SCIENCES
ENVIRON 390K

Systems Thinking and Resource Management Modeling

Fall 2016

Dates / contact hours:	300 minutes of contact time per week for 7 weeks
Academic Credit:	1 course
Areas of Knowledge:	NS (Natural Sciences)
Modes of Inquiry:	STS (Science, Technology, & Society)
Course format:	Lectures; student-led discussions; oral presentations; team-based exercises; lab assignments; learning modules (question/answer sessions on videos); instructional videos

Instructor's Information

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Prerequisite(s), if applicable

Basic knowledge of ecological and environmental principles; elementary calculus helpful

Course Description

In this course, we address real-world problems by taking a systems thinking approach to build mathematical and computer simulation models. All problems in the modern world – such as climate change, air pollution, ground water depletion, coastal development, global economic supply-demand chains – are vexing, challenging and often intransigent. Each of these represents a set of connected "things" or parts that form complex wholes or systems. Hence, learning how to be a "systems thinker" is an invaluable skill. Systems Thinking emphasizes a holistic approach to problem-solving that involves identifying the essential parts of a system; identifying the key pathways of causality of these components or parts (e.g., topology, hierarchy, feedbacks); and valuing the roles of self-organization, nonlinearity and thresholds as determinants of whole-system dynamics. Given the challenge of understanding linked human-ecological-economic systems in our ever-changing world, mathematical and computer simulation models are essential tools across all disciplines. This course is for students (1) with little or no systems thinking or modeling experience but are curious to learn more, especially with an emphasis on resource management problems; (2) students who recognize that simulation modeling is an important tool of choice in the modern world for problem-solving and thus want to be able to "look under the hood" of models; (3)

students that have struggled with journal articles that contain models and equations; (4) students who have wondered if modeling might be useful in their own work; (5) want to learn how to build a model from scratch; and/or (6) students keen to be see how and why becoming a “systems thinker” will be useful in their life (for example, systems thinking is used as the basis for global conservation efforts, is used to train nurses, and constitutes the core curriculum in industrial dynamics, business, and resource management).

Course Goals / Objectives

The specific objectives will be matched to the interests and background of the students. General goals include:

- to provide a working knowledge of systems thinking;
- to establish a basic understanding the methods, language and tools of systems thinking;
- to learn how to apply systems thinking to quickly and efficiently develop conceptual models of relatively complex systems (using mind maps, causal loop diagrams, Forrester diagrams)
- to provide a working knowledge of the basics of modeling and model-building;
- to examine differing philosophies motivating various types of management models – from empirical to phenomenological to mechanistic – and from comprehensiveness to understandability;
- to distinguish between design vs. implementation principles of modeling-building;
- to learn how to develop meaningful and achievable objectives for any given problem;
- to learn (and apply in case studies) the four basic steps of model-building: *lexical* (what’s important? Seeking parsimony using Occam’s Razor), *parsing* (what are the key relationships?), *modeling* (how to express relationships with appropriate mathematical formulations and solutions), and *analysis* (e.g., sensitivity, validation).
- to be able to assess if and when prediction *per se* is relevant to achieve management and/or policy goals;
- to apply “soft systems” methodologies to problematic organizational management cases;

Required Text(s)/Resources

<u>Thinking in Systems. A Primer</u> by Donella Meadows

Chelsea Green Publishing (240pp), 2008

Recommended Text(s)/Resources

Throughout the term supplemental materials are provided via Sakai in response to student needs, class dynamics, etc.

Additional Materials (optional)

Course Requirements / Key Evidences

The classroom consists of the following activities:

1. LECTURES. In lieu of formal lectures, I provide overviews of each topic, lead discussion of key take-home messages of each chapter in Meadow's book, provide context for topics, ask/answer questions in order to gauge student understanding, and provide many examples.
2. VIDEO MODULES. To supplement lectures and discussions, students have access to a video library (>50 to date, ranging from 1-10 min.) on many of the topics. Two examples can see viewed at: https://www.dropbox.com/sh/x0rnboy4kkmsuz8/AACIp23wbPyhSIUFftighQJRa?dl=0

    a. *Jay Forrester* (from a video series on the origins of systems thinking and systems dynamics; Forrester was a pioneer in the field)
    b. *Why do we model?* (from a video series on Introduction to Modeling)

3. CLASS DISCUSSION. Assigned papers are discussed, led by designated discussion leaders.
4. LAB EXERCISES. One to two lab assignments per week, which are designed to match the lecture/reading material. One day per week is designated as a lab (2.5 hrs) where these assignments are introduced, basic visually-based computer programming is taught (no prior experience is necessary), and students begin working on assignments in a step-by-step manner, with assistance from the instructor and their peers.
5. GROUP EXERCISES. Depending upon the size of the class, 2-3 group projects are conducted. Students are given a working model to explore outside of the classroom. Students are encouraged to explore, interpret, critique and apply the model (if possible). Examples of models previously used include:
    a. A coupled human-environment model for desertification simulation and impact studies (based on 2008 paper in Global and Planetary Change doi: 10.1016/j.gloplacha.2008.09.004)
    b. A complex-systems approach to pastoral commons (based on 2009 paper in Human Ecology doi: 10.1007/s10745-009-9253-2)
    c. Hopes for the future: restoration ecology and conservation biology (based on 1997 paper in Science doi: 10.1126/science.277.5325.515)
6. ORAL PRESENTATIONS. Each student will make 2-3 oral presentations (approx. 5-10 mins). Examples include:
    a. Students develop a causal loop and/or Forrester diagram of any topic of choice. These diagrams are projected on the screen and peers then attempt to interpret. A good diagram is clear, unambiguous and easily interpreted.
    b. Role-playing: Teams of students assume the role of authors of a published paper of their choice. As if this was their original work, they present model objectives, identify assumptions, explain the methodology, describe validation, etc. and are then subject to peer questioning as to the paper's shortcomings and/or strengths.

7. TERM PROJECT – TEAM MODELS. Students (two students/team) select a topic based on their interests, in consultation with instructor. Much leeway is given: students may build original models or use (and/or modify) published models as management tools. I work very closely with students on these projects. Results are presented in a formal poster session at the end of term.

Technology Considerations, if applicable

Sakai is used to deliver all course material. Laptops in classroom are encouraged but managed in context of course. I teach students how to program models using Stella (or, alternatively, Goldsim, Vensim, etc.).

Assessment Information / Grading Procedures

Grade is based on:		%	
Class Participation			
	Oral presentations	10%	
	Discussion sessions	15%	
Exams			
	Self-testing	10%	On-line quizzes (can retake up to 3 times)
	Mid-term	20%	
	Final exam	20%	
Term Project		25%	Team (2 students) model, presented in poster session
		100%	

Diversity and Intercultural Learning (see Principles of DKU Liberal Arts Education)

Describe how the course will address the cultural diversity of students and foster intercultural learning. (This may vary among courses and professors.)

Course Policies and Guidelines

- Academic integrity
  Will follow DKU's Honor Code
- Attendance
  Mandatory
- Attention to assignment deadlines
  Mandatory ; No exceptions
- Make-up work
  Illness and/or other unanticipated circumstances that warrant a medical excuse will be honored, consistent with DKU policy. Student must notify the instructor in advance if a project deadline is to be missed. Project extensions requested for medical reasons must be negotiated at the time of illness.

- Appropriate or inappropriate use of cell phone, laptop, or other technology during class
  Cell phones must be turned-off during class; laptops allowed as per instructor’s discretion

Tentative Course Outline or Schedule

WEEK	TOPICS	DISCUSSION	LAB VIDEOS (examples only, not exhaustive)
1	SYSTEMS THINKING AND PRINCIPLES	How to build a pencil; everything is connected to everything else; why systems thinking? wicked science; self-organization; life can be so nonlinear; why systems thinking is so dominant in today's world; S.M.A.R.T. way to set objectives	MODELING OVERVIEW • What are models? Models come in many shapes and sizes. They are also used and abused in science in a plethora of ways • Background information will provide the context for studying process-based simulation models • What are the steps in constructing models?
2	THE SYSTEMS ZOO	Complex adaptive systems; dynamic systems; emergent properties; feedbacks; propagation of effects; chaos; complexity and the "Medawar Zone"	QUALITATIVE TOPICS • Causal loop diagrams • Forrester diagrams • State–space formulations • Input-output: bank accounts, carbon sequestration, water in a bathtub • Types of models (research versus policy-oriented models) • Illustration of symbolic programming: model your bank account
3	WHY SYSTEMS SURPRISE	What does it take to change a system? (resilience and regime shifts); thresholds and tipping-points; limits to predictions – an orchestra in need of a conductor? Predicting earthquakes: science, pseudoscience and public policy paradoxes; alternatives to prediction; why use syndromes?	QUANTITATIVE TOPICS • Simulation versus Analytical Models • Difference versus differential equations • Simple models with complicated dynamics • Equilibrium versus Steady-State • Goal-seeking behavior • Empirical versus Mechanistic Models
4	SYSTEM TRAPS AND OPPORTUNITIES	Functioning of a system; climbing up-and- down the complexity latter; hierarchy theory; mathematical decomposition – who would have thought it was so simple?	STEPS 1-2: LEXICAL AND PARSING • Functional types (biological, physical, economic, etc.) • The problem of self-organization • Feedbacks: positive, negative, reinforcing • Connectivity: time and space • Criteria for Publishing Models
5	LEVERAGE POINTS IN A SYSTEM	When, how and why to intervene; fast and slow variables; buffering capacity and turnover	STEP 3: MODELING • Stocks and flows • Taxonomy of equations • Simulation methods

		times; balancing loops; reinforcing feedback loops	
6	LIVING IN A WORLD OF COMPLEX SYSTEMS	Challenge of communicating with public, policy-makers; review of course principles, key take-home messages; what is the way forward?	STEP 4: ANALYSIS AND EVALUATION • How good is model? • How to verify, calibrate, and validate dynamic models • RMSE terms • Sensitivity • Uncertainty and stability analyses.
7	POSTER SESSIONS	Open	OPEN

Bibliography (optional)