

CHAPTER 14

Global Environmental Sustainability: An “All-Hands on Deck” Research Imperative

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INTRODUCTION

The two-way interaction of societal activity with environmental processes now defines clear and present challenges to our well-being. Human activity is changing the climate system and the ecosystem services that support human life and livelihoods. The changes are occurring at an unprecedented and often bewildering pace. The Earth’s hydrological cycle is intensifying and weather records (e.g., floods, wildfires, droughts, heat waves, etc.) are being regularly revised upwards. The vulnerability of societies to disruptive change is increasing as the world’s population itself grows, as resource limitations of all kinds become more evident, and as people are drawn to live in unsafe settings, often in conditions of poverty.

Reliable and affordable energy is essential to meet basic human needs and to provide for economic stability, but many environmental problems arise from unsustainable approaches in harvesting, generation, transport, processing, conversion and storage of energy. Climate change is a pressing anthropogenic stressor, but it is not the only one. Growing challenges are associated with poverty alleviation, development pathways for the world’s most vulnerable societies, biodiversity degradation, ocean acidification, freshwater availability, hazardous extreme events, coastal vulnerabilities, infectious diseases and food security, to name a few. The three “E’s”: environment, energy and economics, in particular, form a strongly coupled but presently unstable tripod on which everything depends. In fact, any family of solutions worthy of the

simplest definition of sustainability (*meeting the needs of the present without compromising the ability of future generations to meet their own need*) (World Commission, 1987) will require detailed consideration of the interplay of these factors in new and creative ways. Furthermore, in the time domain, solutions will need to address both the long-term *mitigation* of deleterious effects (through, for example, building a low carbon global economy) as well as near-term *adaptation* to changes already underway (through, for example, more effective conservation of freshwater stocks globally and creating greater levels of societal resiliency).

To compound these challenges, detailed solutions are not always self-evident and the problem of global environmental sustainability is one that is sometimes referred to as “Wicked” (Rittel & Melvin, 1984) or even “Super-Wicked” (Levin *et al.*, 2008) — terms used in social planning to describe problems that are difficult or impossible to solve because of incomplete, contradictory and changing requirements that are hard to recognize until after solutions have been tried. Moreover, because of complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems. More ominously perhaps, super-wicked problems are characterized as ones for which 1) time is running out; 2) there is no central authority; 3) those seeking to solve the problem are also causing it; and 4) time-inconsistent discounting occurs (meaning that individuals may make choices today that they their future self would prefer not to make, despite using similar reasoning).

So, in short, we have a global sustainability “perfect storm” on our hands — and on “our watch” — one for which the scientific and technological tools are not, as yet, sufficient, and where responsive societal decision-making processes are arguably too slow and too erratic.

Despite the difficulties, the urgency to identify viable pathways for a healthful future for humanity is well documented and much diagnostic work has been accomplished (Intergovernmental Panel on Climate change, 2007; National Research Council, 2008 and 2011). And, of course, we have magnificent research universities distributed around the world that are, at first glance, almost perfectly designed to create the needed trans-disciplinary knowledge *and* build the human capital base to define and implement such pathways. But I believe that there is a mismatch in cadence between the evolution of the complex emerging sustainability challenges and our evolving state of readiness to respond — a mismatch that demands a new “call-to-arms” for the modern research university.

Part of this mismatch comes from a dangerous misreading of the times scales at play. Even though many recognize the issues at stake, they feel that there is time to work it out — perhaps over decades, perhaps over one or more generations. It is actually very hard for humans — with our inherent optimism, our yearning for stability, and our awe of nature — to fully internalize

the stressors, to recognize the imperatives for collective action and then react in responsive ways. Intuitively for many, the world feels too big and too complex to be under any kind of disruptive human control. Our aspirations, our desire for a high standard of living, our financial and community-based investments for the future and for economic growth, and our religious and ethical beliefs often lead us to assume that continued progress, growth and a promising future are at least a possibility if not an absolute birthright. These human factors — and the central and even dominant role of human decision-making in creating a level of sustainability — bring to the fore the social sciences and the arts and humanities in a fundamental new way and in a very challenging intimate partnership with science, engineering and technology.

We have an historically unique and pivotally important race on our hands: a race between the development, dissemination and application of the knowledge needed to create a sustainable future and a fast moving opponent: the deleterious and disruptive changes, now well underway, that might/will sap our ability to respond in the future. It often strikes me as ironic that this race is such a tight one, with the two horses running neck and neck together at this moment in history (in fact — an even more humbling thought — during our professional careers!) In an ideal world, after all, the required knowledge base could have been available and well-accepted a century or two ago. And, in a non-ideal world, we would never have had even an inkling of what hit us.

I argue here that, because of the need to win this race and because of their unique ability to educate and mobilize the world's brain trust across the full range of disciplines, research universities have the following urgent and specific responsibilities:

- To *transform* education — and not just postsecondary, but the full spectrum of formal and informal education — to educate, engage, empower and energize the next generation of problem solvers;
- To *drive* a robust international and collaborative research agenda designed to identify, invent, test and deploy solutions designed to address the formidable challenges of global sustainability;
- To *insist* on building both disciplinary depth and trans-disciplinary breadth of research and education, connecting the science, engineering, technology, mathematics, social sciences, arts and humanities disciplines in service to society;
- To *assess* the need for societal action, to transmit authoritative information to stakeholders and then *take ownership* of the process of transition of knowledge to application, working in new partnerships.

In this contribution, I describe activities underway to address the second imperative above: defining and carrying forward a vigorous and urgent interdisciplinary research agenda. I describe new plans at the agency (NSF),

national (U.S.), and International (ICSU) levels designed to create a much more fully coordinated sustainability research agenda. Unfortunately, these plans have not yet been adequately driven — or even fully embraced — by academia. However, they all point to the *urgent need for strong research university leadership* to be manifested in building the knowledge base to shape humanity's common future and ensuring that it is a sustainable one for generations to come.

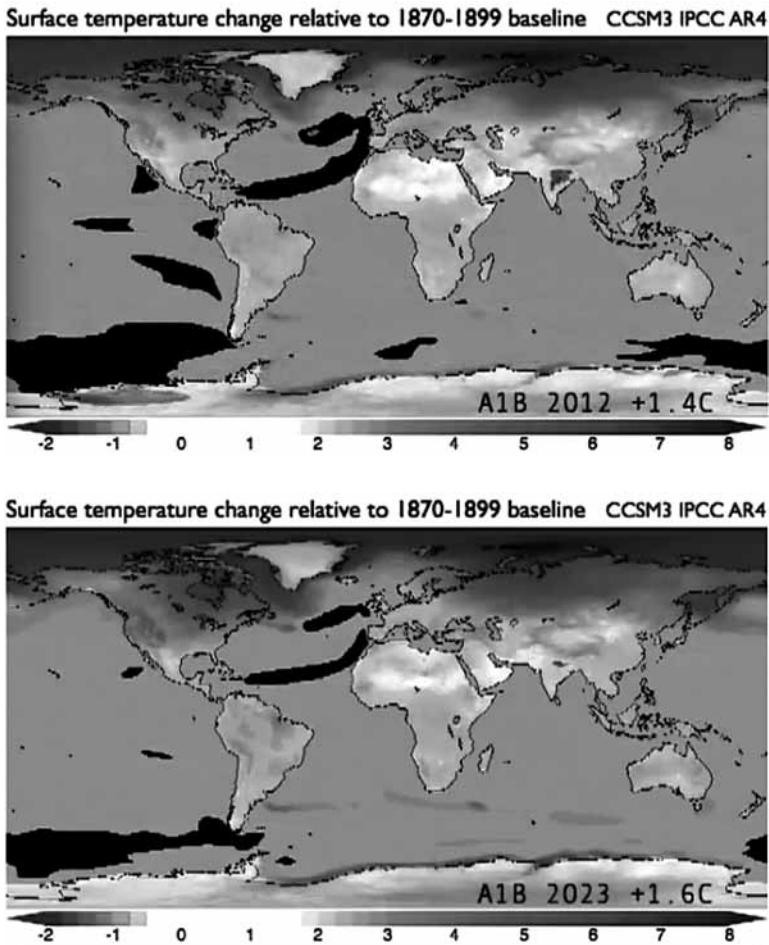
NO TIME TO WASTE

The changes underway in the global climate system are occurring at a rate that exceeds the projections made at the time of the most recent Intergovernmental Panel on Climate Change (IPCC) report in 2007. This is due to increases in greenhouse gas emissions from many parts of the world, coupled with the relatively modest international efforts to limit those emissions and the rapid economic development of China, India, Brazil and other countries (to be celebrated, of course, from the perspective of poverty alleviation). Although decadal predictions are notoriously difficult to make in detail, sophisticated numerical climate system models, running on supercomputers, are able to show plausible responses with a degree of regional fidelity.

These changes will have profound consequences for fresh water availability, food production rates and for the occurrence frequency of extreme events, such as heat waves and droughts. In one study, conducted by the International Food Policy Research Institute (IFPRI, 2011), by the year 2050, continued warming and the accompanying changes in regional precipitation would reduce the production of rice globally by 27% (Mark Rosegrant, private communication). Such changes would, in turn, affect childhood malnutrition significantly, with an estimated increase of 22% of malnourished children by the year 2050 due to the effects of climate change on food production. Clearly, such studies are subject to much uncertainty, since they have to include imperfections in our understanding of climate change, particularly chained modeling projections of both precipitation and temperature regionally, as well as land use patterns, economic development and crop productivity, and assumptions of biome shifts and market variability. The point here is not that these numbers are strictly correct, but that societal management in the near future will increasingly demand such multi-disciplinary collaborations and projections, with results that have major public policy implications.

Freshwater scarcity is also a very near-term problem. In 2006, the International Water Management Institute reported that water scarcity affected fully one third of the world's population. IPCC projections indicate that this proportion will grow over the next years. It is estimated that more than 2 million children die of diarrhea each year due to badly managed and polluted waters.

Figure 1: Modeled Temperature anomalies with respect to 1870-1899 baseline; IPCC A1B scenario¹



More than 500 million subsistence farmers lack irrigation water and are mired in poverty (Rijsberman, 2008). Water rationing in the rapidly growing cities in Africa and Asia is already the norm. The U.N. Millennium goals include a commitment to halve the number of people without access to safe potable water and, although significant progress has been made in Asia, Africa still lags. It is estimated that a diet of 3,000 calories per day requires at least 3000 litres of water to produce, so population pressures will further stress the freshwater security equation. All these water-related issues are likely to become more severe and much more complex to manage with climate change.

So, although it is possible to ponder global environmental sustainability questions from an academic standpoint at leisure and with a sense of distance and perspective, these changes are in fact occurring at rates that can and will simply overwhelm some of the traditional academic processes, where a typical graduate student maturation interval is about five years. Connect the two processes and you find the ratio is 0.1 C global-mean temperature increase per graduate student cycle!

So, Research Universities must respond and respond quickly to these onrushing, complex and multifaceted sustainability questions that demand science and technology analyses, coupled with deep understanding of human decision-making processes under conditions of large — and sometimes poorly defined — uncertainty. These challenges will undoubtedly stress Research Universities in ways that are quite unusual and it is likely that many institutions will simply fail to be relevant to the times. Those that do step up, however, will play an historical role for the future of human well-being.

SCIENCE, ENGINEERING AND EDUCATION FOR SUSTAINABILITY, SEES: A US NATIONAL SCIENCE FOUNDATION INITIATIVE

Funding agencies are beginning to appreciate the need for vigorous new approaches to support the scope and interdisciplinary function of what might be called global environmental sustainability science. One such agency is the National Science Foundation of the United States (NSF). NSF established the Science, Engineering, and Education for Sustainability (SEES) investment area (NSF, 2011) in FY2010 in order to promote the research and education needed to address the challenges of creating a sustainable human future. The SEES portfolio emphasizes a systems-based approach to understanding, predicting and reacting to change in the linked natural, social and built environment. Initial efforts were focused on coordination of a suite of research and education programs addressing future changes in climate and environment, with specific attention to incorporating social and cultural components of sustainability solutions. Eight solicitations were released in 2010 and 2011. These included the following:

- Water: Sustainability and climate
- Ocean Acidification
- Biodiversity (jointly with China)
- Regional and Decadal Earth System modeling (jointly with the U.S. Department of Agriculture and the U.S. Department of Energy)
- Climate Change Science Education (federated with similar efforts by NOAA and NASA)

- Sustainability Research networks
- Sustainable Energy Pathways
- Sustainability Research Fellowships

In all cases, natural, engineering and social sciences were required elements for successful proposals, connecting the environmental, economic, and energy-use elements of the problem, as well as the human capacity-building aspects. SEES is expected to be a five-year effort, extending through FY2015. Continuing efforts will focus on supporting research that facilitates global community sustainability, specifically by building connections between current projects, creating new nodes of activity, and developing the interdisciplinary personnel needed to address sustainability issues.

Efforts such as SEES are designed, not just to conduct frontier research, but to build the community of researchers able and capable of conducting the kinds of interdisciplinary studies relevant to sustainability. New partnerships of natural and social sciences are quickly emerging and the SEES program will be carefully evaluated for effectiveness in the context of important outcomes related to sustainability.

THE UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM, USGCRP

In addition to individual agency activities, such as NSF/SEES, there is a growing emphasis on multi-agency coordination in support of the sustainability research enterprise. The United States Global Change Research Program (USGCRP) is a 13-agency cross cutting program of the federal government designed to further research in global change, including mandated support for the furtherance of international collaborations.

The USGCRP is finalizing a new ten-year strategic plan and vision that will be made available for public comment in the summer of 2011. The new vision for USGCRP has already been released and is of: *A nation, globally engaged and guided by science, meeting the challenges of climate and global change.* The mission of the new USGCRP is “to build a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication and decision support”. The emphasis for the next ten years of the U.S. federal effort in global change research will be to develop what is being called an “end-to-end” approach, that is, developing the science and technology, but also applying the emerging knowledge base to key applications in society. The USGCRP recognizes that “meeting society’s expanding demands for planetary resources, while preserving our global environment is one of the greatest challenges the world faces”. Draft USGCRP materials state that:

“Sustainability requires finding ways to accommodate a growing population and its economy while assuring environmental goods and services needed to maintain our modern way of life will be available for present and future generations. Never in history has there been a greater need for well-founded science to help inform government, business, and public sectors in their efforts to meet this challenge, whether in their roles as voters, investors, homeowners, business owners, or stewards of the planet.”

“The rapidity of the global change occurring today — in temperature, sea level, ice sheet thickness, ocean chemistry, and land surface change — far exceeds anything in recent geological history. The potential implications of this rapid change are profound, including dramatic increases in the severity of heat waves, floods, fires, storms, crop yields, habitat destruction, and water shortages, all occurring too quickly for ecosystems and human communities to adapt gradually. Business as usual could lead to irreversible changes, such as loss of summer sea ice and glaciers, accelerating extinction of species, and changes in critical ocean circulation patterns.”

The USGCRP (2011) recognizes that the “challenge is urgent” and will emphasize several key components including:

- Integrated Observational Systems
- Integrated Modeling
- Regular Sustained National Climate Assessments
- An Interagency Climate Portal
- Climate Adaptation Science
- Climate Services
- Enhancing International Partnerships

The USGCRP also recognizes the importance of social sciences to the new end-to-end approach and is reaching out to academic social sciences community to build capacity. As the U.S. federal inter-agency effort moves towards a more end-to-end approach to the science of global change, the U.S. Research Universities will see opportunities for new levels of integrated sustainability research.

A PATHBREAKING “ALLIANCE” TO ESTABLISH A TEN-YEAR INTERNATIONAL INITIATIVE ON GLOBAL ENVIRONMENTAL SUSTAINABILITY

The NSF agency program and the USGCRP inter-agency programs have been influential in also seeding a new international coordinated research effort of relevance to the world’s research universities. The Belmont Forum (2011) was established in the Fall of 2009 and is a high level group of the world’s major and emerging funders of global environmental change research and interna-

tional science councils. It is co-chaired by leaders of the National Environmental Research Council of the U.K. and the NSF Geosciences Directorate in the U.S. Two key members of the Belmont Forum from outside the funding agency community are the Executive Directors of the International Council of Scientific Unions (ICSU) and the International Social Sciences Council (ISSC), representing international academia from the natural and social sciences.

The Belmont Forum founding was inspired by recognition that the understanding of the environment and human society as an interconnected system, provided by Earth System research in recent decades, now needs to be built on, to provide knowledge for action and adaptation to environmental change. It aims to accelerate the international environmental research most urgently needed to remove critical barriers to sustainability, by aligning international resources.

At its fourth meeting, in Cape Town, October 2010, the Belmont Forum spearheaded a proposal for a new Alliance between funders, researchers, operational agencies and users, to deliver a 10-year environmental science research mission for sustainability. This new partnership for user-driven research was described recently in *Science Magazine* (Reid *et al.*, 2010). The Alliance partnership will launch its research mission at the Planet Under Pressure Conference, London, March 2012. The ten-year Initiative will be designed to address what has come to be called the “Belmont Challenge”: *To deliver knowledge needed for action to mitigate and adapt to detrimental environmental change and extreme hazardous events.*

It is understood that addressing this challenge will require:

- Information on the state of the environment, through advanced observing systems;
- Assessments of risks, impacts and vulnerabilities, through regional and decadal analysis and prediction;
- Enhanced environmental information service providers to users;
- Inter- and transdisciplinary research which takes account of coupled natural, social and economic systems;
- Effective integration and coordination mechanisms, to address inter-dependencies and marshal the necessary resources.

With initial priority foci for the Belmont Forum group of funding agencies being:

- Coastal Vulnerability;
- Freshwater Security;
- Ecosystem Services;
- Carbon Budgets;

- Most vulnerable societies.

Meeting the Belmont Challenge will require much more effective coordination and integration across these elements than has been achieved to date. An integrating conceptual framework with a focus on aligning resources towards an holistic environmental change decision-support system is essential to drive effective coordination and integration of the diverse disciplinary, institutional and financial resources to meet the current global environmental challenges.

The proposed framework for the ten-year initiative is comprised of ideas for:

- Systematic targeting and integration of observations and research to overcome critical limits to predictions;
- Overarching strategic governance to establish key priorities among competing demands and promote cooperation;
- A greater voice for users in informing the research priorities;
- A step-change increase in collaboration across scientific disciplines, especially those between the natural and the social sciences and geographical areas;
- A profound increase in collaboration across geographical regions with a special emphasis on enhancing scientific capacity in developing countries; and
- Improved mechanisms for major transnational funding that overcome current constraints to cross-border support while respecting national requirements and statutes.

The Belmont Forum and this new “Alliance” of Funding Agencies, Researchers (through the participation of ICSU and ISSC), Operational Agencies and Users is pathbreaking in that it offers the possibility for creating a research agenda that is feasible, intellectually rich, fundable and of tailored service to society. Such connective elements have previously occurred on a much more ad hoc basis without explicit a-priori planning. Although Research University leadership has not yet played a role in the development of this international sustainability research initiative, it is anticipated that key opportunities for these institutions will flow from the improved international coordination and alignment of resources to support an aggressive research agenda.

In addition to the Belmont Forum, the International Group of Funding Agencies for Global Change Research (IGFA, 2011) is re-evaluating its role in coordination with the Belmont Forum (which serves as the Council of Principals for IGFA). IGFA will focus on energizing regional research networks, such as the Inter Americas Institute (IAI, 2011), the Asian Pacific

Network (APN, 2011) and AfricaNESS (IGBP, 2011). It will also work to establish strong linkages between scientific funding agencies and development aid agencies worldwide.

CONCLUSIONS

This paper has attempted to illustrate the societal urgency of developing an effective, end-to-end interdisciplinary research agenda for global environmental sustainability. Many new efforts and programs are underway on the agency-specific, national and international levels that will augment present efforts in systematic ways. It is critically important that the Research Universities play their ordained role fully: aggressively educating and empowering the needed human capital to address these historic challenges, while also identifying and driving a vigorous research agenda that address the super-wicked problems of our century in a timely and effective manner.

However, it must be said finally that neither the Research University Community, its leadership, nor the other players in global environmental sustainability stakes (funders, operational organizations, non-profits, stakeholders of various kinds, etc.) should work in isolation. The challenge of sustainability will clearly need everyone, or as President Obama said one day in Ohio in July 2008:

“The fact is, the challenges we face today — from saving our planet to ending poverty — are simply too big for government to solve alone. We need all hands on deck.”

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