ABE4641 Modeling Coupled Natural-Human Systems

Time: MWF, Period 7, 1:55-2:45PM
Rogers Hall 211 and online
Fall 2025

Instructor: Rachata Muneepeerakul, PhD
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Office Hours: TBD and by appointments

Graduate Teaching Assistants (email, office hours and location): N/A

Course Description

Approaches to modeling coupled natural-human systems are explored, drawing from both natural and social sciences. Topics include regime shift from dynamical systems and basic concepts from game theory and social-ecological system literature. These are combined in models that operationalize a conceptual framework. Properties and implications of these models—e.g., resilience and robustness of the coupled systems—will be derived and discussed. Students develop models—with guidance—for final projects. 3 credit hours.

Notes on the online sections: Students enrolled in an online session will participate in lessons through Zoom, which is accessible on Canvas.

Notes on the 80-99% online section: Students enrolled in the 80-99% online session will participate in lessons through Zoom, which is accessible on Canvas, for most of the semester, but will be required to make their final project presentations in person.

Pre-requisites: Basic calculus and college-level probability courses

Course Objectives:

Upon completion of this course, students will be able to:

- Perform stability analysis and construct a bifurcation diagram for simple dynamical systems.
- Articulate the nature of regime shifts or tipping points in the context of coupled natural-human systems.
- Make connections between concepts such as resilience and robustness to their mathematical basis.
- Identify the applicability and limitations of different modeling approaches to coupled natural-human systems.
- Develop a simple model for a coupled natural-human system and analyze it, using tools learned in this course. This is what you are expected to do in your final project.

Materials and Supply Fees: N/A

Relation to Program Outcomes (ABET):

Outcome	Coverage
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	High
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3. An ability to communicate effectively with a range of audiences	Medium
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives	Medium
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	Medium

Sample Readings:

No textbooks are required. The materials for this course will be drawn from several sources. Below are some examples (we would likely not cover all of them):

Anderies, J. M., M. A. Janssen, and E. Ostrom (2004), A framework to analyze the robustness of social-ecological systems from an institutional perspective, *Ecology and Society*, 9(1), 18.

Anderies, J. M., A. A. Rodriguez, M. A. Janssen, and O. Cifdaloz (2007), Panaceas, uncertainty, and the robust control framework in sustainability science, *Proceedings of the National Academy of Sciences*, 104(39), 15194–15199.

Gintis, H. (2000). *Game theory evolving: A problem-centered introduction to modeling strategic behavior*. Princeton University Press.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859), 1243-1248.

Madani, K. (2010). Game theory and water resources. *Journal of Hydrology,* 381: 225-238.

Müller-Hansen, F., Schlüter, M., Mäs, M., Donges, J. F., Kolb, J. J., Thonicke, K., & Heitzig, J. (2017). Towards representing human behavior and decision making in Earth system models–an overview of techniques and approaches. *Earth System Dynamics*, *8*(4), 977.

Muneepeerakul, R. & J.M. Anderies (2017), Strategic behaviors and governance challenges in social-ecological systems, *Earth's Future*, 5: 865–876, doi:10.1002/2017EF000562.

Nowak, M. A. (2006). *Evolutionary dynamics: Exploring the equations of life*. Harvard University Press.

Nowak, M. A. (2006). Five rules for the evolution of cooperation. *Science*, 314(5805), 1560-1563.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: local lessons, global challenges. *Science*, 284(5412), 278-282.

Scheffer, M., *et al.* (2009). Early-warning signals for critical transitions. *Nature*, 461(7260), 53-59.

Scheffer, M., *et al.* (2012). Anticipating critical transitions. *Science*, 338(6105), 344-348.

Young, H. P. (2001). *Individual strategy and social structure: An evolutionary theory of institutions*. Princeton University Press.

Yu, D. J., M. R. Qubbaj, R. Muneepeerakul, J. M. Anderies, and R. Aggarwal. The effect of infrastructure design on commons dilemmas in social-ecological system dynamics, *Proceedings of the National Academy of Sciences*, 112(43): 13207—13212.

Required Computer

Recommended Computer Specifications: https://it.ufl.edu/get-help/student-computer-recommendations/

HWCOE Computer Requirements: https://www.eng.ufl.edu/students/advising/fall-semester-checklist/computer-requirements/

Course Schedule (Tentative):

Week	TOPIC*
1	Overview, introductions, logistics
2	Basic game theory: classic 2x2 games and their Nash equilibriums
3	Mixed-strategy Nash equilibrium
4	3x3 games; Basic evolutionary game theory—replicator equations
5	Analysis of 1-D replicator equations
6	1-D stability analysis Regime shifts; Examples of models with regime shifts
7	MATLAB introduction
8	2D stability analysis
9	2D stability analysis; **MIDTERM**
10	Putting them together: develop CNH models
11	Analysis of selected CNH models
12	Analysis of selected CNH models; **PROJECT PROGRESS REPORTS**
13	MATLAB sessions on selected systems.
14	MATLAB workshops for final projects
15	Review; **FINAL PROJECT PRESENTATIONS**

* The schedule is tentative. Actual schedule would depend on progress and interest in class.

The number of assignments and their topics are tentative; the actual number and topics would depend on progress and interest of class. The assignments are usually due 1 to 1.5 weeks after the date they are assigned. Regardless of the actual number and topics of the assignments, they would collectively count for 45% of the final grade.

There will be 4-5 in-class quizzes, whose topics reflect those of the assignments. These quizzes are designed to help prepare the students for completing their assignments.

There will be a final group project. The students will work in group—with the instructor's guidance—to develop a two- or three-dimensional dynamical model of a coupled natural-human system of their interest. They are to present two progress reports throughout the semester and a final presentation of their project at the end of the semester. It will be encouraged that a group consist of both undergraduate and graduate students. The progress reports and final presentation will be the group's collective work, and the expectations will be the same for both undergraduate and graduate students.

Important Dates

Assignments are usually due within 1-1.5 weeks after the date they are assigned.

Midterm Exam will be held approximately in week 9 or 10

Students are expected to present their final projects in the last week of class

Evaluation of Grades

Assignments: 45% | Midterm Exam: 25% | In-class Quizzes: 5% | Final Project: 25%

Grading Policy

Your final score will be rounded to the nearest integer—for example, 86.5 will be rounded to 87—and your final grade will be determined accordingly to the scale below.

91-100 = A | 86-90 = A- | 81-85 = B+ | 76-80 = B | 71-75 = B- | 66-70 = C+ | 61-65 = C |56-60 = C- | 51-55 = D+ | 46-50 = D | 41-45 = D-| 0-40 = E

Academic Policies & Resources

For information about academic policies and resources, please visit:
https://go.ufl.edu/syllabuspolicies
https://syllabus.ufl.edu/syllabus-policy/uf-syllabus-policy-links/

Commitment to a Positive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Coordinator
- HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
- Pam Dickrell, Associate Dean of Student Affairs, 352-392-2177, pld@ufl.edu