



Planetary Boundaries Update

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Introduction

The Planetary Boundaries (PB) framework was first proposed by a group of scientists led by Johan Rockstrom [1] in 2009. They called it “A safe operating space for humanity”. The framework was updated in 2015 [2] and 2023[3].

As the first title suggests, science proposed 9 PBs, indicating that if humanity collectively remains within these limits, we may be assured to safely continue in the present Holocene state for another 10,000 to 20,000 years.



Johan Rockstrom

Significance

The first update in 2015 coincides with the successful adoption of the 17 SDGs after about 3 years of global consultations by members of a Working Group set up by the UN as an outcome of Rio + in 2012. Hence the apt title: “Planetary Boundaries: Guiding human development on a changing planet”.

We have just crossed the mid-point of the 15 years’ timeframe for the SDGs, and the Covid 19 pandemic has seriously thwarted the limited progress we made. The UN Secretary General has already sounded the warning bell. The second update of September 2023 of the PB framework reinforces this warning, as it proclaims “**Earth beyond six of nine planetary boundaries**”.

Rationale

The fundamental argument in favour of respecting the PBs stems from the history of ‘*Life on Earth*’. The ice ages were so cold that barely some life forms could survive. Then came the present Holocene age, when the Earth became warmer, supporting multiple life forms, and we humans are the latest in the evolutionary history. However, with the advent of the industrial revolution, humanity has been using fossil fuel driven energy for increasingly usurping all of Earth’s resources. Beginning in the 1970s, we have been consuming each year, on a global scale what Mother earth can produce in a year. The IPAT equation states that humanities impact (I) on our planet is a combination of rising population (P) – from 1.65 billion in 1900 to 8 billion in 2022, exponential economic growth from mere 2 trillion USD in 1900 to 55 trillion in 1911 supported by new technologies (T) captured by rising patents from 141 k in 1900 to 1900 k in 1911. The last two rows in the following table indicates the growth from 1900 to 1950 and from 1950 till 2011. It is clear that although rising population

has been continuously pointed out as the sole reason for the troubles we face, the growth in GDP and new technologies have had far greater impact than population growth.

YEAR	I	P-bn	A tr	T k
1900	508	1.8	2	141
1950	5459	2.5	5.3	412
2011	731,500	7	55	1900
00 - 50	975	39	165	192
50 - 11	13,300	180	938	361

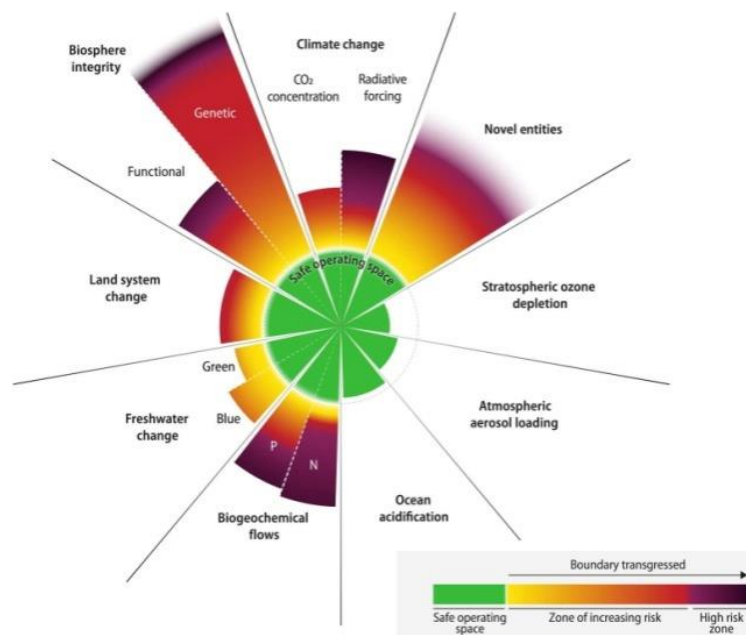
Science tells us that we are heading towards a completely unknown, hot phase likely to impact all forms of life on Earth. The latest PB update now confirms that the sixth massive extinction of species started about 150 years back and we have already crossed 6 of the 9 planetary boundaries. If we may call the present age as **Water Age**, taking a cue from the term **Ice age**, we may be heading for the **Steam Age**. The next section provides the latest update on the PBs.

Past	Present	Future
Ice age	Holocene	Unknown
Ice	Water	Steam (?)
		Anthropocene (?)

Planetary Boundaries 2023 Update

The following figure depicts the latest scientific assessments. The updated PB status shows six out of 9 boundaries have been transgressed

The green shade indicates the safe zone. The other codes indicate moderate (yellow) to high (red) to very high (purple) risks as per IPCC conventions.



Boundary Definitions

If you are interested in going into more details, here is a summary. The table indicates the base value (pre-industrial levels) for each of the boundary, the limit proposed, beyond which the Earth system risks being irreversibly changed with an ‘Upper end’ value signifying high risks.

<i>Planetary Boundary</i>	<i>Unit</i>	<i>Base value</i>	<i>Limit</i>	<i>Upper end</i>	<i>Current value</i>
Change in biosphere integrity					
Genetic diversity	E/MSY	1	<10	100	>100
Functional integrity	HANPP	1.9%	<10%	20%	30%
Climate Change					
CO ₂ concentration	ppm CO ₂	280	350	450	417
Radiative forcing	Wm ⁻²	0	1.0	1.5	2.91
Novel Entities	*****	0	0	N/A	Transgressed
Biogeochemical flows					
Nitrogen	Tg of N year ⁻¹	0	62	82	190
Phosphorous	Tg of P year ⁻¹	0	11	100	22.6
Fresh water change					
Green	**	9.8%	11.1%	50%	15.8%
Blue	***	9.4%	10.2%	50%	18.2%
Land system change	****	100%	75%	54%	60%
Ocean acidification	Ω _{arag}	3.44	≥80%	2.75	2.8
Aerosol loading	*	0.03	0.1	0.25	.076
Ozone depletion	DU	290	276	261	284.6

Table adapted from [3].

Highlighted rows indicate changes made from the earlier definitions. For aerosol loading, the change is in finding a measure for it.

- Mean annual inter hemispheric difference in AoD
- Green water: human induced disturbance of water available to plants (% land area with deviations from preindustrial variability)
- Blue water: human induced disturbance of blue water flow
- Global: area of forested land as the percentage of original forest cover; biome: area of forested land as the percentage of potential forest (% area remaining)
- Percentage of synthetic chemicals released to the environment without adequate safety testing

Notes:

1. Ocean acidification is measured as Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag}) a form of soluble calcium carbonate. The pre-industrial base value was 3.44. Acidification means this

value goes *down*. It should not go down more than 20%. At present it has gone down to 2.8, just a little above the limit of 2.75.

2. Ozone depletion is measured as Stratospheric O₃ concentration, (global average) in DU. The pre-industrial base value was 290. This measure also acts in terms of reduction. It should not go down below 276. At present it is at 284.6.
3. Land system change also follows a similar downward change in forest cover, maximum allowed is 75% and current value is 60% indicating that the boundary is crossed.

References

- [1] J. Rockström, W. Steffen, K. Noone, Å. Persson, S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, J. Schellnhuber, B. Nykvist, C. A. DeWit, 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, D. Liverman, K. Richardson, P. Crutzen, J. Foley, A safe operating space for humanity. *Nature* 461, 472–475 (2009).
- [2] W. Steffen, K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett, R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers, S. Sörlin, Planetary boundaries: Guiding human development on a changing planet. *Science* 347, 1259855 (2015).
- [3] <https://www.science.org/doi/epdf/10.1126/sciadv.adh2458>

