessment Methods: Error Matrix (Confusion Matrix), Overall Accuracy, Producer's Accuracy, User's Accuracy and Kappa Coefficient, F1 Score; Validation Techniques-ROC, AUC; Sources of Error in Image Classification, Accuracy improvement techniques: Post-classification Smoothing, Object-Based Classification Techniques, Ensemble Classification Methods

Books Recommended

Ghosh Sanjoy Kumar, 2013: Digital Image Processing. Narosa Publishing House; ISBN 13: 9788184871746
Drury, S.A., 1987: Image Interpretation in Geology. Allen and Unwin
Gibson, P.J. 2000: Digital Image Processing. Routledge Publication
Joseph George, 2003: Fundamentals of Remote Sensing. Universities Press
Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John Wiley.
Nag P. and Kudrat M. 1998: Digital Remote Sensing. Concept Publication
Pratt.W.K. 2004: Digital Image Processing. John Wiley

DSC T202: Digital Cartography & GPS	**Credits-5**
Objective: To provide a comprehensive understanding of cartography and the GPS, covering principles, techniques, and applications in geospatial data analysis.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will demonstrate proficiency in analysing and comparing conventional and digital mapping techniques. ✓ Applying map scales and projections for precise mapping ✓ Will master the cartographic design principles ✓ Will understand the fundamental concepts of the GPS/DGPS and its operation, including sources of errors and applications in real-time scenarios	
Unit – I	• Introduction to Cartography: Nature, Scope, and Types of Cartography • Digital Cartography: Elements, Advantages and Disadvantages • Conventional mapping Vs digital mapping-Concepts, Relationships and differences
Unit – II	• Maps: Types and Classification; Mechanics of map construction - principles of drawing • Basics of Map scales-types, Scale of Measurement: Nominal, Ordinal, Interval and Ratio • Map projection – Concept, Classification, Reference, and Coordinate System- Lambert Conformal Conic (LCC) and Universal Transverse Mercator (UTM)
Unit – III	• Fundamentals of Cartographic Design, colour, pattern, lettering, compilation, border information, aesthetics, Thematic maps and base maps, Map design principles • Generalization and Visualization of maps, geospatial data, Study of different types of maps, Survey of India national series maps, Layout, Indexing and Numbering of topographical maps
Unit – IV	• Introduction to Global Positioning System (GPS) – Fundamental Concepts, Historical Background; Principle; Operation; Segments • Sources of Errors. Classification of GPS receivers • GPS measurement, Accuracy, Limitations, Applications of GPS • DGPS-Fundamentals
Unit – V	• Basic modes of GPS surveying: Differential GPS surveying vs static GPS surveying. • Rapid static positioning technique -Reoccupation technique- Stop & go technique • Kinematic positioning technique - Relative advantages and disadvantages - Data transfer and analysis • Application of GPS/DGPS in Real World Problem i.e. Cadastral Mapping and g-Governance

Books Recommended

Ahmed el Rabbany, Engineer's Guide to GPS (Mobile Communications Library) (English) 1st Edition, Artech House Publishers , 2002

Anji Reddy, M. 2004: Geoinformatics for Environmental Management.B.S. Publications Mishra R.P and Ramesh A. 1989: Fundamentals of Cartography. Concept Publishing Company Nag P. and Kudrat M. 1998: Digital Remote Sensing. Concept Publication

Mishra R.P., and Ramesh, A. (2014). Fundamentals of Cartography (2nd edition). Prasaranga, University of Mysore.

Monkhouse, F. J., & Wilkinson, H. R. (1952). Maps and Diagrams, their complication and Concentration. Methuen & Co., London.

Rampal K.K. 1993: Mapping and compilation. Concept publication

Robinson A., Morrison, J.L., Muehrcke P.C., Guptil S.C. 2002: Elements of Cartography. John Wiley Taylor,D.R.F. 1985: Education and Training in Contemporary Cartography, John Willey

Satheesh Gopi, Global Positioning System Principles and Applications. Tata McGraw-Hill Publishing Company Limited, New Delhi, 2005.

DSC T203: Statistics for Geospatial Studies	**Credits-5**
Objective: To introduce students to statistical approaches for analyzing geospatial data, including problem framing and method selection. Learners will gain skills in testing procedures, result interpretation, and applying statistical reasoning across multidisciplinary contexts.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Will understand the nature and characteristics of statistical data ✓ Will develop proficiency in data representation, analysis, and interpretation, utilizing techniques such as classification, tabulation, and measures of variation ✓ Gain knowledge of hypothesis testing, correlation analysis, and regression analysis techniques for analysing relationships between variables.	
Unit – I	• Introduction to Statistics: nature, scope and Characteristics of Statistical Data, Statistical Methods, Data Collections techniques and Data sources • Measurement of Central Tendency: Mean, Mode and Median, Geometric mean and Harmonic Mean • Data representation and analysis: classification, tabulation, comparison and interpretation; Techniques for preparation of diagrams for processed data • Measures of variations: Range, Quintile deviations, Mean deviation, Standard deviation and variance, Coefficient of variations;
Unit – II	• Probability Concepts; Discrete Probability Distributions: Uniform, Binomial and Poisson Distributions; Continuous Probability Distributions; Probability Models; Central Limit Theorem and Confidence Intervals.
Unit – III	• Sources of Data; Sampling: types, characteristics and advantages; Hypothesis: Null hypothesis and alternative hypothesis, level of significance; Testing of hypothesis (parametric and non-parametric tests) • Small and large sample test –concerning proportions, means, variances (such as Z, t and F test); Chi square test for goodness of fit and test of independence
Unit – IV	• Correlation Analysis; Regression Analysis (Linear Regression, Multiple Linear Regression, Polynomial regression, Non-linear regression, Logistic Regression; Application in Geospatial Studies. • Time Series Models: Components of Time Series, Measuring Forecasting Accuracy – Testing of ARIMA Models; Multivariate Analysis: Co-Variance Matrix, Correlation Matrix, Multivariate Normal Density Function

Books Recommended

Rogerson, P. A. (2001) Statistical Methods for Geography, Sage Publications, New Delhi.

Paul L. Meyer: Introductory Probability and Statistical Applications, Adsion Wesley.

Kapoor and Gupta: Fundamentals of Mathematical Statistics, S Chand and Sons.

Shanti Narayan: Textbook of Matrices, S.Chand and Co.

R.A.Johnson: Applied Multivariate Statistical Analysis, Pearson

DSC P104: Lab Course- 2

Objective: To impart practical expertise in digital image processing, satellite data interpretation, projection systems, GPS-based mapping, and digital cartography through immersive lab exercises using contemporary software platforms and tools like DIP software, Google Earth Engine, and GPS receivers.

Course Outcomes: After completing this course, the students are expected to learn the following:

- ✓ Process and analyze satellite imagery using multispectral techniques, enhancement methods, classification models, and spectral indices to extract thematic information and compose geospatial maps.
- ✓ Handle coordinate systems and projections by reprojecting spatial data, converting analog maps to digital formats, and visualizing distortions arising from projection changes.
- ✓ Conduct field-based geospatial data collection using GPS receivers, generate spatial features (point, line, area), prepare attribute tables, and produce thematic maps based on domain-specific applications.

Unit – I	• Import / Export of files using DIP Software • Geo-reference of the Toposheet and imageries • Display, Analysis and interpretation of Imageries • Acquisition of Satellite imagery from different portals (USGC, BHUVAN, ESA, COPERNICUS) • Study of multispectral data, image compression and digital image processing (TCC and FCC) • Sub-setting of area of interest from the satellite image • Seamless Mosaic of satellite images • Image enhancement techniques: contrast enhancement and histogram equalization • Geometric and radiometric correction, • Spatial filtering, convolution, edge enhancement. filtering techniques and image smoothing • Principal Component Analysis and Image classification: Supervised, unsupervised classification and accuracy Assessment • Use of machine learning models in Image classification and evaluation of the performance of classification models • Use of model maker for band rationing • Spectral Indices: NDVI, NDWI, NDBI, SAVI, NDWI, LAI, NBR and other popular indices • Satellite Image classification and analysis using Google Earth Engine (GEE) • Map composition
Unit – II	• Familiarization with different types of scale (Simple, comparative, Diagonal) • Familiarization with Projections (Conical, Polyconic, Cylindrical with 1 or 2 standard parallels). • Conversion of data from Analog to Digital form; Visualization of Distortions due to change in projections; SOI topographical sheets and UTM Grids • Coordinate System: Project from a geographic to a projected coordinate system; Import a coordinate system; Project using a Predefined Coordinate System; Reproject a Coordinate System; Reproject a Raster • Digital Cartography, Output Generation and Thematic map composition: eg Tourism/Geologic/ Geomorphologic • Familiarisation with GPS receiver, initial settings, various functions of the GPS • Collection of GCPs; Mobile Mapping • Creation of Code and Attribute table • Data collection in point/line/area features by GPS, Post processing, Map preparation

DSE T205: Internship/Industrial Training with MOOC	**Credits-6**
Objective: To provide students with hands-on experience in geoinformatics through internships or industrial training, complemented by a Massive Open Online Course (MOOC) to enhance theoretical understanding.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Apply geoinformatics theories and techniques to solve real-world problems. ✓ Gain exposure to industry practices, standards, and professional environments in geoinformatics. ✓ Enhance knowledge through a MOOC, integrating theoretical and practical aspects of geoinformatics.	
Unit – I	**Internship/Industrial Training [Credits: 4]** **Duration:** 45 Days during summer vacation **Total Credit: 4** Note (s): 1. Students need to submit a report of their work in the department after the completion of the Internship/Industrial Training. 2. Internal assessment while on job training will be done by the respective authority and needs to be forwarded to the Department/ University.
Unit – II	**MOOC [Credits: 2]** MOOC Courses must be Postgraduate Level and related to the subject of Geoinformatics. For other detailed information, i.e., registration process, examination pattern, is available in the department.

DSE TP106: Programming for Geospatial Analysis	**Credits-6**
Objective: To provide a comprehensive understanding of utilizing programming to solve problems in various applications in geospatial data analysis.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Handle Spatial data in R ✓ Make use of Python for deployment of programs to process spatial data ✓ Make computations using Images & Image Collections in Google Earth Engine	
Unit – I	Introduction and Overview of R, Data Types - R Objects and Attributes, Vectors and Lists, Matrices, Factors, Missing Values, Data Frames, Names Attribute, Reading Tabular Data, Reading Large Tables, Textual Data Formats, Connections: Interfaces to the Outside World, Subletting - Basics, Lists, Matrices, Partial Matching, Removing Missing Values.
Unit – II	Introduction to Python, Basics of Python Syntax, Data Types of Python, Basic Operations of Python, Functions, Modules, and Packages of Python, Extension: Building a Python Environment, conditions, range, Loops, break, continue, and else in Loops
Unit – III	Self-defined Functions, Recursion, Scope of Variable, Standard Library Functions, Exceptions, Handling raster data with Python, and handling vector data with Python. Python tools for digital Image Processing
Unit – IV	Introduction to JavaScript for Earth Engine, Basic JavaScript data types, Earth Engine Objects and Methods, Functional Programming Concepts, Introduction to the Earth Engine JavaScript API, Visualizing Images and Image Bands, Computations using Images, Image Collections, Compositing, Masking, and Mosaicking, NDVI, mapping a Function over a Collection.
	Practical
Unit – V	• Introduction to R and Python environments, Data types, control structures, functions, and libraries • Installing and managing packages for spatial tasks • Reading and writing spatial data (Shapefiles, GeoTIFF, etc.). Coordinate reference systems and projections, Data Visualization. • Raster and Vector Analysis, Statistical Analysis & Modeling, • GEE interface and JavaScript API basics; Accessing satellite imagery (Sentinel, Landsat) • Image classification, change detection, and cloud masking; Integrated Case Studies; Project Development & Presentation

Books Recommended

- Mark Lutz: Learning Python
- Hadley Wickham, Garrett Grolemund: R for Data Science
- Mikhailov, Eugeniy E: Programming with MATLAB for Scientists: A Beginner's Introduction
- Lalit Kumar, Onisimo Mutanga: Google Earth Engine Applications
- Wes McKinney: Python for Data Analysis
- Colin Gillespie, Robin Lovelace: Efficient R Programming
- Stormy Attaway: Matlab A Practical Introduction to Programming and Problem Solving

Semester III Syllabus

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester III							
11	Discipline Specific Core	DSC T301	Sustainability & Geospatial Technology	5	0	0	5
12		DSC T302	Geospatial Modelling & Decision Support System	5	0	0	5
13		DSC T303	Research Methodology & Academic Writing	5	0	0	5
14		DSC P304	Lab Course- 3	0	3	0	3
15	Discipline Specific Elective (Any **ONE** within the list)	DSE TP305	Application of Geoinformatics in Geoscience	4	2	0	6
		DSE TP306	Application of Geoinformatics in Hydrology & Watershed Management				
		DSE TP307	Application of Geoinformatics in Urban Development & Planning				
		DSE TP308	Application of Geoinformatics in Natural Resource Management				
Total Credits (C)				19	5	0	**24**

DSC T301: Sustainability & Geospatial Technology		**Credits-5**
Objective: To explore the foundational concepts, scope, and definitions of sustainable development, with a focused understanding of the SDGs 2030, key indicators and measurements, and the critical issues influencing sustainable development.		
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Understand the pillars of sustainability and theories of sustainability ✓ Understand the concept of sustainable development, theories of Sustainability ✓ Got a knowledge of Sustainable Development Goals 2030 and their target, ranking, and government initiatives for sustainable development. ✓ Understand the principles of sustainable development and their interplay with geospatial technologies ✓ Understand the contemporary issues of sustainable development		
Unit – I	Sustainability: Concept, Meaning, and Definitions – Importance of sustainability goals of sustainability – History of sustainability – Three Pillars of Sustainability – Theories of Sustainability: Systems Theory, Popular sustainability theory, and Ideal scientific model - Issues and Challenges relating to sustainability.	
Unit – II	**Sustainable Development**: Concept, meanings, scope, and definitions of sustainable development – Principle of Sustainable Development – The pillars of sustainable development – Approaches to Sustainable Development: Status Quo Approach, Community Capacity Building Approach, Industrial Sector Approach, Integrated Systems Approach, Human Development Approach, and Green Account Approach.	
Unit – III	**Goals of Sustainable Development**: Nature of Sustainable Development Goals – 2030 Global Agenda for Sustainable Development – Government Policies and their implications for sustainable development in India – Contribution of International Organizations and NGOs – Government Initiatives for Sustainable Development. Measurement and Indicators of Sustainable Development	
Unit – IV	**Applications of Geospatial Technology in the UN SDGs:** Environmental monitoring: Land use/land cover change, deforestation, water quality; Urban sustainability: Smart cities, urban sprawl, and transportation planning. Natural resource management: Water resources, agriculture, and forestry. Disaster risk reduction: Flood mapping, earthquake vulnerability, and early warning	

	systems. Socio-economic applications: Poverty mapping, population dynamics, and public health. Case study analysis: Mapping urban heat islands or flood-prone areas. Developing a geospatial model for sustainable resource management.
Unit – V	**Challenges in Sustainable Development:** Diversity and Social Exclusion: Concept and implications, human development of the socio-cultural and other ethnic groups of the society; Contemporary Issues of Development – Bottom of the pyramid approach; Understanding the importance of social capital, social mobilization, social security, and population stabilization.

Books Recommended

- United Nations. (2020). *The Sustainable Development Goals Report 2020.*
- United Nations Statistical Commission. (2019). *The Global Statistical Geospatial Framework.*
- United Nations Committee of Experts on Global Geospatial Information Management. (2015). *Future Trends in Geospatial Information Management: The Five to Ten-Year Vision, Second Edition, December 2015*.
- *Sustainable Development Goals: Their Impacts on Forests and People* by Katila, P., et al.
- Clark, W. C., & Dickson, N. M. (2003). Sustainability science: The emerging research paradigm. Proceedings of the National Academy of Sciences 100, no. 14: 8059-8061.
- Cochran, F., Daniel, J., Jackson, L., & Neale, A. (2020). Earth observation-based ecosystem services indicators for national and subnational reporting of the Sustainable Development Goals. Remote Sensing of Environment, 244, 111796.
- Geospatial Technologies for Sustainable Development by Bhatta, Basudeb
- Sustainable Development Goals: Connectivity Dilemma and Spatial Thinking (UN Publications)

DSC T302: Geospatial Modelling & Decision Support System	**Credits-5**
Objective: to equip students with the fundamental concepts of geo-spatial modelling & DSS, providing them with essential skills for data analysis and decision-making in remote sensing and GIS applications.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Differentiate two types of spatial analysis techniques: Vector & Raster ✓ Make use of GIS tools and geostatistical analysis techniques to solve real world spatial problems ✓ Acquire the spatial and non-spatial data characteristics, modelling, and Multi-Criteria Decision Analysis (MCDA) for geo-spatial modelling and decision-making in remote sensing and GIS contexts.	
Unit – I	Spatial and non-spatial data: characteristics, types and advantages Spatial Analysis: Definition, Processes & Steps, Classification of Spatial analysis techniques, Raster–Based Techniques: Overlay Analysis, Slope and Aspects, Cost-Distance Calculation, Vector-Based Techniques: Overlay Analysis, Network Analysis : Linear referencing, Optimal Routes, Location and Service Area Problems,
Unit – II	Digital Terrain Analyses and Modeling: TIN and DEM, Surface Representation & Analysis, Architecture of Geodatabase Model, Advantages of using Geodatabase over shapefile and coverage.
Unit – III	Spatial Interpolation: Introduction, Control Points, Global Methods: Trend Surface Analysis, Regression Models, Local Methods: Thiessen Polygons, Density Estimation, Inverse Distance Weighted Interpolation, Kriging: Ordinary Kriging, Universal Kriging.
Unit – IV	Basics of Geospatial modelling: introduction, importance and techniques, Overview of the tools for Geospatial Analysis. Introduction to decision-making process and decision support systems, Introduction of a framework for planning and decision making, Different types of DSS, Components of DSS, GIS and Spatial Decision Making, Difference between DSS & SDSS.
Unit – V	Principles and elements of multiple-criteria decision making, Classification of Multiple-criteria Decision Problem: Multi-objective Vs Multi-attribute, Decision Alternatives and constraints, Criterion weighting, Decision rules, Multiple-criteria decision making in spatial data analysis. Analytical Hierarchy Process (AHP), Basic Principles of AHP, and Fuzzy AHP; Multi-Criteria Decision Analysis (MCDA) and its applications in the field of Remote sensing & GIS

Books Recommended

Bonczek, R.H., C.W. Holsapple, and A.B. Whinston, (1981). Foundations of Decision Support Systems, Academic Press, New York. Basic text on DSS

Geoffrion, A.M., (1983). "Can OR/MS evolve fast enough? Interfaces 13:10. Source for six essential characteristics of DSS.

House, W.C. (1983). Decision Support Systems, Petrocelli, New York. Basic DSS text

Sprague, R.H., (1997). A framework for the development of decision support systems, Management Information Sciences Quarterly 4:1-26. Source for DSS development model.

Sprague, R.H., and Carlson, E.D., (1982). Building Effective Decision Support Systems, Prentice-Hall, Englewood Cliffs NJ. Basic DSS text

Burrough, Peter A. and Rachael McDonnell (1998). Principles of Geographical Information Systems. Oxford University Press, New York.

Laurini, Robert and Derek Thompson (1992). Fundamentals of Spatial Information Systems. Academic Pr., London.

DSC T303: Research Methodology & Academic Writing	**Credits-5**
Objective: To equip students with a comprehensive understanding of the research process, encompassing conceptualization, design, data collection, statistical analysis, and ethical considerations, while enabling them to conduct fieldwork and geospatial surveys, interpret findings, and produce scholarly outputs suitable for academic and professional dissemination.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ To understand the meaning and significance of research. By knowing about the process of research by doing a literature review and creating a research problem, question, and hypothesis.. ✓ To understand the research design, sampling design, data collection methods, research report writing and ethics. ✓ Plan and execute fieldwork, collect data, and perform statistical analysis using appropriate methods. ✓ Interpret findings, draw conclusions, prepare dissertations, and develop scientific articles suitable for publication in academic journals.	
Unit – I	Introduction to research: Research: Meaning, Objective, Types and Significance and; Research Process; Review of Literature; Formulation of research Problem; Research Question and Hypothesis.
Unit – II	Research design and ethics: Selection of Research Design; Sampling Design and Determination of Sample Size; Measurement and Scaling Techniques; Methods of Data Collection: Quantitative and Qualitative.
Unit – III	Structure and Components of Scientific Reports; Writing of Research Proposal, References and Bibliography, Plagiarism
Unit – IV	Statistical methods: Measures of Central Tendency: Arithmetic Mean, Median, Mode and their Geographical Significance; Measures of Dispersion and Concentration: Mean Deviation, Standard Deviation; Coefficient of Variation.
Unit – V	Primary/ geospatial survey procedure, data collection, management, and report writing.

Books Recommended

Gupta, S.P. (2021). Statistical Methods (46th Edition). Sultan Chand and Sons.

Ahuja, R. (2019). Research Methods. Rawat Publication, New Delhi.

Kothari, C.R. (2019). Research Methodology: Methods and techniques. New Age International Publishers, New Delhi.

Healey, J.F. (2018). Statistics: A tool for social research. Rawat Publication, Jaipur.

Dikshit, R. D. (2003). The Art and Science of Geography: Integrated Readings. Prentice-Hall of India, New Delhi.

Mukherjee, N. (2002). Participatory Learning and Action: with 100 Field Methods. Concept Publs. Co., New Delhi.

Kitchin, R., and Tate, N. (2001). Conducting Research into Human Geography. Theory, Methodology and Practice. Prentice-Hall, London.

Mahmood, A. (1998). Statistical Methods in Geographical Studies. Rajesh Publication.

Wolcott, H. (1995). The Art of Fieldwork. Alta Mira Press, Walnut Creek, CA.

Creswell, J. (1994). Research Design: Qualitative and Quantitative Approaches. Sage Publications.

DSC P304: Lab Course- 3	**Credits-3**
Objective: To explore applications of Geospatial Technology in the UN SDGs, GIS-based spatial modeling, and field-based primary data collection for addressing regional and environmental challenges.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Applications of Geospatial Technology in the UN SDGs ✓ Construct and evaluate spatial patterns, and perform multi-criteria decision analysis (AHP, Fuzzy AHP, MCDA) within GIS platforms. ✓ Design and implement structured field surveys, analyze primary data, and synthesize findings into professional field reports addressing regional issues.	
Unit – I	Applications of Geospatial Technology in the UN SDGs: Environmental monitoring: Land use/land cover change, deforestation, water quality; Urban sustainability: Smart cities, urban sprawl mapping. Case study analysis: Mapping urban heat islands or flood-prone areas. Developing a geospatial model for sustainable resource management.
Unit – II	Representing features in Raster data set, Creating TIN surface from vector/ raster data, Pattern analysis, measures of arrangement & dispersion autocorrelation, semi variogram analysis Creating conceptual models - Site Suitability Model- Monitoring of forest fires using DSS Spatial Multi Criteria decision making for site selection; Analytical Hierarchy Process (AHP), Fuzzy AHP, Multi-Criteria Decision Analysis (MCDA) in GIS software
Unit – III	Conduct a primary Survey of any local/regional issues with a Structured Methodology/Questionnaire/Schedule; Prepare a field survey report.

DSE TP305: Application of Geoinformatics in Geoscience	**Credits-6**
Objective: To provide students with a comprehensive understanding of geoinformatics tools and techniques for interpreting geological and geomorphological features, facilitating applications in resource exploration, groundwater assessment, and tectonic analysis.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ To analyze geomorphic and lithological features using remote sensing data for geological interpretation. ✓ Interpret diverse landforms—structural, fluvial, glacial, volcanic, and karst—through satellite and terrain models to understand earth surface processes. ✓ Apply geospatial methods for mapping mineral resources, evaluating groundwater potential, and planning remediation strategies. ✓ Demonstrate competency in tectonic landform analysis and terrain evaluation in active geologic regions, particularly in the Northwest Himalaya.	
Unit – I	Remote sensing in geology – an overview Basic concept of geomorphology, earth surface process and resultant landforms Spectral characteristics of rocks and minerals Drainage patterns – types and its significance in geologic interpretation
Unit – II	Interpretation of drainage patterns through aerial photographs and satellite images Interpretation of landforms due to folding and faulting, geomorphic indices of active tectonics Interpretation of fluvial landforms Interpretation of glacial, coastal, eolian and volcanic landforms
Unit – III	Interpretation of karst landforms Interpretation of structural and denudational landforms – cuesta, hogback , butte, mesa etc. Interpretation of landforms related to igneous, sedimentary and metamorphic rocks Geomorphological mapping and terrain evaluation
Unit – IV	Lithological interpretation of igneous, sedimentary and metamorphic rocks Structure – definition, types and structural mapping Interpretation of folds, faults, unconformities and lineaments Tectonics- active and neotectonics in the Northwest Himalaya Tectonic landform mapping and analysis using remote and digital terrain models
Practical	
	Mineral resources exploration, mineral mapping, mineral resources information system, mineral prospect zonation, mapping mining area, encroachment mapping, GIS in mine remediation, and mine reclamation. Groundwater potential assessment, groundwater prospect zones mapping, modeling, planning and management, forecasting, selecting the appropriate site for artificial recharge by using RS and GIS, quality mapping, ground and surface water interactions, fluorosis, nitrate pollution and heavy metal contamination.

Books Recommended

Drury, S.A., 1987: Image Interpretation in Geology. Allen and Unwin
Gupta, R.P.., 1990: Remote Sensing Geology. Springer Verlag.
Jensen,J.R. 2000 : Remote Sensing of the Environment: An Earth Resource Perspective. Prentice Hall
Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John Wiley.
Pandey, S.N.,1987: Principles and Applications of Photogeology. Wiley Eastern,.
Ray, R.G., 1969: Aerial Photographs in Geologic Interpretations. USGS Paper 373.
Skidmore A.2002: Environmental Modeling with GIS and Remote Sensing. Taylor and Francis

DSE TP306: Application of Geoinformatics in Hydrology & Watershed Management	**Credits-6**
Objective: The course will equip the students with the necessary knowledge of hydrological environments and dynamics in order to understand, apply and plan the usage, exploration, and sustainable management of the earth's water resources.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ To understand the concepts related to hydrology and water resources. ✓ Develop control and mitigation techniques for watershed problems. ✓ Assess the current status of the watershed at field, by taking up accurate investigation measures and conduct survey	
Unit – I	Basic concepts: Hydrology as emerging discipline of earth science; Water budget equation; World water balance; Global Fresh water resources, Hydrologic cycle, Forms of precipitation, Precipitation measurement - conventional vs satellite data based, Data for hydrological studies. Aquifers, Geological materials as aquifers and Aquifer parameters - Porosity, Specific yield, Storage coefficient. Ground water movement - Darcy's Law, Permeability, Hydraulic Conductivity, Transmissivity. Hydrological cycle: Man's intervention in hydrological cycle.
Unit – II	Watershed Management: Watershed management: concept and history of watershed management, Watershed characterization, Classifications: Land Capability, Land Suitability, Land Use Land Cover, Integrated watershed management; Principles of soil erosion- causes of soil erosion, types of soil erosion, Methods of soil conservation, Soil erosion models.
Unit – III	Watershed Modeling: Rainwater harvesting: Potential and Methods, Water resources models; Rainfall runoff modelling; Groundwater modeling; Water quality modeling; Flood inundation mapping and modelling; Drought monitoring; Cropping pattern change analysis; Site selection for artificial recharge; Reservoir sedimentation; Use of RS and GIS in watershed Management.
Unit – IV	Operational Applications: Satellite image based surface runoff modeling, Flood and drought-mapping and modeling, Reservoir sediment estimation, Snow and Glacier Hydrology, Snowmelt runoff modeling, Soil erosion modeling.
Practical	
	Downloading of Satellite Rainfall data (TRMM) and Generating Spatial Rainfall Map. Downloading of Rainfall point data and generating spatial rainfall map using interpolation techniques. Hydrological Modeling with Geospatial Inputs; Digital Elevation Model (DEM) Hydro-processing; Drainage Morphometry; Watershed Characterization; Watershed Delineation and Codification; Runoff estimates from watersheds & GIS database for watershed management; Watershed Prioritization using Geoinformatics. Estimation of USLE parameters for soil erosion modelling. Flood and drought- mapping and modelling.

Books Recommended

1. Allam, Gamal Ibrahim Y., Decision Support System for Integrated Watershed Management, Colorado State University, 1994.
2. Am. Soc. Of Agri. Engr., Hydrologic Modeling of Small Hydrologic Modeling of Small Watersheds, Am. Soc. Agri. Eng., Michigan, 1982.
3. American Soc. of Civil Engr., Watershed Management, American Soc. of Civil Eng, ,ineers, New York, 1975.
4. Black Peter E., Watershed Hydrology, Prentice Hall, London, 1991.
5. Bedient, Philip B. and Huber, Wayne Charles 2002. Hydrology and Floodplain Analysis. Prentice Hall, Englewood Cliffs NJ.
6. Bilas, Ram., Rural Water Resource Utilization and Planning. Concept Publishing Company, New Delhi. 1988.
7. Chow, VenTe.,. Handbook of Applied Hydrology: A Compendium of Water Resources Technology.McGrawHill,NewYork, 1964.
8. Chow, VenTe; Maidment, David R. and Mays, Larry W., Applied Hydrology. McGraw-Hill, New York, 1988.
9. Fetter, C. W., Applied Hydrogeology. Pearson Education, San Francisco, 2001.

DSE TP307: Application of Geoinformatics in Urban Development & Planning		Credits-6
Objective: To equip the students with the necessary knowledge of comprehensive understanding of Geoinformatics approaches employed in the context of urban regional planning.		
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ To Understand urban morphology, hierarchy, and urbanization processes. ✓ To understand the concepts in regional planning and its application ✓ To study different methods in order to compute regional development.		
Unit – I	Concepts in Urban Studies: Urban morphology, Urban hierarchy; urbanization processes conceptual modeling of urban processes; urban indicators and monitoring, urban information system; Land use/Land cover mapping, change detection; Land suitability analysis; Plan formulation, Regional, Master and detailed development, Use of remote sensing and GIS in plan preparation, Urban information system; case studies.	
Unit – II	Geoinformatics for urban mapping: Remote Sensing Data in Urban Studies: Scale, Resolution, Scope and Limitations; Urban Land use/land cover classification; Visual and Digital Techniques; Change Detection; Sprawl Detection and Characterization; Mapping of Urban Morphology	
Unit – III	Concepts in Regional Planning: Region: concept, types and hierarchy of regions; planning, concept and types, planning region: concept and characteristics of a planning region, Delineation of planning region, Indicators for measuring development, Development; meaning, Growth versus development, Measurement of regional development; policies and experiences of regional planning in India.	
Unit – IV	Regional Planning and Geoinformatics: GIS Based Decision making Process, spatial data infrastructure and spatial information system, Applications in planning, population estimation, identification of illegal encampments, sources of pollution etc. Spatial resolution related to level of Planning, Use of remote sensing and GIS in detecting urban heat islands.	
Practical		
	Network Analysis; Urban heat Island and LST; Fringe Dynamic; Urban sprawl and growth modeling , Virtual 3D city modeling and applications; case studies. Geoinformatics for Smart Cities. GIS-based land information management.	

Books Recommended

1. Juliana Maantay, John Ziegler, John Pickles, GIS for the Urban Environment, Esri Press 2006.
2. Allan Brimicombe, GIS Environmental Modeling and Engineering, CRC; 1 edition 2003.
3. Paul Longley, Michael Batty, Spatial Analysis: Modeling in a GIS Environment Wiley,1997.
4. Michael F. Goodchild, Louis T. Steyaert , Bradley O. Parks, Carol Johnston, David Maidment, Michael Crane , Sandi Glendinning, GIS and Environmental Modeling: Progress and Research Issues (Hardcover) by,Publisher: Wiley; 1 edition, 1996.
5. Roland Fletcher, The Limits of Settlement Growth: A Theoretical Outline (New Studies in Archaeology) (First edition), Cambridge University Press; 2007.

DSE TP308: Application of Geoinformatics in Natural Resource Management	Credits-6
Objective: to provide education in the field of geoinformatics for natural resources management, aiming towards policy formulation, sustainable development of society and the environment.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ To understand the concept of different natural resource management ✓ Understand the policies, and ethics regarding conservation practices ✓ Make use of the scientific method of sustainable resources management ✓ Apply Geospatial Techniques for better management of natural resources.	
Unit – I	Basic Concept: Concept and Classification of Natural Resources; Factors Influencing Resource Availability, Distribution and Uses; Ecological, Social and Economic Dimension of Resource Management; Natural Resources and Development. Sustainable utilization of the natural resources.
Unit – II	Natural resources planning & management: Approaches in Resource Management: Ecological approach; economic approach; ethnological approach; Geoinformatics approach, Ecological principles, policies, and ethics regarding conservation practices, The Scientific Method and Adaptive Management, Management of Common International Resources
Unit – III	Land And Wetland Management: Land use: Classification, planning and desertification, Wetland: A brief Introduction, Classification of Wetland, Over-utilization of surface and ground water, drought, conflicts over water, dams-benefits and problems. Water ecology and management, Impact of climate change on land and wetland, Fish and other marine resources: Production, status, dependence on fish resource, unsustainable harvesting, issues and challenges for resource supply, Solid waste Management, Waste water management.
Unit – IV	Forest management and wildlife conservation Forest: Present status, distribution and its contribution as natural resource, Over-exploitation: deforestation and its societal impact, Forest products. Developing and developed world strategies for forestry, Environmental Impact Assessment.
Practical	
	Forest Cover Type Mapping, Agro-Forestry Mapping; Clear-Cut Mapping/ Deforestation and Regeneration Assessment; Burn Delineation; Biomass Estimation; Species Identification. Extraction of Land Surface Temperature from satellite data; Site Susceptible for Forest Fire Zones; Extraction of Water Bodies; Extraction of Forested area; Site suitable for Fishing Zones; Site Suitability for Solid waste and Waste water for an upcoming urbanization;

Books Recommended

1. Michael J. Conroy, James T. Peterson,(2013).Decision Making in Natural Resource Management: A Structured, Adaptive Approach. John Wiley & Sons.
2. Moulton, M.P. and J. Sanderson(1999). Wildlife issues in a changing world. Lewis Publishers, Boca Raton, Florida, 500 pp.
3. Francois Ramade (1984). Ecology of Natural Resources. John Wiley & Sons Ltd.
4. Roy, P.S., and Dwivedi, R. S. (2010). Remote Sensing Application. www.nrsc.gov.in/Learning- Center, E Book. Html.
5. Joshi, P.K. (2009). Geoinformatics for Natural Resource Management. Nova Science Publishers.
6. ISPRS Technical Commission VII(2002). Symposium on Resource Environmental Monitoring. ISRS Annual Convention, IIRS, Dehradun.

Semester IV Syllabus

Sl. No.	Course Category	Course Code (T=Theory, P=Practical)	Course Title	Credits (I=Internship, D= Dissertation)			
				T	P	I/D	Total Credits
Semester IV							
16	Discipline Specific Core	DSC T401	Application of Geoinformatics in Climate Change Studies	5	0	0	5
17		DSC T402	Research Project-II/Dissertation	0	0	10	10
18		DSC P404	Lab Course- 4	0	3	0	3
19	Discipline Specific Elective (Any **ONE** within the list)	DSE TP403	Application of Geoinformatics in Disaster Management	4	2	0	6
		DSE TP404	Advance Geospatial Data Collection Techniques				
Total Credits (D)				9	5	10	**24**

DSC T401: Application of Geoinformatics in Climate Change Studies		**Credits-5**
Objective: To enhance student's understanding about climatic system of earth and its changes over time.		
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Explain weather and climate, local to global climatic variations, and El Nino vs La Nino. ✓ Analyse relationship between different ecosystems (forest, agriculture and glacier) and climatic parameters such as rainfall, temperature, etc. to assess the impact of global warming on these systems using RS and GIS technology. ✓ Describe global policies and EIA methods, and link them with local, regional and national developmental initiatives.		
Unit – I	Introduction to weather and climate: Fundamentals of Weather and Climate; Local, Regional, Continental and global weather Pattern, Global bio-geo-Climatic conditions; Weather variations and associated effects – El Nino, La Nino, and associated Southern Oscillation, Drought and Flood Scenario; Mapping weather parameters with a focus on rainfall, temperature and wind.	
Unit – II	Forest, agriculture and climate: Vegetation growth rhythm and climatic interaction; Carbon accounting with climate change scenario; Time-Series Satellite data; space-time dynamics; Phenology of Vegetation; Global changes in phenology; Drought monitoring mechanism; Forest Fire and climate change with Indian examples. Food security, Drought monitoring and forecast; Weather dependence of Agriculture; Climate change impact on agriculture economy.	
Unit – III	Atmosphere and global warming: Atmospheric structure and composition; Greenhouse effect and Global Warming; Role of aerosols, Aerosol retrieval from space; Climate forcing; Remote Sensing missions for weather monitoring.	
Unit – IV	Global Policies for Climate Change Mitigation: United Nations Framework Convention on Climate Change (UNFCCC); Kyoto Protocol; Intergovernmental Panel on Climate Change (IPCC); Reducing Emissions from Deforestation and forest Degradation (REDD); Convention of Biological Diversity (CBD Scope of EIA); EIA Methods and Mitigation; Criteria and Indicators; Certification; Ecological, Economical and Demographic impact assessment. Indian National Policies on Natural resources monitoring and climate change.	

Books Recommended

1. ECA (Economics of Climate Adaptation),(2009). Shaping climate resilient development: a framework for decision making. ClimateWorks Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank and Swiss Re. 164pp.
2. Morris, P. and Therivel, R.(2008). Methods of Environmental Impact Assessment, 2nd edition, Spon Press, London (2001 reprint).
3. Roy, P.S., Dwivedi, R.S., and Vijayan, D. (2010). Book on Remote Sensing Applications. National Remote Sensing Centre, ISRO, Hyderabad. ISBN: 9788190946001.
4. Milly, P.C.D., R.T. Wetherald, K.A. Dunne and T.L. Delworth(2002). Increasing risk of great floods in a changing climate. Nature Vol 415: 514–517.

DSC P403: Lab Course- 4	**Credits-3**
Objective: To equip students with advanced skills in remote sensing and GIS for analyzing environmental conditions, monitoring climate variability, and designing geospatial strategies to address local and regional challenges in vegetation, hydrology, and atmospheric dynamics.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Visually and digitally differentiate various environmental conditions including vegetated features and shorelines from satellite data. ✓ Use time-series remote sensing data and GIS tools to quantify flood/drought condition, vegetation growth rhythm, glacier dynamics and their environmental impact. ✓ Design appropriate tools, models and strategy for local to regional problems based on various published reports and policies .	
Visual Interpretation of different types of forests and crops Shoreline change mapping of Waterbodies Biomass and Carbon Accounting using RS & GIS To identify El-Nino and La-Nina years using ONI and SST/Temperature anamoly Flood/Drought Condition Assessment using RS based indices and meteorological data Exploring Climatic Research Unit **(** CRU) data set and its utilization of climate change related studies Evaluation of atmospheric dynamics using virtual ballooning TRMM based Rainfall Mapping and relating with Ground Meteorological Data Vegetation Phenology using Time-Series RS data Explore scenarios for future climate using the simple online climate model	

DSE TP403: Application of Geoinformatics in Disaster Management	**Credits-6**
Objective: To build essential knowledge of natural hazards and disaster management, and enable geospatial analysis for risk assessment and mitigation through GIS-based case studies.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Acquire knowledge about hazards, disasters and catastrophes and also Disaster Management ✓ Discover the causes and effects of Cyclone, Flood hazards, Drought, Landslide and Desertification with GIS case studies ✓ Learn about preparation of GIS based parameters and layers for analysis	
Unit – I	**Introduction:** Fundamental concepts of hazards and disasters, their types, and characterization, Zonation of hazards, natural and human induced disasters, Disaster and National losses, historical perspective of disasters in India. Types of Natural Disasters with most well-known Indian examples; Causes and effects; Disaster Management and overview of mitigation strategy; Fundamental concept of Disaster Management, Government, NGOs and peoples participation disaster management, Existing organizational structure for managing disasters in India, Geoinformatics in disaster mitigation.
Unit – II	**Cyclones and Flooding:** Cyclone: Origin and types; effects on land and sea; damage assessment; Flooding: Topography, land use and flooding; GIS based parameters and layers; flood prone area analysis and management; risk assessment; GIS case studies for cyclones and floods.
Unit – III	**Drought and Desertification:** Drought: Types, factors influencing drought; vegetation index; soil erosion; delimiting drought prone areas; short term and long-term effects; Desertification: Processes; GIS based management strategies; GIS case studies for drought and desertification.
Unit – IV	**Landslide Disaster:** Landslide: Inventory, types and influencing factors; major disasters of the world and India; effect of climate change on landslide intensity and frequency; Role of geospatial technology in landslide susceptibility and risk mapping.
Practical	
	Overview of "Bhuvan" Geoportal of ISRO for disaster services; Estimation of flood inundated area using pre and post flood satellite image and its comparison with dataset provided by "Bhuvan"; Identification of coal-mine fire with the help of LST derived from satellite image; Identification of disaster prone areas in a satellite image w.r.t. Earthquake; Identification of regions prone to meteorological drought by downloading and analysing rainfall data and generating drought indices; Identification of disaster prone areas in a satellite image w.r.t. Forest fires and its comparison with dataset provided by "Bhuvan"; Performing air quality analysis by calculating AQI using CPCB dataset; Prepare list of Do's and Dont's for at least three natural disaster and prepare the administrative hierarchy of disaster management of home district. CASE STUDIES Earthquakes in India, Floods in Indo Gangetic plains, Landslides in Himalayan region, Drought in Indian plateau regions

Books Recommended

Roy, P.S. (2000). Natural Disaster and their mitigation. Published by Indian Institute of Remote Sensing (IIRS).

Skidmore A. (2002) Environmental Modeling with GIS & Remote Sensing, Taylor & Francis.

Holechek, J. L., R. A. Cole, J. T. Fisher, and R. Valdez (2003) Natural Resources: Ecology, Economics and Policy (2nd Edition). Prentice Hall Education.

Lillesand, T.M., and Kieffer, R.M., 2015: Remote Sensing and Image Interpretation 7ed, John Wiley.

Colin W. Mitchell (1991) Land Evaluation, Longman scientific& Technical, co published with John Wiley & sons Inc, New York.

Kevin H. Deal (2020) Wildlife and Natural Resource Management 4th Ed., Atithi books, New Delhi

Ramkumar, Mu, (2009) Geological Hazards: Causes, Consequences and Methods of Containment, New India Publishing Agency, New Delhi.

Brian Tomaszewski (2020) Geographic Information Systems (GIS) for Disaster Management, Routledge, U.K.

DSE TP404: Advance Geospatial Data Collection Techniques	Credits-6
Objective: To equip students with advanced geoinformatics competencies spanning LiDAR, UAV, microwave remote sensing, AI-driven analysis, and emerging GIS Science trends for interdisciplinary research and practical applications.	
Course Outcomes: After completing this course, the students are expected to learn the following: ✓ Explore the Airborne Laser Terrain Mapping (ALTM) and Principles of laser altimetry, Components: GPS, IMU, LASER and data formats. ✓ Familiar with the UAV components, types and applications. ✓ To understand artificial intelligence using machine learning and deep learning. ✓ To learn about the emerging branches and future trends of geoinformatics	
Unit – I	**Advances in Microwave Remote Sensing**: Basic and advanced processing techniques: Interferometry of Synthetic Aperture Radar (InSAR), differential InSAR or polarimetric InSAR; Applications of active and passive microwave remote sensing data in areas of geology, Hydrology, Agriculture and environmental sciences, etc.
Unit – II	**LiDAR & UAV:** Introduction to laser ranging; Principle of LiDAR; System components; Range measurements; LiDAR error sources, Accuracy and applications; Advantages of ALTM; Integration of LiDAR technology with GIS mapping; UAV-based LiDAR survey: Topographic, Vegetation mapping of urban areas, building 3D city models, monitoring infrastructure projects, mining etc. Introduction to UAV; Structural Design of UAV; Operational Procedure: Assembling the Drone, Preparation of Flight Planning, Data Collection, Data Transfer and Analysis (Use of Drone instrument); Applications of UAV Remote Sensing.
Unit – III	**Geo-spatial Using ML, DL and Time Series Analysis:** Introduction to Machine Learning and Deep Learning; Types and Uses of ML and DL Classifier; Basics of Python; ML and DL Softwares; Application of ML and DL Techniques; Introduction of time series analysis; Advantages and difficulties in time-series satellite data; Time-composite techniques..
Unit – IV	**Emerging branches and future trends:** Emerging Branches of GIS Science: Geo-Informatics; Hydro-Informatics; Weather-Informatics; Biodiversity-Informatics, and Socio-Informatics; Web Based GIS; Location Based Services and GIS; Volunteer GIS; Cloud GIS; Big Data Analysis; Future Trends of GIS Science and Challenges.

Books Recommended

1. Wolf. P.R., (2014). Elements of Photogrammetry with Application in GIS, McGraw Hill books Co., London.
2. Curran P.J (1985). Principles of Remote Sensing, Longman, London.
3. Lillisand T.M and R.W. Kiefer (1994). Remote Sensing and Image Interpretation (3rd edition). John Wiley & Sons, New York.
4. James B. Campbell, Randolph H. Wynne, Valerie A. Thomas (2022). Introduction to Remote Sensing, Guilford Press, New York
5. Alexey Bunkin and Konstantin Voliak (2001). Laser Remote Sensing of the Ocean, John Wiley and Sons., New York.
6. McEwen, A., & Cassimally, H. (2013). Designing the internet of things. John Wiley & Sons.
7. Heywood, I., Cornelisus, S., Carver, S. (2011). An Introduction to Geographical Information Systems. Pearson Education, New Delhi.
8. Chang, K. T. (2008). Introduction to Geographic Information Systems. Avenue of the Americas, McGraw-Hill, New York Longley.
9. Weiner, D., & Harris, T. M. (2008). Participatory geographic information systems. The handbook of geographic information science, 466-480.
10. Peng, Z. R., & Tsou, M. H. (2003). Internet GIS: distributed geographic information services for the internet and wireless networks. John Wiley & Sons.
11. Lo, C. P., Yeung, A. W. (2002). Concepts Techniques of Geographical Information Systems, Prentice-Hall of India, New Delhi.