

ENVIRONMENTAL MODELING

ENGE 365

Lecture : 3

Tutorial : 2

Practical : 1

Year : III

Part : II

Course Objectives:

The objective of this course is to introduce concepts of environmental modelling using geospatial techniques. The course covers statistical analysis, spatial and attribute data collection, processing, integration, and preparation for modelling. It also includes basic customization and automation techniques. Environmental models support understanding of systems and are essential for scientific research, as well as planning, policy, and decision-making processes.

1 Introduction (5 hours)

- 1.1 Model, modeling and environmental models
- 1.2 Purpose of modeling, modeling elements and approaches in modeling
- 1.3 Types of models: Conceptual, physical and mathematical
- 1.4 Model complexities: Spatial, temporal and physical
- 1.5 Data mining for environmental systems: Pre-processing, data cleaning, outlier detection and cluster analysis, missing value treatment, pattern recognition, transformation, visualization

2 Model Development and Application (5 hours)

- 2.1 Basic steps in environmental modeling process
- 2.2 Problem specification
- 2.3 Model selection
- 2.4 Building model
- 2.5 Good modeling practices (GMP)
- 2.6 Application of model

3 Model Coupling and Model Evaluation (6 hours)

- 3.1 Issues of coupling technologies in environmental modeling
- 3.2 Uncertainty and sensitivity analysis
- 3.3 Model coding and verification
- 3.4 Model calibration and validation
- 3.5 Best practices of model evaluation

- 4 Hydraulic Modeling (8 hours)**
- 4.1 Types of open channel flow: Steady and unsteady; Uniform and non-uniform; Gradually varied and rapidly varied; Sub-critical, critical, and super-critical; 1D, 2D and 3D
 - 4.2 Types of open channels: Natural and artificial, prismatic and non-prismatic, rigid boundary and mobile boundary,
 - 4.3 Types of hydraulic models
 - 4.3.1 Steady flow model – water surface profiles
 - 4.3.2 Unsteady flow model: 1D and 2D simulation
 - 4.3.3 Sediment transport model
 - 4.3.4 Water quality analysis
 - 4.4 Calibration of hydraulic models
 - 4.5 Model outcomes and applications
- 5 Hydrological Modeling (9 hours)**
- 5.1 Hydrological cycle and its components
 - 5.2 Hydrological modeling approaches
 - 5.3 Spatial complexity in hydrological modeling: Lumped, semi-distributed and distributed
 - 5.4 Data requirement for hydrological modeling
 - 5.5 Rainfall-runoff modeling
 - 5.6 Calibration and validation of hydrological model
 - 5.7 Applications of hydrological model
- 6 Soil Erosion Model and Sediment Transport Models (4 hours)**
- 6.1 Soil erosion and types of soil erosion
 - 6.2 Causes and effects of soil erosion
 - 6.3 Empirical models used in soil erosion studies: USLE, RUSLE, and MUSLE
 - 6.4 Introduction to other models: AGNPS, WEPP and SLEMSA
 - 6.5 Sediment delivery ratio (SDR) and estimating sediment yields
 - 6.6 Impact of sediments on environments
- 7 Suitability Analysis (4 hours)**
- 7.1 Site suitability analysis
 - 7.2 Approaches to suitability analysis: Boolean, weighted and fuzzy
 - 7.3 Habitat suitability mapping for wildlife
 - 7.4 Suitability analysis for agriculture or resettlement
- 8 Biomass Estimation (4 hours)**
- 8.1 Biomass as a source of energy
 - 8.2 Biomass potential in Nepal
 - 8.3 Types of biomasses

- 8.4 Methods of estimating biomass: Direct sampling; Indirect sampling; Destructive sampling; Allometric equations; Remote sensing techniques
- 8.5 Primary productivity - NPP, GPP

Tutorial

(30 hours)

1. Rainfall data processing and missing value analysis
2. Runoff calculation using empirical and rational methods
3. Flood frequency analysis
4. Calculation of water surface elevation at selected river cross-section: Standard step method, direct step method, graphical method
5. Estimating water erosion and assess sediment in a watershed
6. Assessment of biomass out of a community forest and estimate carbon stock

Practical

(15 hours)

1. Geometry data extraction using RAS-MAPPER
2. Steady and unsteady flow models in in HEC-RAS
3. Calibration and validation of steady flow model in HEC-RAS
4. Rainfall-runoff modeling in HEC-HMS
5. Calibration and validation of rainfall-runoff model in HEC-HMS
6. Suitability analysis using GIS/RS
7. Biomass estimation using remote sensing and GIS

Students are required to submit a comprehensive report for each practical, including: Methodology, Data analysis, results and interpretation and potential applications of the model in environmental and engineering contexts.

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	5
2	5	5
3	6	8
4	8	12
5	9	12
6	4	6
7	4	6
8	4	6
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Smith, J., Smith, P. (2007). Environmental modeling: An introduction. Oxford University Press.
2. Skidmore, A. K. (Ed.). (2003). Environmental modeling with GIS and remote sensing. Taylor and Francis.
3. Brimicombe, A. (2010). GIS, environmental modeling and engineering. Taylor and Francis.
4. Jørgensen, S. E., Bendoricchio, G. (2001). Fundamentals of ecological modeling (Latest Edition). Elsevier.
5. Hardisty, J., Taylor, D. M., Metcalfe, S. E. (1993). Computerized environmental modelling: A practical introduction using Excel (Latest Edition). John Wiley and Sons.
6. U.S. Army Corps of Engineers (USACE). (2026). HEC-RAS user's manual. Hydrologic Engineering Center.
7. U.S. Army Corps of Engineers (USACE). (2026). HEC-RAS hydraulic reference manual. Hydrologic Engineering Center.
8. U.S. Army Corps of Engineers (USACE). (2026). HEC-HMS user's manual. Hydrologic Engineering Center.
9. U.S. Army Corps of Engineers (USACE). (2026). HEC-HMS technical reference manual. Hydrologic Engineering Center.

PYTHON FOR GEOSPATIAL DATA ANALYSIS

ENGE 366

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to enable students to master advanced Python programming and object-oriented design for professional geospatial applications. Students will learn automated geoprocessing, coordinate transformations, and large-scale spatial data analysis, preparing them to address real-world spatial challenges and pursue careers in geospatial data science.

- 1 Introduction to Python Programming (6 hours)**
 - 1.1 Basic concepts and syntax: Variables, literals, keywords, comments, interactive/script mode, debugging
 - 1.2 Operators, types and precedence
 - 1.3 Expression and statements
 - 1.4 Data Types: Integer, float, string, complex, tuple, range, set, Boolean
 - 1.5 Operations: Conversions, string manipulations
 - 1.6 Environment and software set-up

- 2 Functions, Control Flow, and Data Structures (6 hours)**
 - 2.1 Functions: Definitions, parameters, return values, lambda functions, recursion
 - 2.2 Control Flow
 - 2.2.1 Decision-making: If, elif, else statements
 - 2.2.2 Iteration: For loops, while loops, list comprehensions
 - 2.3 Data Structures for geospatial representation
 - 2.3.1 Sequences: Strings, lists, tuples
 - 2.3.2 Mapping: Dictionaries
 - 2.3.3 Sets: Set operations for uniqueness

- 3 Object-Oriented Programming and File Handling (7 hours)**
 - 3.1 Object-oriented programming: Classes, objects, methods, inheritance, polymorphism, encapsulation
 - 3.2 File handling: Paths, file operations (Open, read, write), context managers
 - 3.3 Error and exception Handling

- 4 Geospatial Python Libraries (6 hours)**
- 4.1 Foundational libraries: GDAL and OGR
 - 4.2 Raster data processing libraries: Rasterio, rioxarray, xarray
 - 4.3 Spatial analysis and scientific computing: NumPy, Pandas, GeoPandas, SciPy, Dask, PyKrige
 - 4.4 Visualization and mapping libraries: Matplotlib, Folium, Seaborn
- 5 Data Handling and Coordinate Transformations (8 hours)**
- 5.1 Vector data handling: Point, line, polygon
 - 5.2 Raster image handling: Raster bands, image loading, metadata, histogram analysis
 - 5.3 Coordinate transformations: Affine and perspective transformations, matrices, interpolation
- 6 Spatial Data Processing (4 hours)**
- 6.1 Spatial join and querying
 - 6.2 Projections, geometric operations
 - 6.3 Spatial operations: Difference, union, buffer, clip, merge
- 7 Spatial Analysis and Applications (8 hours)**
- 7.1 Spatial analysis: Raster processing, terrain analysis, spatial interpolation, statistics, network analysis
 - 7.2 Watershed delineation: DEM preprocessing, flow direction algorithms, watershed modeling
- Tutorial (30 hours)**
- 1. Hands-on exercises in writing python scripts, using variables, operators, and debugging techniques
 - 2. Creating and manipulating strings, lists, dictionaries, and writing functions with parameters and return values
 - 3. Python functions for geometric calculations
 - 4. Tutorials on implementing conditional statements, loops, list comprehensions and handling exceptions
 - 5. Exercises on file operations, context managers and object-oriented programming concepts like classes, inheritance, and polymorphism
 - 6. Application of affine and perspective transformations using matrices and interpolation
 - 7. Reading, writing, and subsetting vector data
 - 8. Loading raster images, analyzing histograms, and working with raster bands and metadata
 - 9. Topology testing, spatial analysis and map algebra
- Practical (15 hours)**
- 1. Branching and looping for elevation classification
 - 2. String handling and coordinate list operations

3. Attribute data handling using dictionaries and files
4. Creating classes and objects for spatial features
5. Edge detection and segmentation of satellite images
6. Batch image transformation and reprojection
7. Creating geometries, handling projections, and calculating attributes

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	6	8
2	6	8
3	7	10
4	6	8
5	8	10
6	4	6
7	8	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Diener, M. (2015). Python geospatial analysis cookbook. Packt Publishing.
2. Symington, A. (2025). Python maps: Geospatial visualization with Python. Locate Press.
3. Westra, E. (2015). Python geospatial development. Packt Publishing.
4. Garrard, C. (2016). Geoprocessing with Python. Manning Publications.
5. Wu, Q. (2025). Introduction to GIS programming: A practical Python guide to open source geospatial tools. Independently published.
6. Lutz, M. (2013). Learning Python. O'Reilly Media.

LAND USE PLANNING AND REGULATIONS

ENGE 367

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to introduce the principles of land use planning and its integration with interdisciplinary issues. The course covers theories, tools, policies, and regulations of land use planning. It also familiarizes students with real-world planning challenges through project-based and case-based learning approaches, enabling effective application of planning concepts in practice and regulatory contexts.

- 1 Land Use Planning and management (9 hours)**
 - 1.1 Definition of land use planning
 - 1.2 Principles of land use planning
 - 1.3 Types of land use planning and approaches
 - 1.4 Core principles of land use change
 - 1.5 Drivers of land use change
 - 1.6 Urban land use models
 - 1.7 Land use planning and land tenure
 - 1.8 Sustainable land use planning and management

- 2 Implementation Tools, Institutions and Policies (11 hours)**
 - 2.1 Planning instruments
 - 2.2 Regulatory provisions
 - 2.3 Economic tools
 - 2.4 Financial planning instrument
 - 2.5 Land pooling/ land readjustment, land consolidation, land sharing, guided land development
 - 2.6 Land leasing, land banking
 - 2.7 Participatory and inclusive planning tools
 - 2.8 Role of government institutions (Federal, provincial, local levels)
 - 2.9 National land use policies, act and regulations

- 3 Integration of Land Use Planning and Transportation (9 hours)**
 - 3.1 Land use and transportation systems
 - 3.2 Travel demand, urban density and modal choice
 - 3.3 Accessibility theory and mobility concepts

- 3.4 Land use–transport feedback cycle
- 3.5 Travel behavior and accessibility
- 3.6 Transit-oriented development (TOD)
- 3.7 National transport policy
- 3.8 Modelling accessibility (Gravity models, utility based models, demand modelling-4 step)

4 Integration of Land Use Planning and Climate Change (7 hours)

- 4.1 Climate change concepts
- 4.2 Global and national framework
- 4.3 Land use planning: Mitigation and adaptation
- 4.4 Land use planning and REDD (Reducing emissions from deforestation and forest degradation)
- 4.5 Climate change and land use nexus
- 4.6 Policy and institutional framework
- 4.7 Land use change models (Cellular automata, agent based modeling, Markov chains, artificial neural network)

5 Integration of Land Use Planning and Disaster (9 hours)

- 5.1 Concepts disaster risk reduction
- 5.2 Sendai framework for disaster risk reduction (2015–2030), early warning for all (EW4All)
- 5.3 Natural hazard assessment and mapping
- 5.4 Exposure, vulnerability and risk analysis
- 5.5 Modelling risk, hazard and vulnerabilities (HECRAS, GEE, ML)
- 5.6 Risk-sensitive land use planning
- 5.7 National disaster response framework (NDRF)
- 5.8 Disaster risk reduction and management policies

Tutorial (30 hours)

- 1. Case studies of land use planning of different countries towards sustainable development goal
- 2. Develop a GIS based land pooling plan based on the land pooling guideline
- 3. Prepare land use plan of a municipality based on the land use regulations and guidelines of Nepal
- 4. Prepare accessibility model of transportation

Practical (15 hours)

- 1. Transportation demand modelling using 4-step network analysis
- 2. Risk modelling using remote sensing (HEC-HMS and HEC-RAS)

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	9	12
2	11	14
3	9	12
4	7	10
5	9	12
Total	60	60

* There may be minor deviation in marks distribution.

References

1. Metternicht, G. (2018). Land use and spatial planning: Enabling sustainable management of land resources. Springer.
2. Metternicht, G. (2017). Land use planning. Global Land Outlook (Working Paper), 2(3), 25–31.
3. Koomen, E., Borsboom-van Beurden, J. (Eds.). (2011). Land-use modelling in planning practice (Vol. 101). Springer Science & Business Media.
4. Bhandari, M. P. (2024). The nexus of climate change and land-use–global scenario with reference to Nepal. River Publishers.
5. UNISDR. (2009). UNISDR terminology on disaster risk reduction. United Nations Office for Disaster Risk Reduction.
6. World Bank, Earthquake and Megacities Initiative (EMI). (2014). Risk-sensitive land use planning guidebook (F. Bendimerad, Ed.). EMI.
7. Darido, G., Pardo, C. (2010). Land use planning and urban transport: Module 2a – Sustainable transport: A sourcebook for policy-makers in developing cities. Sustainable Urban Transport Project (SUTP) of GIZ.
8. Food and Agriculture Organization of the United Nations. (2017). Framework for integrated land use planning: An innovative approach. <https://doi.org/10.4060/cb1170en>