Appendix-5
Resolution No. 27 {27-1 (27-1-1)}

DEPARTMENT OF ENVIRONMENTAL STUDIES
SEMESTER-IV

COURSES OFFERED BY DEPARTMENT OF ENVIRONMENTAL SCIENCE

Category-I

Environmental Science Courses for Undergraduate Programme of study with Environmental Science as a Single Core Discipline

BSC (H) ENVIRONMENTAL SCIENCE

DISCIPLINE SPECIFIC CORE COURSE – 10 (DSC-EVS-10): SYSTEMATICS AND BIOGEOGRAPHY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-EVS-10: SYSTEMATICS AND BIOGEOGRAPHY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Gain insights into the principles and methods of systematic biology for determining evolutionary relationships among organisms
- Describe major biogeographic regions of the world and identify underlying factors responsible for their formation and evolution
- Familiarize with the different types of molecular and morphological characters used in systematic analysis
- Interpret phylogenetic trees constructed using molecular and morphological data in an evolutionary context
- Evaluate literature in systematics and biogeography and critically assess research questions and methods

Learning outcomes

After this course, students will be able to:

- Identify and classify different taxa using morphological and molecular characters
- Construct and interpret phylogenetic trees based on molecular and morphological data
- Analyze biogeographic patterns and use them to make inferences about evolutionary history

- Apply the principles and methods of systematics and biogeography to practical problems in conservation biology, ecology, and biotechnology
- Communicate effectively about the principles and methods of systematics and biogeography, and their applications to various areas of research and practice

SYLLABUS OF DSC-EVS-10

Theory (02 Credits: 30 lectures)

UNIT – I Concept, systematics approaches and taxonomic hierarchy (3 Week) (6 lectures)
Definition of systematics; taxonomic identification; keys; field inventory; herbarium; museum; botanical gardens; taxonomic literature; nomenclature; evidence from anatomy, palynology, ultrastructure, cytology, phyto-chemistry, numerical and molecular methods; taxonomy databases.

Concept of taxa (species, genus, family, order, class, phylum, kingdom); concept of species (taxonomic, typological, biological, evolutionary, phylogenetic); categories and taxonomic hierarchy

UNIT – II Nomenclature and systems of classification (2½ Week) (5 lectures)
Principles and rules (International Code of Botanical and Zoological Nomenclature); ranks and names; types and typification; author citation; valid publication; rejection of names; principle of priority and its limitations; names of hybrids; classification systems of Bentham and Hooker; Angiosperm Phylogeny Group (APG III) classification.

UNIT – III Numerical and molecular systematics (1½ Week) (3 lectures)
Characters; variations; Operational Taxonomic Units; character weighting and coding; phenograms; cladograms; DNA barcoding; phylogenetic tree (rooted, unrooted, ultrametric trees); clades: monophyly, paraphyly, polyphyly; homology and analogy; parallelism and convergence.

UNIT – IV Biogeography, Speciation and extinction (3½ Week) (7 lectures)
Genes as unit of evolutionary change; mutation; genetic drift; gene flow; natural selection; geographic and ecological variation; biogeographical rules – Gloger's rule, Bergmann's rule, Allen's rule, Geist rule; biogeographical realms and their fauna; endemic, rare, exotic, and cosmopolitan species.

Types and processes of speciation – allopatric, parapatric, sympatric; ecological diversification; adaptive radiation, convergent and parallel evolution; dispersal and immigration; means of dispersal and barriers to dispersal; extinction.

UNIT – V Historical and ecological Biogeography (3½ Week) (7 lectures)
Earth's history; paleo-records of diversity and diversification; continental drift and plate tectonics and their role in biogeographic patterns – past and present; biogeographical dynamics of climate change and Ice Age.

Species' habitats; environment and niche concepts; biotic and abiotic determinants of communities; species-area relationships; concept of rarity and commonness; Island Biogeography theory; Equilibrium Theory of Insular Biogeography; geography of diversification and invasion; phylogeography.

UNIT – VI Conservation Biogeography (1 Week) (2 lectures)

Application of biogeographical rules in design of protected area and biosphere reserves; use of remote sensing in conservational planning.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Construct and compare phylogenetic trees based on morphological and molecular data
2. Extract and quantify DNA from various organisms
3. Conduct PCR and amplify a specific gene using a target primer
4. Identify different taxa using morphological and molecular characters
5. Construct, analyze and infer phylogenetic trees based on molecular data by using software like PAUP*, RAxML, and MrBayes
6. Use and construct a phylogenetic tree based on morphological characters
7. Molecular Characters: Students should learn how to use molecular characters to construct a phylogenetic tree
8. Compare and contrast the anatomy of different organisms to understand their evolutionary relationships
9. Map and identify the distribution of organisms across the world and the factors that influence their distribution
10. Analyze the factors explaining biogeographic patterns of distribution of a target species using hypothesis of vicariance and dispersal
11. Estimate the timing of evolutionary events based on molecular clocks
12. Identify and analyze different biogeographic regions of the world and the unique flora and fauna found in each
13. Estimate divergence times between different lineages using molecular data

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Essential/recommended readings

- Baum, D. A., & Smith, S. C. (2013). Systematic Biology. John Wiley & Sons.
- Briggs, C. J. (2016). Biogeography: An ecological and evolutionary approach. Wiley-Blackwell.
- Cox, L. R., & Moore, P. D. (2010). Biogeography: An introduction to the study of plants and animals in time and space. Wiley-Blackwell.
- Heads, M. (2019). Biogeography and evolution. New Zealand. CRC Press.
- Lieberman, B. S., & Garland, R. L. (2020). Phylogenetic trees made easy: A how-to manual. Sinauer Associates.
- Lomolino, I., Riddle, B. R., & Whittaker, R. J. (2016). Biogeography: Principles and Practice. Sinauer Associates.

- Pressey, R. L., Anderson, M. B., & Groves, R. G. (2019). Systematic conservation planning. Oxford University Press.
- Wiley, E. H., & Lieberman, B. S. (2011). Systematics and evolution: Theory and practice. Wiley-Blackwell.

Suggestive readings

- Antonelli, A. (2019). Historical biogeography: An introduction. Princeton University Press.
- Dayrat, B. H. E. W. (2005). Phylogenetic systematics. University of Kansas Press.
- Guglielmino, A. G., & Barbujani, A. V. (2017). Biogeography: A natural science of human diversity. Cambridge University Press.
- Hennig, P. (1966). Systematics: A course of lectures. Columbia University Press.
- Nei, M., & Kumar, S. (2020). Molecular evolution and phylogenetics. Oxford University Press.
- Revell, L. V. (2020). Phylogenetic comparative methods: A guide for ecologists. Princeton University Press.
- Wiley, E. O. (2020). Phylogenetics: Theory and practice of phylogenetic systematics. John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 11 (DSC-EVS-11): ENVIRONMENTAL TOXICOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-EVS-11: ENVIRONMENTAL TOXICOLOGY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Analyze sources, fate, and effects of toxic substances in the environment
- Train in methods relevant to assess and manage environmental risks associated with toxic substances
- Investigate the impact of environmental toxicants on wildlife and ecosystems, including the effects on reproductive success and population dynamics.
- Examine management practices related to the use, disposal, and treatment of hazardous substances and wastes.
- Compare scientific methods and techniques to measure and monitor environmental toxicants in different environmental media.
- Familiarize with emerging issues and technologies in environmental toxicology
- Promote critical thinking and problem-solving skills through case studies and hands-on activities related to environmental toxicology.

Learning outcomes

After this course, students will be able to

- Define and describe the scope and historical background of environmental toxicology.
- Identify, classify, and predict fate and transport of different types of toxic substances in the environment
- Evaluate the risks associated with toxic substances and apply risk assessment and management strategies
- Analyze the effects of toxic substances on wildlife and ecosystems, and propose solutions to mitigate their impacts.
- Compare and contrast the toxicity of different pollutants and their possible mechanisms of action.
- Apply their knowledge of environmental toxicology to current environmental issues and develop potential solutions.

SYLLABUS OF DSC-EVS-11

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Environmental Toxicology (1 Week) (2 lectures)
Definition, Historical perspective, Types of Toxic substances: types, properties, sources, and fate and transport, biomagnification and bioaccumulation.

UNIT –II Toxicology of Air and Water (2 Weeks) (4 lectures)
Toxic air contaminants, Health effects of air pollution, Acid rain and its impacts, Ozone depletion and its impacts, Water pollution and its sources, Health effects of water pollution, Eutrophication and hypoxia in aquatic ecosystems, Marine pollution and its impacts, Emerging issues in air and water toxicology

UNIT –III Toxicology of Soil and Hazardous Waste (3½ Weeks) (7 lectures)
Sources and types of hazardous waste, Health effects of soil contamination: from heavy metals, metalloids, and organic contaminants; Brownfields and urban redevelopment, Superfund sites and environmental justice, Pesticide and Pharmaceuticals: classification, history of use, distribution in environment, fate and transport, health effects, and ecotoxicology; Emerging issues in environmental toxicology by hazardous waste, pesticides and pharmaceuticals

UNIT –IV Toxicology of Radiation and Nanoparticles (3 Weeks) (6 lectures)
Ionizing and non-ionizing radiation, Health effects of radiation, Radioactive waste and nuclear accidents, Nanoparticles: properties, behavior in the environment, fate and transport, health effects, and ecotoxicology; Emerging issues in radiation and nanoparticle toxicology, Risk assessment and risk management of radiation and nanoparticles

UNIT –V Emerging Issues in Environmental Toxicology (2½ Weeks) (5 lectures)
Endocrine disruption and its impacts, Climate change and toxicology, Emerging contaminants (e.g., microplastics, PFAS), Global perspectives, Ethics in environmental toxicology, Careers in environmental toxicology, Future directions in environmental toxicology research

UNIT –VI Management and regulation of environmental toxicants (1½ Weeks) (3 lectures)
Environmental regulations and policy, Hazardous waste regulations and management, Pesticide and pharmaceutical use and regulation, Ecotoxicology and wildlife toxicology, Risk assessment and risk management, Remediation and restoration of contaminated sites

UNIT –VII Environmental forensics (1½ Weeks) (3 lectures)
Definition, Applications in environmental toxicology, Common techniques (e.g., isotope analysis, DNA fingerprinting), Case studies in identifying sources of contamination, Future developments and potential applications in environmental sustainability.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Analyze effects of pH on the toxicity of heavy metals on model organism, such as Daphnia
2-3. Determine toxicity of varying concentration of industrial effluent on common alga and measure its growth and survival rates
4-5. Effects of heavy metal toxicity on plant growth, focussing on different plant parts and physiological characteristics
6. Analyze effects of climate change on the abundance and diversity of pollinators under different climatic conditions
7. Analyze the abundance and diversity of nematodes (e.g., Caenorhabditis elegans) in the background of use of environmental chemicals
8. Effects of herbicides on the abundance and diversity of weed populations in response to the use of different herbicides
9. Test the effects of a target organic contaminant on behaviour and mortality of earthworm
10-11. Measure developmental abnormalities in zebrafish embryos due to toxicity of target environmental chemicals
12-13. Prepare and characterize nanoparticles of selected heavy metal and assess effect of nanoparticles on plant growth
14. Effects of various concentrations of road salt on freshwater organisms (e.g., zooplankton) and measure changes in their behavior and survival

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Crosby, D. G. (2019). Environmental toxicology and chemistry (3rd ed.). CRC Press.
- Landis, W. G., Sofield, R. M., & Yu, M.-H. (2019). Introduction to environmental toxicology (4th ed.). CRC Press.
- Lehrer, I., & Poole, J. B. (2019). Principles of environmental toxicology (4th ed.). CRC Press.
- Newman, M. C., Roberts, M. H., Hale, R. C., & Robinson, E. M. (Eds.). (2020).

Environmental Toxicology: Biological and Health Effects of Pollutants (4th ed.). CRC Press.
- Yu, M.-H., & Yan, G. W. S. (2020). Environmental toxicology: Biological and health effects of pollutants (3rd ed.). CRC Press.

Suggestive readings

- Ballantyne, B., Marrs, T. C., & Syversen, T. (2020). Toxicology: The basic science of poisons (4th ed.). CRC Press.
- Kamrin, M. A. (2020). Introduction to Environmental Toxicology: Molecular Substructures to Ecological Landscapes (5th ed.). CRC Press.
- Meyers, R. A. (Ed.). (2018). Environmental toxicology: Selected entries from the Encyclopedia of Sustainability Science and Technology. Springer
- Smart, R. C., & Hodgson, E. (2018). Molecular and biochemical toxicology (5th ed.). John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 12 (DSC-EVS-12): RESTORATION ECOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-EVS-12: RESTORATION ECOLOGY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Gain insights into principles and concepts of restoration ecology to understand various approaches and techniques used in ecological restoration
- Provide hands-on experience with ecological restoration techniques and field methods
- Promote critical thinking and problem-solving skills in the context of ecological restoration for innovation related methods
- Investigate the interdisciplinary issues and practices linked with ecological restoration

Learning outcomes

After this course, students will be able to

- Describe the ecological, economic and social factors that lead to ecosystem degradation
- Evaluate and select appropriate ecological restoration techniques for different types of ecosystems
- Design ecological restoration projects and identify appropriate methods to monitor and evaluate the restoration practices
- Undertake collaborative programmes to understand and solve ecological restoration problems
- Critically evaluate the scientific and technical aspects of ecological restoration research and practice.

SYLLABUS OF DSC-EVS-12

Theory (02 Credits: 30 lectures)

UNIT – I Fundamentals of Restoration Ecology (3½ Weeks) (7 lectures)

Definition and history of restoration ecology, Principles of restoration ecology, Restoration process: planning, implementation, and monitoring; Ecosystem services and the importance of restoration ecology; Challenges and limitations of restoration ecology; Case studies in restoration ecology; Ethics and values in restoration ecology; Restoration ecology and environmental policy

UNIT – II Ecological Foundations for Restoration Ecology: (3 Weeks) (6 lectures)

Role of ecological concepts in restoration ecology: ecological succession. Biodiversity, ecological interactions, and habitat fragmentation and ecosystems; Climate change and its impact on restoration ecology, Invasive species and their role in ecosystem degradation and restoration, Ecological thresholds, and their relevance to restoration ecology

UNIT – III Techniques and Tools for Restoration Ecology (3 Weeks) (6 lectures)

Ecological site assessment and inventory, Restoration planning and design, Techniques for soil and water conservation in restoration ecology, Seed collection, propagation, and planting techniques for restoration, Wildlife management in restoration ecology, Restoring aquatic ecosystems: techniques and challenges, Biomimicry and ecological engineering in restoration ecology. Evaluating and monitoring restoration outcomes

UNIT – IV Ecosystem Restoration (2 Weeks) (4 lectures)

Restoration of: grasslands, forests, wetlands, agricultural and urban landscapes, mining and industrial sites; Restoration of ecosystem services in aquatic ecosystems

UNIT – V Synthesis and Applications of Restoration Ecology (3½ Weeks) (7 lectures)

Integrating restoration ecology with conservation biology, Adaptive management in restoration ecology, Restoring ecosystem services and human well-being, Restoring cultural and spiritual values in ecosystems, Restoring resilience and resistance in ecosystems, Restoring ecosystem connectivity and migration corridors, Restoring biodiversity in the face of global change, and The future of restoration ecology and its role in sustainability

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Field visits to assess the magnitude of degradation in selected ecosystems
2. Analyse the success of ecosystem restoration case studies in Delhi and identify the underlying principles
3. Assess the current status of a degraded ecosystem and identify potential areas for restoration
4. Learn techniques for collecting and propagating native plant species for use in restoration projects

5-6. Design methods for reducing erosion and managing nutrient runoff in restored ecosystems
7-8. Examine techniques for planting and establishing native plant species in a restored ecosystem
9-10. Evaluate methods for assessing and managing wildlife habitat in a restored ecosystem
10-11. Assess efficacy of different methods for monitoring and evaluating restoration outcomes in a restored ecosystem
12. Learn techniques for managing invasive species in a restored ecosystem
13-14. Design and implement a restoration plan for selected degraded ecosystems (terrestrial and aquatic) to improve the quality of habitat

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Clewell, A. F., & Aronson, J. (Eds.). (2013). Ecological restoration: Principles, values, and structure of an emerging profession (2nd ed.). Island Press.
- Erickson, A. L., Ryan, C. M., & Jones, T. A. (Eds.). (2021). The science of ecological restoration: Creating resilience in a changing world. Island Press.
- Hobbs, R. J., & Suding, K. N. (2018). New models for ecosystem dynamics and restoration. CRC Press.
- Palmer, M. A. (2016). Restoration: The science of restoring ecosystems and the human spirit. Island Press.
- Temperton, V. M., Hobbs, R. J., Nuttle, T., Halle, S., & Tonev, C. (Eds.). (2020). Novel ecosystems: Intervening in the new ecological world order. John Wiley & Sons.
- Yaffee, S. L., & Wondolleck, J. M. (2019). Ecosystem management in the United States: An assessment of current experience. Routledge.

Suggestive readings

- Allison, S. D., & Murphy, S. D. (Eds.). (2019). Ecosystem collapse and restoration. Oxford University Press.
- Benedetti-Cecchi, L. (2021). Marine restoration ecology. Oxford University Press.
- Benson, M. H., & Phillips, A. (Eds.). (2016). Ecosystem services and conservation in urbanizing Asia. Springer.
- Higgs, E. S., Falk, D. A., Guerrini, A., Hall, M. P., & Harris, J. G. (Eds.). (2021). The Routledge handbook of ecological and environmental restoration. Routledge.
- Moreno-Mateos, D., & Perring, M. P. (Eds.). (2019). Ecological restoration and environmental change: Renewing damaged ecosystems in a changing world. Routledge.
- Palmer, M. A., Zedler, J. B., & Falk, D. A. (Eds.). (2021). Foundations of restoration ecology (2nd ed.). Island Press.

- Suding, K. N., & Hobbs, R. J. (Eds.). (2019). Handbook of restoration ecology (2nd ed.). Oxford University Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-10): ECOSYSTEM MONITORING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-10: ECOSYSTEM MONITORING	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Introduce principles and practices of monitoring ecological systems for designing and implement monitoring programmes
- Provide knowledge of the importance of monitoring for conservation and management of natural resources.
- Impart skills in data analysis and interpretation and provide with hands-on experience in monitoring programmes
- Encourage to communicate the results of monitoring programs effectively and promote ethical principles in monitoring

Learning outcomes

After the course, the students will be able to

- Explain the principles of ecosystem monitoring and design and implement monitoring programmes
- Analyze and interpret data from monitoring programmes and identify specific monitoring methods for conservation and management of natural resources
- Conduct monitoring programmes and communicate the results effectively
- Apply ethical and scientific principles in monitoring programmes

SYLLABUS OF DSE-EVS-10

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Ecosystem Monitoring (2½ Weeks) (05 lectures)

Introduction to ecosystem monitoring, Principles of ecosystem monitoring, Importance of monitoring for conservation and management, Types of monitoring programmes, Steps in designing a monitoring programme, Sampling methods, Data analysis and interpretation, Communication of monitoring results, Ethics in monitoring, Case studies in ecosystem monitoring

UNIT – II Ecological Indicators (3 Weeks) (06 lectures)

Definition and types of ecological indicators, Commonly used ecological indicators in different ecosystems (e.g., terrestrial, aquatic, marine), Measurement techniques for ecological indicators (e.g., field sampling, remote sensing, citizen science), Interpretation of ecological indicators and their relationship to ecosystem health and function, Applications of ecological indicators in environmental management and policy

UNIT – III Sampling Techniques (4 Weeks) (08 lectures)

Different types of sampling techniques and their advantages and limitations, Sampling design and planning for ecosystem monitoring (e.g., sample size, spatial and temporal scales), Sampling protocols and techniques for climate and different types of ecosystem components, (e.g., soil, water, air, biota), Quality assurance and quality control in ecosystem monitoring sampling, Data management and analysis considerations for sampling data

UNIT – IV Data Analysis and Visualization (3½ Weeks) (07 lectures)

Types of data collected in ecosystem monitoring (e.g., continuous, discrete, categorical), Statistical techniques and software for analyzing ecosystem monitoring data (e.g., regression analysis, multivariate analysis, machine learning), Data visualization techniques for ecosystem monitoring data (e.g., charts, graphs, maps), Communicating monitoring results to stakeholders (e.g., reports, presentations, online platforms), Ethical considerations in the analysis and visualization of ecosystem monitoring data

UNIT – V Ecosystem Monitoring in Practice (2 Weeks) (04 lectures)

Overview of a specific ecosystem monitoring program (e.g., the National Ecological Observatory Network, Long-Term Ecological Research sites), Planning and design of an ecosystem monitoring project, Analysis of a case study of ecosystem monitoring with respect to different practices mentioned in other units, Reflection on the challenges and opportunities of implementing ecosystem monitoring programs in practice.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Measure plant diversity using different methods to assess species richness, diversity indices, and community structure
2. Survey nearby ecosystem to identify and monitor invasive species and its possible impact
3. Analyze remote sensing data for ecosystem monitoring, including satellite imagery and aerial photographs
4. Learn different soil sampling methods and monitor soil properties
5. Measure potential carbon sequestration by trees of a nearby area
6. Analyze climate data, including temperature, precipitation, and atmospheric carbon dioxide concentrations
7. Hands-on experience in testing water quality parameters such as pH, dissolved oxygen, and nutrients using rapid methods
8. Conduct bird surveys and identify common bird species of nearby ecosystem
9. Hands-on experience in setting up and monitoring wildlife camera traps, and identifying common wildlife species
10. Design and conduct social surveys to understand public perceptions, attitudes, and behaviors related to ecosystem (wetland, etc.) monitoring
11. Record and monitor leaf-out, flowering, and fruiting of selected species of nearby ecosystem
12. Survey amphibians in ecosystems by method of your choice including visual surveys or call surveys or capture-mark-recapture
13. Sample and identify insects in a nearby area, including sweep netting or pitfall traps or light traps
14. Engage citizen scientists in ecosystem monitoring programme, including data collection, quality assurance, and community engagement

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Bartram, J., & Ballance, R. (2017). Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs. CRC Press.
- Becker, C. G., Bastos, R. P., & Silvano, D. L. (2021). Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press
- Burden, F. R., & Pitt, R. F. (2013). Environmental Monitoring Handbook. McGraw Hill.
- Lindenmayer, D., Gibbons, P., & Bennett, A. (2019). Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. CSIRO Publishing
- Stenseth, N. C., & Furevik, T. (2016). Principles and Methods of Ecosystem-based Management. CRC Press.

Suggestive readings

- Aronson, J. (2017). The Practice of Ecosystem Services Evaluation: An Introduction. Springer.
- Ferretti, M., & Fischer, R. (2013). Forest Monitoring: Methods for Terrestrial Investigations in Europe with an Overview of North America and Asia. Elsevier.
- Kobayashi, T., Yang, W., & Qi, Y. (2020). Remote sensing of ecosystem health with prism and modis data. CRC Press.
- Krkosek, M., & Bateman, A. (2019). Wildlife Population Monitoring: Some Practical Considerations. Oxford University Press.
- Rees, Y., Brazeau, M., & Santos, L. F. (2021). Environmental monitoring using UAVs. Springer.
- Schulin, R., & Kutílek, M. (2017). Soil Monitoring: Early Detection and Surveying of Soil Contamination and Degradation. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-EVS-11): ENVIRONMENTAL INDICATORS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-11: ENVIRONMENTAL INDICATORS	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Understand the concept of environmental indicators and their role in measuring and assessing environmental quality
- Learn how to select, analyze, and interpret various types of environmental indicators to evaluate the condition of natural resources and ecosystems
- Develop an understanding of select and use environmental indicators in environmental policy and decision-making
- Learn about the practical applications of environmental indicators in different sectors such as government, business, and non-governmental organizations.
- Gain an appreciation of the interdisciplinary nature of environmental indicators, and the importance of collaboration among different disciplines to address environmental issues

Learning outcomes

After successful completion of this course, students will be able to:

- Define, describe and identify environmental indicators to measure and assess environmental quality
- Select appropriate environmental indicators based on specific environmental issues, and apply appropriate methods for data collection and analysis
- Evaluate the effectiveness of different environmental indicators and their relevance to environmental policy and decision-making.
- Communicate environmental indicator data effectively to different audiences using appropriate formats and techniques.
- Apply knowledge and skills in business, society, policy formulation and implementation, to address environmental issues

SYLLABUS OF DSE-EVS-11

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Environmental Indicators (2 Weeks) (4 lectures)
Environmental Indicators: overview, types, relevance in environmental sustainability, environmental health and social justice, Principles of Environmental Indicator Selection, Environmental Monitoring and Data Collection. Environmental Indicator Reporting and Communication

UNIT – II Air Quality Indicators (2 Weeks) (4 lectures)
Air Pollution Sources and Emissions, Criteria Air Pollutants and their Health Effects, Ozone Depletion and Stratospheric Ozone Protection, Indoor Air Quality and Health; Air Quality: standards, guidelines, monitoring, sampling, management strategies, policies, trends and projections, Quality parameters: particulate matter, ozone, nitrogen oxides, sulfur dioxide, carbon monoxide, volatile organic compounds, lead, radon, and carbon dioxide
.

UNIT – III Water Quality Indicators (2½ Weeks) (5 lectures)
Water Pollution Sources and Pathways, Surface Water and Groundwater Quality Indicators, Drinking Water Quality and Treatment, Water Pollution Control Strategies and Policies, Non-Point Source Pollution and Best Management Practices, Water Quality: standards, guidelines, monitoring, sampling, trends and projections; Quality parameters: dissolved oxygen, pH, temperature, turbidity, nutrient concentrations, chlorophyll-a, biological oxygen demand, fecal coliform bacteria, total dissolved solids, and toxic substances

UNIT – IV Biodiversity Indicators (2½ Weeks) (5 lectures)
Biodiversity: concepts, definitions, components, levels, measurement, assessment, threats, conservation strategies and policies, trends and projections; Ecosystem Services and Biodiversity, Biodiversity and Climate Change, Parameters: species richness and diversity, genetic diversity, endemic species, threatened species, habitat extent, fragmentation and quality, ecosystem services

UNIT – V Land Use and Soil Indicators (3½ Weeks) (7 lectures)
Land Use and Land Cover Change, Urbanization and Suburbanization Trends, Productivity of Agricultural and Forests, Wilderness Management, Mining and Mineral Extraction Impacts, Land Use and Ecosystem Services, Land Use Planning and Policy, Land Use Change and Climate Change; Soil health: soil organic matter, texture, pH, nutrients, biodiversity and microbial activity, respiration aggregate stability, compaction, and water holding capacity

UNIT – VI Climate Change Indicators (2½ Weeks) (5 lectures)
Greenhouse Gas Emissions and Sinks, Climate Change: science, impacts mitigation strategies and policies, adaptation strategies and policies, vulnerability and risk assessment; Climate Change Indicators: for terrestrial and aquatic ecosystems, for human health and societal well-being (average global temperature, sea-level rise, ocean acidification, carbon dioxide concentrations, extreme weather events, arctic sea ice and glaciers and ice sheets,

ecosystem productivity and species phenology, heat-related and mediated illnesses, total energy consumption); and Climate Change and Global Environmental Governance

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Investigate variations in different surfaces to absorb and reflect heat
2. Determine pattern of sea-level rise at selected coastal location over time and propose its causes and potential impacts
3. Investigate the sources and concentrations of carbon dioxide in different indoor and outdoor environments and explore ways to reduce carbon dioxide emissions
4. Collect and analyze data on weather patterns and events over time and investigate the impacts of extreme weather events on human communities and ecosystems
5. Monitor changes in Arctic sea ice extent and thickness over time and investigate the impacts of sea ice loss on Arctic ecosystems and global climate
6. Conduct field surveys to measure plant and animal diversity and abundance in different habitats and investigate the impacts of habitat loss and fragmentation on biodiversity
7. Analyze air and water quality data in different urban and rural environments and investigate the links between environmental pollution and human health outcomes
8. Monitor energy consumption and greenhouse gas emissions in different households, buildings, and industries and investigate strategies for reducing energy use and transitioning to renewable energy sources
9. Compare different land use change for variations in soil health and fertility
10. Analyze the impact of land use on health of selected water bodies
11. Conduct surveys to identify the links between environmental exposure of noise or air pollution and onset of stress and anxiety in humans
12. Monitor glacier and thickness of ice sheet using GIS and identify the changes in glacier and water resources and rise in sea level
13. Analyze the relationship between economic growth and environmental impacts using temporal data from economics and environment and suggest ways to promote sustainable development
14. Use the case study method to analyze companies having prioritized environmental and social concerns in their business practices and their impacts on society, environment, and economy

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Hák, T., Moldan, B., & Dahl, A. L. (2020). Sustainability indicators: A scientific assessment. Springer.
- Mulder, K. F. (2018). Environmental sustainability indicators: An introduction. Routledge.
- Murgante, B., Misra, S., Carullo, A., & Torre, C. M. (Eds.). (2019). Environmental sustainability indicators for industry: Methods and tools. Springer.
- Saad-Sulonen, J., & Horelli, L. (2020). Urban environmental indicators: Tools for liveability and sustainability. Routledge.
- Sala, S., & Farioli, F. (2020). Environmental Indicators: Tools for Evaluation and Decision Making in Resource Management. Springer.

Suggestive readings

- Brouwer, R., & van Ek, R. (Eds.). (2021). Environmental and Resource Valuation with Revealed Preferences: Approaches and Methods. Routledge.
- Campbell, L. M., Gray, N. J., & Fairbanks, L. W. (Eds.). (2021). The Routledge Handbook of Environmental Governance and Sustainability. Routledge.
- Farinha-Marques, P., & Pina, A. (2019). Green supply chain management: Environmental sustainability indicators. Springer.
- Singh, R. B., & Mallick, J. (2019). Eco-friendly and sustainable agriculture: Environmental sustainability indicators. Springer.
- Tukker, A., & Dietz, F. (Eds.). (2020). Environmental Indicator Frameworks for Policy: A Comparative Analysis of Approaches in Europe. Routledge.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-12): ECOSYSTEM STEWARDSHIP

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-12: ECOSYSTEM STEWARDSHIP	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Introduce the principles and practices of ecosystem stewardship for valuing ecosystems from the perspective of ecology, society, and economy
- Explore the challenges and opportunities of managing ecosystems in a changing world.
- Provide hands-on experience in ecosystem management through practical exercises and case studies
- Foster communication and collaboration skills for engaging with stakeholders in ecosystem stewardship

Learning outcomes

After the course, students will be able to:

- Demonstrate an understanding of the key principles and practices of Ecosystem Stewardship
- Identify and describe the ecological, social, and economic values of ecosystems
- Apply practical tools and techniques for ecosystem management, including stakeholder engagement, biodiversity assessment, and habitat restoration
- Analyze and interpret data on ecosystem health and identify strategies for ecosystem restoration and conservation
- Develop effective communication and collaboration skills for engaging with stakeholders in ecosystem stewardship

SYLLABUS OF DSE-EVS-12

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Ecosystem Stewardship (2½ Weeks) (5 lectures)
Concept of Ecosystem Stewardship, Ecological Principles of Ecosystem Stewardship, Historical and Contemporary Perspectives, Role of stewardship in conservation, Ethics and Values in Ecosystem Stewardship, Importance of Ecosystem Services, Ecosystem Resilience and Sustainability, Ecosystem Restoration and Rehabilitation

UNIT – I Ecosystem Management (2 Weeks) (4 lectures)
Principles of Ecosystem Management, Ecosystem Management Planning and Implementation, Multiple Use Management, Ecosystem-Based Management, Adaptive Management, Stakeholder Engagement and Collaboration, Legal and Institutional Frameworks for Ecosystem Management, Economic Valuation of Ecosystem Services

UNIT – I Ecosystem Restoration (2 Weeks) (4 lectures)
Principles of Ecosystem Restoration, Restoration Planning and Implementation, Ecological Succession and Restoration, Restoration Techniques and Strategies, Restoration of Degraded Landscapes, Restoring Biodiversity and Ecosystem Functioning, Community-Based Restoration, Monitoring and Evaluation of Ecosystem Restoration

UNIT – IV Biodiversity Conservation and Ecosystem Services (3 Weeks) (6 lectures)
Biodiversity: importance of conservation, threats, link with ecosystem services; Conservation Planning and Implementation, Protected Areas and their Management, Habitat Restoration and Management, Wildlife Conservation, Invasive Species Management, Community-Based Conservation, Ecosystem Services: types, economic valuation, ecological and social drivers; Trade-offs and Synergies in Ecosystem Services, Payments for Ecosystem Services, Green Infrastructure and Ecosystem Services, Case studies of Ecosystem Services

UNIT – V Human Dimensions of Ecosystem Stewardship (2½ Weeks) (5 lectures)
Human-nature relationship and its impact on Ecosystems, Social-Ecological Systems and their Resilience, Indigenous and Local Knowledge Systems, Community-Based Management and Decision Making, Conflict Management and Resolution, Environmental Justice, Public Participation and Environmental Governance, Cultural Diversity and Ecosystem Stewardship

UNIT – VI Emerging Issues in Ecosystem Stewardship (3 Weeks) (6 lectures)
Influence of Climate Change on: natural ecosystems, agriculture, and urban ecosystems; Integrated watershed management, energy and natural resources, Linking technology with ecosystem stewardship, Ecosystem-based disaster risk reduction, Policy and legal frameworks, Stakeholder participation, Decentralized governance and community-based management, Future directions in ecosystem stewardship.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Conduct a baseline assessment of a local ecosystem, including identifying key ecological features, ecosystem services, and human impacts
2. Develop a management plan for a local ecosystem, including setting objectives, identifying management actions, and monitoring progress
3. Conduct a stakeholder analysis for an ecosystem management project, including identifying stakeholders, assessing their interests and needs, and developing strategies for engagement
4. Identify and map habitats in a local ecosystem, including key species and their ecological roles
5. Develop a restoration plan for a degraded ecosystem, including identifying restoration objectives, selecting appropriate restoration techniques, and monitoring progress
6. Assess the economic value of ecosystem services in a local ecosystem, including identifying beneficiaries, estimating the economic value of services, and developing strategies for payment
7. Carry out a social impact assessment of an ecosystem management project, including identifying and assessing potential social impacts, and developing strategies for mitigating negative impacts and enhancing positive impacts
8. Develop a community-based ecosystem management project, including identifying and engaging stakeholders, developing a collaborative management plan, and evaluating project outcomes
9. Develop a climate adaptation plan for a local ecosystem, including identifying vulnerable species and ecosystems, developing adaptation strategies, and monitoring progress
10. Evolve a payment for ecosystem services (PES) project for a local ecosystem, including identifying beneficiaries, estimating the economic value of services, and developing a PES scheme
11. Conduct an ecosystem-based disaster risk reduction project, including identifying vulnerable ecosystems, developing strategies for risk reduction, and monitoring progress
12. Develop a water resources management project within your institute or residential area, including identifying and addressing water scarcity, improving water quality, and developing water governance mechanisms
13. Plan an urban ecosystem management project, including identifying green infrastructure, improving air quality, and enhancing biodiversity in urban areas

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Baggio, J. A., Barnett, A. J., Perez-Ibarra, I., & Rubiños, C. (Eds.). (2021). Governance for ecosystem stewardship: An institutional perspective. Routledge.
- Chapin III, F. S., Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., & Clark, W. C. (2010). Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Springer.
- Hobbs, R. J., Higgs, E. S., & Hall, C. M. (Eds.). (2019). Ecosystem stewardship: Principles and practices for sustainability and resilience. CRC Press.
- Kareiva, P., & Marvier, M. (2012). Conservation science: Balancing the needs of people and nature. Roberts & Company.
- Peterson, G. D., & Cumming, G. S. (2013). Scenario planning: a tool for conservation in an uncertain world. The University of Chicago Press.

Suggestive readings

- Berkes, F. (2017). Sacred ecology. Routledge.
- Brown, K., & Westaway, E. (2011). Agency, capacity, and resilience to environmental change: Lessons from human development, well-being, and disasters. Routledge.
- Côté, I. M., & Darling, E. S. (2021). Conservation in the Anthropocene ocean. Oxford University Press.
- Kareiva, P., & Marvier, M. (2020). Conservation science: Balancing the needs of people and nature. Roberts & Company.
- Peterson, G. D., Cumming, G. S., & Carpenter, S. R. (Eds.). (2021). Scenario planning for conservation and management. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-13): GREEN URBANIZATION

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-13: GREEN URBANIZATION	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Develop an understanding of the principles, concepts, challenges and opportunities of green urbanization and sustainable urban development
- Impart skills in designing sustainable urban development strategies that promote environmental, social, and economic sustainability
- Empower with evaluating the effectiveness of sustainable urban development strategies.
- Provide insights into the role of urban planning and policy in promoting green urbanization and sustainable urban development
- Gain importance of social equity and community engagement in green urbanization and sustainable urban development

Learning outcomes:

After the course, students will be able to

- Describe the principles and concepts of green urbanization and its linkages with sustainable development
- Design sustainable urban development strategies that promote environmental, social, and economic sustainability
- Evaluate and explain the effectiveness of sustainable urban development strategies and the role of urban planning and policy in promoting green urbanization
- Explain the importance of interdisciplinary and collaborative approaches to green urbanization and sustainable urban development
- Communicate and collaborate effectively with stakeholders in green urbanization and sustainable urban development projects

SYLLABUS OF DSE-EVS-13

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Green Urbanization and Sustainable Urban Design (3½ Weeks) (7 lectures)

What is Green Urbanization?, Concept of sustainability in urbanization, Historical context and evolution of urbanization, Challenges and opportunities of Green Urbanization, Role of urban planning in promoting Green Urbanization

Principles of sustainable urban design, Importance of green spaces in urban areas, Role of urban design in promoting sustainable transportation, Importance of green infrastructure in urban areas, Urban heat island mitigation strategies

UNIT – II Sustainable Transportation (2 Weeks) (4 lectures)

Sustainable transportation planning and policy, Public transportation systems and infrastructure, Active transportation options and infrastructure (walking, biking), Electric vehicles and charging infrastructure, Transit-oriented development (TOD) and its benefits

UNIT – III Green Buildings and Energy Efficiency (2 Weeks) (4 lectures)

Principles of green building design, Energy-efficient building design and technologies, Role of building codes and standards in promoting green building, Renewable energy systems for urban areas, Green building certification programs and their benefits

UNIT – IV Sustainable Water Management (2 Weeks) (4 lectures)

Importance of sustainable water management in urban areas, Water conservation and efficiency strategies, Sustainable stormwater management, Water reuse and recycling strategies, Green infrastructure for stormwater management

UNIT –V Sustainable Waste Management (2 Weeks) (4 lectures)

Importance of sustainable waste management in urban areas, Strategies for reducing waste and increasing recycling, Composting and organic waste management, Waste-to-energy technologies and their benefits, Extended Producer Responsibility (EPR) and its role in sustainable waste management

UNIT –VI Social Equity and Financing Green Urbanization (3½ Weeks) (7 lectures)

Social equity-environmental justice-green urbanization, Community for sustainable urban planning, Strategies for affordable housing and sustainable development, Green spaces for all

Public-private partnerships for sustainable urban development, Green bonds and sustainable urban projects, Tax incentives for green urbanization, Green banks and financing for urban sustainability, Crowdfunding and for financing urban sustainability

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Conduct a case study on a green urban development project and evaluate its effectiveness in promoting sustainability
2. Design a green infrastructure plan for a specific urban area, considering factors such as land use, vegetation, and water management
3. Develop a sustainable transportation plan for an urban area, incorporating options such as public transit, cycling, and walking
4. Conduct a building energy audit and recommend strategies for reducing energy consumption and increasing efficiency
5. Develop a green building certification programme and evaluate its potential benefits for promoting sustainable urban development.
6. Design a stormwater management plan for an urban area, incorporating green infrastructure and water reuse strategies
7. Conduct a waste audit and recommend strategies for reducing waste and increasing recycling in an urban area
8. Develop a green space plan for an urban area, considering factors such as biodiversity, recreation, and community engagement
9. Design a sustainable urban food system plan, considering factors such as local food production, distribution, and waste reduction
10. Conduct a social equity assessment of a green urban development project and recommend strategies for promoting equitable outcomes
11. Survey of public perceptions of green urbanization and evaluate the potential for public support
12. Develop a public outreach campaign to promote green urbanization and sustainability
13. Analyze the potential for green jobs and economic development in the green urbanization sector

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Abbott, C. (2021). Greening cities in Asia: Governance, institutions and urban development. Edward Elgar Publishing.
- Beatley, T. (2018). Biophilic cities: Integrating nature into urban design and planning. Island Press.
- González, J. A. (2020). Green infrastructure in urban planning: A guide for practitioners. Routledge
- Mahmood, A. (2020). Green urbanism: Formulating a sustainable urban future. Routledge.
- Roberts, P., & Sykes, O. (2018). Urban green spaces: A complete guide to parks, gardens, and other outdoor spaces in towns and cities. Routledge.

- Zhang, Y., & Lu, Y. (2021). Smart and green urban development: New concepts and strategies for sustainable mobility. Routledge.

Suggested readings

- Beatley, T. (2021). Green urbanism down under: Learning from sustainable communities in Australia. Island Press.
- Christensen, P., & Nilsson, K. (2020). Sustainable urban development: A smart and green approach to city regeneration. Palgrave Macmillan.
- Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice. Springer.
- Puppim de Oliveira, J. A. (2019). Urban sustainability in the context of climate change: Adaptation, resilience, and opportunities in cities. Springer.
- Zhang, Y. (2019). Urban regeneration and sustainability: Best practices from European cities. Routledge.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-14): ENERGY AND ENVIRONMENT

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-14: ENERGY AND ENVIRONMENT	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Introduce fundamental concepts and principles related to the energy and environment
- Gain knowledge of the sources of energy and the impacts of its production and consumption
- Identify the technological, economic, and social perspective of energy
- Analyze the environmental and social implications of energy sources and evaluate policies related to energy for sustainable environmental practices
- Foster awareness of the interconnectedness of global energy and environmental issues

Learning outcomes:

After the course, students will be able to

- Explain the principles and concepts of energy and its impacts on environment
- Evaluate the merit and demerits of different energy sources and associated technologies
- Analyze the environmental and social implications of energy production and consumption
- Evaluate the effectiveness of policies and strategies for promoting sustainable energy and environmental practices.
- Advocate for sustainable energy and environmental practices as informed and active citizens

SYLLABUS OF DSE-EVS-14

Theory (02 Credits: 30 lectures)

UNIT – I Concepts of Energy and Environment (1 Weeks) (2 lectures)
Definition and scope of energy and environment, Types of energy and their environmental impacts, Energy production and consumption trends, Global warming and climate change, Ecological footprint, Energy and environmental policies, Environmental impact assessment, Sustainable development

UNIT – I Fossil Fuels and their Environmental Impact (1 Weeks) (2 lectures)
Coal, oil, and gas extraction and processing, Greenhouse gas emissions and climate change, Air pollution from fossil fuels, Water pollution from fossil fuels, Environmental impacts of oil spills, Acid rain, Land degradation from mining, Fossil fuel dependence and energy security

UNIT – II Renewable Energy Sources (1 Weeks) (2 lectures)
Solar energy, Wind energy, Geothermal energy, Hydroelectric power, Ocean energy, Bioenergy, Biomass and biofuels, Renewable energy technologies and their environmental impact

UNIT – III Energy Efficiency and Conservation (2 Weeks) (4 lectures)
Energy efficiency in buildings, Energy-efficient appliances and electronics, Transportation efficiency and fuel economy, Energy conservation behaviours, Energy audits and retrofits, Green building design and construction, Smart grids and energy storage, Energy-efficient lighting

UNIT – IV Energy and the Environment in Developing Countries (3½ Weeks) (7 lectures)
Energy access and poverty alleviation, Energy consumption patterns in developing countries, Clean energy technologies for developing countries, Environmental impacts of energy in developing countries, Energy and sustainable development, Energy financing and investment in developing countries, Capacity building and technology transfer, International cooperation on energy and the environment, India's efforts for a sustainable sources of energy and self-reliance

UNIT – V Environmental Impacts of Nuclear Energy (2½ Weeks) (5 lectures)
Nuclear power generation and its environmental impact, Nuclear accidents and their environmental impact, Nuclear waste management and disposal, Nuclear proliferation and security risks, Alternatives to nuclear energy, Public perception of nuclear energy, Nuclear energy and climate change, Nuclear energy policies and regulations

UNIT –VI Energy Policy and Regulation (2½ Weeks) (5 lectures)
International energy policies and agreements, National energy policies and goals, Renewable energy incentives and subsidies, Fossil fuel subsidies and taxation, Energy market regulation, Energy efficiency standards and labelling, Carbon pricing and emissions trading, Energy security and geopolitical considerations

UNIT – VII Emerging Energy Technologies and Future Prospects (1½ Weeks) (3 lectures)
Energy storage technologies, Carbon capture and storage, Artificial photosynthesis, Fusion energy, Energy from waste, Smart cities and energy systems, Future energy scenarios and modelling, Technological innovation and energy transitions

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Measure energy consumption of household appliances and calculate the energy savings from switching to energy-efficient appliances and recommend the most efficient options
2. Conduct an energy audit of a building to identify areas of energy waste in a building and recommend energy-saving measures
3. Analyze the carbon footprint of a household or business and recommend ways to reduce it
4. Evaluate the environmental impact of different waste disposal methods in your city and recommend the most sustainable options
5. Investigate the impact of water usage on the environment and energy sector and recommend ways to conserve water sustainably
6. Analyze the impact of energy policy on the environment and recommend more sustainable policies.
7. Investigate the impact of transportation choices on energy and the environment and develop a sustainable plan for the city
8. Measure the efficiency of solar panels under different light intensities and angles of incidence
9. Assess the environmental impacts of a product or process throughout its entire life cycle, from raw materials extraction to disposal.
10. Measure the concentration of different greenhouse gases in the atmosphere and track their trends over time
11. Set up to convert waste materials into energy using selected biological method(s)
12. Analyze using of electric vehicles or public transportation in your city as sustainable transportation options and evaluate their environmental impacts

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Hoffert, M. I. (2021). Energy and climate change: How to achieve a successful energy transition. Cham, Switzerland: Springer.
- Mebratu, D. (2021). Energy, environment, and sustainable development: A socio-economic approach. Abingdon, UK: Routledge.
- Smil, V. (2020). Growth: From microorganisms to megacities. Cambridge, MA: MIT Press.
- Sovacool, B. K., Heffron, R. J., & McCauley, D. (Eds.). (2020). Energy democracy: Goals and policies. Cham, Switzerland: Palgrave Macmillan.
- Westra, L., & Carbonnier, G. (2021). Energy transition, capitalism and the environment: Problems and solutions. Abingdon, UK: Routledge.

Suggested readings

- Burchell, K., & Rettie, R. (2021). Energy ethics: Conceptualizing a moral compass for energy transitions. London, UK: Palgrave Pivot.
- Levi, M. A. (2021). The power surge: Energy, opportunity, and the battle for America's future. New York, NY: Oxford University Press.
- Monbiot, G. (2021). Heat: How to stop the planet burning. London, UK: Penguin.
- Nye, D. E. (2021). Powering the new civilization: Energy, civilization, and the demands of the future. New York, NY: HarperCollins.
- Raza, S. A. (2021). The political ecology of energy transitions: A political economy approach. Abingdon, UK: Routledge.
- Rifkin, J. (2020). The Green New Deal: Why the fossil fuel civilization will collapse by 2028, and the bold economic plan to save life on Earth. New York, NY: St. Martin's Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-15): BIOINFORMATICS & ENVIRONMENT

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-15: BIOINFORMATICS & ENVIRONMENT	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Introduce the principles of bioinformatics for environmental research
- Provide with hands-on experience of bioinformatics to analyze biological data for environmental research
- Enable to address the challenges and opportunities of using bioinformatics in environmental science
- Enable students to communicate effectively and professionally about bioinformatics research and its implications for environmental science.

Learning outcomes:

After the course, students will be able to

- Use bioinformatics to analyze biological data for environmental research
- Evaluate the quality of bioinformatics data and use it for environmental science
- Communicate effectively the use of bioinformatics for environmental protection
- Apply problem-solving skills to real-world bioinformatics and environmental research challenges
- Use environmental challenges as novel opportunities by applying bioinformatics for developing sustainable approaches for environmental protection

SYLLABUS OF DSE-EVS-15

Theory (02 Credits: 30 lectures)

UNIT – I Bioinformatics Basics (2 Weeks) (4 lectures)

Definition and Scope of Bioinformatics, Biological Data Types and Sources, Introduction to Computer Science and Mathematics for Bioinformatics, Overview of Bioinformatics Tools and Databases, Sequence Alignment and Assembly Algorithms, Phylogenetic Analysis and Molecular Evolution

UNIT – II Genomics and Transcriptomics (2½ Weeks) (5 lectures)
DNA Sequencing Technologies and Platforms, Genome Sequencing, Assembly, Annotation and Visualization, Comparative Genomics, Gene Expression Transcriptomics Analysis and Interpretation, and Epigenetics Analysis

UNIT – III Proteomics and Metabolomics (3 Weeks) (6 lectures)
Proteomics Technologies and Platforms, Protein Separation and Identification, Mass Spectrometry and Peptide Mapping, Protein-Protein Interactions and Complex Analysis, Metabolomics and Metabolic Pathway Analysis, Metabolite Profiling and Identification, Biomarker Discovery and Validation, Integration of Omics Data and Network Analysis

UNIT – IV Computational Biology and Biostatistics (1½ Weeks) (3 lectures)
Biostatistical Methods and Techniques, Hypothesis Testing and Model Selection, Regression Analysis and Linear Models, Machine Learning and Data Mining, Statistical Analysis of Biological Data

UNIT – V Systems Biology and Network Analysis (2 Weeks) (4 lectures)
Systems Biology Concepts and Approaches, Regulatory Networks and Pathways, Signaling Networks and Cell Communication, Metabolic Networks and Flux Balance Analysis, Network Visualization and Analysis

UNIT – VI Environmental Genomics and Metagenomics (4 Weeks) (8 lectures)
Environmental DNA: sampling, sequencing, and analysis; Metagenomics for: biodiversity assessment, community analysis, understand biogeochemistry, determine ecosystem functioning; and ascertain functional diversity

Bioinformatics Applications in: developing stress-tolerant crops, genomics for animal breeding, improving livestock health, management of aquaculture and fisheries, environmental monitoring, bioremediation, bioprospecting and conservation

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1-4. Familiarize with commonly used bioinformatics tools and databases, such as BLAST, ClustalW, NCBI, and UniProt
5-6. Sequence analysis and alignment of nucleotide and protein sequences and analyze their properties
1. Familarize with basics of genome annotation and comparative genomics using different software and tools
8-9. Analyze metagenomic data, identify and classify microbial communities, and explore their functional properties

10-11. Know dealing with RNA sequencing data for transcriptome analysis and explore gene expression patterns

12-13. Explore protein structure and function using different software and tools or learn basics of identification and quantification of metabolites, and exploration of metabolic pathways

14-15. Learn basic statistical techniques and perform data analysis on biological datasets, such as hypothesis testing and regression analysis,

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Bell, T., & Lilley, A. (2019). Environmental Proteomics: Methods and Protocols. Springer.
- Carvalho, R. (2019). Bioinformatics for Biologists. Wiley.
- Li, R. W. (2018). Environmental Metagenomics: Methods, Protocols, and Applications. Humana Press.
- Xia, X. (2019). Ecological Bioinformatics: The Role of Bioinformatics in Studying Ecology. Academic Press.
- Zhu, D. (2021). Environmental Bioinformatics. CRC Press.

Suggested readings

- Hirsch, A. (Ed.). (2020). Environmental DNA: A Practical Guide to Methods, Applications, and Data Analysis. Wiley.
- Liu, Z. (2020). Bioinformatics in Aquaculture: Principles and Methods. Academic Press.
- Karlovsky, P. (Ed.). (2019). Environmental Metabolomics: Methods and Protocols. Humana Press.
- Huang, X., & Madan, A. (2019). Environmental Bioinformatics. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-16): DATA ANALYTICS FOR ENVIRONMENTAL SUSTAINABILITY

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-16: DATA ANALYTICS FOR ENVIRONMENTAL SUSTAINABILITY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Introduce the concepts and principles of data analytics in the context of environmental sustainability
- Enable to collect, process, analyze, and visualize environmental data using appropriate software tools and techniques
- Equip to apply statistical and machine learning techniques to environmental data analysis and interpretation
- Provide practical experience in using data analytics for environmental impact assessment, carbon accounting, and waste management
- Enhance understanding of the role of data analytics in promoting sustainable development and environmental stewardship

Learning outcomes:

After the course, students will be able to

- Describe the principles and importance of data analytics for environmental sustainability
- Collect and process environmental data using appropriate software tools
- Analyze environmental data using statistical and machine learning techniques.
- Visualize environmental data using appropriate software tools and techniques
- Apply data analytics to environmental impact assessment, carbon accounting, and waste management
- Demonstrate critical thinking, problem-solving, and decision-making skills related to environmental sustainability

SYLLABUS OF DSE-EVS-16

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Environmental Sustainability and Data Analytics
(2 Weeks) (4 lectures)

Introduction to environmental sustainability, Overview of data analytics, Importance of data analytics in environmental sustainability, Data types and sources for environmental sustainability, Techniques for data analysis and interpretation, Environmental data visualization, Case studies in data analytics for environmental sustainability, Ethics of data collection and analysis in environmental sustainability

UNIT – II Environmental Data Collection and Processing (2 Weeks) (4 lectures)
Overview of environmental data collection methods, Techniques for cleaning and preprocessing environmental data, Quality assurance and quality control for environmental data, Big data and cloud computing for environmental data processing, Data warehousing and data management in environmental sustainability, Geographic information systems (GIS) for environmental data, Data integration and data fusion for environmental sustainability, Challenges and limitations of environmental data collection and processing

UNIT – III Data Analytics Techniques for Environmental Sustainability
(2 Weeks) (4 lectures)
Introduction to statistical analysis for environmental data, Regression analysis for environmental data, Time series analysis for environmental data, Spatial analysis for environmental data, Machine learning techniques for environmental data analysis, Data clustering and classification for environmental sustainability, Network analysis for environmental sustainability, Visualization techniques for environmental sustainability data

UNIT – IV Modeling and Simulation for Environmental Sustainability
(2 Weeks) (4 lectures)
Introduction to modeling and simulation in environmental sustainability, Modeling techniques for environmental sustainability, Environmental systems dynamics modelling, Agent-based modeling for environmental sustainability, System dynamics modeling for environmental sustainability, Optimization modeling for environmental sustainability, Monte Carlo simulation for environmental sustainability, Case studies in modeling and simulation for environmental sustainability

UNIT – V Environmental management and conservation using data analytics
(2 Weeks) (4 lectures)
Data analytics for: environmental impact and risk assessment, environmental regulations compliance, conservation monitoring; Case studies of using data analytics in: biodiversity conservation, and water and waste management

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Introduction to R programming for environmental data analysis
2. Cleaning and preprocessing environmental data using Excel
3. Visualization of environmental data using Tableau
4. Regression analysis for environmental data using R
5. Time series analysis for environmental data using Python

6. Spatial analysis for environmental data using ArcGIS
7. Data clustering and classification for environmental sustainability using R
8. Monte Carlo simulation for environmental sustainability using Excel
9. Environmental impact assessment using data analytics
10. Carbon accounting and management using Excel
11. Analysis of weather and climate data using Python
12. Social media analysis for environmental sustainability using Netlytic

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Cooper, J. (2016). Environmental impact assessment: A practical guide (2nd ed.). Wiley-Blackwell.
- Grolemund, G., & Wickham, H. (2018). R for data science: Import, tidy, transform, visualize, and model data. O'Reilly Media.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An Introduction to Statistical Learning: With Applications in R. Springer.
- Lawhead, J. (2018). Learning ArcGIS Pro. Packt Publishing.
- Matthews, H. D. (2020). Climate data analytics: An introductory guide. Cambridge University Press.
- Wall, D. H., & Evans, D. A. D. (2018). Environmental analytics: Methods and applications for the chemical and environmental sciences. Wiley.
- Zhang, Y., Lu, Y., & Guo, M. (2020). Big data analytics for environmental sustainability: Challenges, opportunities and practices. Springer.

Suggested readings

- Alexander, M. J., & Walkenbach, J. (2019). Excel 2019 Bible. Wiley.
- Kaufman, L., & Rousseeuw, P. J. (2009). Finding groups in data: An introduction to cluster analysis (2nd ed.). Wiley.
- Murray, S. (2020). Tableau your data!: Fast and easy visual analysis with Tableau Software. Wiley.
- Petts, J. (2018). Handbook of environmental impact assessment (2nd ed.). Wiley.
- Sleeter, B. M., & Davis, K. F. (2019). Mapping with ArcGIS Pro: Design accurate and user-friendly maps to share the story of your data. Packt Publishing.
- VanderPlas, J. (2016). Python data science handbook: Essential tools for working with data. O'Reilly Media.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-17): ENVIRONMENTAL SUSTAINABILITY AND DATA VISUALIZATION

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-17: ENVIRONMENTAL SUSTAINABILITY AND DATA VISUALIZATION	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Develop skills in data collection, cleaning, and preparation for visualization
- Learn various data visualization techniques for environmental data analysis and communication
- Apply data analysis and visualization skills to real-world environmental sustainability problems
- Develop critical thinking skills in environmental sustainability and data visualization

Learning outcomes:

After the course, students will be able to

- Collect, clean, and prepare environmental data for analysis and visualization
- Use various data visualization techniques such as line charts, heat maps, and tree maps for environmental data analysis and communication
- Apply data analysis and visualization skills to real-world environmental sustainability problems and create compelling data visualization presentations
- Develop critical thinking skills in environmental sustainability and data visualization and evaluate the effectiveness of different visualization techniques for different audiences

SYLLABUS OF DSE-EVS-17

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to Environmental Sustainability and Data Visualization (2 Weeks) (4 lectures)

Introduction to environmental sustainability, Introduction to data visualization, Overview of environmental data sources, Role of data visualization in environmental sustainability, Basic statistical concepts, Introduction to data analysis software (e.g. Excel, R, Python), Introduction to data visualization software (e.g. Tableau, Power BI), Case studies in environmental sustainability and data visualization

UNIT – II Climate Change and Data Visualization (2 Weeks) (4 lectures)
Overview of climate change and its causes, Analysis of climate change data (e.g. temperature, carbon emissions), Visualization of climate change data (e.g. line charts, heat maps), Communicating climate change data to various audiences, Case studies in climate change data visualization

UNIT – III Resource Depletion and Data Visualization (2 Weeks) (4 lectures)
Overview of resource depletion (e.g. water, oil, minerals), Analysis of resource depletion data, Visualization of resource depletion data (e.g. bar charts, scatter plots), Communicating resource depletion data to various audiences, Case studies in resource depletion data visualization

UNIT – IV Pollution and Data Visualization (2 Weeks) (4 lectures)
Overview of pollution (e.g. air, water, soil), Analysis of pollution data, Visualization of pollution data (e.g. maps, histograms), Communicating pollution data to various audiences, Case studies in pollution data visualization

UNIT – V Biodiversity Loss and Data Visualization (2 Weeks) (4 lectures)
Overview of biodiversity loss, Analysis of biodiversity data, Visualization of biodiversity data (e.g. network graphs, tree maps), Communicating biodiversity data to various audiences, Case studies in biodiversity data visualization

UNIT – VI Sustainability in Industry and Data Visualization (2½ Weeks) (5 lectures)
Overview of sustainability in various industries (e.g. agriculture, energy, transportation), Analysis of sustainability data in industry, Visualization of sustainability data in industry (e.g. bubble charts, stacked bars), Communicating sustainability data in industry to various audiences, Case studies in sustainability data visualization in industry

UNIT – VII Communicating Environmental Data (2½ Weeks) (5 lectures)
Overview of communication strategies for environmental data, Choosing appropriate visualization types for different audiences, Design principles for effective data visualizations, Best practices for communicating environmental data, Case studies in effective communication of environmental data

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Understand the basics of data visualization and different types of charts/graphs
2. Analyze climate change data and create visualizations using line charts and heat maps
3. Examine data on resource depletion and generate visual representations using bar graphs and scatter plots.
4. Create visual representations of pollution data by using maps and histograms after examining the dataset.

5. Analyze biodiversity data and create visualizations using network graphs and tree maps.
6. Assess sustainability data across different industries and produce visualizations using stacked bars and bubble charts.
7. Design effective visualizations and communicate environmental data to various audiences.
8. Use GIS software to analyze and visualize environmental data
9. Collect environmental data from online sources using web scraping techniques.
10. Use NLP techniques to analyze environmental data from textual sources.
11. Create visualizations that support decision-making processes related to environmental sustainability.
12. Use data storytelling techniques to communicate environmental sustainability issues and solutions

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Berg, L. R., & Hassenzahl, D. M. (2016). Visualizing Environmental Science. John Wiley & Sons.
- Cairo, A. (2019). How Charts Lie: Getting Smarter about Visual Information. W. W. Norton & Company.
- Healy, K. (2018). Data Visualization: A Practical Introduction. Princeton University Press.
- Theus, M. (2019). Interactive Data Visualization: Foundations, Techniques, and Applications. Chapman and Hall/CRC.
- Tufte, E. R. (2017). The Visual Display of Quantitative Information. Graphics Press.

Suggested readings

- Baumer, B., Kaplan, D. T., & Horton, N. J. (2020). Modern Data Science with R. CRC Press.
- Handbook: Berg, L. R., & Hassenzahl, D. M. (2016). Visualizing Environmental Science. John Wiley & Sons.
- Kellner, K., & Niederer, C. (Eds.). (2019). Data Visualization in Society. Amsterdam University Press.
- Mann, D. J. (2018). Data Visualization for Social Science: A Practical Introduction with R and ggplot2. Routledge.
- Theus, M. (2019). Interactive Data Visualization: Foundations, Techniques, and Applications. Chapman and Hall/CRC.
- Wickham, H., & Grolemund, G. (2017). R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. O'Reilly Media.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-18): INTRODUCTION TO OCEANOGRAPHY

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-18: INTRODUCTION TO OCEANOGRAPHY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Familiarize with physico-chemical, and geological characteristics of the ocean
- Gain insights into the interactions among the ocean-atmosphere-land in the background of human activities
- Emphasize the importance of the ocean for human well-being and sustainability

Learning outcomes:

After the course, students will be able to

- Assess the critical linkages among physico-chemical and geological processes occurring in the oceans
- Decipher the interactions between the ocean and Earth's components
- Analyze oceanographic data analysis and interpret it to relate it with human activities and global environmental policies
- Develop an appreciation of the relevance of oceans in society and determining global challenges

SYLLABUS OF DSE-EVS-18

Theory (02 Credits: 30 lectures)

UNIT – I Oceanography basics (2½ Weeks) (5 lectures)

Definition of oceanography, History of oceanography, Importance of oceanography, Scientific methods in oceanography, Oceanographic tools and equipment, Ocean basins and features, Ocean circulation, Oceanography career opportunities

UNIT – II Physical and chemical oceanography (3 Weeks) (6 lectures)

Properties of seawater, Ocean currents, Waves, Tides, Ocean circulation, Heat budget, Water masses, Coastal oceanography

Properties of seawater, Major ions in seawater, Nutrients, Dissolved gases, pH and ocean acidification, Biogeochemical cycles, Marine pollution, Harmful algal blooms

UNIT – III Geological and biological oceanography (3 Weeks) (6 lectures)
Plate tectonics, Seafloor, Marine sediments, Paleooceanography, Mineral resources, Coastal processes, Sea level rise due to climate change, Oceanographic data and its analysis

Marine life and ecosystems: phytoplankton, zooplankton, mammals, and fisheries; Climate change and marine ecosystems

UNIT –IV Marine ecology (2 Weeks) (4 lectures)
Marine food webs and ecosystem dynamics, Mangroves and coral reefs, seagrass beds, Deep-sea ecosystems, Marine conservation and protected areas

UNIT –V Oceanography and climate (2½ Weeks) (5 lectures)
Ocean-atmosphere interactions, Oscillations: El Niño-Southern, North-Atlantic; Monsoons and climate modelling, Hurricanes and typhoons, Climate change policy and oceanography

UNIT –VI Oceanography and human interaction (2 Weeks) (4 lectures)
Maritime history and culture, Oceanographic related: law, policy, economics, technology, education, tourism, and recreation

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Familiarize with common oceanographic equipment such as CTD, Niskin bottles, and plankton nets
2. Measure seawater temperature, salinity, and density using a CTD
3. Analyse satellite imagery for oceanographic data such as sea surface temperature and chlorophyll concentration
4. Calculate oceanographic parameters using remote sensing data
5. Measure seawater pH and carbonate chemistry using a spectrophotometer
6. Calculate pH and pCO2 values from carbonate chemistry data
7. Interpret oceanographic data and preparation of graphical presentations
8. Analyse marine resources such as fisheries and aquaculture using data from government agencies and scientific literature
9. Analysis of marine spatial planning data such as marine protected areas and shipping lanes
10. Calculate spatial distribution of marine resources and assessment of the impact of human activities on marine ecosystems
11. Analyse marine policy and law at national and international levels
12. Calculate the impact of marine policy and law on marine ecosystems and human societies

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Knauss, J. A. (2016). Introduction to Physical Oceanography (2nd ed.). Waveland Press.
- Sverdrup, K. A., Armbrust, E. V., & Armstrong, R. A. (2019). Introduction to the World's Oceans (11th ed.). McGraw-Hill.
- Talley, L. D., Pickard, G. L., Emery, W. J., & Swift, J. H. (2019). Descriptive Physical Oceanography: An Introduction (6th ed.). Academic Press.
- Thurman, H. V. (2017). Introductory Oceanography (11th ed.). Prentice Hall.
- Trujillo, A. P., & Thurman, H. V. (2021). Essentials of Oceanography (13th ed.). Pearson.

Suggested readings

- Garrison, T. (2020). Oceanography: An Invitation to Marine Science (10th ed.). Cengage Learning.
- Martin, J. H., & McCorkle, D. C. (2016). An Introduction to Oceanography (2nd ed.). Jones & Bartlett Learning.
- Pinet, P. R. (2018). Invitation to Oceanography (7th ed.). Jones & Bartlett Learning.
- Segar, D. A. (2019). Introduction to Oceanography: A Life-Earth Science Approach. Springer.
- Stewart, R. H., & Church, T. M. (2019). Oceanography and Marine Biology: An Introduction to Marine Science. Garland Science.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.