COLUMBIA UNIVERSITY
School of Professional Studies

Master of Science in Sustainability Science

SUSC PS5001 Fundamentals of Sustainability Science
3 credits

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Office Hours: 1 hour before and after class in person; by appointment any time, via Zoom.
Response Policy: Within 24 hours by email

Instructor: Jennifer Middleton
Office Hours: 1 hour before and after class in person; by appointment any time, via Zoom.
Response Policy: Within 24 hours by email

Facilitator/Teaching Assistant, if applicable: TBD
Office Hours: 1 hour before class; or by appointment.
Response Policy: Within 24 hours by email.

Course Overview

Sustainability Science draws on a broad range of techniques from natural and social sciences, engineering and mathematics to address specific challenges that arise from the growth and development of human economic and social activity on a finite planet—one we share with millions of non-human species. Each such challenge is unique in its scope, scale, location and goals; each requires a distinct set of knowledge and, to some extent, a unique mix of methods. Almost any of the social, natural or physical sciences might be engaged. Nonetheless, some things are characteristic across nearly all sustainability investigations. The field is inherently integrative, combining social, economic, ecological, and environmental data. The situations we study are complex, including human economic and social parameters alongside environmental and ecological ones; and they are dynamic, changing with time in ways that are critical to our investigations. Sustainability science is goal-oriented, and forward-looking. The genesis of the field is explicitly to assist policymakers, planners, and stakeholders in moving us all toward practices which improve wellbeing and equity now, while preserving the environmental and human conditions necessary to secure the wellbeing and equity of future generations. In this course, these overarching aspects—integration, breadth, complexity, evolution over time, and goals—will be central. But much of our discussion will go through specific case studies. And as we work through cases, we will encounter a wide range of methodological tools and information resources.

Sustainability transitions are in the most immediate sense changes to human economic activities. However, these require (and they drive) changes to social, cultural, and governance structures and involve major impacts on non-human, or only partially-human, ecologies as well. Thus, either explicitly or implicitly, sustainability science is engaged in the mobilization of individuals, groups, classes, institutions, enterprises and governments for change. We are, in the current parlance, change agents. Those of you who follow technical and scientific pathways will join the growing ranks of activist scientists. It is an exciting future; but one that carries special responsibilities and risks, which we will discuss in class.

The course starts with a discussion of how systems, and especially complex systems, operate. This will include positive (reinforcing) and negative (balancing) feedback loops; stocks and flows; temporal, physical and social scales; and the rules and motivating logics of systems. We will segue from qualitative systems thinking to modeling: conceptual models, dynamical systems models, statistical models, etc. These are tools that you will encounter as decision support aids in nearly every large project.

After coming to grips with what these words mean, and achieving some basic familiarity with how these tools are used, we will spend the balance of our semester working through case studies. As noted above, each case will pull in data and/or techniques from additional disciplines. Depending on our cases, we will learn some of the basic elements of, for example, atmospheric dynamics, groundwater chemistry, forest and marine ecology, development economics, or agro-ecology. We will certainly not cover all the topics that you will encounter in your careers as sustainability professionals. Hopefully, however, the course will give you enough of a foundation that you will welcome each new project as a chance to expand the breadth of tools and data types in your professional repertoire.

Course structure: The first two thirds of the course will be instructor-led and designed to situate the class in the field of sustainability science; the last third will be composed mainly of student-presented case-studies. The first part will center on readings, discussions, and short weekly writing assignments. Where it is useful, the instructor will deliver 'mini-lectures' (<15 minutes) on specific, mostly technical, topics. However, most of the class-time will be spent with the instructor facilitating student dialogues in response to the issues raised in the readings.

Learning Objectives

By the end of this course, students will be able to:

L1: Define sustainability and sustainability science and describe their central themes.

L2: Construct a case study in sustainability science.

L3: Explore publicly available data sources for sustainability cases, including time series data, development and environmental indices. Integrate data across environmental, social and economic sources.

L4: Analyze sustainability issues from a dynamical, socio-ecological systems perspective.

L5: Distinguish the temporal, spatial and social scales across which a sustainability issue or case operates. Think about the linkages across scale from an integrative, systems perspective, including identifying material stocks and flows, reinforcing and balancing feedback loops, principal stakeholders, and sources of delay.

Diversity Statement

It is our intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength and benefit. It is our intent to present materials and activities that are respectful of diversity in: gender identity, sexuality, disability, age, socioeconomic status, ethnicity, race, nationality, religion, and culture.

Readings

We start with Donella Meadows' "Thinking in Systems" which will serve as a guide for thinking about the readings to follow. All readings are available as pdf files in Courseworks and listed below in the weekly outline. As I uncover new resources and as the semester progresses, the assigned readings may change some. Courseworks will be your "gold source" for the weekly assignments. On Courseworks, the readings are numbered. Readings 1 and 2 will be the starting points for our in-class conversation. Please read them in detail. The other readings are for your reference, interest, and education. Skim them and read those that you find useful.

Resources

Columbia University Library

Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online: http://library.columbia.edu/.

SPS Academic Resources

The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

Course Requirements (Assignments)

Class Participation (25 %) (L1, L2, L3, L4, L5)

Class participation, including oral and written communication, is critical to learning—both the content, which is consolidated through discussion, and the process of collaboration with colleagues. Weekly readings must be completed before class. At the beginning of each class, we will collect questions from the students to get us started. Please come to class having read the material, having written down one or more questions, and ready to participate. **Absence policy**: Class discussions are a central component of the course. One or two absences will be excused as long as the instructor has prior notice from the student. Students should expect that a third absence will impact their final grade.

Weekly Reflections (40 %) (L1, L2, L3, L4, L5)

Each week you are responsible for an essay of 700 to 1500 words that reflects on your response to the readings, the classroom discussion, or your case study research. I'm interested an honest telling of your response to the material and our discussion of it. In the past, students have used this as an opportunity for: a 'life writing' piece, describing how your own history entangles with these topics; detailing your own point of view on the topics; critiquing the dialogue, or my pedagogical practice; espousing a political stance re. the issues; or discussing the positions of one or more stakeholders. All of these and more are fair game. The writing needs to be cogent and on point to the class dialogue that week. You will be responsible for 8 weekly reflections.

Case Study Presentation (35 %) (L1, L2, L3, L4, L5)

You will research and present a case study. You are strongly encouraged to work in a team of two or three students on your cases; but if you prefer to work on your own, that is fine. You can either present in class (highly recommended) or write a paper (also fine). In-class presentations can be oral, based on a PowerPoint deck, video presentation, a role play, or a combination of formats. Expect to present for about 20 minutes, and then to facilitate

questions and discussion for another 20 minutes. Written papers should be between 3000 and 4000 words long. Early in the semester, you will be responsible to hand in an precis or outline of your proposed project. In the weeks before your presentation, you will be responsible for two intermediate products: a "stocks and flows" diagram of the principal materials (including energy) involved in your case study and a "causal loop diagram" that captures the principal positive and negative feedback loops of your case.

The instructor and TA are available to assist you with your case study research and presentations. You are strongly encouraged to meet with us along the way.

Case study timeline:

- Week 3: decision re. teams
- Week 4: precis or outline of topic.
- Week 6: stocks and flows diagram
- Week 7: causal loop diagram
- Presentations: week 8 through 11.

Evaluation/Grading

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

ASSIGNMENT	% Weight
Class Participation	25
Weekly reflections	40
Case study	35

Course Policies:

The classroom and your weekly reflections constitute a safe academic space in which wide-ranging dialogue is encouraged. We will all treat each other with respect and care. Mistakes, missteps, and novel perspectives will be treasured. We will criticize each other's positions and receive critiques of our positions with open hearts. Our goal will be to learn as much as possible, which will require all of us to acknowledge how little we know.

School Policies

Copyright Policy

Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity

Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Accessibility

Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: http://health.columbia.edu/services/ods/support.

Course Schedule/Course Calendar

Date	Topics and Activities	Readings (due by class time)
W1	● W1: Introduction: why are we here? What do you want to get out of this? Why is sustainability such a hard problem? o What is your definition of "sustainability"? o A little history: sustainability science has roots back at least 200 years, to Malthus (1798) and his interlocutors, including Verhulst (1838, logistic growth), von Liebig (1859, recycling nutrients), and Marx (1867-1894, metabolic rift theory). o References to sustaining the earth's capacities are replete in indigenous cosmologies, which stretch back thousands of years before 'science' in its modern sense. o Post-WWII, the 'great acceleration' has forced sustainability into the center of global debates, and centered sustainability in a range of applied science disciplines. o How do you see your role in all of this?	
W2	Systems Thinking 1 ● What are Socio-Ecological Systems? ● Examples of non-linearities and surprises ● Limits of predictability ● E.g.: Jevon's Paradox. o E.g.: wood to coal to oil o E.g.: Haber-Bosch and impact of synthetic fertilizers. ● Complexity, multiplicity, temporal evolution.	Meadows Ch 1-4. Wilcock et al., Nature Sustainability, 2023 Ostrom, 2009, Nature, SESs
W3	Systems Thinking 2	Meadows Ch 5-7 UN SDGS: Global Sustainable Development Report 2023 – Executive Summary Beyers, Folke, et al., AnnRev, SES … navigating the Anthropocene Folke, et al., 2004

Date	Topics and Activities	Readings (due by class time)
W4	Stocks, Flows, Feedbacks 1: Wealth and income as stock and flow. Stocks/Flows: forest vs plantation. Reinforcing (positive) and balancing (negative) feedbacks in population growth. Ditto for capital accumulation.	Syvitski, et al., 2022, Earth's sediment cycle in the Anthropocene. Schandl et al., 2017, Material Flows … 40 years. Lenzen, et al., 2022, Nat Sust, Implementing Material Footprint to measure SDGs. Weidman, et al., 2023, PNAS: The material footprint of nations UNEP MFA Database: https://www.resourcepanel.org/global-material-flows-database Haberl, et al., 2014, HANPP Ann Rev. Rauch & Pacyna, 2009, G-BGC-C, Earth's Global [metals] Cycles.
W5	Stocks, Flows, and Feedbacks 2: Limits and tipping points. Logistic growth curve. Tragedy of the commons. Equilibria?	Rockstram, et al., 2009 and (or?) 2019. Ecomodernist Manifesto Haberl, et al., 2020, ERL, Review … Decoupling. Stocknes, et al., 2018: Green-growth within planetary boundaries.
W6	Guiding metaphors: Indexes Strong and weak sustainability Ecosystems services Extractivism Ecomodernism and the Environmental Kuznets Curve Non-human rights Indigeneity and relationality	Ostrom, 2008, Environment, The Challenge of Common Pool Resources Torras, M., and Boyce, J.K., 1998. Income, inequality and pollution: a reassessment of the environmental Kuznets Curve. Ecol. Econ. (25) 147-160. Raworth, Donut Economy, Ch. 5, 6 & 7 (edited). Galaz et al., 2015 (metrics) Vitali, et al., 2011 Fichtner et al., 2017 Marshall, et al., 2012 and 2014: Adaptability, peanut farmers. Avelino, 2017: power/disempowerment in sustainability transitions Temper et al., Intra vs inter-generational equity Rocha, et al., 2015: Regime shifts in the Anthropocene Ecomodernist Manifesto

Date	Topics and Activities	Readings (due by class time)
W7	Continuation of W6 discussion: small-group caucuses	Indigenous Climate Action reports: (1) Nature Based Solutions; (2) Decolonizing Climate Policy.
W8	Student case study presentations	Chosen by students and the instructor. Students and instructor choose appropriate background readings. Instructor may insert mini-lectures on relevant technical topics.
W9	Student case study presentations	Chosen by students and the instructor. Students and instructor choose appropriate background readings. Instructor may insert mini-lectures on relevant technical topics.
W10	Student case study presentations	Chosen by students and the instructor. Students and instructor choose appropriate background readings. Instructor may insert mini-lectures on relevant technical topics.
W11	Student case study presentations	Chosen by students and the instructor. Students and instructor choose appropriate background readings. Instructor may insert mini-lectures on relevant technical topics.
W12	Wrapup: Pedagogical comments. Science with an agenda; scientists as change agents; relationships with stakeholders, etc. Complete evaluation forms.	May include spillover from case studies. Indigenous Climate Action: Just Transition Charlier and Fizane, 2023