

**INSTITUTE OF FORESTRY
AND
ENVIRONMENTAL SCIENCES
UNIVERSITY OF CHITTAGONG**

**SYLLABUS FOR
MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE
(THESIS)
AND
MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE
(GENERAL)**

SESSION 2013-2014 AND 2014-2015

Courses for Master of Science in Environmental Science (Thesis) and Master of Science in Environmental Science (General)

1. M. S. in Environmental Science (Thesis):

Course work (five courses)	500 marks (20cr)
Dissertation	200 marks (8cr)
Seminar on dissertation	50 marks (2cr)
Viva-voce on dissertation	50 marks (2cr)
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Total	800 marks (32cr)

2. M. S. in Environmental Science (General):

Course work (six courses)	600 marks (24cr)
Project work	100 marks (4cr)
Seminar on project	50 marks (2cr)
General viva-voce	50 marks (2cr)
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Total	800 marks (32cr)

Core Courses: Following TWO courses to be taken for both M. S. (Thesis) and M. S. (General)

Course No	Course Title	<u>TH</u>	<u>TP</u>	<u>TOTAL</u>
ENV 501	Environmental Management and Planning	75	25	100
ENV 502	Environmental Economics, Policy and Project Analysis	75	25	100

Selective Courses: THREE courses for M. S. (Thesis) and FOUR for M. S. (General) from any of the following Branches.

Branch 1: Environmental Management

ENV 503	Pollution and Ecosystems	75	25	100
ENV 504	Watershed Conservation and Extension	75	25	100
ENV 505	GIS in Environmental Planning	75	25	100
ENV 506	Water Resources Planning and Management	75	25	100
ENV 507	Soil Ecology	75	25	100
ENV 508	Land use Modeling and Policy Analysis	75	25	100
ENV 509	Community Based Natural Resource Management	75	25	100
ENV 510	Environmental Land use Planning and Management	75	25	100
ENV 511	Common Property Resource Management	75	25	100
ENV 512	Ecotourism Management	75	25	100
ENV 513	Advance Statistics in Environmental Science Research	75	25	100

Branch2: Climate Change and Disaster Management

ENV 514	Environmental Modeling	75	25	100
ENV 515	Integrated Coastal Management	75	25	100
ENV 516	Climate Change	75	25	100
ENV 517	Environmental Disaster Management	75	25	100
ENV 518	Climate Change Impact and Adaptation	75	25	100

Branch 3: Environmental Compliance

ENV 519	Environmental Compliance Auditing and Certification	75	25	100
ENV 520	Environmental Biotechnology	75	25	100
ENV 521	Advanced Solid Waste Management	75	25	100
ENV 522	Applied Industrial Ecology	75	25	100
ENV 523	Green Development and Environmental Governance	75	25	100
ENV 524	Renewable Energy Technologies	75	25	100
ENV 525	Development Economics	75	25	100

Project, Dissertation, Seminar, and Viva-voce

ENV 601	Master of Science in Environmental Science (General) Project			100
ENV 602	Master of Science in Environmental Science (Thesis) Dissertation			200
ENV 603	Seminar (Practical) on M. S. Environmental Science (General) project			50
ENV 604	Seminar (Practical) on M. S. Environmental Science (Thesis) dissertation			50
ENV 605	General viva-voce for M. S. Environmental Science (General)			50
ENV 606	Viva-voce on dissertation for M. S. Environmental Science (Thesis)			50

TH – Theoretical; TP – Term Paper

Note: 100 marks = 4 credits; 75 marks = 3 credits; 50 marks = 2 credits and 25 marks = 1 credit.
Internship Report (Non-credit) for Thesis & General Group

ENV 501 ENVIRONMENTAL MANAGEMENT AND PLANNING

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

1. **Environmental Management:** Introduction to environmental management.
2. **Sustainability:** Living in an exponential world; Resource demands, environmental issues and socio-economic constraints. Predictive and scientific instruments; Environmental standards, measuring sustainable development both nationally and globally.
3. **Tools for Environmental Management:** Environmental Impact Assessment (EIA); Strategic Environmental Assessment (SEA).
4. **Solid Waste Management:** Municipal solid waste (MSW); types, amounts, composition; technical methods in waste management and processes; landfill, composting, incineration, recycling, Policies and strategies including case studies.
5. **Energy:** Introduction to energy; Changing requirement with population growth; Fossil fuels and in particular, ever-depleting oil reserves; Future strategies; Feasibility of alternative energies, case studies.
6. **Environmental Chemistry:** Introduction to basic chemical concepts; Air, water and soil chemistry.
7. **Water Resources:** Physical modification of rivers: dams, channelisation; Chemical modification of rivers; phosphates and nitrates, metals DDT etc. Case studies – Rivers of Bangladesh.
8. **Air Quality Management:** Ancient and present-day atmosphere; Historical air pollution through to current day photochemical smog's; health effects, remediation measures, case studies.
9. **Acid Deposition:** Concept and consequences
10. **Global Climate Change:** Natural climate fluctuations; Global energy balance, radiative forcing, global warming potentials; Climate feedbacks, historical temperature records, Milankovitch cycles, ice ages, climate record in last few centuries and decades.
11. **Man-made Climate Fluctuations:** Solar vs. anthropogenic forcing, long-term trends in greenhouse gases, sea-level changes, detection and attribution of climate change; Predicting the future with emissions scenario modeling, Kyoto and beyond

Term Paper:

- i) Assignment on various issues of environmental management and assessment e.g. Major environmental issues, development and environment, poverty and environment, biodiversity, coastal and marine pollution and management, deforestation, climate change, environmental ethics, coastal zone management, waste management, acid rain phenomenon & impact on ecosystems, managing urban environment, industrial pollution management, environmental auditing etc.
- ii) Group/individual project on EIA of specific infrastructure development projects and submission of reports.

Recommended bibliography:

- Andarews, J.E., Brimblecombe, P., Jickells, T.D. and Liss, P. S. 1996 An Introduction to Environmental Chemistry, Blackwell Publishers.
- Barrow C.J. 1999. Environmental Management Principles and Practice, Routledge.
- Brimblecombe, P. and Maynard, R. L. 2001. The Urban Atmosphere and its Effects, Imperial College, London.

- Carson, R. 1963. *Silent Spring*, O’Riordan, T. 2000. *Environmental Science for Environmental Management*, Longman, Harlow.
- Foley G. 1992. *The Energy Question*, Penguin.
- Glasson, J., R. Therivel, and A. Chadwick (1999) *Introduction to Environmental Impact Assessment* (2nd edition), UCL. Press.
- Goudie A. 2000. *The human impact on the natural environment*, Blackwell Publishers.
- Graedel T. E. Crutzen P. J. 1997. *Atmosphere, climate and change*. Scientific American, New York.
- Harrison, R.M. 2001. *Pollution: Causes, effects and control*. The Royal Society of Chemistry, Cambridge.
- Houghton J. 1997. *Global warming: The complete briefing*, Cambridge University Press.
- L aeggett J. 2000. *The carbon war: global warming at the end of the oil ear*.
- Morris, P. and R. Therivel 1995. *Methods of environmental impact assessment*, UCL press.
- Nath, B., Hens, L., Compton, P. and Devuyst 1998. *Environmental Management in Practice*. Voils. 1-3 Routledge, New York.
- Owen L. and Unwin T. 1997. *Environmental Management*, Blackwell Publishers.
- Therivel, R. 2004. *Strategic Environmental Assessment in Action*, Earthscan.
- VanLoon G.W., and Duffy, S.J., (2000), *Environmental chemistry; a global perspective*, Oxford University Press.
- Willilaml, I. 2001. *Environmental Chemistry; a modular approach*, Wiley.

ENV 502 ENVIRONMENTAL ECONOMICS AND PROJECT ANALYSIS

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

1. Environment, Growth, and Development: Economic development and environment, Environmental Kuznet's curve; Income and demand for environmental quality, Income distribution, Lorenz curve and Gini-coefficient, Productivity and technology (total factor growth measurement, Single factor productivity, Bias from omission of environmental factors, Induced innovations), Green national accounting, Governance issues associated with overcoming the tragedy of the commons

2. Pollution Regulation: Grounds for environmental regulations, Basic regulatory instruments (Perspective regulations, Command & control, Economic incentives), Public sources of pollution, Issues and complications for environmental regulation (space and time, efficiency and cost effectiveness, Ambient differentiated regulation and Emission differentiated regulation), Issues, Permits or free? Obtaining private control cost information

3. Emission Prices and Fees: Polluters' response to emission fees, The Pigouvian fee (for single polluter, for multiple polluters) Pigouvian tax versus Subsidy (for short run and long run); Imperfect competition (Monopoly in goods and bads markets with and without tax)

4. Tradable Permits & Regulation Over Space and Time: Tradable permits, two-firm / one receptor case, Permit market operation, initial permit issuance, Dominant firms, Market thinness, Transaction cost, Pollution over space (source, receptor, and transfer coefficients, optimal pollution, marketable ambient permits, Zonal instruments), Pollution over time (Stock pollutant, Temporal variability)

5. Property Rights & the Coase Theorem: The Coase Theorem, Coase's famous example of "Cattle grazing vs crop production; Case I: No transaction cost, Case II: Positive transaction cost, Policy significance of the Coase Theorem.

6. Management of Environmental Risk and Uncertainty: Environmental risk and its complexity, Causation of risk, diversity of environmental risk (subjective vs objective risk, Risk vs Uncertainty, Voluntary vs involuntary risk), Making choices about risk (Expected utility model, the value of risk reduction, value of information, Stock pollution and irreversibility, Cake eating problem), Regulating risk with liability (a model of liability, Strict liability vs negligence, Joint and several liability), Liability and regulation (disadvantage of liability, combined use of liability and regulation), Insurance (Conditions for insurability, Insurability of environmental risk).

7. Economics of Environmental Resources: Economics of resources management-Renewable resources (Forests and fisheries), Recyclable resources, replenishable and depletable resources (Oil, Water).

8. International and Interregional Completion: Pollution heaven; A model on jurisdictional competition model (assumptions: optimal tax on capital is zero, Optimal level of emission, Emission levels when tax on capital is position), Trade and environment (GATT, WTO, NAFTA), Strategic trade, Transboundary pollution (Countervailing tariffs, Issues linkage, Designing International Trade Agreement, Size of these agreements)

9. Project Development: Concept, characteristics and component of project steps in project formulation; Project Concept Paper (PCP); The Net present value criterion, Payback period and Internal rate of return (IRR) of project cost and benefit evaluation.

10. Project Evaluation: Concept, characteristics and component of project steps in project formulation. Project Concept Paper (PCP); Concept, principles of evaluation, types of project evaluation. Techniques and Methods in project evaluation- Project Evaluation and Review Technique (PERT), Critical Path Method (CPM).

11. Environmental Auditing and Accounting: Concept, types, procedures and standard of environmental auditing; Accounting for the environment

Term paper:

Preparing term papers on different aspects related to environmental economics including analysis of environmental impacts of an investment/development project; valuation of environmental resources; environmental externalities; social costs, pollution abatement; determination of marginal control costs and marginal damage costs; pollution tax and transferable pollution taxes.

Recommended bibliography:

- SHED. 1998. Bangladesh Environment: Facing the 21st Century. Society for Environment and Human Development (SEHD), Dhaka, Bangladesh. 306p.
- Baumol, W.J. 1970. Economic Theory and Operations Analysis (2nd edition). Prentice Hall of India Private limited, New Delhi, India. 513p.
- Chowdhury, Q. I. (ed.). 1999. Bangladesh: State of Environment Report 1999 Forum of Environment Journalists of Bangladesh (FEJB), Dhaka, Bangladesh. 249p.
- Cowell, F.A. 2004. Microeconomics- Principles and Analysis, London School of Economics, Pp.688
- Daly, H.E. and Farley, J. 2004. Ecological Economics: Principles and Applications, Island Press, Washington, Pp.484
- Duerr, W.A. 1960. Fundamentals of Forestry Economics, McGraw-Hill Book Company. 579p.
- Dwivedi, D.N. 1997. Principles of Economics. Vikas Publishing Pvt. Ltd., New Delhi, India. 702p.
- Hanley et al. 1999. Environmental Economics in Theory and Practice, McMillan India, 1st Ed, Pp.463
- Kolstad, C.D. 2011. Environmental Economics, Oxford University Press, NY, 2nd ed, Pp.480
- Rahman, A.A., Haider, R., Huq, S. and Jansen, E.G. (eds.) 1994. Environment and Development in Bangladesh. Volume Two. University Press Limited, Dhaka, Bangladesh. 345p.
- Varian, H.R. 2005. Microeconomics, W.W. Norton and Co., NY, 7th ed, Pp.774

ENV 503 POLLUTION AND ECOSYSTEMS

Theory: 75 (3cr);

Term Paper: 25 (1cr);

Total: 100 (4cr)

Course contents:

- 1. Introduction:** Aims and objectives; Significance of studying the soil/plant/water/atmosphere system as a whole. An introduction to the concepts of hydrological and biogeochemical cycling; Sustainability of natural ecosystems.
- 2. People, Energy and the Environment:** Environmental consequences of human evolution and the development; Human demands on environmental resources; Sources and types of pollution; Possible sinks for pollution; Risk of disruption of natural biogeochemical cycles.
- 3. Atmospheric Deposition Effects on Soils:** What is acid rain? Why did it the major issue in the 1980s and 90s? Consequences of enhanced N and S deposition to natural, semi-natural, and managed ecosystems; Soil acidification; Why is it so difficult to quantify mineral soil acidification? Why should we try? Why are some organic soils particularly susceptible to acidification. Consequences to plants and surface waters? What are the options for amelioration? Significance of some recent research findings.
- 4. Critical Loads for Soils:** The Shokloster Workshop and its consequences; How are critical loads calculated? The UK approach; The approach throughout Europe. How are gaps in data handled? Exceedance effects. How useful is the concept in environmental management?
- 5. Plants, Soils, and the Regulation of Surface Water Quality:** Effects of enhanced N, S, H⁺ and heavy metal deposition upon water interactions with vegetation and soils; The importance of geology; Effects of surface water acidification on aquatic biota and their consequences; Acid flushes.
- 6. The Role of Soil in Regulation of the Atmosphere:** The role of natural biogeochemical cycling of C,N,S and water; The crucial roles of soil micro-organisms; Inter-cycle interactions; Anthropogenic disruptions to the global cycling of C,N,S and water; The greenhouse effects; gas rising CO₂ effects on the soil/plant/water system; The importance of methane; The importance of nitrous oxide.
- 7. Other Atmospheric Pollutants:** Atmospheric deposition of heavy metals; Deposition of radionuclides.
- 8. Sewage and Sludge Disposal Problems:** Nature of sewage and sludge; Options for disposal; Potential as a soil improver; Fertility and health problems with terrestrial application; Potential long-term solutions.
- 9. Pollution from Agriculture and Forestry:** Nature and origins of pollutants from these types of soil management; Factors influencing mobility; Inorganic vs. organic phosphorus in drainage water; Particulates; Eutrophication; Impacts of agriculture and forestry on natural biogeochemical cycles.
- 10. Bioassays for Ecotoxicity Testing:** The need for ecotoxicity testing; Biological versus chemical tests pros and cons; Bioassays types; How well do bioassays meet needs of pollution management?

Term paper: students will prepare term paper on topics given by course teacher

Recommended bibliography:

- Alloway, B. J. and Ayres, D. C., *Chemical Principles of Environmental Pollution*, Blackie Academic and Professional, Glasgow, 1993
- Andreac, M. O. and Schimel, D. S., eds. *Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere*, John Wiley & Sons, Chichester, 1989.
- Batey, T., *Soil Husbandry: A Practical Guide to the Use and Management of Soils*, Soil and Land Use Consultants Ltd., Aberdeen, 1988.
- Brady, N. C. *The Nature and Properties of Soils*, 11th Edn., Macmillan.
- Colman, S. M. and Dethier, D. P. *Rates of Chemical Weathering of Rocks and Minerals*, Academic Press, Orlando, 1986.
- Cresser, M. and Edwards, A., *Acidification of Freshwaters*, Cambridge University Press, Cambridge, 1987.
- Cresser, M., Killham, K. and Edwards, T. *Soil Chemistry and its Applications*, Cambridge University Press, Cambridge, 1993 (a useful text, available as a paperback and covering many key points, strong on biogeochemical cycling concepts).
- de Vries, W., Posch, M., Reinds, G. J. and Kamari, J., *Critical Loads and their Exceedance on Forest Soils in Europe*, Water and Environment Research Institute, Report 58, Wageningen, 1992.
- Greenwood, D. J., Nye, P. H. and Walker, A. E. S., *Soil Productivity and Pollution*, The Royal Society, London, 1990.
- Guenzi, W. D., Ed., *Pesticides in Soil and Water*, Soil Science Society of America, Madison, 1974 (reprinted 1981).
- Hutchinson, T. C. and Meema, K. M., Eds., *Effects of Atmospheric Pollutants on Forests, Wetlands and Agricultural Ecosystems*, NATO ASI Series G, Vol. 16, Springer-Verlag, Berlin, 1987.
- Jonlson, R. W. and Gordon, G. E., Eds., *The Chemistry of Acid Rain; Sources and Atmospheric Processes*, ACS Symposium Series 349, American Chemical Society, Washington, 1987.
- Mason, B. J., Ed., *The Surface Waters Acidification Programme*, Cambridge University Press, Cambridge, 1990.
- Maynard, D. G., Ed., *Sulfur in the Environment*, Marcel Dekker, New York, 1998.
- Molders, B. and Cerny, J., Eds., *Biogeochemistry of Small Catchments: A Tool for Environmental Research*, Scope 51, Wiley, Chichester, 1994.
- Neal, C., Smith, C. J. and Hill, S., *Forestry Impacts on Upland Water Quality*, Report No. 119, Institute of Hydrology, Wallingford, 1992.
- Radojevic, M. and Harrison, R. M., *Atmospheric Acidity: Sources, Consequences and Abatement*, Elsevier Applied Science, London, 1992.
- Schulze, E.-D., Lange, O. L., and Oren, O., *Forest Decline and Air Pollution*, Ecological Studies 77, Springer Verlag, Berlin, 1989.
- While, R. E., *Principles and Practice of Soil Science: The Soil as a Natural Resource*, 3rd Edition, Blackwell Science, Oxford, 1997 (a useful paperback).
- Wild, A., *Soils and the Environment: An Introduction*, Cambridge University Press, Cambridge, 1993 (a very readable paperback introductory text).

ENV 504 WATERSHED CONSERVATION AND EXTENSION

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

- 1. Introduction:** Conservation of basic life sustaining natural resources - land, water and vegetation in watershed.
- 2. Bangladesh watershed:** Major features and characteristics of Bangladesh watershed.
- 3. ITK:** Indigenous Technology Knowledge on Watershed Management in Bangladesh for forest, water and soil conservation and intensive production systems; uniqueness in these ITK.
- 4. Land degradation:** Land loss, land degradation, rehabilitation and restoration of land; present status, stages, causes and effects of land degradation in the world and particularly in mountainous slopes of Asia; main objectives, goals and major constraints of rehabilitation of degraded lands; driving forces, causes, impacts and state of land degradation in Bangladesh.
- 5. Environmental aspects of surface water systems:** Surface water system in Bangladesh, morphological modifications of surface water system, problems and probable solutions for water resources in Bangladesh.
- 6. Water harvesting:** Socio-economic and ethnic aspects of water harvesting systems, constraints, opportunities and benefits from water harvesting systems.
- 7. Soil conservation extension:** Historical perspective, causes of past failures, changed approaches,
- 8. Changed activities and thinking on watershed management;** basics and experiences of soil conservation extension - principles, guidelines, improving soil conservation extension, extension strategy in upland farming systems, aggressive soil conservation extension.
- 9. Participatory watershed management:** Concepts, steps, participatory process in mountain watershed management, basic principles for people's participation in watershed management, participatory approaches and participatory action learning.
- 10. Transfer of technology:** Approach of extension technology, procedures of technology transfer, adoption of new technology, constraints, activities for successful adoption, effective training for adoption of technology,
- 11. Farmers' disinterest in technology adoption and participatory approach in adoption.**
- 12. Watershed management extension in CHTs:** Administrative and political settings, CHTs regulations 1900,
- 13. Forest Act, 1927, Headmen rules 1936, land acquisition regulation 1958, HDCs Act 1998, land and forest administration, watershed management institutions in Bangladesh, organizations for soil and water conservation, extension process in CHTs.**
- 14. Village common forests in CHTs:** History, management, sustainable management, administration pattern and significance of VCFs; variations, authority and problems in conservation of VCFs in CHTs.

Term paper: Students will prepare term paper on topics given by the course teacher (s).

Recommended bibliography:

- S. M. Sirajul Haque and Maung Hla Myant, Watershed Management Extension and Environmental Conservation in Bangladesh, IFESCU and USDA, 2011, 188 pp.
- S. M. Sirajul Haque, Watershed Management from Bangladesh Perspective, IFESCU and USDA, 2013, ----- pp.

ENV 505 GIS IN ENVIRONMENTAL PLANNING

Theory: 75 (3 cr); Term Paper: 25 (1 cr); Total: 100 (4 cr)

Course contents:

- 1. Natural Resource Management and GIS:** Natural Resources in Bangladesh-renewable and nonrenewable, spatial module in resources management; Philosophy of GIS; approaches of GIS.
- 2. Digital Representation of Geographic Data:**
Technical issues pertaining to digital representation of geographic data; Database and Database Management System; Raster geographic data representation; Vector data representation; Object-Oriented geographic data representation.
- 3. Maps and GIS:**
Map scale; Classes of maps; Mapping process; Plane coordinate systems and transformations, Geographic coordinate system; Map projection; Geo-referencing.
- 4. Data Quality and Data Standards:**
Concepts and Definitions of Data Quality, Assessment of Data Quality-, Raster and vector data, Managing Spatial Data Errors.
- 5. Visualization of Geographic Information:**
Cartography in the context of GIS; Visualization of geographic information; Digital terrain modeling; Acquisition of digital terrain data; Data processing, analysis and visualization; Application of digital terrain models.
- 6. Spatial Analysis and Modeling:**
Acquisition of spatial data for the terrain: topographic mapping; attribute data for thematic mapping; Descriptive statistics; Spatial autocorrelation; Quadrante counts and Nearest-Neighbor analysis; Trend Surface analysis; GIS modeling.

Term paper:

GIS project (emphasizing Forestry) planning and geographic database design using IDRISI for Windows and ArcGIS.

Recommended Bibliography

- Akthar, S. and Karki, AS. 1999. Application of GIS to Mountain Land-use planning. International Center for Integrated Mountain Development. Kathmandu, Nepal.
- Avery, T.F. and Berlin, G.L.. 1985. Interpretation of aerial photographs. 4th edn. Burgess Publishing Co. Minneapolis, Minnesota.
- Buhmann, S. 1996. Geographic Information System. I3rucnig, E.F. and Bossel, H. (eds.). Natural Resource Systems Analysis.
- Burrough, P. A. and McDonnel, R A. 1998. Principles of Geographic Information Systems. Oxford University Press_ 333 p.
- Chrisman, N. 1997. Exploring geographic information systems. John Wiley & Sons. 298p.
- Clarke, K. C., Parks, B. O. and Crane, M. P. 2002. Geographic Information Systems and Environmental Modeling. Prentico-Hall of India. 306 p.
- Colwell, R.N.; Esters, I.C. and Thorley, G.A (eds.). 1983. Mannual of Remote Sensing Vol. 2. Interpretation and Application. Amer. Soc. of Photogrametry, Virginia.
- De Mers, M.N. 1999. Fundamentals of geographic information systems. Second edition, New York. 498p.
- EGIS. 2000. Geo-spatial tools for analysis of floodplain resources. UPL. 100 p.
- ESRI. 2007. ArcGIS 9 using ArcGIS Desktop-380 New York Street, Redlands, USA 43Spp.

- IDRISI. 2005. IDRISI softwares. IDRISI resource center, Clark University, Worcester, MA, USA.
- Korte, P and George, B. The GIS Book. Onward press. 387 p.
- Lillesand, T.M. and Kiefer, R.W. 1987. Remote Sensing and Image Interpretation. Second Edition. John Wiley and Sons. New York, USA.
- Lo, C. P. and Yeung A. K. W. 2002. Concepts and Techniques of Geographic Information Systems. Prentice-Hall of India. 495 p.
- Moffit. F.H. and Mihlaif, G. W. 1980. Photogrammetry. 3rd Edn. Harper and Row Publishers N York.
- Paine, D.P. 1981 Aerial Photogrammetry and Image Interpretation for Resource Management. John Wiley & Sons New York, USA.
- Sharma, M.K. 1986. Remote Sensing & Forest Surveys. International Book Distributors. Dehra Dun, India.
- Simonett, D.S. and Ulaby, F.T. (eds). 1983. Manual of Remote Sensing. Volume One. Second edition. American Society of Photogrammetry. USA.
- Walford, N. 1995- Geographical data analysis_ John Wiley and Sons. 446 p.

ENV 506 WATER RESOURCES PLANNING AND MANAGEMENT

Theory: 75 (3cr);

Term Paper: 25 (1cr);

Total: 100 (4cr)

Course contents:

1. **Introduction:** Introduction to water resources, its planning and management.
2. **Sources of Water:** Surface water and ground water sources; review of water collection, quality control, and distribution systems.
3. **Hydrologic Process:** Review of descriptive hydrology, such as, precipitation, stream flow, evaporation, and collecting hydrologic data. Review of quantitative hydrology, such as, hydrograph analysis, runoff estimating, basin flow, storage routing.
4. **Ground Water Resource Evaluation:** Groundwater recharge and runoff; development and management of aquifers.
5. **Open Channel Flow Analysis:** Hydraulics of open channel flow, measurement of flow, types of channels, meandering rivers, braided channels.
6. **Hydraulic Structures:** Earth dams, spillways, sluice gates, and outlet works, culverts, bridges and their planning and design.
7. **Flood Damage Mitigation:** Types of flood, flood mitigation reservoirs, levees, and flood walls, floodways, channel improvement, evacuation and flood proofing; land management and flood mitigation; flood-plain management; navigable waterway development.
8. **Probability Concept in Planning:** Flood frequency, flood formulas, rainfall frequency, draught.
9. **Planning for Water Resources Development:** Level, phases, objectives, data requirements, project formulation, environmental considerations, systems analysis, multipurpose projects.
10. **Regional Conflicts on Water Resources:** Cross boundary rivers; inter river linking, international water boundaries and water conflicts.
11. **Engineering Economy in Water-Resource Planning:** Social importance, annual cost comparisons, interest and taxes, frequency and economy, economy studies for public works, cost allocation and budget provision.

Term paper:

Project on water resources planning and management – sampling design, data collection, analysis, and presentation of report.

Recommended bibliography:

- Ali, M.M. et al. (eds). 1998. Bangladesh floods from home and abroad. The University Press Ltd. Dhaka. 285p.
- Chorley, R.J. (ed). 1977. Introduction to Physical Hydrology. Methuen and Co. Ltd. Harper & Row Publishers, Inc. 211p.
- Chow, V.T. 1959. Open Channel Hydraulics. McGrawHill Kogakusha, Ltd. New Delhi.
- Hewlett, J.D. 1982. Principles of Forest Hydrology. The University of Georgia Press, Athens, 183p.
- Linsley, R.K. et al., 1972. Water Resources Engineering. McGrawHill, Inc. New Delhi. 640p.
- Linsley, R.K. et al., 1982. Hydrology for Engineers. McGrawHill International Book Co., New Delhi 508p.
- Nishat, A. et al., 1993. Freshwater Wetlands in Bangladesh: Issues and Approaches for Management. IUCN – The World Conservation Union. 283p.
- Rahman, A.A. et al. (eds) 2000. Environmental Aspects of Surface Water Systems of Bangladesh. The University Press Ltd. Red Criscent Building, 114 Mtijheel C/A, Dhaka. 258p.
- Schwab, G.O. et al., 1966. Soil and Water Conservation Engineering, 2nd ed., John Wiley and Sons, Inc. N.Y.
- Walton, W.C. 1970 Ground Water Resource Evaluation. McGrawHill Kogakusha, Ltd. New Delhi. 664p.
- Wolf, A.T. et al. 1997. Water Resources Development.

ENV 507 SOIL ECOLOGY

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

- 1. Soil Environment:** Soil as a source of energy to the biota; structural aspects of the soil habitat; soil water and nutrient supply to the biota; soil atmosphere as a source of carbon and nutrients to the soil biota; biological activities in soil in relation to redox potential, pH, temperature, and light; soil micro sites.
- 2. Soil Biota:** Components of soil biota and biodiversity of the soil community.
- 3. Ecological Interaction Between the Soil Biota:** Different types of biological interaction occurring in soil; soil biological community dynamics.
- 4. Ecology of Soil Nutrient Cycling:** Nutrient of carbon, nitrogen and sulphur.
- 5. Soil Biotechnology:** Biofertilization by rhizobial inoculation, control of soil biota, biofertilization by mycorrhizal inoculation, genetically modified plants and microbes for using the environment, soil ecological effects of the use of genetically modified plants and microbes.

Term paper: Students will prepare term paper on topics given by course teacher(s).

Recommended bibliography:

- Alan, W. Soils and the Environment – an Introduction.....
- Alexander, M. 1961 Introduction of Soil Microbiology, John wiley & Sons, New York.
- Killham, K .1994. Soil Ecology, Cambridge University Press.

ENV 508 LAND USE MODELING AND POLICY ANALYSIS
Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

- 1. Introduction:** Land and land use change; land cover; Historical land use changes in Bangladesh and other countries; Drivers of land use change; effects/problems of land use change.
- 2. Environmental land Use Management:** Managing human – environment interactions; Environmental planning.
- 3. Land Use Planning For Environmental Management:** Land use and development; Land use and environmental protection; Framework for land Use planning; Emerging approaches for environmental land Use planning.
- 4. Land Conservation for Working Landscapes, Open Space and Ecological Protection:** Dimensions and tools for land conservation.
- 5. Land Use Modeling for Climate Change:** Modeling changes in land use due to climate change impacts at different scales- global, regional, to local; Land use modeling in decision making processes including trade-offs between different policy objectives like, mitigation vs. adaptation.
- 6. Land Use and Ground Water, Steam Flow and Runoff Pollution:** Fundamentals of groundwater hydrology; Land use, Ground water recharge and contamination; Assessing groundwater resources; Groundwater source protection. Effects of land use on stream flow and water quality.
- 7. Land Use Policy:** Approaches to land and land use policies; Need, scope and objectives of land use policy; National policies covering land and land use in Bangladesh, Land use policy in other countries.
- 8. Land Rights, Valuation and Conflict Management:** Land rights and land tenure; Process of land valuation, land use conflicts, land reforms and some experiences.
- 9. Landscape Ecology, Urban Forestry and Wetlands.**
- 10. Land Use, Wildlife Habitats and Biodiversity:** Fundamentals of Wildlife habitats and biodiversity.

Term paper: students will prepare term paper on topics given by course teacher

Recommended Bibliography:

- Brammer, H. 2002. Land Use and Land Use Planning in Bangladesh. The University Press Limited, Dhaka.
- Davidson, D.A. 1982. Soil and Land Use Planning. Longman, London.
- Davies, K.P. 1976. Land Use. McGraw-Hill Inc. USA.
- FAO, 1988. Land Resources Appraisal of Bangladesh for Agricultural Development, UNDP/FAO Project BGD/81/035, Technical Reports 1-7, FAO, Rome.
- FAO. 1993. Guidelines for Land-use Planning. Food and Agriculture Organization of the United Nations, Rome (<http://www.fao.org/docrep/T0715E/t0715e0c.htm>).
- FAO/UNDP. 1971. Bangladesh Soil Resources, Soil Survey Project, AGL: SF/PAK 6 Technical Report 3, 185-198pp.
- Hassan, M.M. 1999. Soils of Bangladesh: Their genesis, classification and use potential. March Printers Ltd., Dhaka.
- Mandal, R.B. 1990. Land Utilization: Theory and Practice. Concept Publishing, New Delhi.

- OECD, 1976. Land Use Policies and Agriculture. Organization for Economic Co-operation and Development, Paris.
- Richards, B.N. and Hassan, M.M. 1988. A Co-ordinate Forest Soil Research Program for Bangladesh, 31-32pp.
- Richards, B.N. and Hassan, M.M. 1989. Dendroecological Regions of Bangladesh: A land capability assessment for tree species. FAO/UNDP Project BGD/81/010, Working Paper-7, BFRI, Chittagong.
- Sabrousse, R. 1984. Preliminary Report on the Ecological Classification of Plantations in the Chittagong and Chittagong Hill Tracts District. Working Paper No. 2, FAO/UNDP Project BGD/79/017.
- Stevens, P.R. 1987. A simplified field manual for site classification and site suitability assessment in Bangladesh forests. FAO/UNDP Project BGD/81/011- Assistance to the Second Agricultural Research Project.

ENV 509 COMMUNITY BASED NATURAL RESOURCE MANAGEMENT

Theory: 75 (3cr); **Term Paper:** 25 (1cr); **Total:** 100 (4cr)

Course contents:

Introduction: Concepts and theories of community based resources management; concepts of participation, groups and organizations, associations; resources identification, assessment and analysis.

Cultural anthropology: Cultural practice, community development; indigenous knowledge and practice; Upland/mountain resources management.

Community: Organizing, community resources mobilization; environmental organizations.

Conceptual framework of participatory resource management: Participatory resources management models.

Concepts and principles of conflicts management; Facilitation, mediation, negotiation and resolution of resources use conflicts.

Concepts of common property resources management: sustainable management; stewardship, sharing, distribution of benefits.

Integrated Conservation and Development Program (ICDP): Ecotourism for natural resource conservation and community development; Community based ecotourism; Participatory Eco-park management; Ecotourism education and development.

Economics and marketing: Marketing of community based resources management; employment regeneration, income and saving; community infrastructure development.

Participatory learning; Participatory planning and action; PME, PAR, PRA and other research tools; research needs and priorities.

Recommended bibliography:

Burke, 1990. Common Property Resources,

RECOFTC, 1997. Ecotourism for Forest Conservation and community development. Report no. 15.

Roy and Chatterjee, 1994. Joint Forest Management, a training manual. Inter-India publications, New Delhi.

TMI, un-dated. Community based tourism for conservation and development: a resource kit. Kathmondu, Nepal

Willigen, Van. 1995. Applied Anthropology. Bergin and Garvey, London.

ENV 510 ENVIRONMENTAL LAND USE PLANNING AND MANAGEMENT

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

- 1. Environmental land Use Management:** Managing Human – Environment Interactions; Environmental Planning.
- 2. Land Use Planning For Environmental Management:** Land Use and Development; Land Use and Environmental Protection; Framework for Land Use Planning; Emerging Approaches for Environmental Land Use Planning.
- 3. Land Conservation for Working Landscapes, Open Space and Ecological Protection:** Dimensions and Tools for Land Conservation.
- 4. Soils, Topography and Land Use:** Land Use Properties of Soils and Soil Quality; Land Evaluation and Site Assessment; Soil Erosion and Assessment.
- 5. Land Use, Steam Flow and Runoff Pollution:** Effects of Land Use on Stream Flow and Water Quality.
- 6. Land Use and Ground Water:** Fundamentals of Groundwater Hydrology; Land Use, Ground Water Recharge and Contamination; Assessing Groundwater Resources; Groundwater Source Protection.
- 7. Land Rights, Valuation and Conflict Management:** Land rights and land tenure, process of land valuation, land use conflicts, land reforms and some experiences.
- 8. Landscape Ecology, Urban Forestry and Wetlands.**
- 9. Land Use Wildlife Habitats and Biodiversity:** Fundamentals of Wildlife habitats and Biodiversity.

Recommended Bibliography:

1. Brammer, H. 2002. Land Use and Land Use Planning in Bangladesh. The University Press Limited, Dhaka.
2. Davidson, D.A. 1982. Soil and Land Use Planning. Longman, London.
3. Davies, K.P. 1976. Land Use. McGraw-Hill Inc. USA.
4. FAO. 1993. Guidelines for Land-use Planning. Food and Agriculture Organization of the United Nations, Rome (<http://www.fao.org/docrep/T0715E/t0715e0c.htm>).
5. OECD, 1976. Land use policies and agriculture. Organization for Economic Co-operation and Development, Paris.
6. Randolph, J. 2004. Environmental Land Use Planning and Management. Island Press, Washington DC, USA.
7. Stevens, P.R. 1987. A simplified field manual for site classification and site suitability assessment in Bangladesh forests. FAO/UNDP Project BGD/81/011- Assistance to the second Agricultural research Project.

ENV 511 COMMON PROPERTY RESOURCE MANAGEMENT

Theory: 75 (3 cr.);

Term Paper: 25 (1cr.)

Total = 100 (4 cr.)

Course contents:

Introduction to political economy of natural resources.

Theories of collective action, cooperation and common property: The problem of collective action; Repeated games and multiple equilibrium; Cross scale linkages among institutions; Experimental collective action, role of communication and enforcement; Prescriptions and remedies; How does Mexican forestry represent a collective action problem?; Historical motivation and precedence of Mexico's agrarian system of common property

Power, influence and the distribution of benefits: Critiques of decentralization and devolution; Equity and efficiency; Distribution of benefits under different governance structures; Endogenous bargaining power; Comparison of common property management regimes with agricultural and industrial cooperatives; Incorporating technical uncertainty and local knowledge into adaptive ecosystem management

Garrett Hardin, "The Tragedy of the Commons" (*Science*, 1968).

Gordon Rausser and Pinhas Zusman, *Political Power and Endogenous Policy Formation*, Cambridge University Press: New York, Forthcoming.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. New York: Cambridge University Press.

Camille Antinori and Rausser, Gordon, "Collective Choice and Community Forestry Management in Mexico: An Empirical Analysis", *Journal of Development Studies*, 43:3, pp. 512-536, 2007.

Bray, Merino and Barry, 2006. *The Community Forests of Mexico: Managing for Sustainable Landscapes*. University of Texas Press: Austin.

Peter Taylor (2000). "Producing More with Less? Community Forestry in Durango, Mexico in an Era of Trade Liberalization", *Rural Sociology* 65:2, pp 253-274.

David Mosse, "Collective Action, Common Property, and Social Capital in South India: An Anthropological Commentary," EDCC 2006

ENV 512 ECOTOURISM MANAGEMENT

Theory: 75 (3 cr.);

Term Paper: 25 (1cr.)

Total = 100 (4 cr.)

Course contents:

1. **Nature and Scope of Ecotourism:** History of ecotourism and its definitions; Nature based tourism, Characteristics of ecotourism; Benefits of ecotourism; Environmental, socio-cultural and economic impacts of ecotourism;
2. **Ecotourism Management:** Concept and procedures; Recreation and the environment; recreational impacts on the environment; ethical and legal concerns; code of practice for ecotourism operators; incorporating ecotourism principles into activities; interpretation; visitor guidelines; planning for minimal impact; quality control; Waste management – concept, needs, design and implementation.
3. **Ecotourism and Protected Areas:** Protection of the ecosystems; Conservation of forests, biodiversity, local cultures and heritage; Assessing Eco-Tourism Potential of a particular area/forest; Role of private sectors in Ecotourism and forest conservation; Co-management of protected areas and Ecotourism in Bangladesh
4. **Ecotourism and Development Issues:** Ecotourism as a growth sector within the tourism industry; Ecotourism and community development;
5. **Marketing Ecotourism:** The ecotourism market; Situation analysis; Market research; Promotion; Advertising; Sales; Trends in international tourism; Understanding the needs of the consumer; Consumer expectations; Development, Promotion and Marketing of ecotourism in Bangladesh; Ecotourism branding, certification and labeling.
6. **Ecotourism Facility Development:** Infrastructures and signage; Interpretations; Accommodation facilities including camp sites, cabins, resorts, etc.; Layout of facilities; Accepted practices for service facilities; Identifying catering options for different ecotourism activities; Tourism attractions and infrastructures in Bangladesh.
7. **Safety in Ecotourism:** Safety strategy, hazards and first aid; Identify/establish safety precautions/requirements/procedures for an ecotourism enterprise.
8. **Sustainability of Ecotourism:** Maintenance of Carrying Capacity; Environmental education program; Community livelihoods; Legal and policy supports from the government;
9. **Ecotourism Management Plan (EMP):** Concept, procedures and implementation of EMP.
10. **Planning an Ecotourism Activity:** A special project where the student plans out an ecotourism activity including: budget, accommodation, licenses, meals, destination, etc.

References :

- Drumm, A. & Moore, A. (2005). *Ecotourism Development: An Introduction to Ecotourism Planning* (Vol. I). (A. Singer, Ed.) Arlington, VA, USA: The Nature Conservancy.
- Drumm, A. & Moore, A. (2004). *Ecotourism Development: Volume II - The Business of Ecotourism Development and Management* (Vol. II). Arlington, VA, USA: The Nature Conservancy.
- Mowforth, M., & Munt, I. (2009). *Tourism and sustainability* (3rd Edition). London, UK: Routledge.
- Newsome, D., Moore, S.A., & Dowling, R.K. (2002). *Natural area tourism*. Bristol, UK: Channel View Publications.
- Weaver, D. (2008). *Ecotourism* (2nd Edition). Hoboken, NJ: JS Wiley.

ENV 513 **ADVANCED STATISTICS IN ENVIRONMENTAL SCIENCE RESEARCH**

Theory: 75 (3 cr.); Term Paper: 25 (1cr.) Total = 100 (4 cr.)

Course contents:

- 1. Basic statistical concepts:** observations and outliers, variables and random variables, accuracy and precision, bias and efficiency; probability distribution, mean and expected value, variance, SE, joint probability, covariance and correlation, Unbiasedness and efficiency, Asymptotic properties of estimators and consistency
- 2. A brief overview of classical linear models:** OLS assumptions; random components of regression coefficient; regression coefficients as random variables; unbiased properties of regression coefficient; efficiency of regression coefficient; maximum likelihood option; weighted generalized least square models.
- 3. Analysis of variance: One-way analysis of variance-**complete randomized design, estimation of parameters; one way ANOVA, individual contrasts, multiple comparison, model diagnostics; **Two-way layout models-**multiple comparison, contrast for main effects and interactions, two-way ANOVA, analysis of the main effect model
- 4. Analysis of covariance:** Variance and covariance; model structure; analysis of covariance; treatment contrast and confidence intervals
- 5. Mixed Effect Model:** an introduction; random effect one-way model; estimation of parameters in mixed effect models; Restricted maximum likelihood estimator
- 6. Generalized Linear Models:** Distinction between classical linear model and generalized linear models; elements of GLM, maximum likelihood methods; deviance and residuals
- 7. Time series analysis:** Data and time series; basic stochastic models; multivariate models
- 8. Nonlinear model:** Linearity and nonlinearity, Double logarithmic models, Semi-log models, Disturbance terms in nonlinear models, Nonlinear regression models
- 9. Model specifications:** Variable misspecifications- omission of a relevant variable, inclusion of an irrelevant variable; multi-collinearity and its omission; heteroskedasticity- concepts, detection through Goldfeld-Quandt test and White test, heteroskedasticity corrected SE, weighted and log-regression models; autocorrelations- concepts, detection of autocorrelation through DW test, Elimination of autoregressive conditional errors, and measurement errors

Objective of the course: This course is designed to introduce advanced statistical concepts in analyzing and interpreting real world research problems. In each section of the course students will learn to select the right model/test/diagnostics for the type data they will have and the result they will need. Thus the mode of learning of this course will be – which and why.

Term Paper-1: Each student will prepare a research paper. For the paper the respective student will select his/her preferred research topic. On that topic, s/he will have to collect data (no matter primary or secondary) and build his model(s) with all necessary statistical tests and quality controlling. Data analysis should be done using statistical softwares like R or SAS.

Term Paper-2: This is equivalent to a number of assignments on data analysis related to first half of the syllabus.

Term Paper-3: This is equivalent to a number of assignments on data analysis related to second half of the syllabus.

Special Note: *Students will NOT be required to memorize any statistical expressions.*

Recommended bibliography:

- Cowpertwait, P.S.P. and Metcalfe, A.V. 2009. *Introductory time series with R*, Springer, Seattle, WA, USA.
- Dobson, A.J. and Barnett, A.G. 2008. *Introduction to Generalized Linear Models*, Taylor and Francis Group, Fl, USA.
- Greene, W.H. 2003. *Econometric Analysis*, 5th Edition, Pearson Education, Prentice Hall, NJ, USA.
- Gujrati, D.N. 2004. *Basic Econometrics*, 4th Edition, McGraw-Hill, NY, USA.
- Kunter et al. 2005. *Applied Linear Statistical Models*, 5th Edition, McGraw-Hill, NY, USA.
- Rawlings et al. 1998. *Applied Regression Analysis*, 2nd Edition, Springer, NY

ENV 514 ENVIRONMENTAL MODELING

Theory: 75 (3cr); Term Paper: 25 (1cr);

Total: 100 (4cr)

Course contents:

- 1. Introduction:** Definition, scope and limitation of environmental modeling; Quantitative and qualitative uses of computer-based models to guide policy in human & environment systems; computer models; Use and abuse of environmental models; Decision Support Systems
- 2. The Systems Perspective:** Theory and practice of environmental analysis and modeling; Overview of environmental systems; The model building process: Developing conceptual models and translating them into mathematical models and abstracting then into computer models; Generic modeling constructs underlying many environmental systems models, Techniques used in applying models; Principles of simulation, Model optimization and sensitivity analysis
- 3. Foundation in Mathematics and Statistics for Environmental Modeling:** Environmental variables and parameters; Continuous, discontinuous and categorical variables; Categorical and binary variables; Procedure for numerical and categorical data analysis; Sample and population; Contingency tables: Two ways, three ways and four ways; Estimation of sample size; Variance of sample means, Confidence interval; Hypothesis, Test of hypothesis; Probability distribution, Gaussian distribution; Student-t probability distribution, Student t-test, Chi-square distribution and Chi-square test; Significance level and power of a test.
- 4. Relationship Among Variables:** Correlation and regression analysis; Linear and non-linear relationships, Relationship between two variables, GLM; Multiple regression analysis of environmental variables;
- 5. Software Tools for Modeling:** Linear and logistic model using SAS; Weighted regression and formation of logistic model; Confounding variables; Test of goodness of fit; Stepwise regression with selection option using SAS; Selection of best model using SAS; Maximum likelihood estimation.
- 6. Computer Programming for Model Development:** Exploring the use of different desktop and web applications for environmental modeling, for example, MS Excel, Visual basic, MatLab, SAS, SPSS, Stella, LINDO, Mapple etc.
- 7. Specific Cases of Environmental Modeling:** Resource modelling: renewable resources. Single species models (the logistic equation); Modelling for harvesting with maximum sustainable yield; predator-prey models and other multi-species models; Modeling for surface water quality, Population dynamics, Modeling air and water pollution, Greenhouse gases and global warming, Carbon modeling; Biodiversity conservation modeling; Ecological modeling; Economic-environmental modelling.
- 8. GIS:** GIS as a visual modeling tool, GIS tools and their applications in spatial and temporal modeling of environmental issues, for example, ArcGIS.

Term paper: Students will prepare term paper on topics given by the course teacher(s).

Recommended bibliography:

- Ackerman, B., S. Rose-Ackerman, J. Sawyer Jr and D. Henderson. 1974. The Uncertain Search for Environmental Quality. New York: The Free Press. Pp.1-78. *Goddard and Marsh HC107 A123 P552.*
- Blankenship, J. and R. Thomas. 1977. "Demographic Impact of Introducing Modern Medicine to a Subsistence-Level Agrarian Population: A Simulation". *Environmental Management*, 1(5). Pp.401-417.

- Brown et al. 2007. Baselines for land-use change in the tropics: application to avoided deforestation projects. *Mitigation and Adaptation Strategies for Global Change* 12: 1001-1026.
- Clarke, Parks, and Crane, 2002. *Geographic Information Systems and Environmental Modeling*, Prentice Hall.
- David G.K, Lawrence L.K, Keith E.M and Nizam A., 1998. *Applied Regression Analysis and other multivariable Methods* Duxbury Press, An International Thomson Publishing Company.
- Deaton and Winebrake, 2000. *Dynamic Modeling of Environmental Systems*, Springer-Verlag.
- Deaton, M.L. and J.I. Winebrake. 2000. *Dynamic Modeling of Environmental Systems*. New York: Springer. Pp.1-23, 66-94.
- Hall, C. (ed.) 2000. *Quantifying Sustainable Development: The future of tropical economies*. San DiegoCA: Academic Press. Pp.121-156.
- Hall, C. 1988. An assessment of several of the historically most influential theoretical models used in ecology and of the data provided in their support. *Ecological Modeling* 43. Pp.5-31.
- Jerald, L. S. 1996. *Environmental Modeling: Fate and Transport of Pollutants in Water, Air, and Soil*, John Wiley & Sons Inc.,
- Morgan, G. and M. Henrion. 1990. *UNCERTAINTY - A guide to dealing with uncertainty in quantitative risk and policy analysis*. New York: CambridgeUniversity Press. Chapters 1-3. Pp.1-46, 220-240.
- Pontius Jr, RG, W Boersma, J-C Castella, K Clarke, T de Nijs, C Dietzel, Z Duan, E Fotsing, N Goldstein, K Kok, E Koomen, C D Lippitt, W McConnell, A MohdSood, B Pijanowski, S Pithadia, S Sweeney, T N Trung, A T Veldkamp, and P H Verburg. 2008. Comparing the input, output, and validation maps for several models of land change. *Annals of Regional Science*, 42(1): 11-47.
- Recent peer reviewed articles on environmental modeling published in reputed journals.
- S. Mahendrarajah, A.J. Jakeman and A.Mc. Aleer, *Modeling change in Integrated Economic and Environmental Systems* John Wiley & Sons Ltd.
- Steven, C. C.1997. *Surface water quality modeling*, McGraw-Hill, Singapore
- Tufte, E. 1983. *The Visual Display of Quantitative Information*. Cheshire CT: Graphics Press. Pp.53-77.

ENV 515 INTEGRATED COASTAL ZONE MANAGEMENT

Theory: 75 (3 cr); Term Paper: 25 (1 cr); Total: 100 (4 cr)

Course contents:

Chapter 1: Introduction to ICM

Concept of ICM, Why ICM is needed, Historical perspectives of ICM, ICM process/cycle, Functions and activities of ICM, ICZM in Bangladesh, Programs under ICZM, Approach of ICZM, Outcomes of ICZM in Bangladesh, Challenges and Opportunities for ICM in Bangladesh

Chapter 2: Coastal and Marine Social Ecological Systems

Ecosystem Structure, Functions & Services to Man, Connectivity of Ecosystems, Social Ecological Systems and The Concepts of Resilience, Human Interactions and interventions, Mangrove Ecosystems Structure & Function, Mangrove services for human-well-being, Coral reef ecosystems structure and function, Coral Reef services for human well-being, Coastal wetlands and Sea grass ecosystems, Estuaries, and Lagoons, Management Challenges and Threats (Human population increase and demographic change, land use change/conflict, Habitat loss and degradation, pollution, climate change)

Chapter 3: Marine Protected Areas and Zonation

Concept of MPAs, Types and categories of MPAs, Definition Marine Protected Area, Benefits from MPAs, Best Practice for Establishing Successful MPAs, MPAs & Integrated Coastal Management (ICM), Design of resilient MPA networks

Chapter 4: Guiding Principles for Integrated Coastal Management

ICM Principles and approaches relating to Sustainable Development (Adaptive Management, Ecosystem Based Approach, Precautionary principle, Human rights and development principles, Environmental Safeguards, Polluter-pays-principles, Participation and Transparency, Good Governance and Co-management)

Principles and approaches that recognize the special character of oceans and coasts (Related to the public nature of the oceans, Related to their biophysical nature, Related to coastal and marine resources and special use)

Enabling conditions for ICM program/project implementation (Stakeholder participation and user groups formation, the special needs of traditional coastal-resource dependent communities, Promoting gender equality and equity, The role and involvement of NGOs and CBOs, The role and involvement of the private sector, Gaining political will, Achieving transparent governance and leadership)

Chapter 5: Tools for Integrated Coastal Management

Introduction to Rapid appraisals and survey tools, introduction to participatory planning for ICM, DPSIR (Drivers, Pressures, States, Impacts, Response) Framework, System Analysis, Stakeholder and institutional Analysis, Vulnerability and capacity analysis, Cause-effect relationship, Spatial Assessment-the use of GIS, Coastal erosion and management, Introduction to ecosystem based approaches for aquaculture and fisheries environmental management, tools for conflict management, Sustainable tourism management, EIA and SEA for ICM, tools for effective communication

Chapter 6: ICM project Design

Recap of ICM process, Outcome based Logical Framework Analysis, Introduction to Theory of Change, Project Management/implementation tools, Sustainable financing mechanisms for ICM plan/project, Resilience analysis, Activity based budgeting for ICM, Lesson learned documentation and knowledge management

Term paper/ Practical work (25 Marks)

- Identify coastal management problems/issues at field level and design project to address them
- Apply learned tools and strategies in the ICM process
- Apply the ICM process in the local context

Term paper: Coastal zone policy, management and land use policies. Disasters in coastal zone and utilization of coastal resources.

Recommended bibliography:

- Cicin-Sain, B. and Knecht R. W.,1998. Integrated coastal and ocean management: concepts and practices
- Clark, J. R. 1995. *Coastal Zone Management Handbook*. CRC Press, Boca Raton, Florida. Library XC3 CLA.
- Clark, J. R. 1998. *Coastal Seas: The Conservation Challenge*. Blackwell Science.
- Clark, J.R. 1992. Integrated Management of Coastal Zones. FAO Fisheries Technical Paper- 327. 167p
- Clark, R. B. 1992. *Marine Pollution*. (Fifth edition). Clarendon Press, Oxford.
- Ecosystems. *Science* 293: 629 – 638.
- Jackson, J. B. C. et. al. (2001). Historical Overfishing and the Recent Collapse of Coastal
- Salm, R. V. & Clark, J. R. (2000). *Marine and Coastal Protected Areas: A Guide for Planners and Managers*. IUCN.
- White, A. T. et al. (1994). *Collaborative and Community Based Management of Coral Reefs*. Kumarian Press.

ENV 516 CLIMATE CHANGE

Theory: 75 (3cr);

Term Paper: 25 (1cr);

Total: 100 (4cr)

Course contents:

1. **Climate Change:** Definition; Scope; Importance for planet with advanced protocols; Impacts on temperature rise, Sea-level rise, Precipitation change, Carbon sequestration; Droughts and floods.
2. **Impacts on Human and Natural Systems:** Food and water resources; Ecosystem and biodiversity; Human settlements; Human health.
3. **Adaptation Process:** Assessment of adaptation practices, options, constraints and capacity. Socioeconomic development paths; Economic growth; Technology; Population and Governance.
4. **Mitigation:** Issues related to mitigation in the long term context; Energy supply, Transport and its infrastructure, Residential and commercial buildings, Industry, Agriculture, Forestry, Waste management. Mitigation from a cross sectoral perspectives.
5. **Emissions and Concentrations:** Advanced knowledge on Greenhouse gases and Aerosols.
6. **Climate Change Scenarios:** Derivation procedure; Modelling approach; Extrapolation methods from international to regional, national and local climate change scenarios.
7. **Future Impacts of Climate Change:** Africa, Asia, Australia and New Zealand, Europe, Latin America, North America, Polar Regions (Arctic and Antarctic) and Small islands of the world.

Term paper:

1. Term paper on issues on climate impact on Bangladesh.
2. Adaptation due to climate change in plants, human being.
3. Mitigation procedure generally followed for changing climate special ref to sea level rise.

Recommended bibliography:

- IPCC. 2001. Climate Change 2001. Synthesis Report. A contribution of working groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R. T. and The core writing team (eds)]. Cambridge University Press. Cambridge. United Kingdom and New York, NY, USA. 398pp.
- Lillesand, T.M. and Kiefer, R.W. 1987. Remote sensing and Image Interpretation. Second edition. John Wiley and Sons. New York, USA.
- Miller (Jr), G.T. 2002. Environmental Science, Working with the Earth. Thompson Learning Inc. 541 pp.
- Moffit, F.H. and Muhlail, G.W. 1980. Photogrammetry. 3rd edn. Harper and Row Publishers NY.
- Paine, D.P. 1981. Aerial Photogrammetry and Image Interpretation for Resource Management. John Wiley & Sons. New York, USA.
- Sharma, M.K. 1986. Remote Sensing & Forest Surveys. International Book Distributors. Dehra Dun, India.
- Simonett, D.S. and Ulaby, F.T. (eds). 1983. Manual of Remote Sensing. Volume One. Second edition. American Society of Photogrammetry. USA.
- Walford, N. 1995. Geographical Data Analysis. John Wiley & Sons. 446p.

ENV 517 ENVIRONMENTAL DISASTER MANAGEMENT

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Course contents:

- 1. The Significance of Disaster:** The traditional and new disaster threats; Geography of disaster; Modern loss factor; Major aspects of significance-, General effects of disaster.
- 2. Foundation Process, Exposure and Impact of Various National Hazards:** cyclones, storms, surges, thunderstorms (Kalbaisakhi), Flooding, Landslides, Tsunamis and earthquake. Disaster management in Bangladesh perspectives.
- 3. Climate Change Vulnerabilities and Disaster Treats:** Climate change scenarios and future natural disasters in coastal areas of Bangladesh.
- 4. Major Requirements for Coping with Disaster:** Scope of disaster related action; the philosophy for coping with disaster; foundation factors; organization; utilization of resources; special skills and training needs.
- 5. Disaster and National Development:** Disaster and the national image; impact of disaster on national development; the need for and value of legislation; main areas covered by legislation.
- 6. Counter Disaster Resources:** Types of resources; evaluation of resources, roles and responsibilities of resources.
- 7. Leadership in Disaster:** Leadership attributes and desirabilities; Leadership under crisis conditions; Ramifications of political leadership; Leadership in the direction of response operations; Leadership in resource organizations; Community leadership.
- 8. Plans:** The need for counter-disaster plans; general considerations applicable to planning; format of plans; the planning process; critical areas in planning; aspects for consideration during planning.
- 9. Prevention and Mitigation:** The need to consider disaster prevention; problem areas in prevention; positive approaches towards prevention; resources relevant to prevention. Guiding principles of mitigation; problem areas in mitigation; requirements for effective mitigation; major mitigation components; formulation and Implementation of mitigation programmes.
- 10. Recovery:** Key points from disaster analysis; transfer of responsibilities from response to recovery; continuation of response activity, the basis for recovery action; problem areas in recovery. Major requirements for effective recovery; human factors in recovery; resources relevant to recovery programmes.
- 11. Post-Disaster Review:** The importance of post-disaster review; reasons for omission of post-disaster review; major investigation into disaster.
- 12. Training and Public Awareness:** The need for training, training policy, types of training and trainee categories; implementation of training, public education; the importance of public awareness, responsibility for public awareness programmes; information format, information channels, effectiveness of information and maintenance of awareness levels.

Term paper: Based on the major man made and natural disasters of Bangladesh. Different approaches of disaster management and cooperation in regional and international perspectives.

ENV 518 Climate Change Impact and Adaptation

Theory: 75 (3cr);

Term Paper: 25 (1cr);

Total: 100 (4cr)

Course contents:

1. **Climate Change impacts on different sectors:**

Water sector- Climate change and the global water cycle, Case studies of River basin scale decision-making, Climate and groundwater resources.

Ecosystem services- Paying for ecosystem services, Climate impacts on ecosystem services.

Agriculture and food security- Food production systems and Climate change impacts, Future food security.

Human migration- Exploring the climate-environment-migration nexus

Biodiversity- Climatic drivers of biodiversity, Climate and conservation

2. **Impact assessment to adaptation pathways:** Understanding vulnerability assessment.

Methodologies of impact assessment-Perspectives on adaptation. Scenario approaches to adaptation assessment. Climate information for adaptation

3. **Lessons from climate prediction:** Challenges in climate prediction: Seasonal and decadal climate predictions; Focusing on the climate modeling and their uncertainties at global and regional levels. Climate change adaptation tools.

4. **Climate smart disaster risk reduction:** Climate extremes, DRR, Climate smart-DRR

5. **Adaptation Techniques:** Case studies from successful adaptation programmes from worldwide. Adaptation programme in policy strategy of Bangladesh and other climate vulnerable countries.

Term paper: Students will prepare term paper on topics given by course teacher(s).

Recommended bibliography:

IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

ENV 519 ENVIRONMENTAL COMPLIANCE, AUDITING AND CERTIFICATION
Theory: 75 (3 cr); Term Paper: 25 (1 cr); Total: 100(4 cr)

Course contents:

- 1. Environmental Auditing:** Scope and significance of environmental auditing, Identifying compliance and sustainability issues in business and industries.
- 2. Environmental Compliance:** Relationship between environmental laws and environmental compliance, sustainability goals.
- 3. Environmental Compliance Reporting Tools:** Communication, monitoring, enforcement of compliance standards
- 4. Environmental Compliance Plans:** Compliance plans for programs such as air quality, storm water, wastewater treatment, hazardous waste management, pollution prevention, or solid waste.
- 5. ISO Quality Assurance and Environmental Management Standards:** The ISO 9000 and 14000 families for international standards and their relation to Sustainability.
- 6. Environmental Performance Evaluation (Indicators):** ISO 14031, Preset indicators and Organization specific defined indicators; Environmental condition indicators (ECIs) and Environmental performance indicators (EPIs).

Term paper: Students will prepare term paper on topics given by course teacher(s).

Recommended bibliography:

- Center for Waste Minimization, 2006. A handy guide for environmental compliance, South Carolina Department of Health and Environmental Control, USA.
- Environment Protection Agency, 2001. Environmental Management System Tools: A Reference Guide, USA
- Waters, J. S. 1998. Environmental Management Systems, Kansas University
- Werksman, J. C. J. and Rederick, P. 1996. Improving Compliance with International Environmental law. Earthscan

ENV 520 ENVIRONMENTAL BIOTECHNOLOGY

Theory: 75 (3cr); Term Paper: 25 (1cr); Total: 100 (4cr)

Contents:

1. **Basics of Microbiology:** Cell, Taxonomy and phylogeny, Prokaryotes and Eukarya, Viruses, Biochemistry, Enzymes, Energy capture, Metabolism, Genetics and information flow, DNA and RNA, Phylogeny, Microbial Ecology, Tools for microbial ecology.
2. **Stoichiometry and Bacterial Energetics:** Empirical Formulas for Microbial cells, Substrate partitioning and cellular yield, Energy reactions, Reactions for biological growth, Energetics and bacterial growth, Yield coefficient and reaction, oxidized nitrogen sources.
3. **Microbial and Biofilm Kinetics :** Basic rate expressions, Mass balances, Soluble microbial products, nutrients and electron acceptors, Hydrolysis of particulate and polymeric substrates, Inhibition, Microbial aggregation, biofilm, steady state biofilm, non-steady state biofilm.
4. **Reactors for Industrial Wastewater Treatment Process:** Reactor types, Batch reactor, Continuous-Flow Stirred-Tank Reactor with effluent recycle, Plug-Flow reactor with effluent recycle, Reactor with recycle of settled cells, reactors in series, Engineering design of reactors.
5. **The Activated Sludge Process:** Characteristics, process configuration, Design and operating criteria, aeration systems, Bulking problems, centrifugal separations, membrane separations.
6. **Lagoons and Aerobic Biofilm processes:** Aerated lagoons, Stabilization lagoons, Types of stabilization lagoons, Aerobic and anaerobic stabilization lagoons, coliform reduction, biofilm process considerations, trickling filters and biological towers, granular media filter, Hybrid biofilm
7. **Nitrification and Denitrification Process:** Biofilm nitrification, Hybrid processes, chemistry and physiology of nitrifying bacteria, common process considerations, activated sludge nitrification, ANAMMOX process, physiology of denitrifying bacteria, tertiary denitrification, one-sludge denitrification
8. **Phosphorus Removal :** Normal phosphorous uptake into biomass, Precipitation by metal-salts addition to a biological process, Enhanced biological phosphorus removal
9. **Anaerobic Treatment of Sludge by Methanogenesis:** Uses for methanogenic treatment, reactor configuration, Process chemistry and microbiology, Process kinetics, Design of anaerobic digesters
10. **Bioremediation:** Scope and characteristics of contaminants, Biodegradability, Contaminant availability for biodegradation, Engineering strategies for bioremediation, *In situ* biobarriers, *Ex situ* bioremediation, Phytoremediation

Term paper: Students will prepare term paper on topics given by course teacher(s).

Recommended bibliography:

1. Rittmann, B. E and McCarty, P. L. (2001). *Environmental Biotechnology: Principles and applications*. McGraw Hill companies, Inc., New York, NY 10020, 754pp.
2. Metcalf and Eddy. (2004). *Wastewater engineering, treatment and reuse*. Mc Graw Hill co. Inc., 1221, Newyork, NY 10020,1819pp.
3. Mino, T., Van Loosdrecht, M. C. M., Heijnen, J. J. 1998. Microbiology and biochemistry of enhanced biological phosphate removal process. *Water Res.*, 32:3193– 207.
4. Satoh H., Iwamoto Y., Mino T., Matsuo T. 1998. Activated sludge as a possible source of biodegradable plastic. *Wat. Sci.Tech.*, 37: 579-582.
5. APHA. 2005. Standard methods for the examination of water and wastewater, 21st ed. American Public Health Association, American Water Works Association, and Water Environment Federation ,Washington, DC.
6. Comeau, Y., Hal, K. J., Huncok, R. E. W., Oldham, W. R. 1986. Biochemical model for enhanced biological phosphorus removal. *Water Res*, 20:1511 –21.

ENV 521 - ADVANCED SOLID WASTE MANAGEMENT

Theory: 75 (3 cr); Term Paper: 25 (1 cr); Total: 100 (4 cr)

Course contents:

SOLID WASTES:

- 1. Introduction:** Waste generation and management in a technological society. Major issues for the management of solid wastes- increasing waste quantities, lack of quality data, need for clear roles and leadership in state, and local government, and resolution of inter-county, inter state, and intra-country waste issues for MSW and its components. Key factors for successful solid waste management.
- 2. Solid Waste Legislation:** Trends in municipal waste generation and management in Bangladesh. The waste reduction legislation movement in Bangladesh. Different waste reduction and management legislation of Bangladesh. The effect of legislation in Bangladesh. Legislating local government and different stakeholder responsibility in solid wastes management.
- 3. Planning for Municipal Solid Waste Management Program:** National solid waste management planning. Factors to be considered in national planning- Geologic, hydrologic, and climatic circumstances, and the protection of ground and surface waters; collection, storage, processing, and disposal methods; methods for closing dumps; transportation; profile of industries; waste composition and quantity; political, economic, organizational, financial, and management issues. Local and regional solid waste management planning and involvement of NGO's and CBO's through privatization.
- 4. Source Reduction:** Concepts relevant to source reduction. Effects of source reduction. Involvement of national government for source reduction. Developing a source reduction plan. Strategies for source reduction. Toxicity reduction and relevant concept of the toxicity of trash. Policies for the reduction of toxicity.
- 5. Recycling:** Recovery of recyclable materials from solid waste; Development and implementation of materials recovery facilities. Equipment for processing of recyclables. Environmental and public health and safety issues.
- 6. Markets and Products for Recycled Material:** Barriers to the development of effective recycling markets. Sustainable recycling- the recycling loop. Recycling markets- market analysis, materials for recycling, e.g.- Glass, Plastics, Aluminum, Tires, etc. Market development for recycled products and factors influencing material processing and value. Demand-side and supply side of recycled products. Trade issues of the recycled products.
- 7. Integrated Solid waste Management Strategies:** Landfill- different issues relevant to land filling. Waste-to-energy combustion- incineration technologies and relevant issues. Composting- principles and technologies of composting.
- 8. Understanding the sources of public concern:** Political, technical, economic, and ethical aspects. A typical siting process- determining need, choosing a technology, site selection, assessing and mitigating impacts, managing the facility.
- 9. Financing and Life-Cycle Costing of Solid Waste Management Systems:** Movement toward privatization of services. Financing options- private equity, traditional loans, tax-exempt bonds, taxable bonds, state grants and loans, public funds. Life-cycle costing of municipal solid wastes management facility.

Term paper: students will prepare term paper on topics given by course teacher(s).

Recommended bibliography:

George Tchobanoglous and Frank Kreith, Handbook of Solid Waste Management, McGraw-Hill.

Christian Ludwig, Stefanie Hellweg, Samuel Stucki, Municipal solid waste management: strategies and technologies for sustainable solutions, Springer.

P. Jayarama Reddy, Municipal Solid Waste Management: Processing, Energy Recovery, Global Examples, CRC Press.

B. B. Hosetti, Prospects and Perspectives of Solid Waste Management, New Age International, India.

William A. Worrell and P. Aarne Vesilind, Solid Waste Engineering, Cengage Learning, USA.

Surendra Kumar, Solid Waste Management, Northern Book Centre.

Elizabeth M. Thomas-Hop, Solid Waste Management: Critical Issues for Developing Countries, Canoe Press.

Thomas Christensen, Solid Waste Technology and Management, John Wiley & Sons.

Urvashi Dhamija, Sustainable Solid Waste Management: Issues, Policies and Structures, Academic Foundation.

ENV 522 APPLIED INDUSTRIAL ECOLOGY

Theory: 75 (3cr); **Term Paper:** 25 (1cr); **Total:** 100 (4cr)

Course contents:

1. Biological and Industrial Ecosystems and Sustainability:

Ecology and ecosystem: Natural and Industrial; Material and energy flow in industrial system and their implications to sustainability; Material constraints: the case of scarce metals and energy; Origin of Industrial ecology (IE); Principal and methodological approaches for studying sustainable consumption- Scenario analysis, ecological footprints and structural decomposition analysis; Concepts of IE and its main themes; Learning from natural ecosystem to improve industrial ecosystem; Utility of the analytic tools of biological ecology in IE; Input-stock-output analysis in IE as a measure of sustainability.

2. Material/Substance Flow Analysis (MFA/SFA):

Conceptual framework for conventional and economy wide MFA; MFA methodologies, software tools and data sources; Scope and rationale of conducting MFA; Planning and conducting and MFA –the data and analysis aspects; Modeling manufactured Stocks and material flows; Presenting MFA results; Implications and applications of MFA results.

3. Life Cycle Assessment (LCA):

Product and process life cycle; LCA methodologies, software systems and databases; System and its boundary; Life cycle design; Application of LCA; Challenges of LCA in developing countries like Bangladesh; Integrating life cycle assessment with in overall framework for environmental management.

4. Industrial Symbiosis:

Materials, energy and water consumption pattern in natural ecosystem and in the industrial world; Definition and concept of industrial symbiosis – its origin and classic examples; Energy, materials and water use minimization through industrial symbiosis; Eco-industrial park and their designs;

5. Economics and Industrial Ecology:

Environmental accounting and material flow accounting at national and firm level; Resource and impact decoupling; Dematerialization, transmaterialization and rematerialization. Optimal resource extraction.

6. Policy Implications of Industrial Ecology: IE and green design; IE and risk analysis; IE and spatial planning; Industrial estates as model ecosystems; Closed-loop supply chains; Industrial ecology and extended producer responsibility; Recycling, reuse and upcycling; IE in environmental management – example from ISO 14000 series

7. National Accounts, Statistics and Databases:

Environmental Input-Output Database; Building and managing databases - developed world experiences; The LCA and MFA databases – state of Bangladesh and way forward

Term paper: Students will prepare term paper on topics given by course teacher.

Recommended Bibliography:

Robert U. Ayres and Leslie W. Ayres, A Handbook of Industrial Ecology, (Edt.), Edward Elgar Publishing Limited, UK.

Ehrenfeld, John and Nicholas Gertler. *Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg*. Journal of Industrial Ecology (1997) 1(1): 67-79.

Chris T. Hendrickson, Lester B. Lave and H. Scott Matthews, Routledge, Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach,

- Marry Ann Curran, *Environmental Life-Cycle Assessment*, McGraw-Hill.
- Henrickson, C.; et. al. *Economic Input-Output Models for Environmental Life-Cycle Assessment*. Environmental Sci. & Tech., (1998) 32: 184A-191A.
- Hunt, Robert G., Jere D. Sellers, and William E. Franklin. *Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures*. Environmental Impact Assessment Review, Spring (1992): pp. 245-269.
- R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, *Industrial Ecology and Global Change*, (Edt.), Cambridge University Press, UK.
- T. E. Graedel, and Braden R. Allenby, *Industrial Ecology*, Prentice Hall.
- ISO 14040 International Standard, Environmental management – Life cycle assessment – Principles and framework, 1997, 06-15.
- Jelinski, L.W., T.E. Graedel, R.A. Laudise, D.W. McCall, and C. Kumar N. Patel. *Industrial Ecology: Concepts and Approaches*. Proceedings, National Academy of Sciences, USA 89 (1992): pp. 793-797.
- Robert H Crawford, *Life Cycle Assessment in the Built Environment*, Taylor & Francis.
- Life Cycle Assessment: Inventory Guidelines and Principles* (EPA 600/R-92/245). Cincinnati, OH: U.S.EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, February 1993.
- Wackernagel, M. and W. Rees, Chapter 3 in *Our Ecological Footprint*, New Society Publishers: Gabriola Island, B.C. Canada (1996) pp. 61-124.

ENV 523 GREEN DEVELOPMENT AND ENVIRONMENTAL GOVERNANCE
Theory: 75 (3 cr); Term Paper: 25 (1 cr); Total: 100 (4 cr)

Course contents:

- 1) **Green Development:** Concept, scope and significance; Environmental information collection and development of environmental indicators; Domains of green development; Resource management; Energy conservation, Sustainable production of energy
- 2) **Stages of Green Development:** Eco-Living- Design of environmentally optimized facilities, Recycling of wastes, Water conservation and water recycling provisions, Air filters for better health of personnel; Eco-learning- promotion/education; Social interaction; and Eco-Lending- development of eco-financing criteria; Ecological bonds; Project development- Eco-tourism hotel, wind generator farms, fields of photovoltaic arrays; Industrial air pollution equipment; Eco-food, eco-labelling, eco-clothing and eco-fashion
- 3) **Design Elements for Eco-house/Eco-village Planning:** Options for ecological development; eco-standards- biodiversity and landscape, sustainable community development, delivery of infrastructure, economy, energy and carbon strategy, green infrastructure, holistic housing approach, inclusive design, community transport planning, sustainable community waste management, sustainable community water management.
- 4) **Ecological Development for Generating Environmental Information for Decision-makers:** biodiversity, village community development.
- 5) **Introduction to Environmental Governance:** Defining Governance, Governance Components and Principles, Debate on theory of governance, Governance in practice, Natural resource governance in Bangladesh.
- 6) **Assessment and Monitoring of Governance:** Framework for assessing and monitoring governance.
- 7) **Collaborative Governance:** Collaborative governance; Theory and practice; Collaborative action framework; Partnership as collaborative governance mechanisms.
- 8) **Environmental Governance:** Emerging global environmental governance, Themes; mechanism and strategy of environmental governance; Neoliberal environmental governance; Integrated climate governance; Good governance and environmental compliance and enforcement; Forest Governance- mainstream and critical views, Forest governance in decentralized systems, Forest governance in Asian countries, Forest governance and REDD+; Governance of ecosystem services: Instruments for governance of ecosystem services; Spatial planning in governance of ecosystem services.

Term paper: Students will prepare term paper on topics given by the course teacher(s).

Recommended bibliography

- Andre Gunder Frank, 1996. *The Underdevelopment of Development*, Thousand Oaks: Sage Publications, 427 pp.
- Bonfiglioli, A. 2004. *Lands for the poor: Local Environmental Governance and the Decentralized Management of Natural Resources*. UNCDF, New York.
- Castro, A. P. and Nielsen, E. (editors). 2003. *Natural resource conflict management studies: An analysis of power, participation and protected areas*. FAO, Rome.
- Colfer, P, C.J. and Capistrano, D. (editors). 2005. *The politics of decentralization: Forests, people and power*. Earthscan, London.
- Contreras-Hermosilla, A., Gregersen, H. M. and White, A. 2008. *Forest Governance in countries with federal systems of government: Lessons for decentralization*. CIFOR Governance Brief.
- Edmunds, D. and Wollenberg, E. (editors). 2003. *Local forest management: The impacts of devolution policies*. Earthscan, London.
- Glasbergen, P., Biermann, F. and Mol, A.P.J. (editors) 2007. *Partnerships, governance and sustainable development: Reflections on theory and practice*. Edward Elgar Publishing Limited, the UK.
- Industrial Symbiosis: Paths towards Eco-efficiency and Eco-development* (internet)
- Jan Nederveen Pieterse, 1998. *My Paradigm or Yours? Alternative Development, Post-Development, Reflexive Development, Development and Change* Vol. 29 (1998), 343-373. Institute of Social Studies 1998. Published by Blackwell Publishers Ltd, 108 Cowley Rd, Oxford OX4 1JF, UK.
- Kishor, Nalin and Kenneth Rosenbaum. 2012. *Assessing and Monitoring Forest Governance: A user's guide to a diagnostic tool*. Washington DC: Program on Forests (PROFOR).
- M. Adams, *Green Development- Environment and Sustainability in the third world*. 2nd edition, Routledge (Taylor and Francis), London, New York
- Miller, W. L., Dickson, M. and Stoker, G. 2000. *Models of local governance: Public opinion and political theory in Britain*. Palgrave, New York.
- Moeliono, M., Wollenberg, E. and Limberg, G. (editors). 2009. *The decentralization of forest governance: Politics, economics and the fight for control of forests in Indonesian Borneo*. Earthscan, London.
- Noel et al., 2009. *A Companion to Environmental Geography*. Wiley-Blackwell.
- Oxford Historical Monographs, 2006. *Modernizing Nature: Forestry and Imperial Eco-Development 1800-1950*, Oxford University Press, USA, 304 pages
- Patti Moore, Xuemei Zhang, and Ronnakorn Triraganon (2011). *Natural Resource Governance Trainers' Manual*. IUCN, RECOFTC, SNV, Bangkok, Thailand.
- Rashid K.Y. et al., 2012. *Natural resource governance: Best practices and lesson learned*. IUCN, Dhaka.
- Rhodes, R. A. W. 1997. *Understanding governance: Policy networks, governance, reflexivity and accounting*. Open University Press, Philadelphia.
- Robert Riddell, 1981. *Ecodevelopment: economics, ecology and development: an alternative to growth imperative models*, Gower - Business & Economics - 218
- Sebastian Berger, 2009. *The foundations of Non-equilibrium economics*, Routledge
- Swiderska, K., Roe, D., Siegele, L. and Grieg-Gran, M. 2008. *The Governance of Nature and the Nature of Governance: Policy that works for biodiversity and livelihoods*. IIED.
- Thomas Greiber and Simone Schiele (eds.) (2011), *Governance of Ecosystem Services*. Gland, Switzerland: IUCN.
- Van Bodegon, A.J., Klaver, D., van Schoubroeck, F and van der Valk, O. 2008. *FLEGT beyond T. Exploring the meaning of 'Governance' concepts for the FLEGT process*. Wageningen University & Research Center, the Netherlands.
- Webb, E. L. and Shivakoti, G. P. (editors). 2008. *Decentralization, forests and rural communities: Policy outcomes in South and Southeast Asia*. SAGE Publications, India.

ENV 524 RENEWABLE ENERGY TECHNOLOGIES

Theory: 75 (3cr); **Term Paper:** 25 (1cr); **Total:** 100 (4cr)

Course contents:

1. Global energy crisis; Non-renewable and renewable energy and their statistics; Rationale, opportunities and challenges of renewable energy future; Climate change and sustainability in relations to renewable energy; Historical perspective on renewable energy.
2. Sources of renewable energy; Prospects and problems related to these sources
3. Solar energy technologies - fundamentals; solar cell, solar tower, mirror array, solar ponds, solar concentrator.
4. Wind energy technologies - fundamentals, wind turbines,
5. Geothermal energy technology
6. Hydropower - large hydroelectric projects and micro-hydro projects, Ocean and tidal energy technology
7. Bioenergy technologies, biofuel, bioethanol and biodiesel, Biorefinary, wood energy, charcoal making, wood gasification and pyrolysis, biofuel cell, Biogas and landfill gas recovery.
8. Micro grid and smart grid technology; Cogeneration and microgeneration; System loss reduction for renewable energy; On- and off-grid solutions
9. Renewable energy and Bangladesh; Public policy in relation to renewable energy; Private initiatives in renewable energy technology; Geographic distribution of renewable energy resources in Bangladesh.

Term paper: Students will prepare term paper on topics given by course teacher(s).

Recommended Bibliography

- Ahmed, K., and C.D. Anderson. *Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies*. World Bank, 1994.
- Jordan-Korte, K. *Government Promotion of Renewable Energy Technologies: Policy Approaches and Market Development in Germany, the United States, and Japan*. Betriebswirtschaftlicher Verlag Dr. Th. Gabler GmbH, 2011.
- Kaltschmitt, M., W. Streicher, and A. Wiese. *Renewable Energy: Technology, Economics and Environment ; 66 Tables*. Springer-Verlag Berlin Heidelberg, 2007.
- Kristoferson, L.A.A., V.A. Bokalders, and Beijer Institute. *Renewable Energy Technologies: Their Applications in Developing Countries : A Study by the Beijer Institute, the Royal Swedish Academy of Sciences*. Intermediate Technology Publications, 1991.
- Maczulak, A.E. *Renewable Energy: Sources and Methods*. Facts On File, Incorporated, 2010.
- Mallik, A., D. Bhave, and N. Mate. *Renewable Energy Technologies: Special Focus on Distributed Power Generation: Potential for Applications to Rural Sector in India*. Academic Foundation, 2009.
- Sabonnadire, J.C. *Renewable Energy Technologies*. Wiley, 2010.
- Singh, G. *Exploit Nature-Renewable Energy Technologies*. Aditya Books Pvt. Ltd.
- Solanki, C.S. *Renewable Energy Technologies: Practical Guide for Beginners*. Prentice-Hall Of India Pvt. Limited, 2008.
- Zobaa, A.F., and R.C. Bansal. *Handbook of Renewable Energy Technology*. Singapore: World Scientific Publishing Company Incorporated, 2011.

ENV 525 DEVELOPMENT ECONOMICS

Theory: 75 (3 cr.); Term Paper: 25 (1cr.) Total = 100 (4 cr.)

Course Contents:

- 1. Development and Development Economics:** Development- consensus and differences in definition; Development Economics (DE) - definitions, urban and rural development; sustainability issues in development; historical legacies, global perspectives of economic development; the grounds for the study of DE
- 2. Theories of Economic Growth and Development:** modeling economic growth; major economic growth models- Solow-Swan model of growth; optimal growth model, endogenous growth model
- 3. Poverty and Inequality:** definitions, causes, sustenance, and measurement of poverty, globalization of poverty-the politics of inequality, economic growth and quality of life
- 4. Health, Education, and Human Capital:** Health and nutrition; development-environment-health-poverty trap; health and productivity; basic healthcare - a comparison between developed, developing, and under developed countries; intellectual property and health in developing countries; major ailments and economics of risky behavior, the primacy of education; facilities and outcomes of education in developing countries; educational interventions; education, income, and fertility; gender, family, and society; child labor in the global economy
- 5. Saving, Credit, and Entrepreneurship:** Credit, savings, and investment; constraints in credits access; microcredit- promises, prospects, implementation, and socio-economic development; risk and insurance, insurance failure
- 6. Political Economy and Corruption:** Public goods- ownership, markets, and economic development; national leadership and economic growth; Corruption-administrative system and corruption; culture of corruption; policy and political commitments; policy debates
- 7. Theories of Consumption, Investment and Unemployment:** Consumption under certainty and uncertainty; savings; interest rate and savings; investment and cost of capital; effects of uncertainty on investment; cash flow and investment; theories of unemployment; a generic efficiency-wage model; employment contracts- wage contract; efficient contracts; implicit contracts; implications of contracts
- 8. Inflation and Monetary Policy:** Monetary policy; Accomplishment of monetary policy; interest rate and the conduct of policy; issues in designing an interest rate, term structure of interest rate; inflation and money growth; dynamic inconsistency of and solution to inflation in monetary policy; cost of inflation; benefits of inflation
- 9. Budget Deficit and Fiscal Policy:** Government budget constraints; measurement issues in budget constraints, Ponzi scheme; strategic debt accumulation- political assumptions; economic assumption; extreme preferences; weak government and budget deficit; the cost of deficit
- 10. Development and Economic Growth- Bangladesh Perspective:** Economic growth in Bangladesh-historical trend and projection; growth and environmental responsibility; environmental accountability and economic efficiency; major industries and their contribution to national development; workplace and workers' rights in Bangladesh; development partners and foreign aid- aid availability, liberty in aid use; transparency in foreign-aided development projects; foreign aid and development policy

Objective of the course: This course is designed to acquaint the students with the development-environment interface. The students will get a clear picture on how local and global policies impact

macro and microeconomic attributes of development like human capital, economic growth and development, and environment.

Term Paper: Each student will be required to work on a number of term papers on important issues of development having local, regional, and global consequences. Term papers will be both analytical and empirical. Empirical analysis MUST include real world development data (no matter, primary or secondary), econometric models, and relevant interpretation.

Recommended bibliography:

A number of journal articles on development issues (will be discussed in the class)

Development Effectiveness Reviews: <http://www.adb.org/publications/search/1185>

Human Development Reports (<http://hdr.undp.org/>)

Romer, D. 2006. Advanced Macroeconomics, 3rd edition, McGraw-Hill, NY, USA.

Todaro, M.P. and Smith, S.C. 2009. Economic Development, 10th edition, Pearson Education, NY, USA.

Wickens, M. 2008. Macroeconomic Theory- a dynamic general equilibrium approach, Princeton University Press, NJ, USA.

World Development Reports (<http://wdonline.worldbank.org/>)

World Economic Outlooks (<http://www.imf.org/external/pubind.htm>)