Lahore University of Management Sciences

EE5612/SCI302: Socio-Ecological Systems and Sustainability

Spring 2022-23

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Course URL (if any)	

Course Teaching Methodology (Please mention following details in plain text)
• Teaching Methodology: In person • Lecture details: two 75 mins lecture in a week

Policy for Cross listed course (SCI 302)
A version of this course is also offered to undergraduate students as SCI 302. The course outline for both versions remains the same and the lectures will take place jointly. However, the students enrolled in SCI 302 will not be required to submit a term paper and their deliverables in the assignments and exams will be fewer as compared to those enrolled in EE 5612. Moreover, in place of the term paper, the students enrolled in SCI 302 will be required to give a presentation on a textbook topic not covered in the lectures.

Course Basics				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	75 min
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	
Tutorial (per week)	Nbr of Lec(s) Per Week		Duration	

Course Distribution	
Core	
Elective	
Open for Student Category	Juniors (SCI 302 only), Seniors, MS, PhD
Close for Student Category	

COURSE DESCRIPTION
This course is aimed towards students interested in working on environmental problems, especially on problems where environmental phenomena overlap with societal and technological processes. In the course, a systems-based approach will be adopted to study socio-ecological systems. The concept of a system will be introduced, followed by different theoretical frameworks commonly used to study such systems. Modern notions of sustainability will be discussed along with their implications. Finally, the complex linkages between water, energy and food flows in socio-ecological systems will be studied as a systems analysis case study.

COURSE PREREQUISITE(S)
• Juniors and Seniors (SCI 302): Differential Equations and Linear Algebra • Seniors (EE 5612): Feedback Control Systems (or instructor's consent) • Graduate Students: None

COURSE OBJECTIVES
• To introduce students to the systems perspective of thinking • To develop a working understanding of the major theoretical frameworks commonly used for systems analysis • To familiarize students with modern applications of sustainability science • To prepare the students to undertake a project or thesis dealing with interacting natural, social and (or) technological systems.

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Learning Outcomes
At the end of the course, the students should be able to • Understand the complex environmental, social and economic dimensions underlying sustainability • Identify and apply the appropriate systems analysis framework to a given system towards a specified objective • Appreciate both the benefits and disruption brought about by the application of technology to coupled human natural systems • Read and understand a research paper of moderate difficulty in the area of environmental systems analysis • Be poised to undertake further graduate studies in this area

Grading break up: Component Details and weightages	
EE 5612 Assignment(s): 30% Quiz(s): 10% Class participation: 5% Midterm Examination: 20% Term Paper: 15% Final Examination: 20%	**SCI 302** Assignment(s): 30% Quiz(s): 10% Class participation: 5% Midterm Examination: 20% Presentation: 15% Final Examination: 20%

Assessed Course Learning Outcomes
The students should be able to: CLO1: Identify key components and interconnections in systems of moderate complexity CLO2: Apply systems analytical tools to predict system behavior under given conditions CLO3: Outline the conditions that promote sustainability in a given system w.r.t the modern definitions of sustainability Additional CLO for EE 5612 only CLO4: Present the work of an independent project effectively in written form

Relation to EE Program Outcomes

EE-5612 CLOs	Related PLOs	Levels of Learning	Teaching Methods	CLO Attainment checked in
CLO1	PLO1: Engineering Knowledge	Cog1: Knowledge	Lectures	Exams, Quizzes, Assignments
CLO2	PLO2: Problem Analysis	Cog3: Application	Lectures	Exams, Quizzes, Assignments
CLO3	PLO7: Environment and Sustainability	Cog4: Analysis	Lectures	Exams, Quizzes, Assignments
CLO4	PLO10: Communication	Cog2: Comprehension	Lectures	Project

Examination Detail	
Midterm Exam	Yes/No: Yes Combine Separate: Duration: Preferred Date: Exam Specifications:

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Final Exam	Yes/No: Yes Combine Separate: Duration: Exam Specifications:

Week	Lecture	Topics	Recommended Readings	Related CLOs
1 – Jan 16	Introduction	The definition of a system; Socio-ecological systems; What is systems analysis? What is sustainability? An overview of the course.	Handouts	
	Complex systems and feedback	Policy resistance and Unintended consequences in complex systems; Analysis and synthesis; Feedback; Revisiting complex systems (Jevon's paradox, Levi's effect, American wildfires); Limits to growth and the Tragedy of the Commons.	Handouts	
2 – Jan 23	System Dynamics 1	Causal loop diagrams; Motivating examples; Practical issues and pitfalls in constructing CLD's;	Sterman Ch 5	
	System Dynamics 2	Analyzing causal loop diagrams; Detailed examples	Sterman Ch 5	
3 – Jan 30	System Dynamics 3	Introduction to stocks and flows; Dynamics of simple structures; Exponential growth and decay	Sterman Ch 6	
	System Dynamics 4	Dynamics of growth; Goal seeking behavior; Time constants and half-lives; Multiple loop systems; Density dependent growth; Loop dominance;	Sterman Ch 8	
4 – Feb 06	System Dynamics 5	Multiple stock dynamics; S-shaped growth; Logistic model of innovation diffusion; Fundamental modes of dynamics behavior; Predator prey systems	Sterman Ch 9	
	ODE Systems 1	Introduction to dynamical systems; Stability of first order systems; Bifurcations; Linearization; Eigenvalues and stability; The phase portrait; Stability in two dimensions	Handouts	
5 – Feb 13	ODE Systems 2	Bio-economic model of an open-access fishery; The steady state equilibrium and comparative statics; The dynamics of renewable resource harvesting	Perman Ch 17	
	ODE Systems 3	The private-property fishery model; Static profit-maximization; Introduction to present value maximization	Perman Ch 17	
6 – Feb 20	ODE Systems 4	Present value-maximization and discounting in the private property fishery; Necessary conditions in optimization; The Maximum Principle	Perman Ch 17	
	ODE Systems 5	Application of the Maximum Principle to the harvesting model; Combining the open-access, static private-property and present-value maximizing models;	Perman Ch 17	
7 – Feb 27	ODE Systems 6	Applications of the Maximum principle for policy insights; Sustainability in dynamical systems	Handouts	
		Midterm		
8 – Mar 06	Game theory 1	Introduction and reasoning about behavior in a game; Efficiency and optimality; Best response and dominant strategies; Nash equilibrium	Easely Ch 6	
	Game theory 2	The pollution abatement game; Free-riding; Binding solutions to the pollution dilemma; Other forms of	Perman Ch 9	

		dilemmas; Games in extensive form		
9 – Mar 13	Game Theory 3	Games with large number of players; Pollution abatement with a group of countries; Games with continuous actions spaces	Perman Ch 9	
	Game theory 4	The Cournot game; the continuous abatement game	Perman Ch 9	
10 – Mar 20	Networks 1	Introduction to networks; Basic structural characteristics of networks; Small world phenomenon; Network representations; Network statistics	Barabasi Ch2	
	Networks 2	Mathematical properties of networks; Degree distributions; Random networks; The scale-free property; Adjacency matrix; Paths and distances; Measuring connectivity in networks	Barabasi Ch 3	
11 – Mar 27	Networks 3	Measures of centrality in networks; Ecological networks; A formalism of ecological stability	Handouts	
	Networks 4	Food webs and community stability; Entropy as a measure of stability; Capacity, ascendency and reserve; Balancing efficiency and redundancy; System robustness and application to real-world networks	Handouts	
12 – Apr 03	Mathematical Programming 1	Decision making through optimization; A simple resource allocation problem; Feasibility sets and constraints; Graphical solutions for two-dimensional optimization	Handouts	
	Mathematical Programming 2	Optimization models for sectoral decision making; A water quality management problem; Incorporation of dynamics; Introduction to the MESSAGE energy supply model	Handouts	
13 – Apr 10	Mathematical Programming 3	The water energy food nexus; multi-sectoral decision making; Linking optimization models	Handouts	
	Mathematical Programming 4	Case Study: The Irrigation Efficiency Paradox	Handouts	
14 – Apr 17		**Course Review**		
15 – Apr 24		**Prep Week**		
16 – May 01		**Final Exam Week**		

Textbook(s)/Supplementary Readings
Textbooks: 1. "Natural Resource and Environmental Economics" (4th edition) by Perman, Ma, Common, Maddison & McGilvray. 2. "Networks, Crowds and Markets: Reasoning about a highly connected world" by Easley and Kleinberg. 3. "Network Science" by Albert-Laszlo Barabasi 4. "Business Dynamics: Systems thinking and modeling for a complex world" by Sterman Additional/Supplementary Reading: 5. "Sustaining the commons" by Anderies & Janssen 6. "Thinking in Systems" by Meadows

Prepared and Revised by:	**Talha Manzoor**
Revision Date:	**November 2022**