ECOSYSTEM SIMULATION MODELING

Zoology 800/Agronomy 875

Course Description, Spring Semester 2023

Version 23 January 2023

Instructors:	Prof. Monica G. Turner, Department of Integrative Biology (turnermg@wisc.edu) Prof. Christopher J. Kucharik, Department of Agronomy (kucharik@wisc.edu)
Credits:	2 credits
Time & place:	Thursdays, 9:50 – 11:45 am, 158 Birge Hall **(**The room is off the main lobby, go down the hall to the left (east) as you enter from the main doors; the classroom will be straight ahead at the end of that hallway).
Instruction mode:	Face-to-face

Requisites:

- Graduate student status
- Background courses and/or training in ecology
- Strong quantitative skills
- Strong desire to learn about ecosystem simulation modeling!
- Consent of instructor

CLASS SIZE: Admission limited to 20 students.

Course description: All ecological models are simplifications of nature. This course will introduce graduate students in ecology to process-based mathematical models of ecosystems that are simulated on the computer. Ecosystem simulation models describe the major pools and fluxes in an ecosystem and the factors that regulate those fluxes. Mathematical equations are used to represent the processes that control how major pools (*state variables*) of an ecosystem change over time. Mechanistically rich, process-based ecosystem models are increasingly seen as critical for anticipating ecosystem change in a no-analog world.

Students in this class will understand why and how ecosystem simulation models are used in ecology through: (1) class lectures; (2) readings from a textbook and the primary literature; (3) individual- and group-based computer exercises designed to introduce the building blocks of computer simulation modeling; and (4) development by each student of a simple ecosystem simulation model related to their research or field of study.

This class is recommended for graduate students who will develop and/or use ecosystem simulation models in their research. Topics will include specifying the system, mathematical formulation, parameter estimation and calibration, model evaluation, sensitivity and uncertainty analysis, and modeling pitfalls. Programming experience is useful but not required; simulation exercises and model development will use the academic version of the simulation software, VenSim.

Course learning outcomes: Graduate students enrolled in this class will learn to:

- Use systems thinking to link research questions to appropriate model structure and experiments
- Develop and interpret a simple ecosystem simulation model
- Diagram inputs, stocks (state variables), flows, controls and outputs for an ecosystem model
- Translate system diagrams to mathematical equations
- Parameterize, calibrate and evaluate a model
- Design simulation experiments and analyze results
- Communicate results of a modeling study in written and verbal modes
- Actively promote diversity, equity, and inclusion of all at UW-Madison

Office hours: Office hours are by appointment. Please email Monica or Chris to schedule a time.

Course structure: Class meets for two hours on Thursdays each week. The first hour is lecture by Chris, Monica or a guest. The second hour is hands-on, using exercises from the text or that we develop.

Text: Ford, A. 2010. MODELING THE ENVIRONMENT, 2nd edition. Island Press, New York. The book is available from Amazon as well as other sources.

https://www.amazon.com/Modeling-Environment-Second-Andrew-Ford/dp/1597264733
https://islandpress.org/books/modeling-environment-second-edition
https://modeling-the-environment.com/

Software: Each student should download the VenSim software package on their computer. It is available for PCs and Macs, and should be downloaded for free under the educational licensing. Please go to https://vensim.com/ then click Downloads and Free Downloads.

HOW ARE CREDIT HOURS MET BY THE COURSE? Learning will take place in at least 90 hours of learning activities, including time spent in class meetings (lecture, discussions, labs); reading; writing; developing and analyzing simple models; completing an independent research project related to their thesis work; and any other activities as described in the syllabus or assigned during the semester.

ABSENCE POLICY:
Attendance is recorded at each class meeting. If you have an anticipated absence (e.g., planned conference travel or necessary field work), please let us know before the class that you will miss. If you are unexpectedly absent (e.g., illness), please inform us at your earliest convenience and let me know what happened.

Students are responsible for all material that was covered in a missed class and for completing the readings and assignment. A summary of the assigned readings (one single-spaced page maximum for each assigned paper) should be submitted no later than one week after the missed class. The summary should include a brief statement of what was covered in the reading, your thoughts on the key points or primary contribution(s) of the assignment, any insights that were new for you, and questions that were raised in your mind by the paper. Students must complete the hands-on exercise and turn in that work. Depending on the timing of the due dates and the travel/illness, the deadline may be extended. Students should check with me and confirm arrangements.

READING ASSIGNMENTS:
The 2nd edition of MODELING THE ENVIRONMENT by Andrew Ford will be used as the base text for the class. Additional reading assignments will be posted in Canvas. ***Students are expected to have read all assigned readings prior to class.***

Other useful general references:

Canham, C. D., J. J. Cole, and W. K Lauenroth, editors. 2003. Models in ecosystem science. Princeton University Press, Princeton, NJ. *There are a number of very good chapters.*

O'Sullivan, D. and G. L. W. Perry. 2013. Spatial simulation. Wiley-Blackwell. *Again, some excellent chapters; this is authored, not edited.*

Sala et al., editors. 2000. Methods in ecosystem science. Springer.
Chapter 25 is by Hank Shugart on Ecosystem Modeling. *Short but sweet overview*.

Swartzman, G. L., and S. P. Kaluzny. 1987. Ecological simulation primer. Macmillan Publishing, New York. *Older book, but good on many of the basics of modeling (they hold their own over time, even as computing advances.)*

COVID SAFETY: All campus protocols in place to ensure COVID safety will be followed in this class. Guidance continues to evolve, and current guidelines can be found at: https://covidresponse.wisc.edu/ Please be respectful an each person's choice about masking, and please do not come to class if you have Covid symptoms or a positive Covid test. This is an in-person class, but students who must isolate or feel ill can participate in class over Zoom, provided they arrange for a classmate to Zoom them in.

MODELING EXERCISES:
Hands-on experience will provide students with experience in various aspects of ecosystem simulation models and will be assigned in class. Most in-class exercises will be group activities focused on learning the basics of model development and how to use VenSim. These are outlined in the syllabus but are subject to change as we see how things go.

INDEPENDENT MODELING PROJECTS:

Model Objectives: Students will use VenSim to develop a simple ecosystem simulation model that allows them to apply what they are learning to their own research. The project should be an opportunity for students to augment their research (e.g., thesis or dissertation work). Recognizing that there will be a wide array of interests represented in the class, the choice of topic for the project is not restricted. However, approval of a student's selection is required. Samples of models might be: (1) stocks and fluxes of an essential elements, such as carbon or nitrogen; (2) changes to a hydrological cycle; or (3) food web structure or trophic dynamics. Models should reflect ecosystem (or landscape) dynamics rather than those of a single population. We will also consider projects in which students will use an existing model and work through critical steps of the modeling process (e.g., parameterization, calibration, evaluation against independent data.) Students considering this should talk with the instructors to make sure there is enough application of the modeling process in the goals of the project.

Format for Project Proposals: Proposals must be typewritten, double spaced with one-inch margins and 12-pt type with a **2-page maximum length,** excluding references. Please present the system and the problem, then be specific about the dynamic problem (see Table 1.2 in Ford) -- i.e., what question is your model specifically designed to address? Please define the system, the spatial and temporal scales you will represent, and the general approach used to exercise the model and answer the question. For example, you might compare results from particular scenarios; or perform a factorial simulation experiment; or explore the consequences of varied estimates of key parameters.

Format for Project Reports: Reports should be written in manuscript form and be double-spaced with one-inch margins with a standard type font (e.g., Times New Roman, Ariel, etc.) no smaller than 11 pt. Main body text (i.e., Introduction through Conclusions) should **not exceed 3000 words** excluding the title page, abstract, acknowledgements, references, figures, and tables. The format should follow that required for submission to the journal ECOLOGICAL MODELLING, which is available on the journal's website. A PDF of author guidelines will also be on Canvas. Pay careful attention to ALL details in the instructions to authors (which you must do any time you submit your own manuscript for publication.) And, don't forget to proof read your references for completeness, typos and format; use of bibliographic software does not eliminate the obligation to proof read and correct.

Presentations:
Each student will give an oral presentation to the class of their modeling project in the format of a professional conference. Time slots will be 15 minutes, and students should aim for 10 minutes of presentation and 5 minutes of Q&A. Note that it is essential to practice any presentation in advance to make sure you fit within the time limit. Visuals (typically Powerpoint) should be clear and prepared for your audience. Class members will provide constructive feedback to each presenter.

DUE DATES: See course syllabus for all due dates.

GRADING: Numerical grades will be assigned to letter grades as follows: 93-100 (A), 90-92 (AB), 83-89 (B), 80-82 (BC). Weighting is assessed as follows:

Before spring break (50%):
- Individual and group exercises (worked on during 2nd hour each week) (25%)
- Midterm exam, first hour of class in Week 7 (25%)

Second half after spring break (50%):
- Discussion board in Canvas with current topics to respond to (15%)

- Course project work (35%)
    - Project report (25%) and in-class presentation (10%)

COURSE EVALUATIONS:
Students will be provided with an opportunity to evaluate this graduate seminar and your learning experience. Please complete the university's general course evaluation when you are notified that it is available. Your feedback is important!

DIVERSITY & INCLUSION STATEMENT:
Diversity is a source of strength, creativity, and innovation for UW-Madison. In this course and across the campus, we value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

ACADEMIC INTEGRITY:
By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary action include, but is not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion.

ACCOMODATION FOR STUDENTS WITH DISABILITIES:
The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. (See: McBurney Disability Resource Center)

DRAFT SYLLABUS - ECOSYSTEM SIMULATION MODELING
Note: Syllabus is subject to change, some readings are TBD.

Additional readings (beyond the Text) are posted in Canvas.

Class	Date	Topic (1st hour)	Readings & assignments	Activities (2nd hour)
1	Jan 26	**Journeys in modeling** (Chris & Monica)	—	Share your previous experiences with models
2	Feb 2	**Getting started** (Chris & Monica) • What is ecosystem simulation modeling? • Why do we use models? • Introduction to basic terminology	Ford (2010) Chap.1 & 13; Essington (2021) Chap. 1	**Group work** for ecosystem types; *Develop a question, conceptualize system, define a question, decide on assumptions*
2	Feb 9	**Building blocks** (Monica) • Specifying the system • Model structure • Systems diagrams • Introduction to VenSim • *VenSim tutorials recommended*	Ford (2010) Chaps 2, 3 & 4; Turner (2003)	**Guided walk** *through translating the Turner model to VenSim (Monica)*
4	Feb 16	**Mathematical formulation** (Monica) • Conventions for notation • Flows among compartments • Controls (feedbacks) on flows • Change in state variables • Solving numerically	Ford (2010) Chaps. 5 & 9	**Group work**: *Develop model diagrams in VenSim & share with class*
5	Feb 23	**Parameter estimation and calibration** (Chris) • Starting values • Honing in • Importance of units	**TBD** **Model prospectus due**	**Group work**: *Set parameters and get the model running*
6	Mar 2	**Model evaluation** (Chris) • Model-data comparison • Sensitivity analysis • Uncertainty analysis	Essington (2021) Chap 15; Ford (2010) Appendix D	**Group work**: *Explore sensitivity and uncertainty of parameters in your model*
7	Mar 9	**Midterm Exam** (in class)	—	**Group work**: *Exercise the model to answer your question.*
--	Mar 16	**SPRING BREAK WEEK**		
8	Mar 23	**Exercising the model** (Chris) • Equilibrium vs. transient dynamics • Role of "spinup" • Designed experiments • Scenarios • Reporting results	Ford (2010) Chap. 6 **TBD**	**Model project peer review**; *share system diagram and equations*

9	Mar 30	**Modeling pitfalls and model comparisons** (Monica & Chris)	Ford (2010) Chap 17; Grimm et al. 2020; Petter et al. (2020); Boettiger (2022)	Work on modeling projects
10	Apr 6	**Applications of simulation modeling: agroecosystems** (Guest lecture by Dr. Kelsie Ferin, Agronomy)	**TBD**	Work on modeling projects
11	Apr 13	**Applications of simulation modeling: Lake ecosystems** (Guest lecture by Dr. Paul Hanson, Center for Limnology)	**TBD**	**Model project peer review**; *share modeling progress and results in small groups*
12	Apr 20	**Status and future of ecosystem modeling - Discussion**	Special Feature, "Ecosystem modeling for the 21st century"	Work on modeling projects
13	Apr 27	Final project presentations	—	—
14	May 4	Final project presentations	—	—
15	May 8 (Monday of final exam week)	**Project report due**		

ADDITIONAL READINGS

Boettiger, C. 2022. The forecast trap. Ecology Letters, doi 10.1111/ele.14024

Essington, T E. 2021. Introduction to Quantitative Ecology. Oxford University Press.
Chapter 1 - Why do we model?
Chapter 15 - Sensitivity analysis

Grimm, V., A. S. A. Johnston, H.-H. Thulke, V. E. Forbes, and P. Thorbek. 2020. Three questions to ask before using model outputs for decision support. Nature Communications 11:4959.

Petter, G., P. Mairota, K. Albrich, P. Bebi, J. Brüna, Harald Bugmann, A. Haffenden, R. M. Scheller, D. R. Schmatz, R. Seidl, M. Speich, G. Vacchiano and H. Lischke. 2020. How robust are future projections of forest landscape dynamics? Insights from a systematic comparison of four forest landscape models. Environmental Modelling and Software 134:104844.

Turner, M. G. 2003. Modeling for synthesis and integration: forests, people, and riparian coarse woody debris. Pp. 83-110 *In:* Canham, C.D., J.J. Cole, and W.K. Lauenroth, editors. Models in Ecosystem Science. Princeton (NJ): Princeton University Press.

Special Feature in Ecosystems, Volume 20, on "Ecosystem modeling for the 21st Century." The whole SF will be posted in Canvas, specific readings TBD.