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Transforming innovation for sustainability

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Insight

Transforming Innovation for Sustainability

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ABSTRACT. The urgency of charting pathways to sustainability that keep human societies within a "safe operating space" has now been clarified. Crises in climate, food, biodiversity, and energy are already playing out across local and global scales and are set to increase as we approach critical thresholds. Drawing together recent work from the Stockholm Resilience Centre, the Tellus Institute, and the STEPS Centre, this commentary article argues that ambitious Sustainable Development Goals are now required along with major transformation, not only in policies and technologies, but in modes of innovation themselves, to meet them. As examples of dryland agriculture in East Africa and rural energy in Latin America illustrate, such "transformative innovation" needs to give far greater recognition and power to grassroots innovation actors and processes, involving them within an inclusive, multi-scale innovation politics. The three dimensions of direction, diversity, and distribution along with new forms of "sustainability brokering" can help guide the kinds of analysis and decision making now needed to safeguard our planet for current and future generations.

Key Words: *development goals, grassroots, planetary boundaries, sustainable innovation, sustainability*

INTRODUCTION

As the world gears up for the Rio+20 conference in June 2012, many are pinning their hopes on "Sustainable Development Goals" (SDGs) as a concrete outcome. First mooted by the Colombian government, the idea is now supported by many governments north and south and figures prominently in the conference's "zero draft" document and the recommendations of the UN High Level Panel on Global Sustainability (UN GSP). Many are now arguing that a set of SDGs should fill gaps in the Millennium Development Goals (MDGs) up to their 2015 target date and beyond, becoming a successor to the MDGs in thinking and action on environment and development. Yet, as highlighted in a recent briefing from New York's Centre on International Cooperation, there is little clarity on what SDGs should involve, who should set them, and how they can be realized in practice (Evans and Steven 2012).

This commentary article draws on recent research by the STEPS Centre, the Stockholm Resilience Centre, and the Tellus Institute to argue that SDGs that keep human societies within a "safe operating space" are indeed now urgently needed. However, delivering on these requires a radically new approach to innovation, one that gives far greater recognition and power to grassroots actors and processes, involving them within an inclusive, multi-scale innovation politics.

FROM PLANETARY BOUNDARIES TO SUSTAINABLE DEVELOPMENT GOALS

The urgency of charting pathways to sustainability, already emphasized by scientific analysis, has now been clarified with unprecedented precision. A series of nine planetary boundaries has been identified, referring to the biophysical processes in

the Earth's system on which human life depends (Rockström et al. 2009). Together, these define a safe operating space for humanity. Human actions are rapidly approaching or have already transgressed key global thresholds, increasing the likelihood of unprecedented ecological turbulence. Potentially catastrophic thresholds are in prospect, which will compromise development both globally and locally—undoing past progress. The future is uncertain, with surprises and shocks in store. It is increasingly clear that development pathways must reconnect with the biosphere's capacity to sustain them (Folke et al. 2011).

For the UN GSP, the Tellus Institute has now applied its Polestar modeling approach to construct a series of high-level scenarios linked to the planetary boundaries data (Gerst et al. 2011). These indicate that, even with far-reaching policy reforms implemented across nations and within key sectors, from energy supply to food production, the world is still likely to transgress critical planetary boundaries, in particular loss of biodiversity. The conclusion, in a world where affluence among billions of formerly poor communities is rapidly rising and where equity must be a core pillar of world prosperity in an environmentally constrained planet, is that business as usual is not an option; even a strong, sustained program of policy adjustments may be insufficient to counter harmful trends. Our assessment is that the recommendations in the UN GSP report, although certainly being the most ambitious set of policy reforms in support of sustainability on the global policy scene today, still fall short of delivering what the scenarios suggest is required. Furthermore, based on past experience, the outcome of the UN Rio+20 summit could well be far less ambitious than the UN GSP recommendations. In other words, we face a deeply unsettling risk that the UN

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Table 1. Selected provisional sustainable development goals (from among those defined by planetary boundaries and Polestar transition scenarios, Raskin et al. 2010)

Indicator	Measure	Base year (2005)	2025	2050	2100
Incidence of chronic hunger [†]	% of 2005 value		50	25	6
Population in water stress	Billion people	1.73	<2	<2	<2
	Volume of freshwater use from rivers, lakes, aquifers in km ³ /yr	2,600 km ³ /yr	<4,000 km ³ /yr of consumptive use of blue water resources (runoff for irrigation, industry, and domestic use)		
Climate change	CO ₂ concentration in ppm	Current level 391 ppm	Stabilize <350 ppm by 2100 and/or A total climate forcing at equilibrium of <1 W/m ²		
Land-use change	Fraction of global land cover converted to cultivated systems (%)	~12%	<15% of land surface on Earth converted to cropland		
Rate of biodiversity loss	Extinction rate as extinctions per million species per year (E/MSY)	100–1000	<10 species lost per million species each year, which still is roughly 10 times the natural background rate of loss of species on Earth		

[†]Proxy also for reduction of absolute poverty

Rio+20 Summit will not deliver an adequate action plan for the required transition to a sustainable future. Rather, radical transformations are required in order to steer away from potential earth system thresholds and tipping points, and SDGs need, at a minimum, to keep global societies within this safe operating space. An alternative scenario is linked to a set of provisional SDGs, including those summarized in Table 1.

THE NEED FOR NEW APPROACHES— CONNECTING GLOBAL AND GRASSROOTS EFFORTS

So, compared with previous major moments of global reflection about human and planetary futures—Stockholm in 1972, Rio in 1992—we now know much more about what the dynamic planetary boundaries are and the scale of the challenges to be met. Yet our degrees of freedom are closing in. Crises in climate, food, biodiversity, and energy are already playing out across local and global scales and are set to increase as we approach critical thresholds. What is now needed is nothing short of major transformation—not only in our policies and technologies, but in our modes of innovation themselves—to enable us to navigate turbulence and meet SDGs that respect the safe operating space. Goals such as those in Table 1 are inevitably highly ambitious, so how can they be met? Innovation—broadly defined as new ways of doing

things, in science and technology but also associated institutions and social practices—has essential roles to play. But what kinds of innovation are needed?

Recently, a variety of high-level panels have convened to address sustainability challenges, among them the UK Government Foresight exercise on Global Food and Farming Futures; The Economics of Ecosystems and Biodiversity (TEEB) initiative, and the Inter-governmental Panel on Climate Change (IPCC). All agree on the enormity and urgency of the challenges. But most settle on solutions based on combinations of international cooperation and top-down global and national policies and management, often relying on rather nebulous notions of “political will.” So, for example, the synthesis report of the UK Foresight project states: “... [T] here is still much more that national and international organizations can do to tackle hunger... This will not occur without a series of targeted interventions which will themselves require the development of a more robust and consistent consensus on tackling hunger and strong levels of political will and leadership to carry it through to actions” (UK Foresight 2011: 3), but details of how this will be achieved remain sketchy. Michael Jacobs recently argued in *Nature* for a Leaders’ Summit in 2015 as a central way forward on climate change (Jacobs 2012). Such “top-down” policy proposals are often coupled to particular forms of technological fix, whereby

advanced science and engineering are harnessed toward solutions that can be rolled out at scale—whether in biotechnology (to produce high-yielding crops to feed 9 billion people) or geo-engineering and low carbon energy technologies (to mitigate climate change). Much of the pre-Rio+20 discussion of SDGs implies this kind of approach.

But are such high-tech, top-down approaches to policy and innovation enough? We need to recall the past 20 years of experience in attempting to realize the ambitions of sustainable development following the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The 1990s saw a proliferation of international conventions and agreements linked to global science, focused on challenges such as biological diversity, climate change, and desertification. At the same time, “Agenda 21,” launched at Rio, envisaged a community-led response to sustainable development challenges, based on local initiatives. But these two strands of sustainable development rarely connected. The top-down managerialism driven by high-level panels, Conferences of Parties, and meetings of senior officials related only sporadically, if at all, to the array of innovative grassroots initiatives springing up in farms and forests, villages and municipalities, factories and homes, across the globe. Local initiatives often flourished and drew on people’s own, vibrant forms of knowledge, technology, and experimentation, but for the most part they remained at the margins, focused on local sustainable development needs rather than meshing with bigger-picture global challenges (Berkhout et al. 2003). We believe that there is now a new urgency to (re)connect these two strands of sustainable development in order to find ways to navigate a safe operating space for humanity from the bottom up. Global and multi-scale planetary boundaries and SDGs now, more than ever, need to be met by embracing local action in multi-scale approaches.

Examples—Dryland Agriculture, Rural Energy

What might this mean in practice? Let us consider this in relation to selected examples of the key planetary boundaries and SDGs mentioned above. Drawing on our work at the STEPS Centre and the Stockholm Resilience Centre, we offer two examples, both involving particularly pressing challenges.

One example concerns the challenges of dryland agriculture in East Africa. Here, biophysical processes relevant to multiple planetary boundaries—land use, biodiversity, freshwater and soil nutrient availability, and climate—are interacting to create growing local pressures in places where some of the world’s most vulnerable people live. If SDGs around reducing global hunger are to be met, addressing such place-specific agricultural sustainability challenges must be taken seriously. In the maize-dominated farming systems of dryland Kenya (Brooks et al. 2009), for instance, a variety of different technological and policy options are possible. Some focus on

addressing current and impending food crises from the top down through sophisticated plant-breeding and high-level biotechnology to engineer drought-resistant hybrid and GM maize seed and large-scale irrigation, often linked to the development of large-scale commercial farms—from which smallholders will be excluded, or transformed into laborers. Other options focus on building sustainability from below, for instance through alliances between crop breeders and farmers to combine scientific and farmers’ indigenous knowledge and practices to select and develop other more appropriate crop and seed varieties, or to apply soil and water conservation technologies to improve fertility and productivity. Farmers’ own grassroots innovations play a central role, for instance in attuning technologies to local social and ecological conditions. Such farmer-led strategies emphasize sustaining smallholder livelihoods and recognize the importance of diversity—of crops, seed varieties, agro-biodiversity, and strategies—in building resilience in complex, dynamic local environments. Dialogs and fora that bring farmers, scientists, businesses, and policymakers together, such as those conducted in Kenya (see Brooks et al. 2009), have helped to clarify the roles of these different innovation pathways in addressing diverse national and local sustainability priorities and both the need for and challenges of building the multi-scale approaches that will be essential to address dryland challenges. A second example concerns the challenges of building sustainable energy systems in Latin America, where energy demands are expected to increase by 75% by 2030 and where existing trajectories will intensify pressure on climate and impair the capacity of ecosystems to generate essential services (Inter-American Development Bank (IDB) 2012). Some Latin American governments have made political commitments to increase renewable energy sources—hydropower, wind, biomass, and solar—and the IDB recently announced a US\$30 million loan to the Emerging Energy Latin America Fund, focused on promoting private-sector involvement in clean technology. These regional deals repeat the international pattern, with elites negotiating finance and hardware deals and successors to the oft-cited Clean Development Mechanism. Although the latter has definitely underpinned successful energy projects, their distribution has been highly uneven, often reflecting priorities of efficiency in generating carbon credits, rather than local development benefits for poorer communities (Byrne et al. 2011). In contrast, locally engaged initiatives, such as [CE DECAP](#), the Appropriate Technology Demonstration and Training Centre in rural Perú, works with local communities to identify their priority uses for electricity and then to develop energy schemes that those communities control, run, and benefit from. CEDECAP develops, trains, and pilots alternative forms of distributed renewable energy for rural areas, focusing on low-cost technologies with low environmental impact, and fostering local research and capacity. The wider communications efforts of NGOs such as CEDECAP have helped to foster greater attention to local

energy priorities, needs, and innovative capacities, highlighting the need to address these more fully along with national and global priorities, in multi-scale energy policy debates.

Even presented briefly, these examples highlight the contrast between top-down and more grassroots-led approaches to policy and innovation in each setting, and the value of multi-scale approaches. Furthermore, they illustrate what we suggest are a set of underlying principles that need to guide the elaboration and meeting of SDGs. Three interlinked dimensions need to be assessed together (STEPS Centre 2010, Stirling 2010).

TRANSFORMING INNOVATION—DIRECTION, DIVERSITY, DISTRIBUTION

The first dimension concerns the specific *Direction* of change. This means being clear on the particular goals and principles driving policy and innovation, not leaving them open, undiscussed, or driven by general imperatives of growth or progress, but actively steering them toward the kinds of transformation needed to stay within a safe operating space and meet SDGs. Of course, different groups will frame the details in different ways—the particular priorities of plant breeders and female smallholders in dryland Kenya will differ, for instance. But it is only by directly engaging with such differences that we may hope to steer the most robust overall directions. And attention to direction also means more deliberately steering away from unsustainable trajectories—fossil-fuel-driven energy pathways, for instance, or land-use schemes geared only to maximum commercial profit—by more rigorously and accountably channeling the incentives and interests that drive innovation. It involves innovations that can improve the capacity to learn from, respond to, and manage environmental feedback from dynamic social–ecological systems. In these, grassroots innovations that draw from local knowledge and experience, and social and organizational innovations—for instance, the development of community micro-hydroelectricity projects—are at least as crucial as advanced science and technology.

Second, *Diversity* is also crucial. Nurturing more diverse approaches and forms of innovation (social as well as technological) allows us to respond to uncertainty and surprise arising from the complex, interacting biophysical and socioeconomic shocks and stresses highlighted in both these dryland agriculture and energy cases, avoiding the risks associated with “putting all our eggs in one basket.” Likewise, fostering diversity—of biophysical resources and biodiversity, ecologies, strategies, and institutions (as well as innovations)—provides a richer resource to foster more robust and resilient innovation pathways into the future. In all these fields, despite their differences, diversity is about sustaining an evenly balanced variety of disparate options (Stirling 2007). Here, diversity also resists the powerful process of lock-in and so

helps catalyze more transformative forms of innovation. Moreover, as we see with the Clean Development Mechanism and energy projects, singular policy and technological solutions that appear optimal from a global perspective rarely prove viable or desirable in *all* localities; instead, different cultural and ecological settings typically require contrasting approaches. Thus, high-tech innovations to enhance maize productivity may well suit certain of Kenya’s better-watered, so-called “high potential” agroecological zones, but fail amid the social and ecological realities of its poorer, drier regions. And although regions like Guajira in Colombia have very promising wind resources, issues of grid-based electrification can prove prohibitively complicated and costly for, say, Andean communities that are isolated or dispersed across wide distances far from populated cities in mountainous terrain.

A third dimension is *Distribution*. This means taking seriously how the safe operating space is shared between different people, and asking about who gains and who loses from particular policies and innovations aiming to navigate within it. There are often trade-offs at stake, between contrasting environmental and poverty reduction goals, for instance, or national and local interests. So large-scale irrigated land developments in East Africa may contribute to sustainability from the perspective of national food security, increased GDP, and the intensification of productive land use, but also be locally experienced as “land and water grabs” that displace poor rural people and destroy the livelihoods of marginal groups such as pastoralists and women farmers. Large-scale dams for hydroelectric projects in Brazil and elsewhere are similarly controversial. Setting SDGs and steering policy and innovation toward any goals requires keeping distributional issues at center stage—not just in achieving “trickle down,” but in shaping fundamental directions of change and engaging instead of excluding people in ecosystem stewardship. Beyond global questions over sharing of the safe operating space—for instance, with respect to per capita carbon dioxide emissions and “climate footprints” across different countries and regions—there arise more local questions. Here again, grassroots innovations offer particular value, helping to favor and prioritize more fairly the interests of the most marginal groups.

CONCLUSIONS

Looking across these dimensions—the “three Ds” of Direction, Diversity, and Distribution—it becomes clear that defining and navigating the particularities of sustainability ultimately reflect political values and choices, as much as scientific and technical ones. Some have posed the idea of “social boundaries” as a complement to planetary boundaries, drawing attention to the importance of poverty reduction and human development goals akin to the MDGs (Raworth 2012). We argue, however (and our cases illustrate), that broad calls for integration need to be underpinned by finer-grained attention to what sort of sustainability and development are being pursued, for whom and how, and what this implies for

improved stewardship of our planet. This brings further and ultimately more fundamental sociopolitical and justice questions to bear, concerning how such choices are made in relation to what values, by real decision makers in particular social and political contexts, and their implications for ecosystem stewardship and sustainability. A “3-D” analysis, we suggest, can help to reveal the nature and stakes of such choices and guide decision makers as they grapple with challenges in their own particular settings. So, for example, a Kenyan agriculture minister or Peruvian energy minister might consider the 3-D implications of choices in an array of relevant arenas, from allocating scarce resources to different kinds of research, to deciding regulatory policy, or investing in infrastructures. How government relates to business, civil society, and farmer and consumer groups—and the space and support afforded to growth of bottom-up networks—is crucial in shaping how far grassroots innovations can flourish as a means to deliver SDGs.

But a fundamental challenge remains in more effectively connecting local, grassroots innovation capacity with the global parameters set by planetary boundaries. To facilitate this broader, deeper debate in Kenya or Perú, dialogs and communications efforts have made some headway. But a key missing link lies in the role of what we dub “sustainability brokers.” Drawing on ideas from the management sciences (Roe and Schulman 2008), navigating the complex, uncertain world and dynamic thresholds that challenge sustainability requires us to track between big-picture planetary and social boundaries and the ways they interact in particular local settings (Westley et al. 2011). Global and regional scenarios, forecasting, and back-casting need to be triangulated with grounded local processes and implications. An understanding of shifting global planetary boundaries, safe operating spaces and the global SDGs required to stay within them needs to be combined with appreciations of particular local sustainable development meanings and goals, and of how to draw from innovative grassroots capacity. Such sustainability brokering involves skills and competencies that are currently seriously neglected. Building these requires new kinds of training, capacity building, and recognition. Guided by wider political debate about values, interests, and priorities—informed by analysis of the 3 Ds for any particular issue or setting—such sustainability brokers could form the vanguard of transformation now needed to safeguard our planet for current and future generations.

Responses to this article can be read online at:
<http://www.ecologyandsociety.org/vol17/iss2/art11/responses/>

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LITERATURE CITED

- Berkhout, F., M. Leach, and I. Scoones. 2003. *Negotiating environmental change*. Edward Elgar, London, UK.
- Brooks, S., J. Thompson, H. Odame, B. Kibaara, S. Nderitu, F. Karin, and E. Millstone. 2009. *Environmental change and maize innovation in Kenya: exploring pathways in and out of maize*. STEPS Working Paper 36. STEPS Centre, Brighton, UK.
- Byrne, R., A. Smith, J. Watson, and D. Ockwell. 2011. *Energy pathways in low-carbon development: from technology transfer to socio-technical transformation*. STEPS Working Paper 46, STEPS Centre, Brighton, UK.
- Evans, A., and D. Steven. 2012. *Sustainable development goals—a useful outcome from Rio+20?* Briefing, New York Centre on International Co-operation, New York, New York, USA.
- Folke, C., Å. Jansson, J. Rockström, P. Olsson, S. R. Carpenter, F. S. Chapin, A.-S. Crepín, G. Daily, K. Danell, J. Ebbesson, T. Elmqvist, V. Galaz, F. Moberg, M. Nilsson, H. Österblom, E. Ostrom, Å. Persson, G. Peterson, S. Polasky, W. Steffen, B. Walker, and F. Westley. 2011. Reconnecting to the biosphere. *Ambio* 40:719–738. <http://dx.doi.org/10.1007/s13280-011-0184-y>
- Gerst, M. D., and P. D. Raskin. 2011. *Turning toward sustainability: a business-as-usual and an alternative scenario prepared for the UN high-level panel on global sustainability*. Tellus Institute, Boston, Massachusetts, USA.
- Inter-American Development Bank (IDB). 2012. *IDB approves \$30 million investment in green fund for Latin America and the Caribbean*. Inter-American Development Bank news release, 13 January 2012. [online] URL: <http://www.iadb.org/en/news/news-releases/2012-01-13/latin-america-renewable-energy-investment-fund,9807.html>
- Jacobs, M. 2012. Climate policy: deadline 2015. *Nature* 481 (7380):137–138. <http://dx.doi.org/10.1038/481137a>

Raskin, P. D., C. Electris, and R. A. Rosen. 2010. The century ahead: searching for sustainability. *Sustainability* 2:2626–2651. <http://dx.doi.org/10.3390/su2082626>

Raworth, K. 2012. *A safe and just space for humanity: can we live within the doughnut?* Oxfam Discussion Paper. Oxfam, Oxford, UK.

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. A. Foley. 2009. A safe operating space for humanity. *Nature* 461:472–475. <http://dx.doi.org/10.1038/461472a>

Roe, E., and P. Schulman. 2008. *High reliability management: operating on the edge*. Stanford University Press, Stanford, Connecticut, USA.

STEPS Centre. 2010. Innovation, sustainability, development: a new manifesto. STEPS Centre, Brighton, UK.

Stirling, A. 2007. A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society Interface* 4(15):707–719. <http://dx.doi.org/10.1098/rsif.2007.0213>

Stirling, A. 2010. *Direction, distribution and diversity! pluralising progress in innovation, sustainability and development*. STEPS Working Paper 32. STEPS Centre, Brighton, UK.

UK Foresight. 2011. *Foresight project on global food and farming futures*. Synthesis Report C11: Ending Hunger. UK Foresight, Government Office for Science, Department for Business, Innovation and Skills, London, UK.

Westley, F., P. Olsson, C. Folke, T. Homer-Dixon, H. Vredenburg, D. Loorbach, J. Thompson, M. Nilsson, E. Lambin, J. Sendzimir, B. Banarjee, V. Galaz, and S. van der Leeuw. 2011. Tipping towards sustainability: emerging pathways of transformation. *Ambio* 40:762–780. <http://dx.doi.org/10.1007/s13280-011-0186-9>