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GLOBAL DYNAMICS, MULTIPLE SHOCKS AND RESILIENCE
Planetary stewardship and catastrophic shifts in the Earth system

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The Beijer Institute of Ecological Economics
The Royal Swedish Academy of Sciences
Box 50005 SE-104 05 Stockholm Sweden
Phone: +46 8 673 95 00 Fax: +46 8 15 24 64
E-mail: beijer@beijer.kva.se

GLOBAL DYNAMICS, MULTIPLE SHOCKS, AND RESILIENCE
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A Beijer Institute/Stockholm Resilience Centre research program

Anne-Sophie Crépin, Brian Walker, Stephen Polasky, Will Steffen, Victor Galaz, Carl Folke, and Johan Rockström

This research program aims at exploring the overall research question:

What are the critical unrecognized, ignored or missing social-ecological links and feedbacks at the global scale, and what kinds of governance structures can create long term conditions/ positive trajectories for human development?

Human activities have global level imprints. Local and regional drivers with repercussions at a global level generate major, intertwined global-scale challenges like climate disorder, ocean acidification, declining fisheries, emerging diseases, antibiotic resistance or crises in energy, food, and water. The current development of human society fails to adequately address systemic environmental change and might transgress planetary boundaries in a way that fundamentally affects human well-being. These activities where environmental and social changes interact, creating unexpected links and feedbacks, are very likely to result in nonlinear, and perhaps, irreversible shifts in the behavior of the planetary system.

Such alterations cause at minimum concern about future human well-being, and in the worst cases challenge the survival of our species. In addition, institutions and human decision-making are embedded in social-ecological interactions across scales, which sometimes generate destructive feedbacks and traps and other times contribute to transformations towards more adaptive modes of governance of social-ecological systems.

In addition, the world lacks institutions capable of addressing global-scale social-ecological system governance, which reinforces this unlucky development. This is particularly true in regard to interlinked challenges that cross sectors and scales where existing fragmented governance efforts each deal with only part of the challenges. It is these unrecognized, and sometimes deliberately ignored, links and feedbacks that will most likely give rise to major, unwanted shifts in social-ecological systems, at all scales, but most worryingly at the global scale.

We face a twin problem: i) global scale shocks are looming in many 'sectors' (food, health, economics, water, biodiversity) and ii) we are approaching the limits to the safe operating space in terms of a number of planetary boundaries. Moreover, current global development and governance efforts fail to fully recognize and confront these challenges, and often continue to perform in silos, leading to partial understanding and solutions; the interactions between these silos (links and feedbacks) might lead to surprising dynamics including threshold effects and regime shifts.

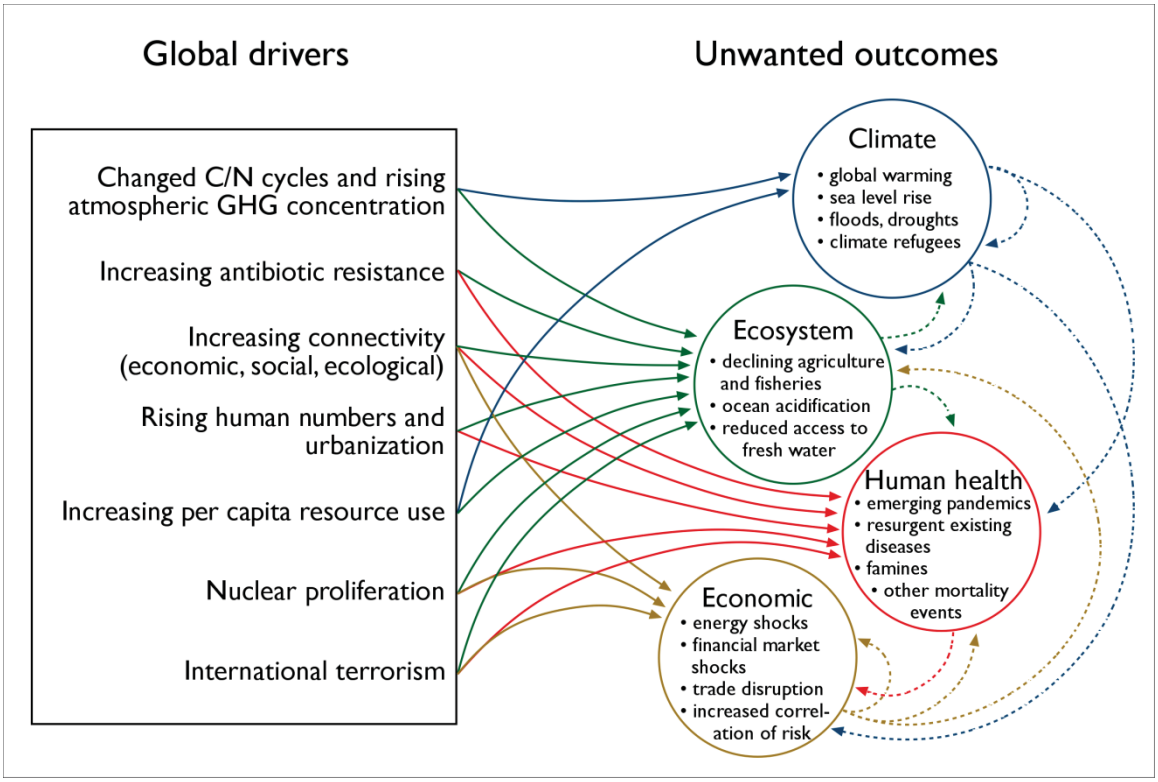

Figure 1: Inconvenient links and feedbacks

Figure 1, developed from Walker et al. (2009), illustrates how global drivers may cause shocks and impacts on climate, human health, ecosystems or the economy. The total effect of each of these drivers on the global social-ecological system is difficult to encompass because of all the invisible connections that sometime create feedbacks with accelerating effects implying that changes in one part of the system may spread in an uncontrolled and unnoticed way to other parts of the system. Many of these connections will likely turn out to be of no great concern, but some "inconvenient connections" could result in major surprises with large impacts on human well-being. How could these be identified and characterized?

A Research Program

The Beijer Institute of Ecological Economics jointly with the Stockholm Resilience Centre has started a research program to address these issues under the leadership of Anne-Sophie Crépin, Brian Walker, Stephen Polasky, with Will Steffen focusing on the planetary boundaries issues and Victor Galaz on their governance.

The aim of the program is to gain a better understanding of the global social-ecological system, the likelihood and consequences of sequential or coincident multiple shocks, and how society responds or fails to respond to these crises and shocks. The ambition is to start developing a 'framework' for conceptualizing how the interlinked global system responds to crises and shocks, and to develop ways for analyzing options for intervention to improve the odds of beneficial system outcomes. Accordingly, the overarching question is:

What are the critical unrecognized, ignored or missing social-ecological links and feedbacks at the global scale, and what kinds of governance structures can be developed to create long term conditions/positive trajectories for human development?

Hence, the Global Dynamics, Multiple Shocks, and Resilience research programme attempts to improve the understanding of global system dynamics by linking islands of insights (compartmentalized knowledge and models) in an ocean of ignorance about intertwined social-ecological systems.

Three activities

The *core research activity* is coordinated from and based in Stockholm, and consists of several interlinked projects applying different methodological approaches to exploring the research program challenges. The main part of the projects host active collaboration with researchers from various disciplines from all over the world.

The ambition with a *collaborative research network* is to communicate and interact with other groups doing research on related global issues to learn from their experiences and make sure to develop complementarities and help identify unrecognized or ignored social-ecological links and feedbacks.

Insights of the program and the policy implications will be *communicated* in a comprehensive fashion and *discussed and further developed in collaboration* with all kinds of actors on the global arena.

The research program emerged from a scoping workshop held at the Royal Academy of Sciences in September 2009. A second and a third workshop in April and September 2010 engaged a number of scientists in diverse fields and their task was to develop overarching research questions and core research activities. Additional workshops of the programs' five research clusters have also been organized. The program grew out of two recent papers; Rockström et al. 2009 on planetary boundaries and a safe operating space for humanity and Walker et al. 2009 on looming global crises and missing institutions. Given the difficulty of the topic and the challenges that research across very different disciplines imply, it was decided that this would be a relatively long term program.

The outcome of the program, in addition to the many envisioned scientific publications and science-practice-policy insights, is expected to be a short and comprehensive synthesis of the 5-10 most important global feedbacks that we need to get our attention on.

Research focus

The research effort is divided into six core research clusters.

1 Progressing the Science of the Planetary Boundaries Framework

This research effort draws upon the concept of planetary boundaries. The planetary boundaries approach aims at defining a safe global environmental operating space for humanity with respect to a small number of critical Earth System processes. A boundary was suggested for each of seven such processes (and two additional processes were identified), designed to avoid the triggering of abrupt or irreversible changes in the Earth System or the undermining of resilience in the global environment. Each of the nine boundaries was identified and analysed individually and separately. Interactions among the boundaries were recognised as being important, but there has not yet been any serious or detailed analysis of the nature of such boundary-boundary interactions and their importance. It is thus natural to follow up work on the science of the planetary boundaries – to create a more solid scientific base on which to build policy and management actions. These efforts go in three directions:

1.1 Further development of individual boundaries **-** Define or refine the identified individual planetary boundaries. For two of the boundaries – aerosols and chemical pollutants – an initial quantification could not be attempted. For several of the others the initial quantification was only a first guess and the control variables too crude. Metrics for the control variables (or perhaps "control variable clusters") that represent sub-global scale processes will be developed.

1.2 Interactions between control variables and boundaries **-** Identify and quantify boundary interactions using a cocktail of methods like qualitative and quantitative matrix approaches as well as minimal modeling exercises.

1.3 Earth System model development – A tool to test thresholds/boundaries, There is need to develop an Earth System model as a tool to test thresholds/boundaries, influences of slow variables, spatial distribution of control variables and heterogeneity of Earth System processes at continent/ocean basin scale, etc.

2 Planetary Boundaries and Interacting Global Crises - Exploring the Governance Implications

A second cluster explores and analyses multilevel governance challenges posed by the notion of planetary boundaries and multiple interacting global shocks. Human activities drive multiple, interacting effects that cascade through the Earth system and challenge planetary boundaries with possible non-linear and threshold effects. Does the insight that global actors need to govern not only one, but in fact multiple and interacting boundaries at the planetary scale have any implications for global governance? Where are the strengths and weaknesses of global environmental governance in trying to deal with not only incremental change, but also multilevel interactions and surprises that emerge as the result

of biogeophysical interactions? Can we identify innovative international governance approaches with the potential to build bottom-up capacity for innovation, learning and transformation?

Governance challenges include; the interplay between Earth system science and global policies; the implications of differences in risk perceptions in defining these boundaries; the capacity of international institutions to deal with individual planetary boundaries, as well as interactions between them; the challenges posed by institutional interactions and interlinkages; the role of international organizations in dealing with interactions amongst planetary boundaries; and the role of global governance in framing social-ecological innovations (Galaz et al., 2010).

Global governance implications that arise from inconvenient/ignored links and feedbacks between the governance systems, the other social parts and the ecological part of the global social-ecological system, is further raised in each of the different research clusters mentioned below.

3 Building an Architecture of Global Crises and Feedbacks

A first approach aims to use case studies and empirical observations as a basis for exploring important links and feedbacks. The hope is

3.1 to identify patterns, trends and typologies that would help build a theory of global crises and feedbacks.

3.2 A complementary approach is to develop a theory of critical social-ecological links and feedbacks by building simple, exploratory models of these syndromes and developing a framework to visualize global crises and apply it to a set of case studies. Such a framework would hopefully incorporate important global dynamics, links and feedbacks and explain and help visualize how a global crisis builds up and occurs.

4 Are the Missing Feedbacks Strong Enough to Shift Global Scenarios in Important Ways?

This cluster takes an explorative onset using scenario thinking to map possible futures involving missing links and feedbacks in the social-ecological global system that may impact on global welfare in a substantial way. The focus is on the complex dynamics in the natural system and the links between social and ecological aspects of global changes. This approach focuses particularly on the provisioning of life support services in a resilience context, like food security for a growing human population.

4.1 Thinking the unthinkable: How should dynamics of natural capital be incorporated into global environmental scenarios and what missing feedbacks have the potential to shift global trajectories?

4.2 Can we feed the world within the planetary boundaries? What are the options for feeding the 9 billion while remaining within the guardrails of the planetary boundaries? Agricultural demand is linked to the full set of pressures placed on sectors of natural capital including climate and carbon, water flows and quality, nutrients, biodiversity and others. The interactions are strong and in some cases nonlinear, so there is considerable opportunity for surprise, threshold-crossings and cascading changes as the future unfolds. How should they be incorporated in forward-looking analyses of global change?

4.3 Important human drivers and social imprints on the land: mental models, cultures, institutions, technologies and their role in generating and responding to shifts, shocks, pathways, trajectories and threshold of global concern.

5 Exploring Missing Feedbacks

This cluster tests and aims at extending existing modeling exercises to incorporate potentially important missing links and feedbacks and explore their significance. Some examples of research questions:

5.1 Can human activities change the self-organizing/self–regulating properties of the biosphere? The ambition is to characterize the value of regulating, provisioning and cultural services of ecosystems in the context of simple “essential” earth system models in relation to economic activities.

5.2 Incorporate tipping elements of the earth system/planetary boundaries into simple climate economy models. This activity aims at building theoretical models of the links and feedbacks between food production (agriculture and aquaculture) and planetary boundaries (climate and Nitrogen) linked to population growth. That could be tested on specific regions like the Baltic Sea where good data are available.

5.3 What is the role of specific regions for global dynamics? Certain regions may play a more important role than others in earth dynamics. One such region is the Arctic and the idea is to look at regional interactions where human activities connect different systems such as fisheries, oil, water and climate within a region and how these connections feedback to the global level. A resilience assessment of the Arctic region would uncover possible thresholds that could cause cascading global changes.

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Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

The Beijer Institute of Ecological Economics