Unit 2.1 System Dynamics: How can we analyze interactions of nature and society?

Part I of this course presented a largely static view of the relationships among human well-being, nature and society. But sustainable development is ultimately about the dynamics of those relationships – how they change through time. The Fishbanks exercise carried out as a "warm up" for this course in its Unit 0.2 explored the simple dynamics of how one year's choices about how many boats to build and how many fish to catch changed both the bank accounts of the fishers and the number of fish available for harvest a year hence. More generally, the assessment of resource trends with which we concluded Part I invited us to consider whether society's current consumption of resources to support its own well-being would leave enough resources for future generations to provide comparable levels of well-being for themselves. Answering these questions about changes in resources through time requires an understanding of how nature and society interact as a system – how the state of each is simultaneously both a consequence and a cause of changes in the other.

This unit introduces Part II of the course in which we will draw on the science of complex adaptive systems to understand and forecast the dynamics of nature-society interactions. Following an overview of "systems thinking" in this unit 2.1, we will then dive more deeply into system properties particularly relevant to sustainability: stocks, flows and feedbacks that shape resource dynamics (Unit 2.2); nonlinearity, tipping points and path-dependence that make ubiquitous "big effects from small causes" (Unit 2.3), horizontal connections through which processes such as pollutant flows, human migration, and the spread of ideas partially couple the dynamics of different places around the world (Unit 2.4), vertical connections through which micro- and macro-scale processes interact with one another to reshape phenomena as different as impacts of climate change and the spread of innovations (Unit 2.5), the actors, institutions and power dynamics through which people seek to change development pathways (Unit 2.6), and the inequalities that emerge from those efforts (Unit 2.7). Part II closes with a synthesis of all these elements and relationships into a more detailed version of the framework for analyzing sustainability that was introduced earlier in the course (Unit 2.8).

To prepare for this first unit of Part II, please:

a) **Read**: Matson, P., Clark, W. C., & Andersson, K. (2016). *Pursuing Sustainability: A Guide to the Science and Practice*. Princeton University Press. Read pp. 52-57, end of first sentence.
We will continue to use the Matson et al. book to keep the "big picture" of the pursuit of sustainability in the foreground as we dive into particular topics throughout the course. The material covered in the readings assigned here provides an introduction to how and why "systems thinking" is essential for understanding the dynamics of nature-society systems, and for evaluating the likely consequences of interventions intended to guide those dynamics toward sustainability.

b) **Watch**: Sweeney, L. B. (Director). (n.d.). *In a world of systems* [YouTube]. Donella Meadows Institute. https://youtu.be/A_BtS008J0k (9 mins.)
This short video, based on the teachings of the late systems thinking guru Donella Meadows, provides a whimsical and accessible but deep introduction to the topic.

c) **Read**: Sterman, J. (2002). *System Dynamics: Systems Thinking and Modeling for a Complex World* [Working Paper]. Massachusetts Institute of Technology. Engineering Systems Division. https://dspace.mit.edu/handle/1721.1/102741
MIT's Jay Forrester and John Sterman pioneered the application of systems thinking to analysis of complex systems and policies for their management in the 2nd half of the 20th Century. Their motivation was the blunders they found their colleagues and students making in extrapolating linear thinking and single-cause/single-effect analysis to complex real world problems. Their initial applications were to urban design and business management, but later applications extended into the realms of resource management (Sterman is author of the Fishbanks game we explored earlier in the course, climate change and sustainability more broadly. The first sections of this working paper

provide an introduction to their approach. Subsequent units of the course will pick up on later sections and applications.

d) **Review**: Matson, P., Clark, W. C., & Andersson, K. (2016). *Pursuing Sustainability: A Guide to the Science and Practice*. Princeton University Press. Section on the case study "London: The struggle for sustainable development in an urban environment" (pp. 143-165; originally assigned in Unit 1.4).

Study Questions to help you get the most out of the readings:

Return to the London case study you analyzed in Part I. Recall that the analysis was as an exercise in qualitatively mapping the connections among capital asset stocks, flows in and out of those stocks due to human activities, and consequences for well-being. Think of those as the elements that would be needed for a systems analysis of the dynamics of nature-society interactions in the period in London you focused on. Starting with one human activity, think through the following:

I. How did it alter human well-being in the short term? Long term?

II. What are the most significant "examples of policy resistance" (Sterman, exhibit 1) that it encountered?

III. What are the processes connecting it to stocks and flows of assets and to and well-being?

IV. What are the most significant time lags in the causal chain connecting your chosen activity to impacts on well-being?

V. Which are the characteristics of dynamic systems most relevant to nature-society interactions in London you are trying to explain? (Consider the checklist of candidates in Exhibit 2 in the Sterman reading 'c').

VI. Your case?

Digging deeper (optional materials for further exploring frontiers in the pursuit of sustainability):

e) More extended readings on dynamics of nature-society interactions in the Anthropocene system are listed in the Matson et al. course book Under Appendix B: Additional Resources (pp. 202ff). See especially the entries there for Chapter 3 (pp. 205-206).

f) Here are two classic primers in general systems thinking and modeling that will repay any time you can give to them:
   - Meadows, D. H. (2008). *Thinking in systems: A primer*. Chelsea Green Publishing.
   - Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Irwin/McGraw-Hill.