COLUMBIA UNIVERSITY
School of Professional Studies

SUSC PS5001 Fundamentals of Sustainability Science
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Sustainability Science is defined by the questions it asks and the problem it addresses. It 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. But 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 with 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 policy-makers, 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.

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 also one that carries special responsibilities and risks, which we will discuss in class.

The core characteristics cited above give Sustainable Science researches their common attributes and basic tools, including Integrative, descriptive statistics, probability and uncertainty analyses; complex dynamical systems analysis; and various forms of earth systems modeling. These are the distinguishing elements of Sustainability Science, and are the focus of this course.

After coming to grips with what these words mean, and achieving some basic capacity in using these tools, we will spend most of our semester working through case studies. As noted above, each case will pull in data and/or techniques from additional disciplines. As we foray into those subjects, we will learn some of the basic elements of, for example, atmospheric dynamics, groundwater chemistry, development economics, and decision science. The specifics will depend on the cases we all agree to work on; 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.

Class will be discussion-based, starting from the week's reading.

- W1: Introduction: why are we here? What do you want to get out of this? Why is sustainability such a hard problem?
    - What is your definition of "sustainability"?
    - 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).

- References to sustaining the earth's capacities are replete in indigenous cosmologies, which stretch back thousands of years before 'science' in its modern sense.
- Post-WWII, the 'great acceleration' has forced sustainability into the center of global debates, and centered sustainability in a range of applied science disciplines.
- How do you see your role in all of this?

- W2: Systems Thinking 1:
  - **Meadows Ch 1-4.**
  - **Wilcock et al., Nature Sustainability, 2023**
  - **Rocha et al., 2015, Regime shifts in the anthropocene**
  - What are Socio-Ecological Systems?
  - Examples of non-linearities and surprises
  - Limits of predictability
  - Earth Systems Models (and their kin)
  - g.: Jevon's Paradox.
    - g.: wood-to-coal-to-oil
    - g.: Haber-bosch and the impact of synthetic fertilizers
  - Complexity, multiplicity, temporal evolution.

- 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**
  - How to approach change? Theories of power; theories of change. Where to start?
  - Listening and understanding the system in front of you.
  - Leverage points: what may work and what may not?
  - Realistic goals.
  - Changing the goals of an SES.
    - g.: production for use vs production for profit
    - g.: conservation vs growth

- W4: Stocks, Flows, Feedbacks 1:
  - **Schandl et al., 2017, Material Flows … 40 years.**
  - **UNEP MFA Database.**
  - **Haberl, et al., 2014, HANPP Ann Rev.**
  - What is the growth trend in economic mass throughflow?
  - What is the composition of human consumption?
  - What is the gross impact of human economy on the living environment?
  - Domestic vs adjusted (for trade); production vs consumption – based analysis.
  - What measures or indexes are useful?

- W5: Stocks Flows Feedbacks 2: limits and tipping points. (Need to pare this down still)
    - **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.**
    - Green growth vs degrowth discussion.
    - What drives growth?
    - Can growth be decoupled from environmental harm?
    - … material throughput?
    - What stabilizing feedbacks are (could be) in SESs?
    - Critical reading of the Kuznets curve.
    - Getting from exponential to logistic growth curves.

- W6: Guiding metaphors, Indexes, and Strong and Weak Sustainability
    - **Galaz et al., 2015, Why ecologists should care about financial markets**
    - **(Matson lecture: https://www.youtube.com/watch?v=EZJ7PXk9xnM) (?)**
    - **Matson, et al., Ch 5 (types of capital)**
    - **Marshall, et al., 2012 and 2014: Adaptability, peanut farmers.**
    - Overarching goals: Resilience, adaptability, and transformation.
    - Guiding metaphors:
        - society as a business with capital stocks
        - vs an organism with metabolism
        - vs an ecosystem with species relationships
    - Anthro-centered vs biodiverse frameworks
    - Financial (capital) vs material (physical flows) analyses
    - 5 types of capital (Natural, Manufactured, Human, Social, Knowledge)
    - Economic/capital-based indicators
        - (Matson et al.). Chapter on 5 capitals.
        - Vitali et al., 2011
        - Fichtner et al., 2017
    - Human/Social/Knowledge capital and equity
        - Marshall, NA, et al., 2012 and 2014: Adaptability, peanut farmers N. Australia.
        - Avelino, 2017, power/disempowerment in sustainability transitions
    - Intra- vs Inter-generational equity
        - Temper et al., etc.
    - Inter-species equity
        - Barad?
    - Intra- vs inter-modal change.
    - Exponential vs logistic growth. Prime example: human population Others?

Case studies:

- W7: Forest
    - g.: Indonesian forestry and oil palms; Cree Canadian goose hunt
- W8: Inland

- g.: Mining (Uranium in Gabon and Dine lands; rare earths in Chile), lithium for electric vehicle batteries, etc.
- Gabriele Hecht

- W9: Ocean
  - g.: Tuvaijuittuq (Last Ice Area marine protected area); deep-sea mining; EU Blue Growth initiatives
  - Regime shifts in ocean ecology.
    - Lees, et al, 2006
    - Osterblom et al., 2015
  - Folke et al., 1998
  - Ziegler et al, 2012
  - Gelcich et al, 2010
- W10: Coasts
  - g.: Atlantic bight wetlands; Bering Sea pinnipeds (Rolands dissertations)
- W11: Cropland
  - Nitrogen fertilizer: Data from Our World in Data, start here: https://ourworldindata.org/grapher/world-population-with-and-without-fertilizer
  - g.: Soy beans in Brazil; Coffee in Costa Rica (Perfecto et al. chapters)
  - Rist et al., 2014
  - Hanspach et al, 2017
  - Rockstrom et al 2017
- W12: Cities
  - g.: Water resources and waste processing in Nairobi (June Kimani) and NYC.

Wrapup:

- W13: Activist science:
- **Davis, 2010, Who will build the ark?**
- What does it mean to be scientists and change agents?