Advanced Environmental Systems Analysis

Lecturer: Matteo Giuliani

Aims and Objectives

The course offers a systematic overview of policy analysis and decision-making under global change. The emphasis will be on concepts and tools for modeling human decisions in environmental systems subject to demographic, land-use, energy, and climate change. The course develops knowledge and skills for modeling these changes across different spatial and temporal scales, quantifying their impacts at the local scale, assessing the variety of uncertainties associated to future projections, and developing tools to assist decision makers. Real world examples and numerical applications will be developed. The course is aimed at graduate students preparing to work in the environmental engineering field.

Course delivery and contents

The course is delivered via lectures (30 hours) complemented by practical, laboratory sessions (20 hours) that will contribute to the course assessment. Detailed topics covered include:

1. Scenario-based analysis: the top-down approach, from global scenarios to the local scale; demographic projections; climate projections (Representative Concentration Pathways), climate models and IPCC assessment reports; socio-economic projections (Shared Socioeconomic Pathways) and Integrated Assessment Models (e.g., DICE, WITCH); impact models, land-use models (e.g., AQUACROP), energy system models (e.g. OSeMOSYS); downscaling techniques.
2. Scenario-neutral analysis: the bottom-up approach, from local vulnerabilities to global scenarios; sensitivity analysis and synthetic generation of external drivers; stress test and scenario discovery; exploration of adaptive capacity.
3. Robust decision making: decisions under risk vs decisions under deep uncertainty; robustness analysis; robustness, flexibility, and adaptation pathways.

Main bibliography

- Dessler, A.E. (2019). *The Science and Politics of Global Climate Change*. Cambridge University Press (third edition)
- Ray, P. and C. Brown (2015). *Confronting Climate Uncertainty in Water Resources Planning and Project Design.* The Decision Tree Framework. World Bank Group.
- Peterson, M. (2017). *An introduction to decision theory*. Cambridge University Press (second edition).

Exam

The final grading combines a written exam on the lectures' topics (max 20 points; 12/20 required to pass the exam) with a report on a project related to the laboratory activities (max 12 points).

Lec01	Environmental systems under change	Course introduction; the climate change debate; framework for decision making under change (example of Red River management); from climate to global change
Lec02	Decision making problems	Classification of Decision Making problems; decision-biases in multi-objective DM; Arrow paradox; DM under risk
GAME	DM under risk vs uncertainty	Game simulating flood risk decisions under risk and under uncertainty
Lec03	How to model DM under global change?	Top-down vs bottom-up models of changing drivers; behavioral models (descriptive vs normative); the challenges related to the temporal and spatial scales
Lec04	Scenario-based approach: global scenarios	Introduction to top-down (scenario-based) approach; global scenarios of climate change; SRES vs RCP and SSP; demographci projections
Lec05	Climate models	Introduction to Climate Models; the main physical processes simulated by CMs; IPCC reports and scenarios; example application on Lake Como; the issues of equifinality and chaotic regimes
Lec06	Downscaling	Introduction to downscaling methods; dynamical vs statistical vs combined downscaling; quantile mapping
Lec07	Integrated Assessment Models	Introduction to Integrated Assessment Models; DICE model; WITCH model; Nash equilibria; simulation of climate negotiations
Lec08	Impact models	Impact models for the Water-Energy-Food Nexus; hydrologic models; land use/crop growth models, FAO models, example applications on Lake Como and global scale analysis; energy system models, OSeMOSYS, example application on hydropower planning in Africa
Lec10	Generation of the exposure space	Introduction to bottom-up (scenario neutral) approach; synthetic scenario generation; additive vs multiplicative scaling; random generation techniques (random, hypercube sampling, Sobol sequence); autoregressive models; parametric and non parametric weather generators

Lec12	Scenario discovery & adaptive capacity	Introduction to scenario discovery; Monte Carlo Filtering and Patient Rule Induction Method; exploration of adaptive capacity; coupling of synthetic and scenario-based projections
Lec13	Robust Decision Making	Introduction to problems under deep uncertainty; alternative robustness metrics; problems for consistent robust decision making
Lec14	Beyond robustness: flexibility and adaptation pathways	Illustration of robust DM taxonomy; open points in RDM; robustness vs flexibility; adaptation pathways

lab1	IPCC scenarios	Laboratory session on IPCC scenarios; data access and manipulation in MATLAB
lab2	QQ mapping	Laboratory session on quantile mapping method (using the IPCC scenarios from lab 1); climate change impact assessment on crop production in the Muzza district using a MATLAB model
lab3	Generation of exposure space	Laboratory session on synthetic scenario generation via additive and multiplicative scaling factors
lab4	Identification of adaptive capacity	Laboratory session on exploration of adaptive capacity for cropping pattern decision in the Muzza district