SUSTAINABILITY SCIENCE: INTERACTIONS BETWEEN HUMAN AND ENVIRONMENTAL SYSTEMS

A Distributed Course among Univ. Minnesota, Arizona State Univ., Universidad Nacional Autótonoma de México, and Universidade de Sao Paulo

Semester: Spring term 2016

Proposed Initial meeting times: Tues. (individual sessions) and Thursday (joint session), 12:00-1:30pm **Central Time,** 11:00-12:30, **Mountain time**; 16:00-17:30 **Brasil time**. These change throughout the semester as indicated in part C.

Central course web page:

A website will by hosted by UMN that all participants can access. Individual institutions can also host their own websites.

University of Minnesota Faculty:

Jeannine Cavender-Bares (cavender@umn.edu)
Steve Polasky (polasky@umn.edu)

Faculty from participating Institutions:

Arizona State Univ. **(ASU)**: Osvaldo Sala (Osvaldo.Sala@asu.edu), Bill Turner (Billie.L.Turner@asu.edu)
Universidad Nacional Autótonoma de México **(UNAM)**: Patty Balvanera (pbalvanera@cieco.unam.mx), Tuyeni Mwampamba (tuyeni@cieco.unam.mx), Carlos Gonzalez (cgesquivel@cieco.unam)
Universidade de Sao Paulo **(USP)**: Lúcia Lohmann(llohmann@usp.br)
Participating faculty: Jean Paul Metzger

Contents

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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 studnets 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 seminar 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 experimenting with this distributed, interdisciplinary graduate seminar on sustainability science. The goal of this seminar is to bring together faculty and students from different countries, cultures, universities, and disciplinary backgrounds, to discuss key concepts, findings and controversies in the field. An initial course along these lines was run in 2010, and the course has had four iterations. The 2016 course will be the fifth time we have taught it. This 2016 version will involve faculty and students at four universities recognized as leaders in sustainability science (the University of Minnesota, Arizona State University, the National Autonomous University of Mexico, and Sao Paulo University). Our specific goal is to discuss and develop new insights arising from differing cultural, political, economic, and ecological perspectives from Latin America and the U.S.

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 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. Students taking the course for credit will be required to meet additional requirements imposed by their home university. (See below in this syllabus). Student collaboration across institutions is highly encouraged.

The seminar is an ongoing experiment in developing approaches to the sorts of

collaborative, distributed, travel-minimizing networking that almost certainly must be part of any sustainable future. Students and faculty will be asked to participate in an on-going adaptation of the course to better realize its objectives and to evaluate the course at its conclusion.

B) BASIC ARCHITECTURE –

Part I (2 weeks): **Introduction** to the challenges of sustainable development, and the idea of an emergent field of sustainability science organized as a problem-driven field of inquiry to address those challenges. This section sets out the history of these concerns, the idea of interactions between humans and the environment as a complex adaptive system, and the long term trends and large scale patterns in the human-environment system that sustainability science seeks to understand and to help manage. It sets the stage for course. In doing so, we specifically highlight contrasting perspectives across cultures and disciplines on the central issues and methods of analysis.

Part II (4 weeks): **Conceptual frameworks** for thinking about the sustainable development challenge and the tasks of sustainability science. We begin with the premise that there does not yet exist a truly integrative coherent and practical framework for analyzing sustainable development in terms of coupled human-environment systems. However, we present a theoretically consistent and coherent approach to sustainable development that harnesses the central components of sustainability. These include the four major planetary and human assets that contribute to human well-being: 1) Ecosystem services and biodiversity, 2) Human capabilities and assets, i.e., knowledge, education, health, 3) Technology and infrastructure, and 4) Institutions and culture. This approach integrates across biophysical, social and economic dimensions. We introduce conceptual frameworks for considering sustainability that are consistent with this approach, including "inclusive wealth" where "inclusive" signifies that attempt to include all forms of capital assets (natural capital, manufactured capital, and human capital) and institutions (social capital) that contribute to current and future human well-being. However, this framework is economic in its nature, and we choose to present the components of sustainability using a more expansive perspective.

We step through each of these components and focus on what is known about socio-ecological system dynamics. We start with ecosystems and biodiversity, referred to in economic terms as natural capital, and emphasize how biodiversity and ecosystem functions contribute to provision of ecosystem services that support human well-being. In doing so, we introduce the notion of *stocks and flows*, referring here to natural capital stocks, and the flow of ecosystem goods and services from these stocks. The first problem set is given that allows students to work through the mathematics of stocks and flows, concepts which will be used throughout the rest of the course. We then turn to the other three components of sustainability.

A particularly difficult issue is measuring and monitoring progress towards or away from sustainability. For example, the inclusive wealth framework requires measuring the value of all forms of capital assets in a common monetary metric but many forms of human, natural, social capital are not readily measured in monetary terms. Other approaches, including the MESMIS approach, which focuses on agroecosystems at small scales, use multiple indicators or metrics but face difficulties of how to interpret overall trends when some indicators show improvement while others deteriorate. We will discuss issues of what to measure, how to measure, and how to interpret evidence in terms of what it indicates for sustainability. We first address how this might be done at

global and national scales (top-down) using the inclusive wealth framework and then consider bottom-up approaches that start from the ground up. Linking bottom-up and top-down approaches requires participation at all scales of governance and behavior. How do we link the two effectively? Equity is a critical component for achieving global goals from the bottom-up, and is a consistent theme in the course that we address in terms of how sustainability can be or should be defined.

Part III: Complex system dynamics in human-environment systems that pose special challenges to sustainable development and sustainability science, including considerations of resilience, accurately measuring natural capital, ecosystem services and biodiversity, and measuring and monitoring progress toward sustainability.

The components of human-environment systems introduced in Part II interact in complex and uncertain ways that defy accurate prediction and necessitate adaptive approaches to management. Some of these interactions pose special challenges for sustainable development. Such challenges are in part due to temporal lags between human actions and environmental response, spatial heterogeneity, and the embedding of human-environment systems in multiple scales of interaction from the local to global. Complex system dynamics can generate thresholds or tipping points leading systems into rapid changes in fundamental system behavior. Such factors make trial-and-error adaptation difficult and highlight the importance of a better understanding of systems vulnerability and resilience.

Ecosystem services and components of sustainability involve complex trade-offs that arise from biophysical constraints in the stocks and flows of assets that contribute to human well-being. The way stakeholders and societies choose to navigate these trade-offs depends on their values. Complex system dynamics, including tipping points and temporal lags, influence both the nature of the trade-offs and human preferences for outcomes.

Part IV: Governance is an essential component of achieving sustainable development. Effective governance of complex human-environment systems requires interface between science and policy and linking knowledge to action. Knowledge is not the exclusive domain of experts and scientists, those who live and work in social-ecological systems have knowledge. We will discuss **participatory research** and impact assessment for sustainability science. In addition, policy and decisions about what *should* be done to achieve sustainable outcomes is not determined solely by knowledge or scientific information, it also involves values. A theme that will come up throughout the course are the role of values and differences in values in determining social choices regarding sustainability.

C) SCHEDULE OF CLASS SESSIONS

Week	Topic
1	Sustainable development and sustainability science; historical overview and long-term trends.
2	Definitions and components of sustainability: 1) Ecosystem services and biodiversity, 2) human capability: knowledge, education, health, 3) technology and infrastructure; 4) institutions and culture. Problem set 1.
3	Ecosystem services and biodiversity (stocks and flows).
4	Human capability: Knowledge, education and health.
5	Technology and infrastructure.
6	Institutions and culture. Institutions for managing human-environment systems sustainably.
7	Measurement of sustainability: Inclusive wealth – top down approach (Natural capital, manufactured capital, human capital, social capital). Problem set 2.
8	Measurement of sustainability: MESMIS framework – bottom-up approach.
9	Equity and ethics in sustainability.
10	Social-ecological resilience - Tipping points and uncertainty. Problem set 3.
11	Social-ecological resilience – Cross scale dynamics in time and space
12	Trade-offs in components of sustainability. Problem set 4.
13	Participatory research and impact assessment for sustainability science
14	Student presentations
15	Wrap up

Each week in Parts I, II and III of the course is focused on a conceptual framework or theoretical perspective that we, the course faculty, judge to be of central importance to sustainability science.

For each of the topics to be covered in the 4 Parts of the course, we provide here a brief overview and teaching objective. The table above presents the schedule of topics. Lecturers (including guests from other institutions), readings, and student team responsibilities will be posted well in advance of each session.

1. Sustainable development and 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 turns 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. Definitions and components of sustainability
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. **Problem set 1:** The first problem set will allow students to work through these concepts mathematically.

3. Ecosystem services and biodiversity.
This session explores the concept of ecosystem services and biodiversity as key assets 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 and biodiversity, 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. Biodiversity conservation is often considered essential to sustainable development. Yet justifying biodiversity in terms of natural capital is problematic and often leads to conflict, given competing land-uses. Agriculture, for example, offers more direct benefits to human welfare than preserving habitat for other species. The session examine motives that drive biodiversity conservation: 1) the biocentric perspective that other organism beyond humans have claim to planetary resources, 2) spiritual and cultural factors that lead humans to value the existence of other organisms, and 3) empirical linkages between biodiversity and ecosystem services. The latter justifies biodiversity conservation from an anthropocentric perspective, and hence carries weight politically, but does little to solve conflicts over

competing land-use.

4. Human capabilities and assets: knowledge, education and health
Human capabilities and assets are the attributes of individuals (rather than society) that can contribute directly to sustainable development. This topic is concerned with relevant scholarship regarding how these attributes relate to the environmental dimensions of sustainability. 'Knowledge' makes contributions to human well-being that are every bit as important as those provided by various other assets. We focus first on involving users to identify the knowledge most needed for promote sustainability. We then turn to the integration of practitioner (or indigenous) knowledge and expert knowledge. The third involves the fact that knowledge is power, and thus that the struggle for defining knowledge needs and access is an inherently political one. Readings review the evidence on how environmental degradation affects human mortality and morbidity and -- through these and directly – human well-being and consider what is known of the options for mitigating these health-related problems. Finally, the topic deals with the role of values and knowledge in shaping people's behavior relevant to sustainable development, and the role of education in changing those factors.

5. Technology and infrastructure: Industrial ecology perspectives on reducing the environmental footprint
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.

6. Institutions and culture.
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.

7. Assessing and measuring sustainability using "inclusive wealth" – a top down approach
Any approach to understanding and promoting sustainable development demands that we be able to evaluate the extent to which past trajectories of human-environment systems were sustainable and the sustainability of alternative future trajectories. One approach for doing so entails non-decreasing human well-being, measured as "inclusive wealth." This latter term is defined as a function of the capital assets we have just discussed in the four previous

sessions. We review the conceptual issues involved in such evaluations, how they are similar to and different from conventional social benefit cost analysis. We then discuss evidence on changes in ecosystem services, natural capital and inclusive wealth at local/regional scales and attempts to measure inclusive wealth at national scales.

8. Assessing and measuring sustainability using the MESMIS framework – a bottom-up approach

The MESMIS approach has been developed for and widely applied in the context of evaluating agroecosystems, sustainable livestock production, intercropping, alternative crops and biological control in Latin American agro-ecological systems. It is a bottom-up approach that uses many criteria consistent with other "dashboard" approaches for measuring and evaluating sustainability. A decade of case studies in its application provide a basis for considering how ground-based evaluation of sustainability operates.

9. Equity and ethics in sustainability

A central issue that we confront in the course is the issue of equity in sustainable development. Progress in developing and reaching global goals for sustainability require both bottom up and top down approaches. Bridging bottom-up and top-down efforts requires attention to equity and ethics, without which diverse groups will cease to contribute and work towards common goals. One common definition of sustainability references meeting the needs of both the current generation and future generations. How can we organize society to meet everyone's needs? Meeting the needs of everyone in society both now and in the future requires dealing with issues of equity and justice.

10. Discontinuities and tipping points--Irreversibilities and multiple equilibria

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. **Problem Set 3.**

11. Cross-scale dynamics in time and space

This session focuses on the particular difficulties for understanding and management posed by the fact that human-environment systems operate simultaneously at multiple temporal and spatial scales. In the time dimension, we address the challenges for adaptive response raised by temporal lags between human actions and environmental response. In the spatial domain, we begin with a look at the significance for human well-being and environmental services of organizing human-environment interactions in spatially homogeneous (e.g. monoculture) vs. heterogeneous ways. We then turn to the implications, especially for governance, that human-environment systems generally entail multiple scales of interaction from the local to global.

12. 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. **Problem set 4.**

13. Participatory research and impact assessment for sustainability science: Linking knowledge to action

This session explores sustainability mostly from the point of view of practitioners: how they define it, how they apply it, and the tools they use to evaluate whether they are achieving their objectives. The focus is on linking knowledge to action in the context of forest conservation initiatives considering the practice and participatory methods as the general approach and social impact assessment as one specific tool. The session highlights the importance of boundary spanning organizations and their role in integrating knowledge and practice.

[Not addressed in weekly sessions] **Population and sustainability**

The size and growth rate human population enters into the determination of human well-being and inclusive wealth in multiple ways. At the micro level, individuals choosing whether to have additional children face tradeoffs regarding their own well-being, some of them shaped by the state of and prospects for the environment. At the macro-level, people are a source of the creation of the capital assets, knowledge and institutions but also the denominator by which total wealth must be divided to determine overall human well-being. Population change is both a cause of and a response to environmental change. This topic, which will not be covered in class, would be where to discuss whether there are optimal levels of population size and growth for sustainable development.

D) HOW THE COURSE WILL BE RUN

The course will meet twice a week and will start at the beginning of the semester for each institution. Prior to the first joint meeting, sessions will be conducted by each university individually.

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 the following times:

Course start:
Minnesota 12:00-13:30
Arizona 11:00-12:30
Mexico 12:00-13:30
Brasil 16:00-17:30

22 February; Brasil turns clock back
Minnesota 12:00-13:30
Arizona 11:00-12:30

Mexico 12:00-13:30
Brasil 15:00-16:30

March 8 – Minnesota turns clock forward; course start time changes for Arizona, Mexico, Brasil
Minnesota 12:00-13:30
Arizona 10:00-11:30
Mexico 11:00-12:30
Brasil 14:00-15:30

March 29 – Mexico turns clock forward.
Minnesota 12:00-13:30
Arizona 10:00-11:30
Mexico 12:00-13:30
Brasil 14:00-15:30

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 the University of Minnesota 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 by the Friday before the relevant Tuesday 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.

E) 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. Most of these readings will draw from the on-line compilation of "Readings in Sustainability Science and Technology." This document, edited by Robert Kates, was published in 2010 under the auspices of the Sustainability Science Program at Harvard University. It is a structured and annotated bibliography of critical readings that cover the essential topics in the field. Each week we will specify 1-2 papers from the scholarly literature as assigned readings. Given the scope of the class, its 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. These additions will be considered for inclusion in future editions of the "Kates Reader."

F) RESPONSIBILITIES FOR ALL PARTICIPANTS

All participants in the seminar, whether they are taking it for credit or not, are expected to do all of the work listed immediately below. Additional requirements for students taking the course for credit vary by university, and are listed at the end of this section.

a) **Attend all sessions** of the seminar, including the joint (Tuesday) and local university (Thursday) sessions. Participants who must miss a class should inform their lead faculty in writing advance, with a copy to the lead TF Christina Ingersoll. Because this seminar is intended to accumulate knowledge as it proceeds, and to involve a lot of team work (see below), repeated absences are unfair to all. If you can't attend regularly, don't enroll.

b) **Do all the assigned reading** (and lecture watching) for each week before the Tuesday class. (See section 'E' above). 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. So if you can't commit to doing the readings and such in advance, don't enroll. And if the realities of your own world means that you occasionally have not been able to get to the readings for a particular session, please constrain yourself to listening quietly.

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

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.

e) Participate actively in one or more **topic teams**. For each Tuesday session in Parts II-IV of the seminar, one or more interdisciplinary teams of participants from across all of the sponsoring universities will prepare and present a formal critique of the readings and lecture of the week. These teams will be assembled by the faculty based on information supplied by the participants about their backgrounds and interests during the first weeks of the seminar. Each team will be expected to 'meet' in virtual space during the two weeks prior to the session in which they present to plan their approach. (How these virtual meetings take place is the choice of the team. Guidance will be available from the lead teaching fellow). Each participant can expect to participate in about 3 teams during the course of the seminar, with the actual details depending on enrollment.

f) Participate in a **problem-focused team** responsible for making a presentation to the seminar on one of the topics selected for Part IV of the course.

G) RESPONSIBILITIES SPECIFIC TO EACH UNIVERSITY

Students taking the course for credit 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 "UMN only" sessions of the course and complete a term paper.

Thursday sessions: Thursday meetings of the course will generally be conducted by each university on its own. Joint (virtual) sessions with one or more groups from the other participating universities can be arranged as suggested by participants. We will generally use the Thursday sessions to i) deepen discussion of the lecture delivered the previous Tuesday; ii) provide background for the next week's reading and lecture. We can also use the Thursdays to pursue topics of special interests to a sufficient number of our local participants. All participants in the seminar are expected to attend the Thursday sessions and to lead discussions there as appropriate.

Problem sets: Four problem sets will be given to students to work through the concepts mathematically. This will help provide a common language across disciplines and help develop concrete skills in sustainability science. Students will be able to get assistance from the teaching assistant and from faculty and will receive feedback. Problem sets will be graded and represent 15% of the total course grade.

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. More information on the nature of the term papers is forthcoming.

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 **mid May**. This should be between 4000 and 8000 words, not including references, captions, tables and appendices.

Grades for students taking the course for credit will be computed as follows:

a) Problem sets: 15%
b) Individual contributions to discussion through verbal comments during weekly discussions and course site entries: 15%
c) Group contributions through the topic teams to which the participant belongs: 20%
d) Term paper and presentation: 50%

Students taking the course at the 3xxx level are required to participate fully in the discussions and responses, to turn in problem sets and to write a term paper. However, the term paper can be in the form of a survey or literature review.
Students taking the course at the 5xxx level are level are required to participate fully in the discussions and responses, to turn in problem sets and to write a term paper. The term paper must be on a research topic, potentially of publication quality that addresses a fundamental question and contributes new information to the discours in sustainability science; these students must also take a leadership role in organizing topic teams.
Students auditing the course are expected to participate fully in the discussions and responses.

H) 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

Stephen Polasky is a Regents Professor and Fesler Lampert Professor of Ecological/Environmental Economics and an interdisciplinary chair in the Departments of Applied Economics and Ecology, Evolution and Behavior at the University of Minnesota. He joined the UMN in 1999 after serving professor positions at Boston College and Oregon State University. Polasky's research interests include ecosystem services; natural capital; biodiversity conservation; endangered species policy; integrating ecological and economic analysis; renewable energy; environmental regulation; and common property resources. As an Institute on the Environment resident fellow, Polasky is working to expand current integrated models showing the impact of land use on ecosystem services. In addition, he seeks to engage public and private sector groups to improve land use planning.
http://faculty.apec.umn.edu/spolasky/

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

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 Yucata'n, 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

Universidad Nacional Autónoma de México (UNAM)

Patricia Balvanera studies the links between biodiversity, the functioning of ecosystems, and the benefits or services society obtains from them. Given the present rates at which biodiversity is lost as a result of human enterprise, it is crucial to understand the consequences of such loss on the way ecosystems function and the potentially negative effects on human well-being. She conducts field work on the Pacific Coast of Mexico, in a very dry and hot tropical forest that has been transformed to pastures for cattle raising and recently for tourism development. Once abandoned, these pastures host a large biodiversity and provide key benefits to the local population and to global society. At the local scale, she studies how tropical dry forest biodiversity responds to management and contributes to provision of food and other resources, climate regulation, and flood regulation. At the regional scale, she collaborates with scientists of other disciplines to understand the links between plant biodiversity and the provision of ecosystem services, as well as the socioeconomic factors that drive ecosystem management. She also develops both regional and national maps to highlight key socio-ecological tradeoffs and inform decision-making. She enjoys brainstorming and thinking collectively with students and colleagues. She teaches undergraduate and graduate courses on ecosystem services and community ecology.
http://ww2.oikos.unam.mx/CIEco/comunidades/

Carlos Gonzalez Esquivel studies and teaches sustainability evaluation in agroecosystems, sustainable livestock production, intercropping, alternative crops and biological control. He has a degree in Veterinary Medicine and Animal Production from the University of the State of Mexico (1994) and a Ph.D. in Agroecology from the University of London (1998). He worked for the University of the State of Mexico from 1999 to 2008, the University of East Anglia from 2009 to 2011, and is currently a researcher at the Ecosystems Research Centre (CIEco-UNAM). He is also an invited lecturer at the Masters in Agroecology from the University of Cordoba and the International University of Andalucia, Spain. http://www.oikos.unam.mx/agroecologia/

Tuyeni Mwampamba is a researcher at the Centre for Ecosystems Research (CIEco) of the National Autonomous University of Mexico (UNAM), Morelia Campus and a native of Tanzania. She received her PhD in Ecology and a graduate certificate in Conservation Management from UC Davis in 2009. Her research interests include quantification and management of ecosystem services in community managed landscapes; policy and forest impacts of charcoal production and consumption in the Tropics; forest use and conservation; and participatory research. Her research is inter-disciplinary in nature, straddling social, ecological, and political aspects of forest management by communities, primarily in Tanzania and Mexico. Dr. Mwampamba has been working closely with the international NGO Forest Trends' to develop good practices for community participation in assessing the social and biodiversity impacts of forest-based carbon projects and payment for watershed services schemes.

Universidade São Paulo de Brasil (USP)

Lúcia Lohmann is professor of botany at the University of São Paulo in Department of Botany. She has experience in the area of botany with an emphasis on plant systematics, particularly in phylogeny, evolution, biogeography, evolutionary ecology, conservation. She has participated in numerous activities at the interface between academia, civil society and policy through the Association for Tropical Biology and Conservation and the DIVERSITAS Core Project BioGENESIS. She was President of the Association for Tropical Biology and Conservation (ATBC) from 2012-2014 and has been a member of the Scientific Committee of BIOGENESIS since 2006; she has been involved in a variety of initiatives through this program including the transition to Future Earth.