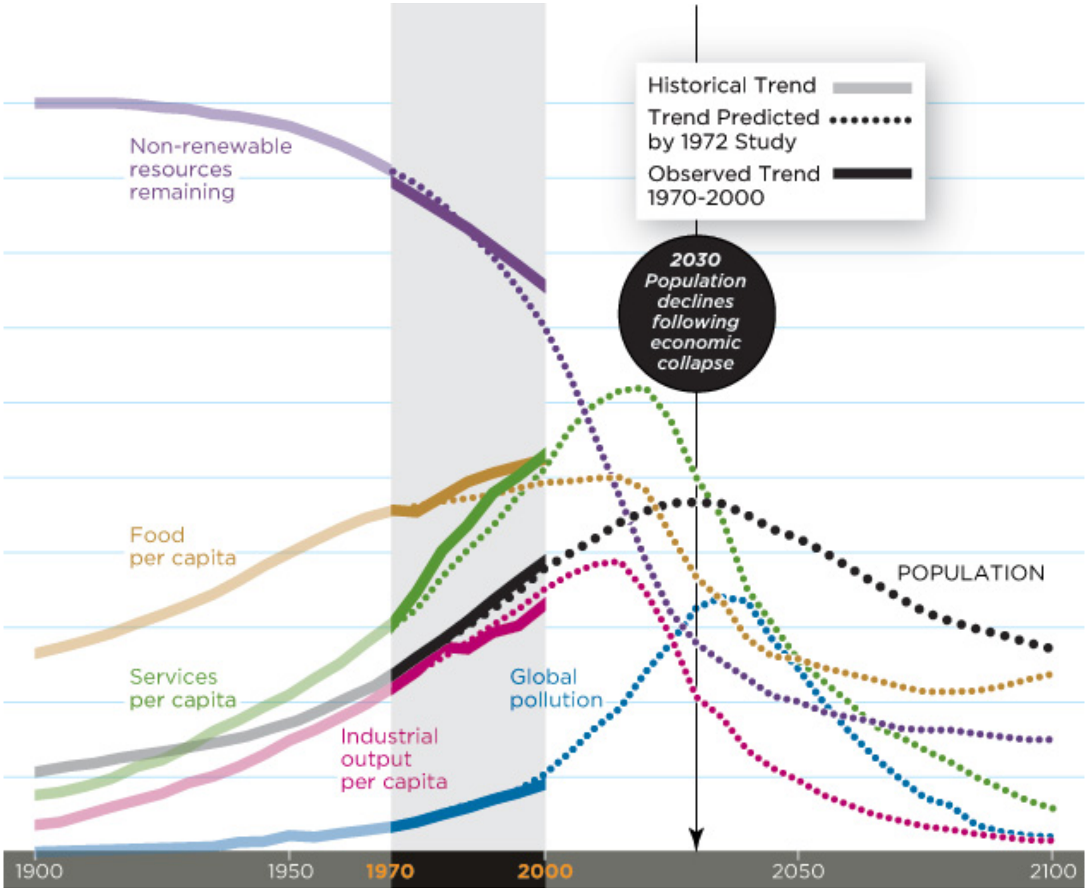
Syllabus



Trend lines depicting one of the output scenarios from the famous 'Limits to Growth' study. From thwink.org.

Course Description

Every day, we interact with systems that impact sustainability outcomes—from deciding how to commute, to what to eat for dinner. Some of us—wildlife managers, farmers, engineers, and many others—must make strategic interventions in these systems in order to fulfill personal, societal, or institutional goals. As we navigate environmental and human systems, we use models to predict their behavior and plan interventions, although we may not be aware that we are doing so. Most of the time, the structure of these models stays hidden inside our heads. These mental models are powerful tools which help us to navigate the complex and dynamic systems in which we are embedded, and for some purposes they function quite well. On the other hand, recent research has demonstrated that human beings are not very good at predicting the behavior of complex systems. We as a species are quite bad at intuitively grasping exponential growth, stocks and flows, delayed feedback, and many other common characteristics of systems. Understanding how to effectively use models of complex systems, and how to construct and evaluate these models, is valuable for anyone working within the sustainability arena, which is just about all of us.

There are many approaches to modeling systems. This course is developed around a quantitative, dynamic modeling approach called 'system dynamics' modeling (after Jay Forrester). 'Quantitative' means we'll be using numbers and mathematical relations to describe systems; 'dynamic' means that these relations may change over time, or be influenced by other variables. We will also provide an introduction to participatory modeling approaches.

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Course Objectives

This course is intended to introduce quantitative modeling approaches as tools for students interested in addressing real-world problems in complex environmental systems. By the end of this course, you should be able to:

1. Identify the characteristics and behavior of complex systems, and be able to define a problem in a systems context;
2. Explain why we use models to understand systems and what makes a 'good' model;
3. Know the steps involved in formulating a research or management question and building a model to address it;
4. Build and use models of real-world systems (using Stella® software) that display exponential growth; equilibrium-seeking; S-curve growth; and oscillatory behavior
5. Construct quantitative, dynamic models with appropriate, data-derived relations between variables, and evaluate model results against other data
6. Understand why, when and how we might use participatory modeling to address a natural resource problem
7. Build your own model to address a research or management question

Instructor

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Class Schedule

Classes will take place on Mondays from 11:30 to 2:20 p.m. either online, or in Natural Resources Building 306. The first third of class (11:30 to approximately 12:30) will usually consist of a lecture/demonstration, while the second two-thirds of class (from 12:30 to 2:20 p.m.) will involve computer lab work.

Prerequisites

This course is designed with upper-level undergraduates and graduate students in mind. There are no prerequisites, but calculus and some familiarity with ecological principles will be an advantage. If you already have some experience with modeling, you will be able to create more advanced versions of the models we'll be using in class. You do not need to know a programming language, but if you do, you should feel free to program your models in the language in which you feel most comfortable.

Course Expectations and Policies

This course is reading-intensive. We lean heavily on the readings to provide you with (1) The theory behind what we do in class and in the lab, and (2) Some of the 'how-to' nuts and bolts of building models, so it is essential that you keep up with the readings. In addition, you will have to spend time outside of class learning how to model—there is no way around this. Think of it as learning a new language; if you are taking a Spanish immersion course (let's say), and all you do is show up to class once a week, your language skills will not advance very far in a semester. If, on the other hand, you make flash cards with vocabulary and get together with other students to practice, you will see remarkable progress. It's the same thing with learning modeling, which is very much like learning how to translate the 'language' of complex systems into mathematical equations. There are many resources online to help with building your modeling skills, and I have provided links to some of the most important on the course D2L site.

Regarding the programming skills you will be learning in Stella, this course takes a 'learn by doing' approach. Most of your modeling skills will be developed as you work on the labs and on your projects. The modeling 'lab' work is therefore the largest component of this class. The lab assignments are carefully designed to help you build the skills that will allow you to develop, run and analyze your own models. We will start out by modifying and running models that will be provided for you, but by the end of the course you will be designing, building, running and de-bugging your own models for a given lab topic. You will need to take advantage of the lab time to try out your new skills, ask questions, and get help on designing and de-bugging your programs. This is another reason to keep up with the reading assignments, so that you will always be prepared for the lab work! During class time, you should feel free to work with your fellow students and share ideas around the assignments, but you will turn in your assignments individually.

In addition to the lab assignments, you will be required to complete a take-home midterm and a final project. The project will involve working on your own to build a model of a system you are interested in. You might want to use a model to address a research question related to your thesis/dissertation or to a project you are working on for your advisor. I will consult with you to ensure that your modeling question is appropriately formulated, and that your research plan is reasonable given the time limitations of the course. Although we will devote some lab time to working on your projects, you will need to work outside of class to complete the project. You will give a short presentation on your project during the course final exam period.

COVID-19 Pandemic Grading Policy

We are still in unprecedented circumstances both in our personal lives and in our learning environments due to the ongoing pandemic. Therefore, **I will not be imposing any penalty for late assignments this semester.** Please still do your best to turn in the assignments in a timely manner, so that all of us can stay on track in regards to the learning objectives. I also ask that if you have to turn in an assignment late for any reason, please let me know that and give me a date by which you expect to have it completed. If you fall more than two weeks behind in your assignments during the semester, I may speak to you about taking a deferred grade in the course.

If you require special accommodation due to a disability, please contact the Resource Center for Persons with Disabilities at 517-884-RCPD or on the web at rcpd.msu.edu. Once your eligibility for an accommodation has been determined, you will be issued a Verified Individual Services Accommodation ("VISA") form. Please present this form to me at the start of the term and/or two weeks prior to the accommodation date (test, project, etc.). I am happy to work with you to make sure you have the environment and materials necessary for your successful performance in the class. In addition, please feel free to contact me if any of the online materials present accessibility challenges.

Grading and Assignments

Lab writeups	40% (8% each for 5 labs)
Midterm exam	15 %
Final report and presentation	35 % (20% report; 10% presentation; 5% proposal)
Participation and effort	10 %
Total	100 %

Each assignment is graded on a 100-percentage point scale, and weighted according to the course percentage points assigned above. The final course grade is converted to a 4-point scale as follows:

MSU grade points	Composite class points
4.0	93.0 - 100.0
3.5	88.0 - 92.9
3.0	80.0 - 87.9
2.5	75.0 - 79.9
2.0	68.0 - 74.9
1.5	60.0 – 67.9
1.0	50.0 – 59.9
0.0	0 – 49.9

Required Materials

1. Donella Meadows. 2008. *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green Publishing.
2. Andrew Ford. 2009. *Modeling the Environment, Second Edition*. Washington, DC: Island Press
3. Marjan Van den Belt. 2004. *Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building.* Washington DC: Island Press.

Optional: Peter Hovmand. 2014. *Community Based System Dynamics.* New York: Springer.

I will also post some readings on Desire2Learn, and some readings will be chosen by your classmates.

Each student will also be **required** to purchase at least a semester license for Stella® Architect or Professional.

Academic Integrity

If an academic integrity violation has taken place, you may receive a failing grade for the course or be referred to appropriate campus authority. Ignorance of the rules is NOT an excuse for an academic integrity violation. In addition, if you are found to be using pirated software in this course, you will receive a 'zero' for assignments you completed using this software. Please see Prof. Schmitt Olabisi if you have any questions about this policy.

Provisional Land Acknowledgement

We collectively acknowledge that Michigan State University occupies the ancestral, traditional, and contemporary Lands of the Anishinaabeg – Three Fires Confederacy of Ojibwe, Odawa, and Potawatomi peoples. In particular, the University resides on Land ceded in the 1819 Treaty of Saginaw. We recognize, support, and advocate for the sovereignty of Michigan's twelve federally-recognized Indian nations, for historic Indigenous communities in Michigan, for Indigenous individuals and communities who live here now, and for those who were forcibly removed from their Homelands. By offering this Land Acknowledgement, we affirm Indigenous sovereignty and will work to hold Michigan State University more accountable to the needs of American Indian and Indigenous peoples. (from http://aisp.msu.edu/about/land/ accessed 1/5/19.)

COURSE SCHEDULE

WEEK	TEACHING FOCUS	ASSIGNMENTS	LAB WORK
1/10	**Introduction to Systems Theory** Course overview What are systems? What does 'systems thinking' mean? How is 'systems thinking' important in addressing natural resource issues? Why do we use models to represent systems?	Daniels & Walker 2012	Characteristics of complex systems; feedback loops and delays; introduction to causal loop diagrams
1/17	**NO CLASS—MLK DAY**		
1/24	**System Dynamics Modeling: the Basics** How to build a model; how to think about modeling	Meadows ch. 1 Ford ch. 1-2 Silvert	Introduction to Stella: How is the atmosphere like a bathtub?
1/31	**Water Systems I** Stocks and flows: the building blocks of systems	Meadows ch. 2 Ford ch. 3-4	Stock and flow modeling; exploring equilibrium
2/7	**Water Systems II** Integrating multiple flows; testing policies	Meadows ch. 4-6	Pollutant modeling *(Lab 1)*
2/14	**Population Dynamics and Limits to Growth; Mathematics of Limits to Growth** Exponential growth: are there limits?	Ford ch. 7 Meadows et al. authors' preface, ch. 2 **Lab 1 Due**	Population growth modeling, S-curve growth, overshoot and collapse. *(Lab 2)*
2/21	**Predator-Prey Dynamics** System oscillation	Ford ch. 18, 20-21 **Lab 2 Due**	Modeling predator-prey dynamics *(Lab 3)*
2/28	**Renewable Resource Use** Managing a resource for human consumption while (hopefully) avoiding collapse and resource degradation	Ford ch. 15 **Lab 3 Due**	Modeling fish harvest ***Take-home midterm assigned***
3/7	**NO CLASS—SPRING BREAK**		
3/14	**Sensitivity Analysis** Understanding the system drivers—implications for science and policy	Ford Appendix D Hekimoğlu & Barlas **Midterm Due**	Sensitivity analysis on fish model *(Lab 4)*
3/21	**Participatory Modeling Exercise**	Van den Belt ch. 1, 5 **Project Proposal Due**	

WEEK	TEACHING FOCUS	ASSIGNMENTS	LAB WORK
3/28	**Participatory Modeling Exercise**	**Lab 4 Due**	
4/4	**Energy and Nonrenewable Resources** Nonrenewable resources; energy return on investment	Bardi et al.	Modeling peak oil
4/11	**Analyzing Model Results** Statistical and scenario methods to better understand model output	Oreskes et al. Ford Appendix D	Validation of peak oil model *(Lab 5)*
4/18	**Modeling as Learning** ***Guest Lecturer: Dr. Steven Gray*** How can models facilitate learning and knowledge-sharing?	Readings TBA **Lab 5 due**	Final project work
4/25	**Introduction to Spatial Modeling** ***Guest lecturer: Dr. Moira Zellner*** Including spatial variables in a model	Ford Appendix G	Course wrap-up
5/2		**Final project write-ups due 5 pm**	
TBA	**Final Presentations**		