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Can Humanity's 'Great Acceleration' Be Managed and, If So, How?

By Andrew C. Revkin January 15, 2015 5:00 pm

Updated below | Through three-plus decades of reporting, I've been seeking ways to better mesh humanity's infinite aspirations with life on a finite planet. (Do this Google search — "infinite aspirations" "finite planet" Revkin – to get the idea. Also read the 2002 special issue of Science Times titled "Managing Planet Earth.")

So I was naturally drawn to a research effort that surfaced in 2009 defining a "safe operating space for humanity" by estimating a set of nine "planetary boundaries" for vital-sign-style parameters like levels of greenhouse gases, flows of nitrogen and phosphorus and loss of biodiversity.

The same was true for a related "Great Acceleration" dashboard showing humanity's growth spurt (the graphs below), created by the International Geosphere-Biosphere Program.

Who would want to drive a car without gauges tracking engine heat, speed and fuel levels? I use that artwork in all my talks.

Now, both the dashboard of human impacts and planetary boundaries have been updated. For more detail on the dashboard, explore the website of the

geosphere-biosphere organization.

In a prepared statement, a co-author of the acceleration analysis, Lisa Deutsch, a senior lecturer at the Stockholm Resilience Center, saw little that was encouraging:

> Of all the socio-economic trends only construction of new large dams seems to show any sign of the bending of the curves – or a slowing of the Great Acceleration. Only one Earth System trend indicates a curve that may be the result of intentional human intervention – the success story of ozone depletion. The leveling off of marine fisheries capture since the 1980s is unfortunately not due to marine stewardship, but to overfishing.

And all that acceleration (mostly since 1950, as I wrote yesterday) has pushed us out of four safe zones, according to the 18 authors of the updated assessment of environmental boundaries, published online today by the journal Science here: "Planetary Boundaries: Guiding human development on a changing planet."

The paper is behind a paywall, but the Stockholm Resilience Center, which has led this work, has summarized the results, including the authors' conclusion that we're in the danger zone on four of the nine boundaries: climate change, loss of biosphere integrity, land-system change and alteration of biogeochemical cycles (for the nutrients phosphorus and nitrogen).

Their work has been a valuable prod to the community of scientists and policy analysts aiming to smooth the human journey, resulting in strings of additional studies. Some followup work has supported the concept, and even broadened it, as with a 2011 proposal by Kate Raworth of the aid group Oxfam to add social-justice boundaries, as well: "A Safe and Just Space for Humanity – Can We Live Within the Doughnut?"

But others have convincingly challenged many of the boundaries and also questioned their usefulness, given how both impacts of, and decisions about, human activities like fertilizing fields or tapping aquifers are inherently local — not planetary in scale. (You'll hear from some critics below.)

In 2012, the boundaries work helped produce a compelling alternative framework for navigating the Anthropocene — "Planetary Opportunities: A Social Contract for Global Change Science to Contribute to a Sustainable Future."

I hope the public (and policy makers) will realize this is not a right-wrong, win-lose science debate. A complex planet dominated by a complicated young species will never be managed neatly. All of us, including environmental scientists, will continue to learn and adjust.

I was encouraged, for instance, to see the new iteration of the boundaries analysis take a much more refined view of danger zones, including more of an emphasis on the deep level of uncertainty in many areas:

The authors, led by Will Steffen of Australian National University and Johan Rockström of the Stockholm Resilience Center, have tried to refine how they approach risks related to disrupting ecosystems – not simply pointing to lost biological diversity but instead devising a measure of general "biosphere integrity."

That measure, and the growing human influence on the climate through the buildup of long-lived greenhouse gases are the main source of concern, they wrote:

> Two core boundaries – climate change and biosphere integrity – have been identified, each of which has the potential on its own to drive the Earth System into a new state should they be substantially and persistently transgressed.

But the bottom line has a very retro feel, adding up to the kind of ominous, but generalized warnings that many environmental scientists and other scholars began giving with the "Limits to Growth" analysis in 1972. Here's a cornerstone passage from the paper, reprising a longstanding view that the environmental conditions of the Holocene – the equable span since the end of the last ice age – is ideal:

> The precautionary principle suggests that human societies would be unwise to drive the Earth System substantially away from a Holocene-like

condition. A continuing trajectory away from the Holocene could lead, with an uncomfortably high probability, to a very different state of the Earth System, one that is likely to be much less hospitable to the development of human societies.

I sent the Science paper to a batch of environmental researchers who have been constructive critics of the Boundaries work. Four of them wrote a group response, posted below, which includes this total rejection of the idea that the Holocene is somehow special:

> [M]ost species evolved before the Holocene and the contemporary ecosystems that sustain humanity are agroecosystems, urban ecosystems and other human-altered ecosystems….

Here's their full response:

The Limits of Planetary Boundaries

Erle Ellis, Barry Brook, Linus Blomqvist, Ruth DeFries

Steffen et al (2015) revise the "planetary boundaries framework" initially proposed in 2009 as the "safe limits" for human alteration of Earth processes (Rockstrom et al 2009). Limiting human harm to environments is a major challenge and we applaud all efforts to increase the public utility of global-change science. Yet the planetary boundaries (PB) framework – in its original form and as revised by Steffen et al – obscures rather than clarifies the environmental and sustainability challenges faced by humanity this century.

Steffen et al concede that "not all Earth system processes included in the PB have singular thresholds at the global/continental/ocean basin level." Such processes include biosphere integrity (see Brook et al 2013), biogeochemical flows, freshwater use, and land-system change. "Nevertheless," they continue, "it is important that boundaries be established for these processes." Why? Where a global threshold is unknown

or lacking, there is no scientifically robust way of specifying such a boundary – determining a limit along a continuum of environmental change becomes a matter of guesswork or speculation (see e.g. Bass 2009; Nordhaus et al 2012). For instance, the land-system boundary for temperate forest is set at 50% of forest cover remaining. There is no robust justification for why this boundary should not be 40%, or 70%, or some other level.

While the stated objective of the PB framework is to "guide human societies" away from a state of the Earth system that is "less hospitable to the development of human societies", it offers little scientific evidence to support the connection between the global state of specific Earth system processes and human well-being. Instead, the Holocene environment (the most recent 10,000 years) is assumed to be ideal. Yet most species evolved before the Holocene and the contemporary ecosystems that sustain humanity are agroecosystems, urban ecosystems and other human-altered ecosystems that in themselves represent some of the most important global and local environmental changes that characterize the Anthropocene. Contrary to the authors' claim that the Holocene is the "only state of the planet that we know for certain can support contemporary human societies," the human-altered ecosystems of the Anthropocene represent the only state of the planet that we know for certain can support contemporary civilization.

Human alteration of environments produces multiple effects, some advantageous to societies, such as enhanced food production, and some detrimental, like environmental pollution with toxic chemicals, excess nutrients and carbon emissions from fossil fuels, and the loss of wildlife and their habitats. The key to better environmental outcomes is not in ending human alteration of environments but in anticipating and mitigating their negative consequences. These decisions and trade-offs should be guided by robust evidence, with global-change science investigating the connections and tradeoffs between the state of the environment and human well-being in the context of the local setting, rather than by framing and reframing environmental challenges in terms of untestable assumptions about the virtues of past environments.

Even without specifying exact global boundaries, global metrics can be highly misleading for policy. For example, with nitrogen, where the majority of human emissions come from synthetic fertilizers, the real-world challenge is to apply just the right amount of nitrogen to optimize crop yields while minimizing nitrogen losses that harm aquatic ecosystems. Reducing fertilizer application in Africa might seem beneficial globally, yet the result in this region would be even poorer crop yields without any notable reduction in nitrogen pollution; Africa's fertilizer use is already suboptimal for crop yields. What can look like a good or a bad thing globally can prove exactly the opposite when viewed regionally and locally. What use is a global indicator for a local issue? As in real estate, location is everything.

Finally, and most importantly, the planetary boundaries are burdened not only with major uncertainties and weak scientific theory – they are also politically problematic. Real world environmental challenges like nitrogen pollution, freshwater consumption and land-use change are ultimately a matter of politics, in the sense that there are losers and winners, and solutions have to be negotiated among many stakeholders. The idea of a scientific expert group determining top-down global limits on these activities and processes ignores these inevitable trade-offs and seems to preclude democratic resolution of these questions. It has been argued that (Steffen et al 2011):

Ultimately, there will need to be an institution (or institutions) operating, with authority, above the level of individual countries to ensure that the planetary boundaries are respected. In effect, such an institution, acting on behalf of humanity as a whole, would be the ultimate arbiter of the myriad trade-offs that need to be managed as nations and groups of people jockey for economic and social advantage. It would, in essence, become the global referee on the planetary playing field.

Here the planetary boundaries framework reaches its logical conclusion with a political scenario that is as unlikely as it is unpalatable. There is no ultimate global authority to rule over humanity or the environment. Science has a tremendously important role to play in guiding environmental

management, not as a decider, but as a resource for deliberative, evidence-based decision making by the public, policy makers, and interest groups on the challenges, trade-offs and possible courses of action in negotiating the environmental challenges of societal development (DeFries et al 2012). Proposing that science itself can define the global environmental limits of human development is simultaneously unrealistic, hubristic, and a strategy doomed to fail.

I've posted the response online as a standalone document for easier downloading; there you can view the authors' references, as well.

Update, 9:40 p.m.| Will Steffen, the lead author of the updated Planetary Boundaries analysis, sent this reply to Ellis and co-authors tonight:

Response to Ellis et al. on planetary boundaries

Of course we welcome constructive debate on and criticism of the planetary boundaries (PB) update paper. However, the comments of Ellis et al. appear to be more of a knee-jerk reaction to the original 2009 paper than a careful analysis of the present paper. In fact, one wonders if they have even read the paper, including the Supplementary Online Material (SOM) where much methodological detail is provided.

One criticism seems to be based on a rather bizarre conflation of a state of the Earth System with (i) the time when individual biological species evolved, and (ii) the nature and distribution of human-altered terrestrial ecosystems. This makes no sense from an Earth System science perspective. The state of the Earth System (a single system at the planetary level) also involves the oceans, the atmosphere, the cryosphere and very important processes like the surface energy balance and the flows and transformation of elements. It is the state of this single complex system, which provides the planetary life support system for humanity, that the PB framework is concerned with, not with fragmentary bits of it in isolation.

In particular, the PB framework is based on the fact – and I emphasise the word “fact” – that the relatively stable Holocene state of the Earth System (the past approximately 11,700 years) is the only state of the System that has allowed the development of agriculture, urban settlements and complex human societies. Some argue that humanity can now survive, and even thrive, in a rapidly destabilizing planetary environment, but that is a belief system based on supreme technological optimism, and is not a reasoned scientifically informed judgment. Also, Ellis et al. seem to conflate human alteration of terrestrial environments with human alteration of the fundamental state of the Earth System as a whole. These are two vastly different things.

The criticisms show further misunderstanding of the nature of complex systems like the Earth System and how they operate. For example, Ellis et al. claim that a process is not important unless it has a threshold. Even a cursory understanding of the carbon cycle, for example, shows that this is nonsense. Neither the terrestrial nor the marine carbon sinks have known large-scale thesholds yet they are exceedingly important for the functioning of the climate system, which does indeed have known large-scale thresholds such as the melting of the Greenland ice sheet. Sure, it is more challenging to define boundaries for processes that are very important for the resilience of the Earth System but don’t have large-scale thresholds, but it is not impossible. The zone of uncertainty tends to be larger for these boundaries, but as scientific understanding improves, this zone will narrow.

An important misrepresentation of our paper is the assertion that we are somehow suggesting that fertilizer application in Africa be reduced. Nothing could be further from the truth. In fact, if Ellis et al had taken the time to read the SOM, the excellent paper by Carpenter and Bennett (2011) on the P boundary, the equally excellent paper by de Vries et al. (2013) on the N boundary, and the paper by Steffen and Stafford Smith (2013) on the distribution and equity issues for many of the PBs, including N and P, they wouldn’t have made such a misrepresentation.

Finally, the Steffen et al. (2011) paper seems to have triggered yet another misrepresentation. The paragraph of the paper quoted by Ellis et al. is based on contributions from two of the authors who are experts in institutions and governance issues, and does not come from the natural science community. Nowhere in the paragraph quoted, nor in the Steffen et al. (2011) paper as a whole, is there the proposal for a "a scientific expert group determining top-down global limits…". The paragraph reprinted by Ellis et al. doesn't mention scientists at all. That is a complete misrepresentation of our work.

We reiterate that we very much welcome careful and constructive critiques of the PB update paper, preferably in the peer-reviewed literature. In fact, such critiques of the 2009 PB paper were very helpful in developing the 2015 paper. Knee-jerk reactions in the blogosphere make for interesting reading, but they are far less useful in advancing the science.

Update, Jan. 16, 2:09 p.m. | Johan Rockström and Katherine Richardson, authors of the boundaries analysis, sent these additional reactions to the Ellis et al. critique:

We are honored that Erle Ellis, Barry Brook, Linus Blomqvist and Ruth DeFries (Ellis et al.) show such strong interest in our Planetary Boundaries research. The 2015 science update draws upon the over 60 scientific articles that have been published specifically scrutinizing different aspects of the Planetary Boundaries framework (amongst them the contributions by all these four researchers), and the most recent advancements in Earth System science. This new paper scientifically addresses and clarifies all of the natural science related aspects of Ellis et al.'s critique. It can also be noted that Ellis et al.'s critique simply echoes the standpoints regarding Planetary Boundaries research that the same group (Blomqvist et al., 2012) brought forward in 2012. Now, as then, their criticisms seem largely to be based on misunderstandings and their own viewpoints:

(1) We have never argued that there are planetary scale tipping points for all Planetary Boundary processes. Furthermore, there does not need to be a tipping point for these processes and systems in order for them to function as key regulators of the stability of the Earth system. A good example here is the carbon sink in the biosphere (approximately 4.5 Gt/year) which has doubled over the past 50 years in response to human emissions of CO_2 and, thus, provides a good example of Earth resilience at play;

(2) Establishing the Planetary Boundaries, i.e. identifying Earth System scale boundaries for environmental processes that regulate the stability of the planet, does not (of course) contradict or replace the need for local action, transparency and democratic processes. Our society has long accepted the need for local – and to some extent regional- environmental management. Scientific evidence has now accumulated that indicates a further need for management of some environmental challenges at the global level. Many years of multi-lateral climate negotiation indicate a recognized need for global management of the CO_2 emissions that occur locally. Our Planetary Boundaries research identifies that there are also other processes critical to the functioning of the Earth System that are so impacted by human activities that they, too, demand management at the global level. Ours is a positive – not a doomsday – message. It will come as no surprise to any reader that there are environmental challenges associated with all of the 9 Earth System functions we examine. Through our research, we offer a framework that can be useful in developing management at a global level.

It is important to emphasize that Ellis et al. associate socio-political attributes to our work that do not exist. The Science paper published today (16^{th} January 2015), is a natural science update and advancement of the planetary boundaries framework. It makes no attempt to enter the (very important) social science realm of equity, institutions or global governance. The implications attributed to the PB framework must, then, reflect Ellis et al.'s own normative values. Furthermore, Ellis et al. argue that the "key to

better environmental outcomes is not ending human alteration" but "anticipating and mitigating the negative consequences" of human environmental perturbation. While Planetary Boundaries research does not dictate how societies should use the insights it provides, "anticipating negative consequences" is at the absolute core of our approach!

Regarding Earth system tipping points. As Will Steffen points out in his earlier response, it would have been scientifically more correct for Ellis et al. to refer not only to their own assessment of uncertainties regarding a potential biosphere tipping point but also to the response to their article by Terry Hughes et al. (2014). These researchers presented the current state of empirical evidence concerning changes in interactions and feedbacks and how they can (in several cases do!) trigger tipping points at ecosystem and biome scale, and that such non-linear dynamics at local to regional scale can add up to impacts at the Earth system scale.

A different worldview. The Ellis et al. critique appears not to be a scientific criticism per se but rather is based on their own interpretation of differences in worldview. They do not substantively put in question the stability of the Earth system as a basis for human development– see Will Steffen's response. Thus, it appears that we and Ellis et al. are in agreement here. Of course species and ecosystems have evolved prior to the Holocene but only in the stable environment of the Holocene have humans been able to exploit the Earth system at scale (e.g., by inventing agriculture as a response to a stable hydro-climate in the Holocene).

Ellis et al. argue that the only constructive avenue is to "investigate the connections and trade-offs between the state of the environment and human well-being in the context of the local setting..:". This is clearly not aligned with current scientific evidence. In the Anthropocene, there is robust evidence showing that we need to address global environmental change at the global level, as well as at the regional, national and local contexts, and in particular understanding cross-scale interactions between them.

On global governance. It seems hardly surprising, given the Ellis et al.'s misunderstanding of the Planetary Boundaries framework that their interpretation of the implications of operationalizing the framework rests also on misunderstandings. They claim the Planetary Boundaries framework translates to an "ultimate global authority to rule over humanity". No one would argue that the current multi-lateral climate negotiations are an attempt to establish "ultimate global authority over humanity" and this is certainly never been suggested by the Planetary Boundaries research. In essence, the Planetary Boundary analysis simply identifies Earth System processes that – in the same manner as climate – regulate the stability of the Earth System, and if impacted too far by human activities potentially can disrupt the functioning of the Earth System. The Planetary Boundaries is, then, nothing more than a natural sciences contribution to an important societal discussion and which presents evidence which can support the definition of Planetary Boundaries to safeguard a stable and resilient Earth system. How this then translates to governance is another issue entirely and important social science contributions have addressed these (Galaz et al 2012). As our research shows, there is natural science evidence that global management of some environmental challenges is necessary. From the social science literature (Biermann et al., 2012) as well as from real world policy making, we see that such global scale regulation is possible to construct in a democratic manner and does establish a safe operating space, e.g. the Montreal protocol, a global agreement to address one of the identified planetary boundaries and which, to our knowledge, is never referred to as a "global authority ruling over humanity". As noted above, the UNFCCC process is also fundamentally concerned with establishing the global "rules of the game" by which society can continue to develop within a climate planetary boundary. The Aichi targets (within the UN Convention on Biological Diversity) of setting aside marine and terrestrial areas for conservation are also good examples of the political translation of a science based concern over global loss of biodiversity. The coming SDG (Sustainable Development Goals) framework includes a proposed set of four goals (oceans, climate, biodiversity and freshwater), which is a de-facto example of applying planetary boundary thinking to create a global framework for

safeguarding a stable environment on the planet for societies and communities across the world. We find it interesting – and encouraging – that societies and the world community are already developing management tools within several “planetary boundary domains”. In all cases, this is happening in good democratic order and building upon bottom-up processes and informed by science. This ought to be reassuring for Ellis et al. who portray implementation of Planetary Boundary thinking as a dark force of planetary rule.
