SUSTAINABILITY SCIENCE:
INTERACTIONS BETWEEN HUMAN AND ENVIRONMENTAL SYSTEMS

A Distributed Course between Arizona State University and Colorado State University with participation of faculty from University of Minnesota and Harvard University

Semester: Spring term 2016

Proposed Initial meeting times: Tues. (individual sessions) and Thursday (joint session), 12:00-1:30pm **Arizona Time**.

Arizona State University Faculty:

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A) COURSE OVERVIEW

This course addresses core ideas in sustainability science -- an emerging field of problem-driven research dealing with the interactions between human and environmental systems. The problem that motivates the course, and the field, is the challenge of sustainability: improving the well-being of present and future generations in ways that conserve the planet's life support systems over the long term. The goal of the course is to introduce students interested in sustainability science to the field's principle themes, cutting-edge findings, active debates and unresolved research questions. To this end, participants will critically discuss a set of presentations and papers covering the field in a systematic way, drawing on and integrating contemporary research from earth systems science, resource economics, institutional analysis, ecology, geography, development studies, health sciences, engineering, and other disciplines.

The motivation for the course is the need to integrate the various communities working on sustainability science. The fragmentation of those communities, by discipline, by institution, by applications focus, is a major impediment to the growth and maturation of the field. In response, we are teaching this distributed, interdisciplinary graduate course on sustainability science. The goal of this course is to bring together faculty and students from different, cultures, universities, and disciplinary backgrounds, to discuss key concepts, findings and controversies in the field.

The course meets twice a week. The first session each week will be conducted individually at each university to prepare for focused discussion in the second session that will be held jointly with all participants linked through web conferencing technology. We will use the Vidyo software, hosted by ASU. For each joint session, a faculty member will begin by presenting a prepared lecture to all participants through video (30-45 minutes). Following the lecture, an interdisciplinary team of students drawn from each institution will present a short list of questions to guide discussion of critical themes raised by the readings and lecture. All participants in the seminar will be expected to have read both the assigned readings and the discussions questions and come prepared for an in-depth discussion. A faculty moderator will guide discussion on the material, paying special attention to the discussion questions.

All students will be expected to contribute regularly to an on-line discussion of the lectures and assigned literature. Student collaboration across institutions is highly encouraged.

B) SCHEDULE OF CLASS SESSIONS

Week	Joint session date	Topic	Speaker
January 16	19 January	The origins of the concept of sustainability science	Billie Turner III - ASU
January 23	26 January	Sustainable development and sustainability science; historical overview and long-term trends.	Billie Turner III - ASU
January 30	2 February	Ecosystems services, reconciling supply and demand	Osvaldo Sala ASU
February 6	9 February	Technology and infrastructure.	Charles Redman - ASU
February 13	16 February	Social-ecological resilience - Tipping points and uncertainty.	Osvaldo Sala - ASU
February 20	23 February	Planetary Boundaries	Dale Lockwood-CSU
February 27	2 March	Human capability: Generating knowledge for sustainability	William Clark - Harvard
March 6	9 March	Spring Break	
March 13	16 March	Spring Break	
March 20	23 March	Trade-offs in components of sustainability.	Jeannine Cavender-Bares - UMN
March 27	30 March	Institutions and culture. Institutions for managing human-environment systems sustainably	Marco Jansen - ASU
April 3	6 April	Equity and ethics in sustainability.	Ken Shockley-CSU
April 10	13 April	Energy and the economy	Bill Ritter-CSU
April 17	20 April	Ozone - Atmosphere and Sustainability	Ravi Ravishankara
April 24	27 April	Wrap up	Everyone

For each of the topics to be covered in the course, we provide here a brief overview and teaching objective. The table above presents the schedule of topics.

1. The origins of the concept of sustainability science

The introductory session explores the relationship between "sustainable development" and "sustainability science." It portrays "sustainable development" as an ultimately political issue arena in which people are grappling with the appropriate long term relationships between human development and the natural environment. It portrays "sustainability science" as an

emerging field of scholarly inquiry into the origins and nature of the sustainable development problem, and into possible responses to that problem. The session will review competing perspectives on sustainable development and sustainability science, and present the approach taken here as an outline and justification of the topics covered in the course. We begin with a review of the foundations of sustainability science: i.e. modern conceptualizations regarding the interactions between human and environmental systems. We highlight similarities and differences in the key assumptions, variables and relationships that have figured in alternative conceptualizations, and in the central questions that have concerned them. We then turn to a sampling of historical data and future forecasts or scenarios regarding long term trends and transitions in key attributes of human-environment systems. The session concludes with a discussion of the challenges posed by those trends and transitions for policy and the knowledge needed to support it.

2. Sustainable development and sustainability science; historical overview and long-term trends.

This session presents the conceptual framework for analyzing sustainable development that we will use throughout the rest of the course. Sustainable development is argued to be development that entails non-decreasing human well-being, measured in terms of the assets that contribute to human well-being including 1) ecosystem services and biodiversity, 2) human capabilities and assets, such as knowledge, education, and health; 3) technology and infrastructure; and 4) institutions and culture. These various components link the environmental and social dimensions of sustainable development. The framework helps to understand the central components of planetary and human assets that contribute to human well-being and advance sustainable development. The session will introduce the concept of stock and flows of various assets.

3. Ecosystems services, reconciling supply and demand

This session explores the concept of ecosystem services as key asset contributing to human well-being, sometimes referred to as natural capital. In this session, we review what is known about the environmental services generated by ecosystems, the ways in which humans benefit from those services, and the ways in which human activities impact natural capital and change the future flow of services derived from it. We distinguish between supply and demand for ecosystem services. The former is determined by the biophysical conditions such as climate and soils. In contrast, the demand for ecosystem services depends on stakeholders' values. We conclude by discussing how land management results from reconciling supply and demand for ecosystem services.

4. Technology and infrastructure

Technology and infrastructure are critical in our cities, factories, transportation networks, water and sanitation systems, housing and the like. These assets power income growth and provide jobs, and represent an essential component of development strategies to improve human well-being. But manufactured technologies and infrastructure can be designed and operated in ways that are more or less conserving of natural capital and environmental services. We focus here on recent advances in "industrial ecology," "green chemistry" and similar programs regarding how systems of manufactured capital can be constructed that achieve their aims with lower environmental "footprints" and are thus more likely to promote sustainable development.

5. Social-ecological resilience - Tipping points and uncertainty.
Coupled human-environment systems frequently display thresholds, discontinuities, and multiple-equilibria. The difficulties that these complex behaviors pose for prediction, adaptation, monitoring and management are profound, and have received extensive attention under the rubrics of "resilience," "vulnerability," and "tipping points." This session will review that literature and its implications for sustainability. It will explore how such complex trajectories found in nature can sometimes be captured in simple differential equations that, when coupled, lead to surprisingly complex non-linear dynamics. How such dynamics can be dealt with in models, monitoring and adaptive management regimes will receive special attention.

6. Populations and Planetary Boundaries: Is the sky falling?
"Planetary Boundaries" is a description of large scale dynamics that suggest that we are heading for a rapid collapse. This description mirrors the arguments of both Malthus and Ehrlich and to a lesser degree, Hubbert's Peak Oil theory. Why have past predictions of collapse failed to materialize and how does this reflect on the concepts of Planetary Boundaries? How should we think about local dynamics and global dynamics when considering the overall changes to the planet? What is the effect on social and policy processes of claims of collapse?

7. Human capability: Generating knowledge for sustainability.
Institutions and culture are the formal and informal rules, norms and expectations that shape human interactions with one another and the environment. We begin with a survey of the particular institutional challenges for sustainable development posed by the need to create or protect public goods (e.g. environmental services, "green" technologies) in the face of multiple externalities and opportunities for free-riding. We then review current understanding of the multiple institutions that societies have self-organized to provide such public goods at local scales, before turning to even more challenging task of designing institutions that promote cooperation in the production of global public goods.

8. Trade-offs in components of sustainability.
We present an approach, developed through the course in previous years, that provides a sustainability framework derived from a synthesis of economic and ecological literature. It integrates the ecological mechanisms that underpin ecosystem services, the biophysical trade-offs that constrain management options, the preferences and values of stakeholders, and the dynamic nature of these components.

9. Institutions and culture.
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10. Equity and the economy
We will be discussing the interplay of sustainable development, climate change, and environmental integrity. He will focus on two particular points: (1) the relation between policy initiatives such as the Sustainable Development Goals and our policy responses to climate change, and (2) the way in which the idea of harm underpins our concerns over climate change, motivates sustainable development, and centers our worries over environmental degradation.

11. Energy and the economy
The nexus of government policy and the role of economic forces in the energy sector are critical to understanding the transition to a clean energy driven economy. In this session we will hear from one of the nation's experts in energy policy. We will explore the tools needed to move the energy infrastructure to a sustainable footing.

12. Ozone-atmosphere and sustainability
This unit will address the role of chemically active gases in the atmosphere and how they relate to both the ozone hole and climate effects. There will be a look at both policies on a global scale and on scientific questions regarding the interactions of atmospheric chemistry.

C) THE COURSE MECHANICS
The course will meet twice a week and will start on the week of 16th January.

Tuesday Session: The first (Tuesday) session each week will be conducted by each university on its own. The purpose of this session is to discuss papers assigned for Thursday lectures and be prepared to ask questions.
Thursday (or 2nd) session: We propose to meet jointly on Thursdays during an agreed upon time.

These sessions will be conducted among all universities participating simultaneously via appropriate A/V technology. A faculty member will moderate each session. (Technical guidelines and instructions will be provided separately). Most Thursday sessions will involve i) a presentation by the lecturer for the week; ii) general Q&A involving all participants.

Course web site discussion lists:
A common course web site hosted through Colorado State University will be available to all participants enrolled in the seminar. The discussion lists on that site will be our principal mode of carrying on substantive exchanges regarding the main issues of the seminar. There will be a separate discussion area for each of the weekly topics. The "response group" responsible for leading the discussion on a given topic will be responsible for posting a set of comments and questions to anchor our discussion before the relevant Thursday joint session. All participants are expected to respond to one or more of these postings, or to post at least one of their own questions or comments, to the site by the end of the Wednesday after the Tuesday session. Thursday discussions at each university to pick up on the "crowd" reactions to and views on the topic, lecture and discussion of the week. Participants are, of course, encouraged to post additional discussion items at any time.

D) REQUIRED READINGS AND BACKGROUND MATERIAL

Our discussions in each week of the course will be anchored by readings from the primary literature. Specific assigned readings will be posted on the course web site well in advance of the week in which they will be discussed. Each week we will specify 1-2 papers from the scholarly literature as assigned readings. Given the scope of the class, it is inevitable that some participants will want more basic introduction to the topic, while others will have already encountered the core reading and will therefore want something more advanced. In addition to the required core reading, we will therefore try to post as optional readings for each session at least one more basic and one more advanced paper that participants can read if they wish to do so. Faculty and students will be invited to suggest additional readings as appropriate from the literatures with which they are familiar.

E) RESPONSIBILITIES FOR ALL PARTICIPANTS

All participants in the course are expected to do all of the work listed immediately below.

a) **Attend all sessions** of the seminar, including the joint (Thursday) and local university (Tuesday) sessions. Participants who must miss a class should inform their lead faculty in writing advance. Because this course is intended to accumulate knowledge as it proceeds, and to involve a lot of team work (see below), repeated absences are unfair to all.

b) **Do all the assigned reading** for each week before the Tuesday class. Sustainability science is a complex, interdisciplinary field. We all – faculty and students – will find ourselves bewildered by some of the assigned readings that come far from our own fields of training. That means that "dumb questions" are fine. But comments or questions uninformed by a serious effort to grapple with the readings will impose an unfair burden on everyone.

c) Participate actively in the **class discussions**. This means both the joint sessions (for which the number of students and the electronics will admittedly pose some limitations) and the local sessions with their own universities on Tuesdays.

d) Participate actively in the **on-line discussions** associated with each week's unit. There will be a common web site for all participants in the seminar. Each participant is expected to make at least one substantive entry on each week's discussion. Additional substantive comments, and general contributions regarding the course, papers and events of interest, etc. will also, of course, be welcome.

F) RESPONSIBILITIES SPECIFIC TO EACH UNIVERSITY

Students taking the course must meet all the general requirements noted above.
In addition, each student must (or, with instructor's permission, team of students) participate actively in the Thursday sessions of the course and complete a term paper. Tuesday meetings of the course will be conducted by each university on its own. We will generally use the Tuesday sessions discuss assigned readings and identify questions for Thursday's lecture.
Term paper: The purpose of this paper is to provide students with an opportunity to connect the themes of the course with the student's own research or policy interests. Possible topics include: i) a proposal for research on a topic of human-environment interactions that engages relevant sustainability science theory; ii) a policy analysis of a particular sustainable development problem that uses relevant sustainability science to critique current practice and advance recommendations; iii) a critical review of the literature at the intersection of a particular substantive area and the relevant literatures of sustainability science; iv) another approach that meets the goal noted above that is proposed by the student and approved by the

faculty. Students are invited to discuss possible paper topics with the faculty throughout the course.

Required submissions are:
1) A **proposal** submitted by **mid-March**. This should include a tentative title; a narrative of 100-500 words on the topic to be addressed describing its importance and connection to sustainability science; and a list of 5-10 of the principal sources from the literature [not including those from the syllabus] that the author intends to utilize in preparing the paper. Faculty will return comments to the student on the proposal.
2) A **final paper** submitted by **the end of classes**. This should be between 4000 and 8000 words, not including references, captions, tables and appendices.

G) FACULTY BIOGRAPHIES

Jeannine Cavender-Bares is an associate professor in the Department of Ecology, Evolution and Behavior at the University of Minnesota. Her research focuses on linking functional traits of plants and their evolutionary history with current ecological processes in order to understand the organization of plant biodiversity and its consequences. Cavender-Bares' latest projects link remotely sensed measures of functional diversity to plant and microbial diversity, examine climatic niche evolution in plants from the tropics to the temperate zone, local adaptation of trees to climate, and impacts of perturbation on plant diversity and community assembly. These projects are part of a long-term effort to investigate impacts of global change on biodiversity in human-dominated landscapes.
http://cbs.umn.edu/contacts/jeannine-cavender-bares

William Clark is the Harvey Brooks Professor of International Science, Public Policy and Human Development at Harvard University's John F. Kennedy School of Government. Trained as an ecologist, his research focuses on sustainability science: understanding the interactions of human and environmental systems with a view toward advancing the goals of sustainable development. He is particularly interested in how institutional arrangements affect the linkage between knowledge and action in the sustainability arena.
At Harvard, he currently co-directs the Sustainability Science Program. He is co-author of *Pursuing sustainability: A guide to the science and practice* (Princeton, 2016), *Adaptive environmental assessment and management* (Wiley, 1978), and *Redesigning rural development* (Hopkins, 1982); editor of the *Carbon dioxide review* (Oxford, 1982); coeditor of *Sustainable development of the biosphere* (Cambridge, 1986), *The earth transformed by human action*(Cambridge, 1990), *Learning to manage global environmental risks* (MIT, 2001), *Global Environmental Assessments* (MIT, 2006) and *The global health system: Institutions in a time of transition* (Harvard, 2010); and co-chair of the US National Research Council's study *Our Common Journey: A Transition Toward Sustainability* (NAP, 1999). He serves on the editorial board of the *Proceedings of the National Academy of Science.* Clark is a member of the National Academy of Sciences and a Fellow of the American Association for the Advancement of Science. He is a recipient of the MacArthur Prize, the Humboldt Prize, the Kennedy School's Carballo Award for excellence in teaching, and the Harvard College Phi Beta Kappa Prize for Excellence in Teaching.

Dale Lockwood is the academic coordinator at the School of Global Environmental Sustainability, faculty in the Graduate Degree Program in Ecology and holds a Senior Teaching Appointment in the Department of Biology at Colorado State University. As a population ecologist, he has conducted research in marine larval dispersal and its role in the design of Marine Protected Areas, complexity and population dynamics of rangeland grasshoppers and the role of ecological genetics in sampling strategies for ex situ collections and in the life cycle of plants in seed banks. He has been active in local and regional environmental policy servicing as the chair of the Larimer County Environmental Advisory Board.

Ravi Ravishankara holds a joint assignment as a Professor in the Departments of Chemistry and Atmospheric Science at Colorado State University. He was at National Oceanic and Atmospheric Administration Chemical Sciences Division (CSD) of Earth System Research Laboratory for nearly 30 years in Boulder, CO. There he served as the Director of CSD from 2006 through 2014, and was a Senior Scientist prior to the Directorship. Before coming to NOAA, he was at Georgia Institute of Technology in Atlanta. Dr. Ravishankara has worked over the past three and a half decades on the chemistry of the Earth's atmosphere as it relates to stratospheric ozone depletion, climate change, and regional air quality. His measurements in the laboratory and in the atmosphere have contributed to deciphering the ozone layer depletion, including the ozone hole; to quantifying the role of chemically active species on climate; and to advancing understanding of the formation, removal, and properties of pollutants. He is an author or coauthor of nearly 350 peer-reviewed publications.

Charles Redman has been committed to interdisciplinary research since as an archaeology graduate student he worked closely in the field with botanists, zoologists, geologists, art historians, and ethnographers. Redman received his BA from Harvard University, and his MA and PhD in Anthropology from the University of Chicago. He taught at New York University and at SUNY-Binghamton before coming to Arizona State University (ASU) in 1983. Since then, he served nine years as Chair of the Department of Anthropology, seven years as Director of the Center for Environmental Studies and, in 2004, was chosen to be the Julie Ann Wrigley Director of the newly formed Global Institute of Sustainability. From 2007-2010, Redman directed ASU's School of Sustainability. Redman's interests include human impacts on the environment, sustainable landscapes, rapidly urbanizing regions, urban ecology, environmental education, and public outreach. He is the author or co-author of six books including *Explanation in Archaeology, The Rise of Civilization, People of the Tonto Rim, Human Impact on Ancient Environments*. He is editor or co-editor of nine books, including: *The Archaeology of Global Change, Applied Remote Sensing for Urban Planning, Governance and Sustainability, Agrarian Landscapes in Transition,* and *Polities and Power: Archaeological Perspectives on the Landscapes of Early States*. Redman is currently working on building upon the extensive research portfolio of the Julie Ann Wrigley Global Institute of Sustainability and teaching in the School of Sustainability, which is educating a new generation of leaders through collaborative learning, transdisciplinary approaches, and problem-oriented training to address the environmental, economic, and social challenges of the 21st Century.

Bill Ritter was elected Colorado's 41st governor in 2006. During his four-year term, Ritter established Colorado as a national and international leader in clean energy by building a New Energy Economy. After leaving the Governor's Office, Ritter founded the Center for the New Energy Economy at Colorado State University, which works with state and federal policy makers to create clean energy policy throughout the country. Governor Ritter has authored a book that was recently published entitled, *Powering Forward – What Everyone Should Know About America's Energy Revolution.*

Osvaldo Sala is the Foundation Professor and Julie A. Wrigley Chair at Arizona State University. He has explored several topics throughout his career from water controls on carbon and nitrogen dynamics in arid and semi-arid ecosystems to the consequences of changes in biodiversity on the functioning of ecosystems, including the development of

biodiversity scenarios for the next 50 years. He is particularly interested in working with scenarios as a way of simplifying, understanding, and communicating the complex relationships that emerge from the study of social- ecological systems. He employs a wide variety of tools; especially direct observations, manipulative field experiments, and simulation modeling. He has worked in the Patagonian steppe, annual grasslands of California, steppes of Colorado and deserts of Southern Africa and currently he has experiments in the Chihuahuan Desert in New Mexico. http://sols.asu.edu/people/faculty/osala.php

Ken Shockley holds the Holmes Rolston III Chair in Environmental Ethics and Philosophy. His research interests are in the expression of environmental values in public policy, the ethical dimensions of climate policy, ecological restoration, and several problems in philosophical ethics. Currently, he is exploring the intersection of environmental ethics, climate ethics, and sustainable development. He is coeditor of Ethics and the Anthropocene (forthcoming, MIT), has coedited several special journal issues on the ethical dimensions of climate change and climate policy. His work has appeared in such journals as Philosophical Studies, Environmental Ethics, Environmental Values, Ethics, Policy, and Environment, Journal of Social Philosophy, Philosophy of the Social Sciences, and Philosophy and Public Policy Quarterly. He taught previously at the University at Buffalo, Barnard College, and the University of Malawi.

B. L. Turner II is the Gilbert F. White Professor of Environment and Society at Arizona State University. He took his B.A. and M.A. degrees in geography from the University of Texas at Austin in 1968 and 1969 respectively, and his Ph.D. in geography from the University of Wisconsin-Madison in 1974. Turner came to ASU after 28 years in the Graduate School of Geography, Clark University. Professor Turner has examined human-environment relationships from the past to the future via examination of the rise and fall of the ancient Maya, smallholder cultivation in the tropical world, contemporary deforestation in the tropics, especially in Yucatán, and the future of Earth's land systems relative to ecosystem services, vulnerability, and sustainability. http://geoplan.asu.edu/turner; https://sites.google.com/a/asu.edu/turner/home