

Planetary Boundaries: Exploring the safe operating space for humanity in the Anthropocene (*Nature*, 461 : 472 – 475, Sept 24 - 2009)



FEATURE

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A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

SUMMARY

- New approach proposed for defining preconditions for human development
- Crossing certain biophysical thresholds could have disastrous consequences for humanity
- Three of nine interlinked planetary boundaries have already been overstepped

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years¹. This period of stability – known to geologists as the Holocene – has seen human civilizations arise, develop and thrive. Such stability may now be under threat. Since the Industrial Revolution, a new era has arisen, the Anthropocene, in which human activities have become the main driver of global environmental change². This could see human activities push the Earth system outside its stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world. During the Holocene, environmental change occurred naturally and Earth's capacity to absorb and regulate the conditions that enabled human development. Regular temperatures, freshwater availability and biogeochemical flows all stayed within a relatively narrow range. Now, largely because of a rapidly growing reliance on fossil fuels and industrialized forms of agriculture, human activities have reached a level that could damage the system that kept Earth in the desirable Holocene state. The result could be irreversible change, leading to a state less conducive to human development. Without pressure from humans, the Holocene is expected to continue for at least several thousands of years³.

Planetary boundaries

To meet the challenge of maintaining the Holocene state, we propose a framework based on 'planetary boundaries'. These boundaries define the safe operating space for humanity with respect to the Earth's physical subsystems or processes. Although Earth's complex systems sometimes respond successfully to changing pressures, it seems that this will prove to be the exception rather than the rule. Many subsystems of Earth react in a nonlinear often abrupt way, and are particularly sensitive around threshold levels or certain key variables. If these thresholds are crossed, then important subsystems, such as a monsoon system, could shift into a new state, often with deleterious or potentially even disastrous consequences for humans⁴. Most of these thresholds can be defined by a critical value for one or more control variables, such as carbon dioxide concentration. Not all processes or subsystems on Earth have well-defined thresholds, although human actions that undermine the resilience of such processes or subsystems – for example, land use degradation – can increase the risk that thresholds will also be crossed in other processes, such as the climate system. We have tried to identify the Earth-system processes and associated thresholds which, if crossed, could generate unacceptable environmental change. We have found nine each necessary to define planetary boundaries: climate change, rate of biodiversity loss (terrestrial and marine), interference with the nitrogen and phosphorus cycles, stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, chemical pollution and stratospheric aerosol loading (see Fig. 1 and Table).

In general, planetary boundaries are values for control variables that are either at a 'safe' distance from thresholds – for processes with evidence of threshold behaviour – or at dangerous levels – for processes without

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standing represents the proposed safe operating space of biodiversity loss, climate change and land use have exceeded.

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Research

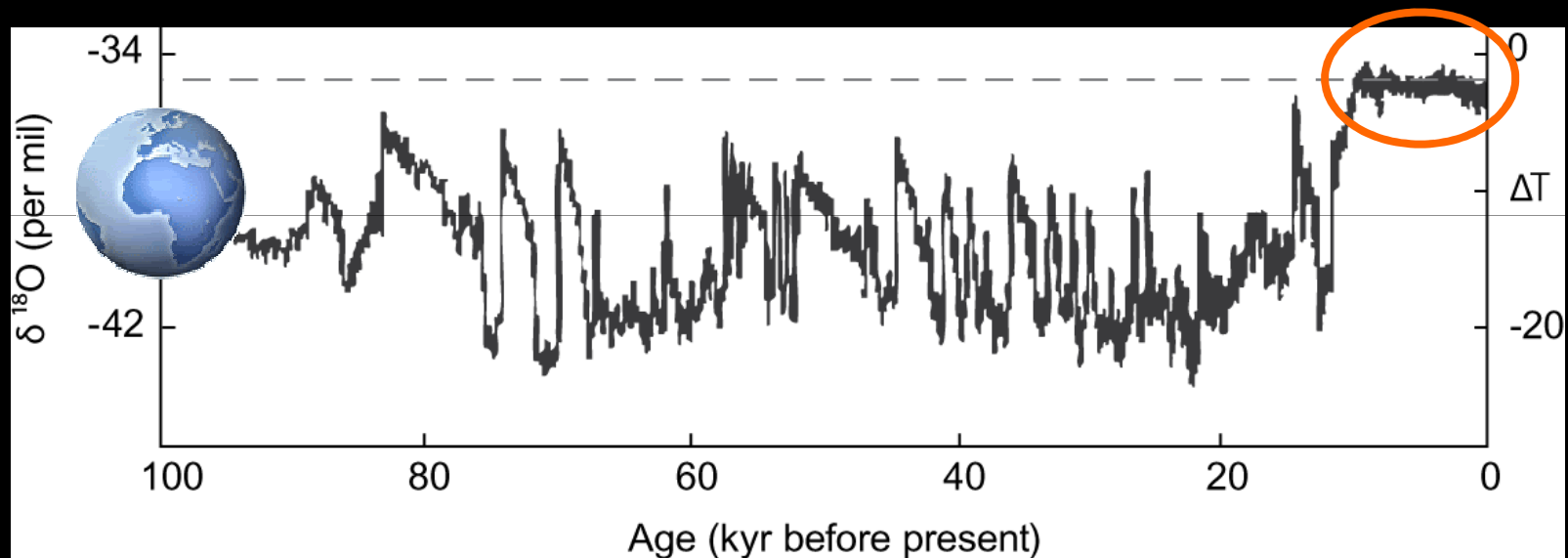
Planetary Boundaries: Exploring the Safe Operating Space for Humanity

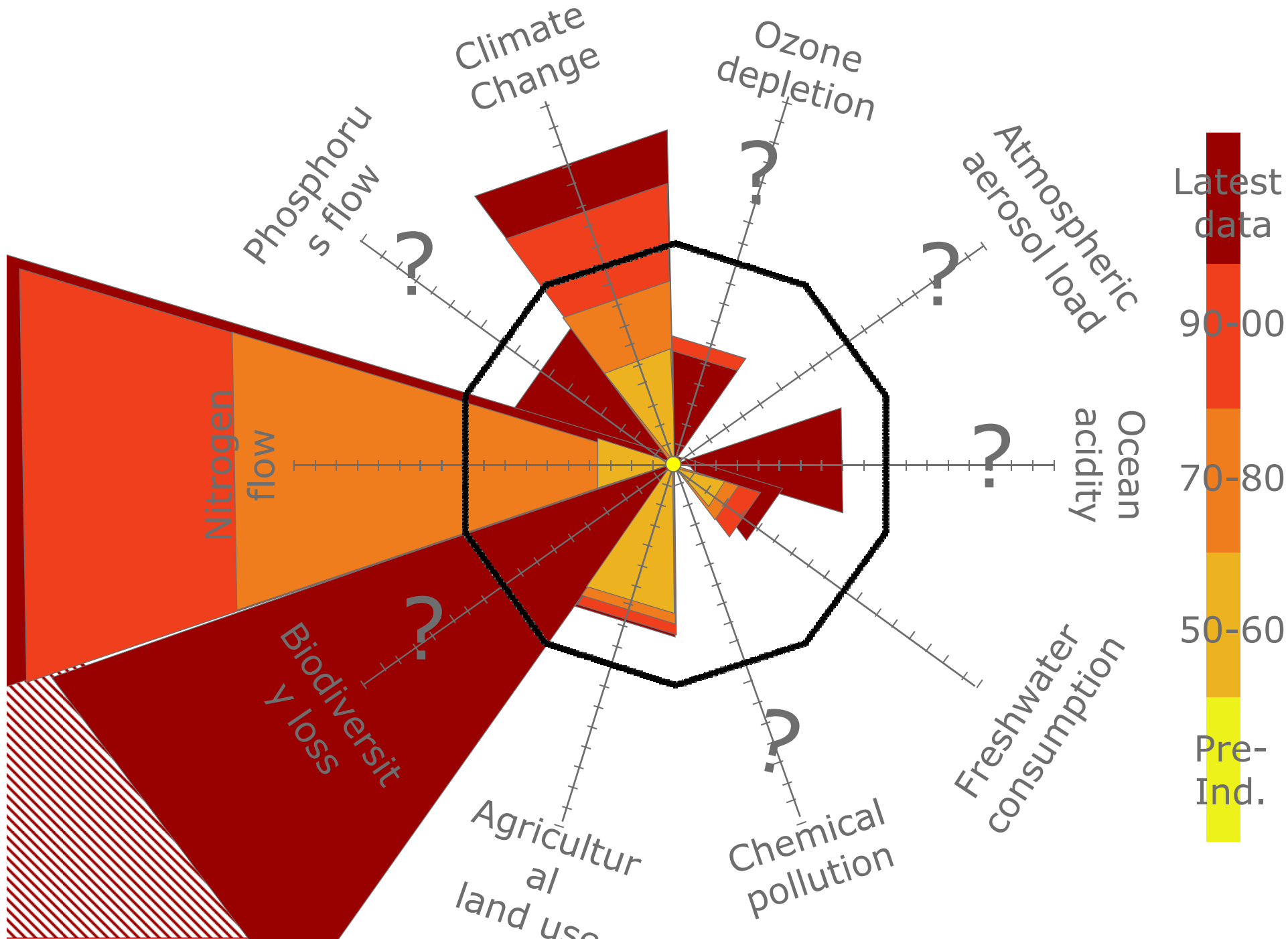
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Humanity's 12,000 years of grace







Challenge of the 21st Century!

Sharing the Earth's resources
among (incl. **Feeding**) 9
billion people AND staying
within the Planetary
Boundaries

A new "global spec" for world food production:

1. Stay within 350 ppm, an agricultural system that goes from being a source to a global sink
2. Essentially a green revolution on current cropland (expansion from 12 % to 15 %) *(efficiency and resilience)*
3. Keep global consumptive use of blue water < 4000 km³/yr, we are at 2,600 km³/yr today and rushing fast towards 4000 km³/yr
4. Reduce to 25 % of current N extraction from atmosphere
5. Increase P-use efficiency and not increase P inflow to oceans
6. Reduce loss of biodiversity to < 10 E/MSY from current 100-1000 E/MSY