Connecticut College
ECO 312: Natural Resource Economics[†]
Spring 2023 (1/23 - 5/17)

Professor:	Pierce Donovan	pdonovan@conncoll.edu
Lectures:	Fanning 101	TR 9:00 am - 10:15 am
Office Hours:	Winthrop 305	MWF 10:00 am - 11:00 am
		TR 10:30 am - 11:30 am

Course Description and Objectives

When is the last time you went a day without hearing about climate change, pollution, overfishing, deforestation, or biodiversity loss? Today's most salient policy issues concern how we use natural resources, and it's clearly important to learn how to tackle these problems. But perhaps you're wondering, how does economics fit into all of this?

At its core, economics is a discipline focused on allocating scarce resources. And this extends to natural resources, naturally! In fact, we can't really understand how to properly manage the environment *without* economics. Why is this? Economists study the incentives that motivate stakeholder behavior, like the decisions to plant water-intensive crops in arid lands, flare natural gas at the oil wellhead, or race to fish until our oceans are empty. By understanding the root of the problems concerning resource use, we can prescribe the right policy intervention.

My plan for this course is to teach you some of the techniques in natural resource economics that are used to inform environmental policy. The level of analysis that we'll take on will be more rigorous than a qualitative explanation. You'll study and solve mathematical models in order to discover for yourselves how to optimally allocate natural resources. We'll encounter real-world examples in fisheries and forestry, oil and mineral extraction, pollution control, and elsewhere.

Each lesson is structured in the following way: (1) I'll introduce an environmental problem and we will boil it down to its key components. (2) Then we will go through the process of modeling the behavior that creates the problem. (3) Using our model, we will investigate what can be done to correct any behavior we aren't thrilled about. You will walk away with a consistent strategy toward taking on new problems that you encounter well after this course.

At the end of this course, you should be able to explain how to address environmental policy issues in a detailed manner. You'll acquire the means of doing so—skills in mathematical modeling and computational methods—and thus be able to back up your explanations with the deeper intuition that natural resource economics is meant to provide.[††]

[†] As the semester goes on, I may change the contents of this syllabus regarding the schedule, grading, or other details.

[††] This course complements ECO 212: *Environmental Economics*, which is about using the principles of economics to create better environmental policy. The analysis in 212 is qualitative and emphasizes developing strong *written* arguments—in contrast to our modeling-based approach here.

Expectations

There are two prerequisites: (1) MAT 112 (Calc B), and (2) either ECO 205 (Intermediate Micro) or ECO 212 (Environmental Economics). A solid background in calculus is particularly important because this class is about developing and solving models in natural resource economics, and calculus happens to be the ideal language for the modeling/optimization process. I might introduce some mathematical concepts that you haven't seen before (from multivariable calculus, dynamic optimization, differential equations, linear algebra, etc.), but I'll make sure these are sufficiently covered before applying them to our class.

ECO 205 and 212 provide two different pathways into this course—each with their own strengths. Those with ECO 205 background will have discussed some of the core upper-level economics concepts applied in our course and have a strong understanding of the goals of economic theory, why economists simplify the world with models, and how to use models and graphical analysis for the purpose of optimization. Those coming from ECO 212 will have a strong qualitative understanding of the theory that we will discuss and the policy insights that will come from our modeling efforts. In a sense, ECO 212 students may be coming in already knowing what the solution may look like, and they'll use this class to bolster their intuition, while ECO 205 students will have a head start on the general modeling framework, so they'll focus on learning how to apply their models to natural resource and environmental mangement.

This course will have a computational component that will complement your pen-and-paper abilities. This is a direct response to comments from students that feel as if they do not yet know how to *do* economics and that their classes are perhaps too theoretical. For those of you who have not done any programming before, fear not. I will be providing you with the tools you need to succeed.

Importantly, you're responsible for wanting to learn how to become a successful economic modeler! It's a great objective to have, and there are some meta-skills that are worth developing in this class to help you with that:

1. So that you do not underestimate this course, I want to make it clear that **success likely mandates office hour attendance**. I expect to hear from you regularly outside of the classroom. Within the first two weeks of class, you must stop by my office hours at least once to reflect on your understanding of the material and how you are studying outside of lecture.

2. Before coming to me, reflect on what you have tried and write down what didn't work and *why you think it didn't work*. You'll either spot the issue yourself, or come to me with exactly what I need to know in order to help.

3. Consider that you will be confronted with problems in life that cannot be solved quickly (note: the alternative—a life of solving trivial problems—would hardly be as rewarding), and that not being able to resolve your problem immediately isn't the end of the world. That attitude will keep you from giving up at the first moment of struggle.

4. When programming, there are two things I would focus on: (1) leave lots of comments in your code (so you can understand what you wrote later) and (2) learn to be self-sufficient when debugging coding problems, because your bugs have been squashed many times before (and answered online in great detail).

Course Website, Tools, and Materials

I'll be using Moodle to upload any resources (notes, readings, assignments, grades, etc.) we will be using throughout the course, and you'll submit assignments on Gradescope.

We'll use a portion of lecture time and the homework as opportunities to learn Matlab, a programming language built for numerical analysis and optimization. It's a great resource for us, because models—no matter how simple they look—can become difficult to solve with pen-and-paper rather quickly. Matlab's syntax is incredibly simple compared to other programming languages, which means we can spend less time coding and debugging and more time on natural resource economics. Importantly, I'll be helping you learn how to code in a general sense, so anything you pick up here can be applied to any other programming language later.

I have written a textbook just for this class, and it can be found on Moodle.[†] I strongly recommend reading ahead before class and taking down a "parallel" set of notes in your own words. If you like this class and want to push yourself further, here are some (higher-level) books that I like:

Conrad and Clark (1987). *Natural Resource Economics: Notes and Problems*.
Clark (1990). *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*.
Hanley, Shogren, and White (2007). *Environmental Economics in Theory and Practice*.
Conrad and Rondeau (2020). *Natural Resource Economics: Analysis, Theory, and Applications*.

Homework and Exams

Roughly every other week, there will be a homework problem due at the beginning of class (specifically 9am on Tuesday morning, to be submitted as a PDF via Gradescope). Each assignment should take around ten hours, assuming that you also regularly review your notes outside of class and keep up with office hours. I strongly recommend working on these assignments in groups of two or three—although this isn't necessary or required—and you may submit in up to groups of three. Submissions are graded for good-faith effort and completion. I will provide solutions once everyone has submitted. My late policy is that homework will be accepted for two additional days, with a ten percentage point penalty per day.

My exams are not directly cumulative, however, each unit builds upon the one before it and several concepts are shared between the exams. You will find that the structure and language of the exam questions very closely follow from my lecture notes and homework assignments. Both the homework and exam problems are designed to be engaging—engrossing even. They are very challenging and rewarding to work through, but only if you put in a significant amount of good-faith effort preparing for them.

Grading

I don't "give" grades or "take off" points, you *earn* them for doing the required work. (I am the personal trainer who prescribes your regimen—and you're responsible for your success.) I also won't measure your performance relative to your peers (i.e. curve your grades) during the term in order for you to have the clearest signal about your performance. I will validate a proven understanding of the course material via six homework assignments (8% each) and four exams (13% each).

[†]This book has existed for only a brief moment in time and is likely full of typos. So I propose a "bug bounty;" every five typos discovered will earn you 1% on your final grade. You must show me the typo in office hours to collect your bounty. The spirit of this is not to report spelling errors, but issues in the math—typos in the equations and solutions—which interfere with student understanding. I will consider improvements in explanation/sentence structure too.

Not Boilerplate (please take a moment to read)

- Missing lecture isn't the end of the world. For example, if you feel sick, please don't come to class, recover, and get notes from a friend. I don't need an excuse, but be in touch if you will be out for multiple days. Chronic *undocumented* absences may result in course failure.
- Come to office hours! They're there for you! Asking clarifying questions about my material or assignments and talking with me about your interests beyond my courses are both good habits to start and can greatly improve your college experience (or a recommendation letter).
- When asking for help outside of class, the best students show me how they have approached a problem and their progress up to that point. Simply asking for an answer is not a productive use of our time. I hope to facilitate critical thinking, and that takes effort on everyone's part.
- While I'll be accessible by email, I strongly prefer communicating during class/office hours. Regarding boundaries, I do not plan on answering emails late at night or on the weekend.
- There are lots of things to learn in college besides my material, and there are lots of ways to optimize your learning experience. The Academic Resource Center (`link`) can assist you in getting the most out of your time and effort at Connecticut College.
- I can't recommend the tutoring services at the Roth Writing Center (`link`) enough if you want to work on clear and coherent communication. Focused writing takes practice, and college is a great time to put in the hours.
- If you have a learning disability or a physical disability that requires accommodation, please let me know as soon as possible. For more information on accommodation, you can contact Student Accessibility Services (`link`).
- I will not tolerate academic dishonesty. You can review Connecticut College's Honor Code [`here`]. I will report any suspected cheating, plagiarism, manipulation, or other misconduct.
- You do not have permission to make any form of recording during class or office hours (with the exception of those granted accommodations through Student Accessibility Services). You also do not have permission to share or publish my course materials (lecture notes, homework answers, exams)—or any derived content like your responses to homework and tests.
- You are responsible for your technology problems. Submit assignments well ahead of the due date if you want to be sure that your submission is received/in the proper format/etc.
- Please be respectful to your classmates. Refrain from talking during class if it is not relevant to lecture or discussion. Cell phone or tablet use should not detract from your ability to follow along with class. No activity on your part should undermine the efforts of other students.
- If you have any issues within or outside this course that are affecting your work, and you lack someone to talk to, I will do my best to help. Keep in mind that I am a mandatory reporter under Title IX, and will need to report information regarding gender-based discrimination or sexual misconduct if you choose to share it with me. In cases where I'm not the appropriate resource, please seek support from Student Counseling Services (`link`).
- In my contribution towards an inclusive and intellectually-vibrant community, I aim to reflect the ideals presented in our school statements on Freedom of Expression (`link`) and Principles of Community (`link`) in my capacity as a professor at Connecticut College. I hope you do too.

Course Outline

Principles of natural resource economics

An introduction to constrained optimization problems ..... Tuesday, 1/24

Concepts: utility function, convexity/concavity, budget constraints, static optimization, isoquants, conditions for a maximum, agriculture and crop choice

The *Lagrangian* ..... Thursday, 1/26

Concepts: Lagrange multipliers, shadow values first-order conditions for extrema, comparative statics, inequality constraints, optimal freshwater allocation

The Kuhn-Tucker conditions ..... Tuesday, 1/31

Concepts: objective function, Lagrange representation, FOCs w/ inequality constraints, checking for binding constraints/scarcity/feasibility, numeraire good

The theory of externalities ..... Thursday, 2/2

Concepts: the role of capitalism, economic rationality and private incentives, social planner, profit-maximizer, regulator, externalities, Pigouvian taxation, efficient environmental policy

(**Lab**) An introduction to numerical methods (and MATLAB) ..... Tuesday, 2/7

Concepts: variables, functions, matricies, root-finding, Newton's method; water conflicts, externalities, cap-and-trade, clean energy vs agriculture, market power, equity

Office-hours check-in must be completed by this point.

Public goods provision ..... Thursday, 2/9

Concepts: common property, free-riding, under-provisioning, coasian bargaining, ecosystem protection, trade and water quality

Cost-effective pollution control ..... Tuesday, 2/14

Concepts: marginal damages of pollution, abatement costs, carbon tax, cap-and-trade, permit allocation, distribution of welfare

Homework #1 due. (**Balancing water use upstream and downstream**)

(**Lab**) Combatting local air pollutants ..... Thursday, 2/16

Concepts: local air pollution vs global reduction objectives, distributive effects, environmental justice, naïve and savvy planning, solving more complicated systems of equations

Review session ..... Tuesday, 2/21

Exam 1: Saving some water for the future ..... Thursday, 2/23

Concepts: intertemporal optimization, discounting, watering grass in the desert

No class (placeholder for travel, don't count on this) ..... Tuesday, 2/28

Homework #2 due. (**Combatting local air pollutants**)

Introduction to dynamic optimization

Mining for fossil fuels and other non-renewables ..... Thursday, 3/2

Concepts: economic scarcity and bounded stocks, rent, dynamic optimization, time preferences and discounting, marginal user cost, intertemporal externality, oil extraction

(**Lab**) Oil extraction and externalities ..... Tuesday, 3/7

Concepts: socially-optimal oil extraction, natural gas flaring, global warming, tipping points, setting extraction taxes, anticipating industry response to policy

Optimal silviculture ..... Thursday, 3/9

Concepts: net present timber value, optimal stopping and the Wicksell rotation, comparative statics, infinite series, land rent and the Faustmann rotation

No class (Spring Break) ..... Tuesday, 3/14

Homework #3 due. (Oil extraction and externalities)

Non-timber values ..... Tuesday, 3/28

Concepts: non-timber values, Leibniz integral rule, Hartman rotation, amenity values, ecosystem services, forest policy; *potential extension*: wildfire risk

(**Lab**) Choosing which tree species to plant ..... Thursday, 3/30

Concepts: land use decisions and policy, numerical comparative statics

Review session ..... Tuesday, 4/4

Homework #4 due. (Choosing which tree species to plant)

Exam 2: How long should you age that bottle of wine? ..... Thursday, 4/6

Concepts: orchards, inventory problems, branding, marketing, and wine vintage

A little bioeconomics

Biological dynamics and differential equations ..... Tuesday, 4/11

Concepts: logistic growth, steady-states, carrying capacity, predator-prey models, phase diagrams, stability of equilibria

The problems with open-access fisheries ..... Thursday, 4/13

Concepts: overfishing, over-capitalization, rule of capture, Gordon-Schaefer model

Regulated open-access ..... Tuesday, 4/18

Concepts: fishing permits, subsidies, fisher rents, total allowable catch, derbies

Individual fishing quota systems ..... Thursday, 4/20

Concepts: IFQ/ITQ, efficiency, grandfathering, consolidation, stewardship

An introduction to optimal control theory (if schedule permits) ... Tuesday, 4/25

Concepts: the *Hamiltonian*, time horizon, scrap value, Pontryagin maximization principle, transversality conditions, setting dynamic fisheries regulation

Homework #5 due. (Open access and the risk of extinction)

Fully-dynamic models of the fishery (if schedule permits) ..... Thursday, 4/27

Concepts: beyond steady-state solutions, planning for the future, sustainability, the turnpike theorem, a preview of graduate school

Review session ..... Tuesday, 5/2

Homework #6 due. (Marine protected areas)

Exam 3: Political economy and fisheries ..... Thursday, 5/4

Concepts: exclusive economic zones, U.N. Law of the Sea, multinational fisheries, *seas* vs *lakes*, oil, natural gas, caviar, snow crab and cooperative fisheries

Review session ..... Tuesday, 5/9

Exam 4: Urban planning and public goods ..... (self-scheduled)

Concepts: urban planning, road widening, induced demand, traffic, public transit

Note: there are no designated lab sections for HW5&6:

Homework 5: Open access and the risk of extinction

Concepts: predator-prey relationships, minimum viable populations, too many boats, duopoly

Homework 6: Marine protected areas

Concepts: second-best policy, age-class models, nurserys, spatial externalities, site selection, numerical phase diagrams, dynamic TACs