PLANTARY BOUNDARIES TABLES

Table 1, on the following page, is reproduced from the Nature feature which presented the planetary boundary concept in 2009. It sets out:
• the nine Earth-system processes, although this does not seem to be an accurate description of each of them;
• the suggested numerical parameters and the proposed boundary for seven of them; and
• a quantification of their current status and pre-industrial value.

Table 2 contains a summary of the seven short expert commentaries on the planetary boundary concept that were published at the same time as the Nature feature, with one addition.

The commentators are: Myles Allen, a physicist specialising in climate at University of Oxford; Christián Samper, Director of the Smithsonian National Museum of Natural History, Washington DC; William H. Schlesinger, President of the Cary Institute of Ecosystem Studies in Millbrook, New York; Mario J. Molina, Director of the Mario Molina Center for Strategic Studies in Energy and the Environment, Mexico City; Peter Brewer, Ocean Chemist and Senior Scientist, Monterey Bay Aquarium Research Institute, Moss Landing, California; David Molden, Deputy Director General for Research, International Water Management Institute, Colombo, Sri Lanka; and Steve Bass, Senior Fellow at the International Institute for Environment and Development.

(No commentaries were published on the two processes for which boundaries were not proposed, atmospheric aerosol loading and chemical pollution.)

The addition is the inclusion in the Table of text from a paper by Stephen Carpenter (Center of Limnology, University of Wisconsin) and Elena Bennett (McGill University), relating to the phosphorus cycle.

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1 Rockström, J, et al, 2009, Nature 461: 472-475 (A safe operating space for humanity). The fuller scientific paper on which this feature is based, along with Supplementary Information, can be accessed from the ‘Relevant Info’ box on this web page: http://www.stockholmresilience.org/planetary-boundaries
3 The paper is entitled ‘Reconsideration of the planetary boundary for phosphorus’, which was published in February 2011 in Environmental Research letters and is available here: http://iopscience.iop.org/1748-9326/6/1/014009/pdf/1748-9326_6_1_014009.pdf
<table>
<thead>
<tr>
<th>Earth system process</th>
<th>Parameters</th>
<th>Proposed Boundary</th>
<th>Current Status</th>
<th>Pre-industrial value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>(i) Atmospheric carbon dioxide concentration (parts per million by volume)</td>
<td>350</td>
<td>387</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>(ii) Change in radiative forcing (watts per metre squared)</td>
<td>1</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Rate of biodiversity loss</td>
<td>Extinction rate (number of species per million species per year)</td>
<td>10</td>
<td>&gt;100</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Nitrogen cycle (part of a boundary with the phosphorus cycle)</td>
<td>Amount of N\textsubscript{2} removed from the atmosphere for human use (millions of tonnes per year)</td>
<td>35</td>
<td>121</td>
<td>0</td>
</tr>
<tr>
<td>Phosphorus cycle (part of a boundary with the nitrogen cycle)</td>
<td>Quantity of P flowing into the oceans (millions of tonnes per year)</td>
<td>11</td>
<td>8.5-9.5</td>
<td>-1</td>
</tr>
<tr>
<td>Stratospheric ozone depletion</td>
<td>Concentration of ozone (Dobson unit)</td>
<td>276</td>
<td>283</td>
<td>290</td>
</tr>
<tr>
<td>Ocean acidification</td>
<td>Global mean saturation state of aragonite in surface sea water</td>
<td>2.75</td>
<td>2.90</td>
<td>3.44</td>
</tr>
<tr>
<td>Global freshwater use</td>
<td>Consumption of freshwater by humans (km\textsuperscript{3} per year)</td>
<td>4,000</td>
<td>2,600</td>
<td>415</td>
</tr>
<tr>
<td>Change in land use</td>
<td>Percentage of global land cover converted to cropland</td>
<td>15</td>
<td>11.7</td>
<td>Low</td>
</tr>
<tr>
<td>Atmospheric aerosol loading</td>
<td>Overall particulate concentration in the atmosphere, on a regional basis</td>
<td>To be determined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical pollution</td>
<td>For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of the Earth system thereof</td>
<td>To be determined</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2 - COMMENTARIES ON PLANETARY BOUNDARIES

<table>
<thead>
<tr>
<th>Earth system process parameters &amp; proposed boundary</th>
<th>Commentaries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate change</strong></td>
<td></td>
</tr>
<tr>
<td>(i) Atmospheric carbon dioxide concentration (parts per million by volume) - 350</td>
<td>“defin[ing] a ‘climate boundary’ in terms of long-term CO₂ concentrations [is] an unnecessary distraction... it misses the point...The actions required over the next couple of decades to avoid dangerous climate change are the same regardless of the long-term concentration we decide to aim for.” Even if we keep to 2°C, “it will probably be many centuries, and possibly millennia, before concentrations return naturally to 350 ppm”. “There is, however, one important respect in which aiming for 350 ppm, even without a date attached, may be a helpful target – it implies that we limit net anthropogenic carbon emissions to less than one trillion tonnes...this is simply what we need to do to keep the most likely peak CO₂-induced warming below 2°C”. Allen</td>
</tr>
<tr>
<td>(ii) Change in radiative forcing (watts per metre squared) - 1</td>
<td></td>
</tr>
<tr>
<td><strong>Rate of biodiversity loss</strong></td>
<td></td>
</tr>
<tr>
<td>Extinction rate (number of species per million species per year) - 10</td>
<td>Boundaries for individual physical &amp; chemical variables are more amenable to measurement than extraordinarily complex interactions between species &amp; ecosystems. Limited data on species abundance &amp; distribution. Good data (e.g.) on bird extinctions, but not on insects or most marine invertebrates. Extinction rates almost certainly higher than proposed boundary in the past. A single biodiversity boundary across all taxa and habitats “may not be useful” (e.g., as rates of extinction and speciation vary across different organisms and habitats). Alternatives might be “a measure of how population size, distribution and threat levels are changing for specific groups...[or] express species extinction as a probability based on evolutionary history and the tree of life, instead of a range of values”. Samper</td>
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<tr>
<td><strong>Nitrogen cycle (part of a boundary with the phosphorus cycle)</strong></td>
<td>The nitrogen threshold “seems arbitrary” and “waiting to cross the threshold allows much needless environmental degradation”. In areas of excess nitrogen deposition from the atmosphere, e.g. in pastures in Great Britain, species decline linearly as a function of increasing nitrogen inputs to land. “Unfortunately, policymakers face difficult decisions, and management based on thresholds, although attractive in its simplicity, allows pernicious, slow and diffuse degradation to persist nearly indefinitely...Setting boundaries is fine, but waiting to act until we approach these limits merely allows us to continue with our bad habits until it’s too late to change them.” Schlesinger</td>
</tr>
<tr>
<td>Amount of N₂ removed from the atmosphere for human use (millions of tonnes per year) - 35</td>
<td></td>
</tr>
<tr>
<td><strong>Phosphorus cycle (part of a boundary with the nitrogen cycle)</strong></td>
<td>“[A] lenient limit”. Schlesinger</td>
</tr>
<tr>
<td>Quantity of P flowing into the oceans (millions of tonnes per year) - 11</td>
<td>“The planetary boundary for freshwater eutrophication has been crossed while potential boundaries for ocean anoxic events and depletion of phosphate rock reserves loom in the future.” Carpenter &amp; Benett (February 2011)</td>
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<tr>
<td><strong>Stratospheric ozone depletion</strong></td>
<td>“[a] very interesting and useful concept”. The boundary is “reasonable, but a bit arbitrary”. The tipping point for ozone depletion is 30 ppb of atmospheric concentration of effective equivalent stratospheric chlorine (EESC), so 10 or 20 ppb would maintain a safe distance. 10 ppb would lead to a 15 % stratospheric ozone loss. The Montreal Protocol limited EESC to about 4 ppb, leading to ozone loss of about 5-6%. “[T]he [PB] concept is a very important one, and its proposal should now be followed by discussions of the connections between the various boundaries and of their association with other concepts such as the ‘limits to growth’. Molina</td>
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<tr>
<td>Concentration of ozone (Dobson unit) - 276</td>
<td></td>
</tr>
<tr>
<td><strong>Ocean acidification</strong>&lt;br&gt;Global mean saturation state of aragonite in surface sea water – 2.75</td>
<td>The limit of 3.44 “seems reasonable”, but other boundaries might also be necessary because of impacts other than changes in pH. “But is it truly useful to create a list of environmental limits without serious plans for how they may be achieved?” Brewer</td>
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<tr>
<td><strong>Global freshwater use</strong>&lt;br&gt;Consumption of freshwater by humans (km$^3$ per year) – 4,000</td>
<td>“[A] welcome new approach in the ‘limits to growth’ debate.” “As a scientific organizing principle, the concept has many strengths”. The 4,000 km$^3$ value “may well be too high”, because “the concept of a global limit overlooks the importance of local conditions and the role of management in magnifying or ameliorating problems”. “[T]he [PB] concept and its first estimate of numeric values give us an important warning call that must be heeded. Rather than get bogged down in detailed arguments about the weaknesses of the approach or the methods of analysis, we now have a tool we can use to help us think more deeply – and urgently – about planetary limits and the critical actions we have to take.” Molden</td>
</tr>
<tr>
<td><strong>Change in land use</strong>&lt;br&gt;Percentage of global land cover converted to cropland - 15</td>
<td>“[A] sound idea”. “Their paper has profound implications for future governance systems.” “That said, there is much work to be done before the concept can be used practically”. The 15% limit is based on “a sensible – though apparently arbitrary – expansion factor” – why not 10 or 20%? “[S]ustainability of land use depends less on percentages and more on other factors”, such as intensively farmed cropland in large blocks. 15% is “a premature policy guideline that dilutes the authors’ overall scientific proposition”. Might want to consider a limit on soil degradation or soil loss – “a more valid and useful indicator of the state of terrestrial health”. Bass</td>
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</table>
Draft Declaration on Planetary Boundaries

V.1, 24th October 2011
An Introduction to the Draft Declaration on Planetary Boundaries

In 2009, 29 scientists published a paper putting forward the planetary boundaries concept. The concept posits that there are nine critical Earth-system processes and associated thresholds that we need to respect and keep within, in order to protect against the risk of irreversible or even catastrophic environmental change at continental to global scales. Doing so would create a safe operating space for humanity, within which human economy and society would be able to play out. According to the concept’s authors, three of the nine suggested thresholds have already been crossed (for climate change, biodiversity and the nitrogen cycle).

What is new about the concept is that, rather than understanding environment, economy and society as three pillars of sustainable development, it makes clear that sustainable development can only take place within the safe operating space identified by the biophysical realities of critical natural thresholds.

The idea has been acknowledged by the Secretary-General's High-Level Panel on Global Sustainability: the overall goal for its report later this year and input into Rio+20 is “To eradicate poverty and reduce inequality, make growth inclusive, and production and consumption more sustainable while combating climate change and respecting the range of other planetary boundaries.”

The planetary boundaries concept has important implications for future governance systems. Current systems, including international laws, have not yet developed sustainability principles that ensure stable and resilient ecological systems for protecting human health and well being. Instead our institutions are often caught in conflict between short-term financial gains and long-term sustainability.

The draft Declaration on Planetary Boundaries on the following pages is intended as a statement of first principles that lay the institutional framework for such planetary boundary thinking. It calls for humanity to recognize, respect and be responsible for not transgressing planetary boundaries – internationally, regionally, nationally and locally. It sets out general requirements under each of these three heads, and provides for an over-arching institutional home which cooperates with current institutions and actors across the range of human activities that affect planetary boundaries. In time, such an institution could become - under a UN Convention on Planetary Boundaries - an over-arching Planetary Boundaries Commission.

Rio +20 is an obvious opportunity to explore this innovative approach to sustainable development, including in order to develop ideas around Sustainable Development Goals and/or Millennium Consumption Goals.

Those behind this Declaration believe there is an urgent need to take action on this governance issue to ensure that everyone, including present and future generations and particularly the vulnerable and marginalised, have the protections and rights necessary to live in a social and physical environment that provides for their health and well being.

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Draft Declaration on Planetary Boundaries

We, the peoples and nations of our planet, Earth,

Cherishing its beauty, diversity, vitality and community of life,

Recognising the innate linkages between components of the ecosystems that sustain life, and valuing their fundamental role for human existence, development and well-being,

Conscious of facing a critical period in the history of our planet,

Concerned that rapidly growing dependence on fossil fuels, industrialised forms of agriculture and escalating demands on natural resources have reached a level that could damage the biogeochemical feedback systems that maintain a habitable planet, resulting in irreversible and, in some cases, abrupt environmental change, which could profoundly undermine long-term human existence and that of other forms of life,

Recalling commitments made at the United Nations Conference on Environment and Development in respect of sustainable development and future generations, and in particular, Principle 15 of the Rio Declaration concerning application of the precautionary principle,

Determined to respond to the strong scientific consensus and growing evidence base that there are identifiable Earth-system processes on which human existence, development and well-being depend, and which must be safeguarded from the threats of serious or irreversible damage as a result of human activities,

Recognising that safeguarding those processes from such threats is necessary in order to promote sustainable human development and social justice, and likewise that promoting sustainable human development and social justice is necessary for safeguarding those processes,

NOW DECLARE AS FOLLOWS:

Principle 1 – The Fundamental Principle
Earth-system processes that are necessary for ensuring a safe operating space for humanity should be recognised and respected. We are all responsible for safeguarding those processes from the threats of serious or irreversible damage as a result of human activities.
Principle 2 – Recognition
Recognition of necessary Earth-system processes means:
(1) acknowledging that such processes exist;
(2) acknowledging the need to act in order to safeguard such processes from the threats of serious or irreversible damage as a result of human activities;
(3) researching and developing our understanding of the nature and vulnerabilities of such processes, including of the thresholds at which they could shift into new states and of where boundaries at a safe distance from such thresholds would lie;
(4) identifying the human activities that affect such processes, and monitoring the effects of such activities, including collecting, collating and presenting scientific data and information by reference to such processes and the human activities which affect them; and
(5) developing and communicating information about such processes in ways which are transparent and designed to encourage public engagement, trust, common understanding and acceptance of shared responsibility for safeguarding them.

Principle 3 - Respect
Respect for necessary Earth-system processes means:
(1) using scientific information to understand their thresholds;
(2) determining their boundaries transparently on the basis of scientific advice, having taken into account social and economic considerations, public opinion and having assessed the risk of crossing the boundaries;
(3) making decisions, across the range of human activities which affect such processes, to minimise the risk of crossing the boundaries;
(4) designing appropriate public and private sector institutions in order to safeguard such thresholds and boundaries.

Principle 4 - Responsibility
Being responsible for safeguarding necessary Earth-system processes means:
(1) establishing over-arching legal principles and duties to recognise and respect such processes across the range of human activities that affect them;
(2) ensuring people have the right to have them recognised and respected;
(3) guaranteeing rights to information, participation and access to justice, including appropriate and effective remedies; and
(4) creating an independent public enforcement body with appropriate and effective legal powers and duties.
Principle 5 - Institutions

(1) The function of promoting and developing these Principles should be conferred on an over-arching international body (the Planetary Boundaries Institution (PBI)), coordinating a network of regional, national, and sub-national bodies.

(2) The function of promoting and developing these Principles involves cooperation among the PBI and the network, and institutions and organisations with responsibilities across the range of human activities that affect necessary Earth-system processes, at the appropriate levels, as well as engagement and communication with the public.

(3) The PBI and network will also have the function at the appropriate level of providing scientific information and advice for the purposes of Principle 3(1) and (2), based on coordination of the evidence available from research on the thresholds and boundaries of necessary Earth-system processes.

(4) The PBI and network will be assisted in its work by independent, transparent and participative panels at international, regional and national levels, especially in relation to scientific and other research evidence, socio-economic considerations and public engagement.

Principle 6 - Commitments

(1) UN bodies and agencies, other international institutions and inter-governmental organisations with responsibilities for activities that affect necessary Earth-system processes, regional economic integration organisations and States will:

(a) review the laws, policies, strategies and arrangements they have in place for recognising, respecting and being responsible for safeguarding necessary Earth-system processes from the threats of serious or irreversible damage as a result of human activities in accordance with these Principles;

(b) make any improvements necessary to apply these Principles;

(c) cooperate with, provide to and exchange data and information with the PBI and network at the appropriate level; and

(d) report periodically to the PBI and the network at the appropriate level and the independent enforcement body under Principle 4(4) on the effects of activities on such processes and on the extent to which they are applying these Principles.

2. In reviewing and improving their laws, policies, strategies and arrangements, States and regional economic integration organisations will, in conjunction with the PBI and network at the appropriate level, consider:

(a) the impact of their activities on Earth-system processes that are necessary for ensuring a safe operating space for humanity, and

(b) how they can ensure that their activities do not exceed their fair share of that safe operating space.