MEES622 Sustainability Science: Quantitative and Systems Approach

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Guest Lecturers: Michael Wilberg (UMCES-CBL) and Wei Peng (Harvard University)
Meeting time and location: MW 8:30-10, AL and IVN
Office hours: TBD
Credits: 3

Course Description

In 2015, all 193 member countries of United Nations have ratified the Sustainable Development Goals, demonstrating their ambitions towards sustainability. Sustainability, defined as "sustainable development" by the United Nations World Commission on Environment and Development in 1987, "meets the needs of the present without compromising the ability of future generations to meet their own needs". However, what exactly sustainability means for a country as well as individuals, how it could be achieved, and how progress could be assessed remain elusive. Although sustainability encompasses topics beyond the natural sciences, the environmental sciences can offer tools to help define and assess sustainability. Indeed, forestry and fisheries management have a long history of developing sustainable yield concepts, with varying historical success in implementation. Modern sustainability science goes beyond single-resource management and integrates biophysical and socio-economic considerations of sustainability. This course is designed to help provide students with a historical background, critical thinking approaches, and analytical tools to address sustainability from a scientific perspective by:
1) reviewing and discussing basic concepts, past and active debates, and cutting-edge ideas;
2) learning and applying system and quantitative analysis skills;
3) developing a case study for a country/topic of interest in a highly-diversified group.

Learning Outcomes

Through this class, students are expected to
- gain an in-depth understanding of sustainability issues.
- implement basic quantitative methods for modeling and analyzing a system.
- develop a research project, individually or in a small group, on a sustainability issue of interest and provide quantitative analysis to identify challenges and opportunities.

Grading guidelines

Evaluation	**100%**
Class Participation	15%
Discussion Leader	15%
Mid-term	20%
Project presentation	20%
Term paper	30%

Course Schedule

Date	Course contents
Jan 24	**Course overview (contents, organization, Q&A, etc.)**
	Environmental Dimension
Jan 29	**Lecture** • An historical perspective from Malthusian warnings of impending famine to current estimates of planetary boundaries
Jan 31	**Reading & Discussion** • What is Sustainability?
Feb 5	**Lecture** • An overview of human disturbances to biogeochemical cycles (C, N, P, H_2O), to alterations of biophysical properties of the earth system (land surface, net primary productivity, water, climate change, etc.), and to biodiversity
Feb 7	**Reading & Discussion:** • Planetary Boundaries (Rockstrom et al., 2009; Steffen et al., 2015); You Can't Eat GNP excerpts (Davidson, 2000)
	Socioeconomic Dimension
Feb 12	**Lecture** • Integration of concepts of neoclassical and ecological economics with ecology, such as fungibility of resources, discounting future costs and benefits, valuation of unpriced resources, etc.
Feb 14	**Reading & Discussion** • Is there an Environmental Kuznets Curve? (Grossman and Krueger, 1995; Dinda, 2004)
Feb 19	**Lecture** • Social welfare: nutrition, education, equality, food security
Feb 21	**Reading & Discussion** • The impacts of international trade on sustainability (Liu et al., 2013; Bailey and Wellesley, 2017) • The trade-offs in revitalizing world rural community (Liu and Li, 2017)
	System Thinking (Case studies in sustainability)
Feb 26	**Lecture (CASE Study)** • Assessing sustainability in agricultural production with a Sustainable Agricultural Matrix
Feb 28	**Data Exploration: Indicator systems** • SDG Index and dashboard, Environmental Performance Index, Sustainable Agriculture Matrix
Mar 5	**Lecture (Sustainable Fisheries and a CASE Study; Wilberg guest lecture)** • A brief history of sustainable fisheries efforts • A recent case of fishery management using quantitative modeling approach
Mar 7	**Brain storm course project ideas and organize research groups** **Data Exploration** • Project can be developed by individual students or a student group (no more than 4 members)
Mar 12	**Lecture (Renewable Energy: A CASE Study; Peng guest lecture)**

	• A case of Energy-Water Nexus (e.g., a guest lecture on quantifying energy source trade-offs; by Wei Peng, Harvard University)
Mar 14	**Mid-term exam**
	System Solutions
Mar 26	**Lecture** • Basics and examples to describe, conceptualize, analyze, and optimize a system
Mar 28	**Reading & Discussion** • How to assess the tradeoffs among environmental, economic, and social dimensions of sustainability? • How to make policy in the context of complex trade-offs?
Apr 2	**Lecture** • Model and optimize a system with multiple stakeholders (e.g. Agent Based Model)
Apr 4	**Reading & Discussion** • How to assess and model the resilience of a system? (e.g., Network analysis, model-based approach) • What are the systemic risks in global agricultural system?
Apr 9	**Lecture** • A review of major international agreements for sustainability (e.g., SDGs, MDGs, Montreal Protocol, The Paris Agreement, …)
Apr 11	**Reading & Discussion** • Lessons and experiences learned from the major international agreements • The role of governments and international organizations in Sustainable Development
Apr 16	**Lecture** • Technology innovation and sustainable development (major innovations in renewable energy, agriculture, fisheries and other fields; how technology may help with tunneling through the Environmental Kuznets Curve; what is the backfire effect, unintended consequences, and the efficiency paradox?)
Apr 18	**Reading & Discussion** • The role of academics and industry in sustainable development
Apr 23	**Lecture** • Education and communication for sustainable development
Apr 25	**Reading & Discussion** • The role of individuals in Sustainable Development (e.g. dietary change, behavioral change, …)
Apr 30	**Project presentation and discussion**
May 2	**Project presentation and discussion**
May 7	**Project presentation and discussion**
May 9	**Project presentation and discussion**
May 14	**(Exam week: no final exam)**
May 21	**Deadline for submitting term paper**

Examples of case studies for students:

1. China: How could China achieve zero growth in fertilizer consumption in 2020 while still ensure sufficient and resilient food supply? What are the spatial tradeoffs between renewable energy development and water supply?
2. US: How does trade policy change affect the environment and economic performance, considering the agricultural sector and nutrient pollution?
3. Uganda (or other African countries): What are the trade-offs of intensifying cash crop and staple crop production?
4. Tropical Countries: What are the tradeoffs of using Marine Protected Areas as the primary management tool in fisheries?
5. Southeast Asia: What are the effects of aquaculture on wild capture fisheries, how does aquaculture affect local protein availability?

Available resources for case development:

The impacts of human activities on the Environment (historical trends).

- *http://www.fao.org/faostat/en/#home;*
- *http://databank.worldbank.org/data/home.aspx; http://www.sdgindex.org/;*
- *https://www.nature.com/nature/journal/v528/n7580/full/nature15743.html ;*
- *http://epi.yale.edu/*
- *http://www.fao.org/fishery/statistics/global-production/en (database of global fishery and aquaculture production)*
- *http://ramlegacy.org/ (database of abundance estimates and yield)*
- *LINKS TO DATASETS ON TERRESTRIAL OR AQUATIC BIODIVERSITY AND ENDANGERED SPECIES*

Potential drivers (e.g. food demand, policy, etc.) for the trend in the environmental impacts.

- *http://databank.worldbank.org/data/home.aspx*

Reading list:

There is no required text book for this course. Here is a list of suggested reading. Reading materials required by each class will be posted to the student before the class.

Books

- Pursuing Sustainability: A guide to the science and practice. by Pamela Matson, William C. Clark, Krister Andersson.
- The Age of Sustainable Development. by Jeffrey Sachs
- You can't eat GNP: Economics as if ecology mattered. by Eric A. Davidson
- Biogeochemistry: An analysis of global change. by William H. Schlesinger
- The Big Ratchet: How humanity thrives in the face of natural crisis. by Ruth DeFries

Journal articles (Here are several examples of journal articles will be reviewed in this class)

Liu, Jianguo, et al. "Framing sustainability in a telecoupled world." Ecology and Society 18.2 (2013).

Liu, Yansui, and Yuheng Li. "Revitalize the world's countryside." Nature 548.7667 (2017): 275.

Bailey, Rob, and Laura Wellesley. "Chokepoints and Vulnerabilities in Global Food Trade." London: Chatham House (2017).

Dinda, S., 2004. Environmental Kuznets Curve hypothesis: A survey. Ecol Econ, 49(4): 431-455.
Grossman, G.M. and Krueger, A.B., 1995. Economic-Growth and the Environment. Quarterly Journal of Economics, 110(2): 353-377.
Rockstrom, J. et al., 2009. A safe operating space for humanity. Nature, 461(7263): 472-475.
Steffen, W. et al., 2015. Planetary boundaries: Guiding human development on a changing planet. Science: 1259855.
Zhang, X. et al., 2015a. Managing nitrogen for sustainable development. Nature, 528(7580): 51-59.
Zhang, X., Mauzerall, D.L., Davidson, E.A., Kanter, D.R. and Cai, R., 2015b. The economic and environmental consequences of implementing nitrogen-efficient technologies and management practices in agriculture. J Environ Qual, 44(2): 312-324.