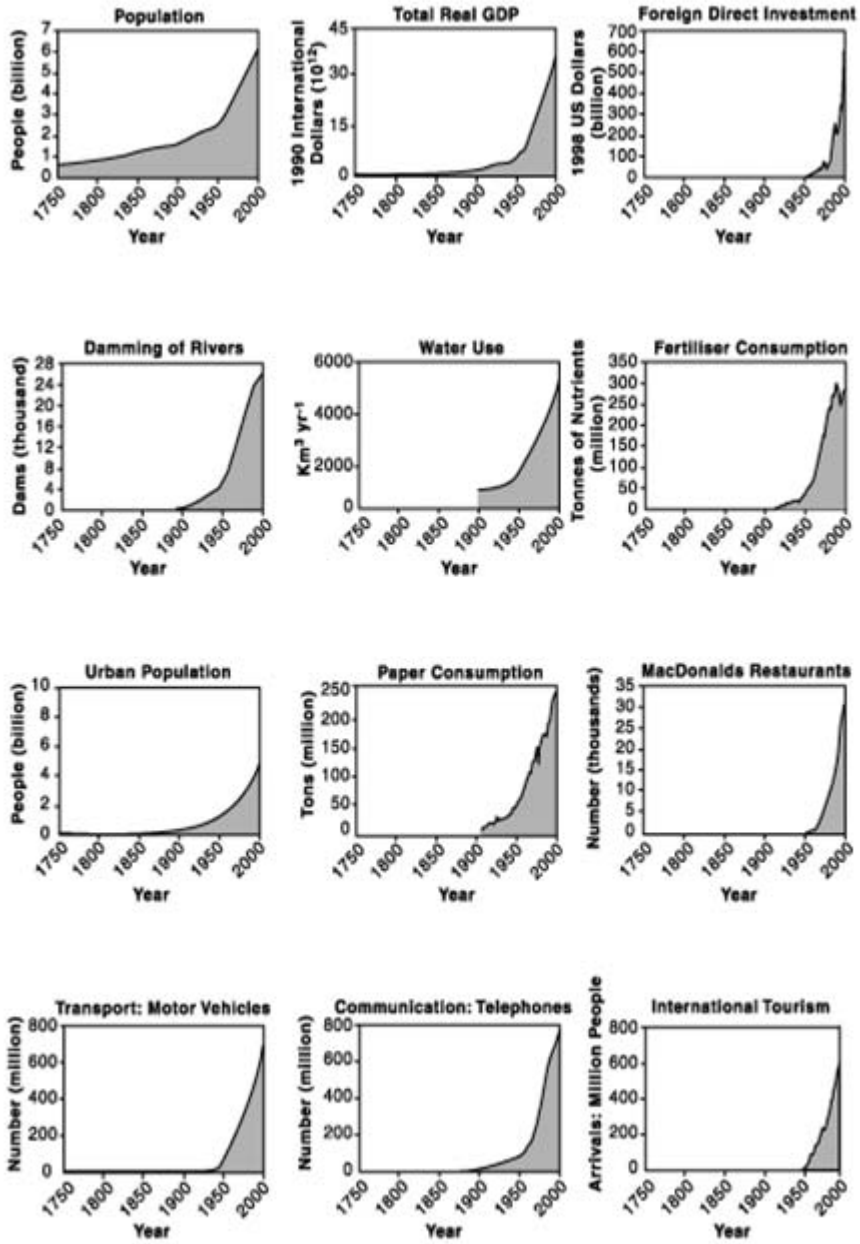
Biodiversity, a global threshold

Why preserving biodiversity should go hand-in-hand with climate mitigation in agro-ecosystems

Prof. Katherine Richardson
Center for Macroecology, Evolution and Climate
University of Copenhagen

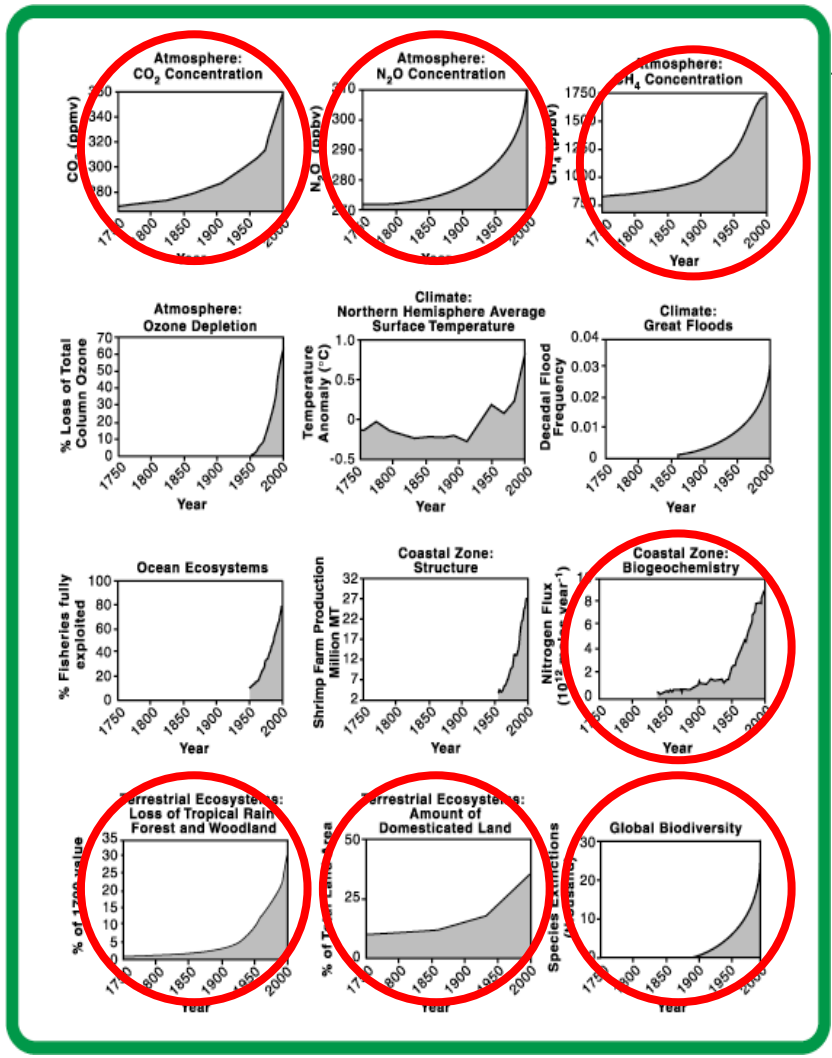
Human activities have dramatically increased over the last approx. 60 years



From: Steffen et al. 2004

The response to these activities can be measured at the global level

Related to agriculture



Steffen, W., et al. 2004

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

nature

FEATURE

Vol 461|24 September 2009

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

ROAD TO COPENHAGEN

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years[1–3]. 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[4], in which human actions have become the main driver of global environmental change[5]. This could see human activities push the Earth system outside the 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 regulatory capacity maintained 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 systems that keep Earth in the desirable Holocene state. The result could be irreversible and, in some cases, abrupt environmental change, leading to a state less conducive to human development[6]. Without pressure from humans, the Holocene is expected to continue for at least several thousands of years[7].

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 system and are associated with the planet's biophysical subsystems or processes. Although Earth's complex systems sometimes respond smoothly 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 of 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 humans[8,9].

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 and water 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 such processes for which we believe it is 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 atmospheric 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

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. 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. Foley. 2009. Planetary boundaries:exploring the safe operating space for humanity. *Ecology and Society* **14**(2): 32. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art32/

E&S

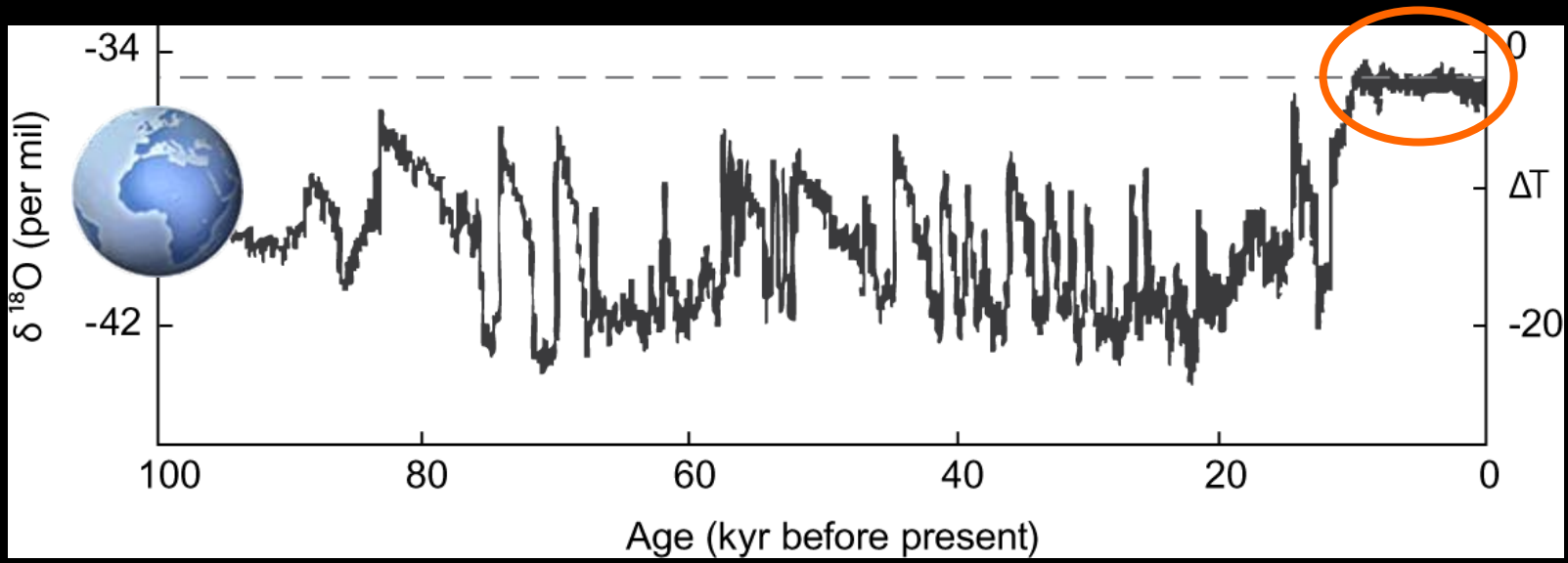
Research

Planetary Boundaries: Exploring the Safe Operating Space for Humanity

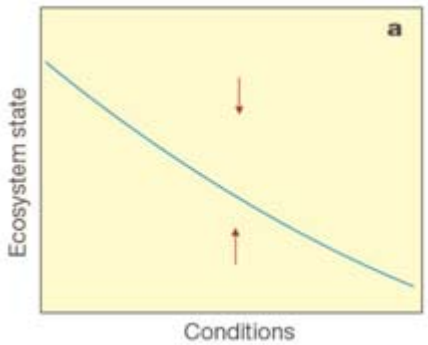
Johan Rockström [1,2], *Will Steffen* [1,3], *Kevin Noone* [1,4], *Åsa Persson* [1,2], *F. Stuart III Chapin* [5], *Eric Lambin* [6], *Timothy M. Lenton* [7], *Marten Scheffer* [8], *Carl Folke* [1,9], *Hans Joachim Schellnhuber* [10,11], *Björn Nykvist* [1,2], *Cynthia A. de Wit* [4], *Terry Hughes* [12], *Sander van der Leeuw* [13], *Henning Rodhe* [14], *Sverker Sörlin* [1,15], *Peter K. Snyder* [16], *Robert Costanza* [1,17], *Uno Svedin* [1], *Malin Falkenmark* [1,18], *Louise Karlberg* [1,2], *Robert W. Corell* [19], *Victoria J. Fabry* [20], *James Hansen* [21], *Brian Walker* [1,22], *Diana Liverman* [23,24], *Katherine Richardson* [25], *Paul Crutzen* [26], and *Jonathan Foley* [27]

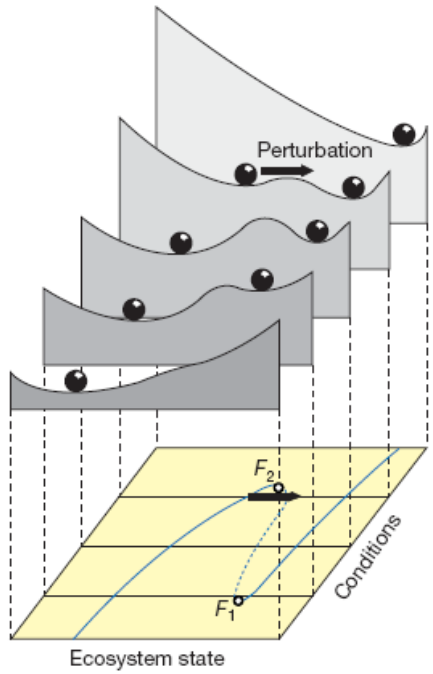
Ecology and Society **14**(2): 32
http://www.ecologyandsociety.org/vol14/iss2/art32/

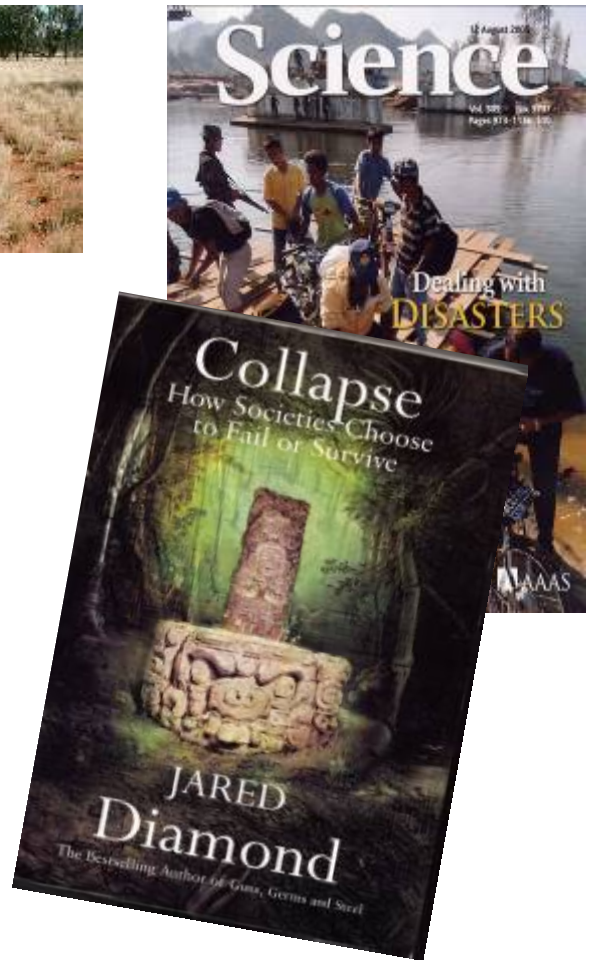
Humanity's 12,000 years of grace



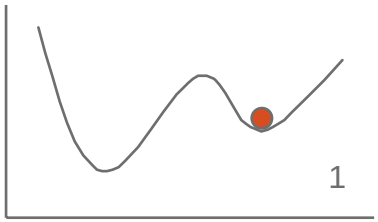
Critical transitions or regime shifts







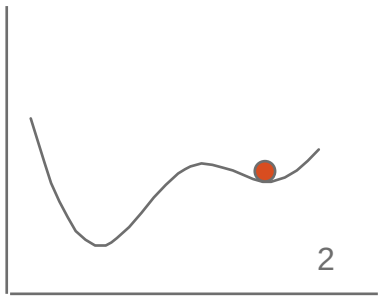
Valuable Ecosystem Services (Desirable) → Loss of ecosystem services (Undesirable)



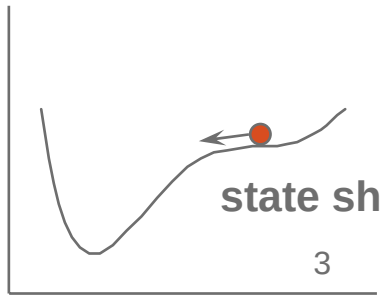
coral dominance

clear water

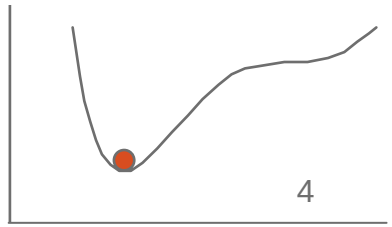
grassland



- overfishing, coastal eutrophication
- phosphorous accum-ulation in soil and mud
- fire prevention



- disease, hurricane
- flooding, warming, overexploitation of predators
- good rains, continu-ous heavy grazing

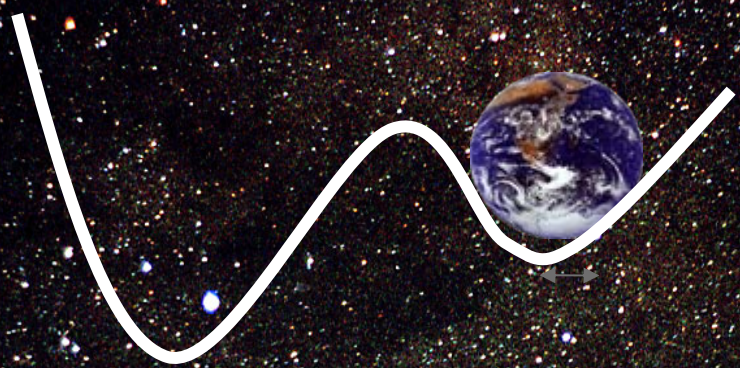


algal dominance

turbid water

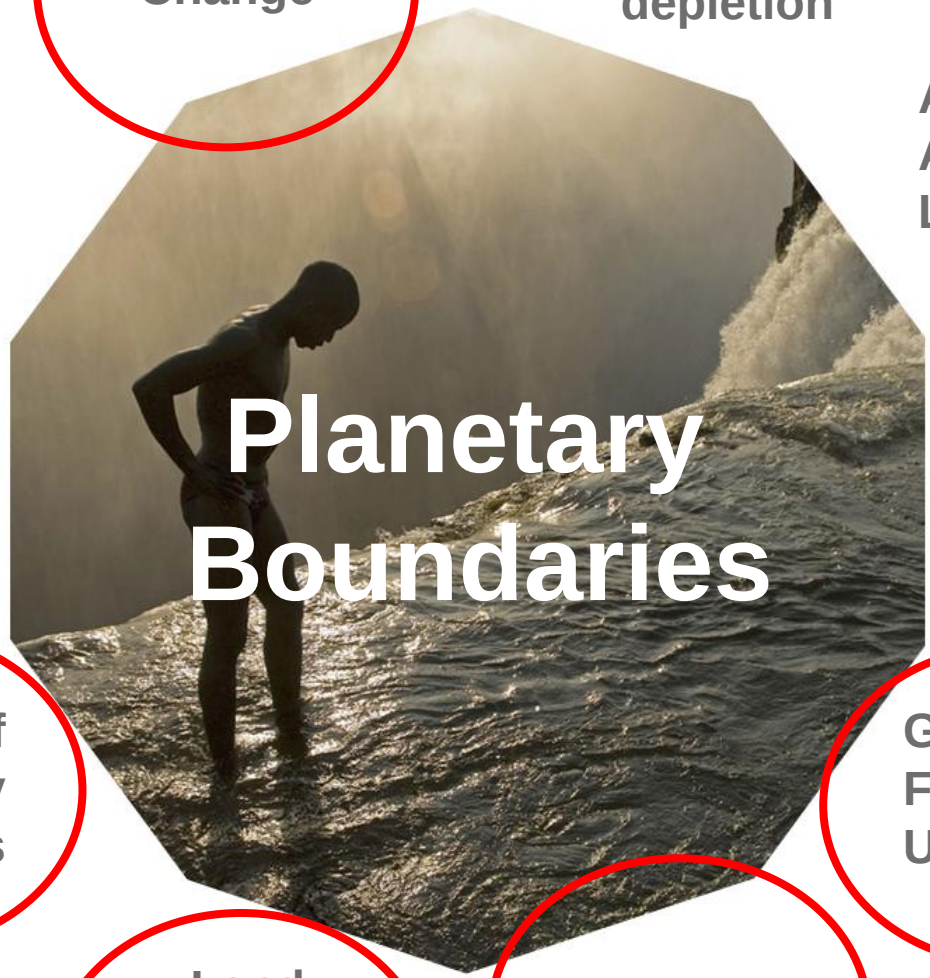
shrub-bushland

The Resilience of the Earth System



Our precarious predicament

”We have our foot on the accelerator
driving towards the Abyss...”
Ban Ki-moon Secretary General of the UN
Sept 2009



Climate Change

Ozone depletion

Atmospheric Aerosol Loading

Biogeochemical loading: Global N & P Cycles

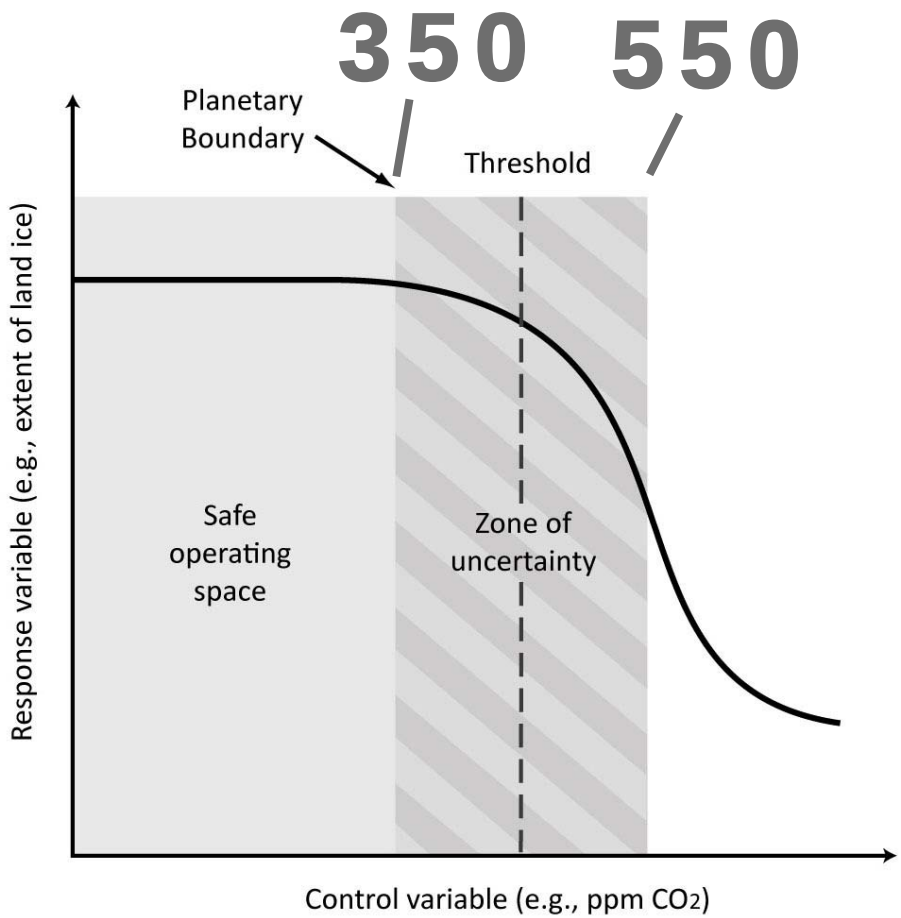
Ocean acidification

Rate of Biodiversity Loss

Global Freshwater Use

Land System Change

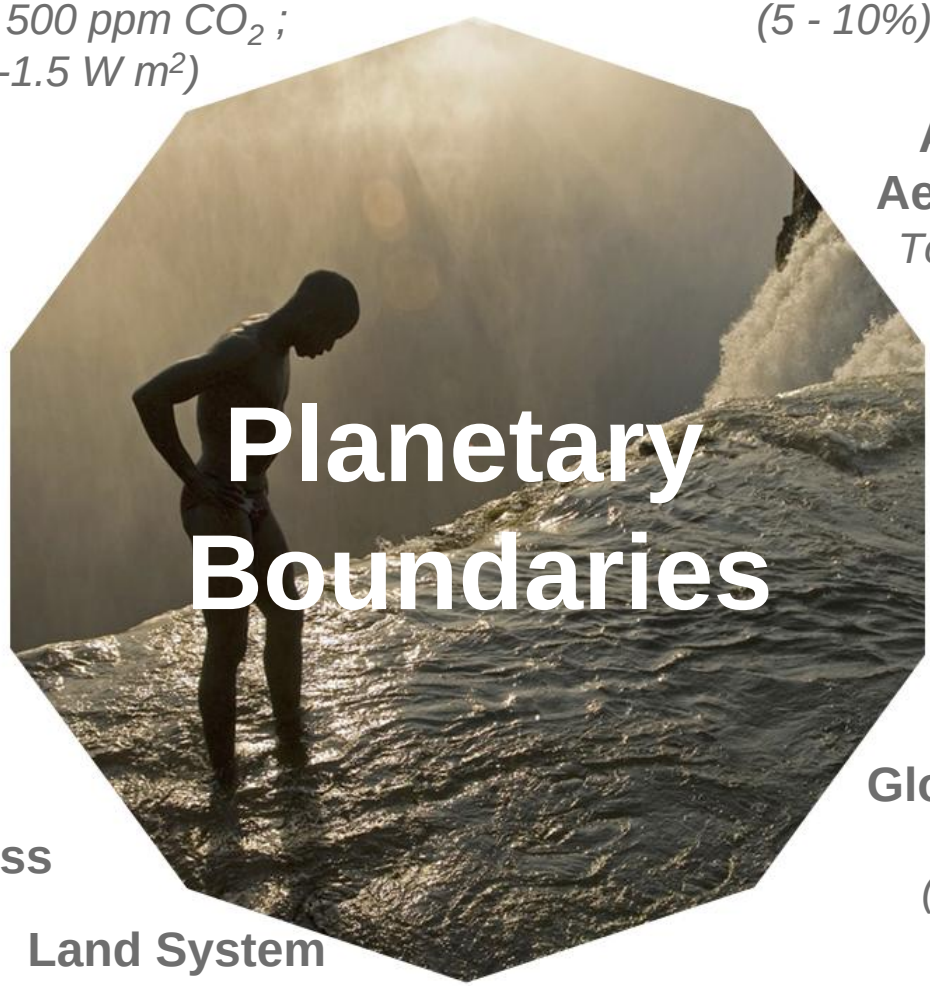
Chemical Pollution


350
550
Planetary Boundary
Threshold
Response variable (e.g., extent of land ice)
Safe operating space
Zone of uncertainty
Control variable (e.g., ppm CO2)

Climate Change
< 350 ppm CO_2 < 1W m^2
(350 – 500 ppm CO_2 ; 1-1.5 W m^2)

Ozone depletion
< 5 % of Pre-Industrial 290 DU
(5 - 10%)

Biogeochemical loading: Global N & P Cycles
Limit industrial fixation of N_2 to 35 Tg N yr^{-1}(25 % of natural fixation)
(25%-35%)
P < 10× natural weathering inflow to Oceans
(10× – 100×)



Atmospheric Aerosol Loading
To be determined

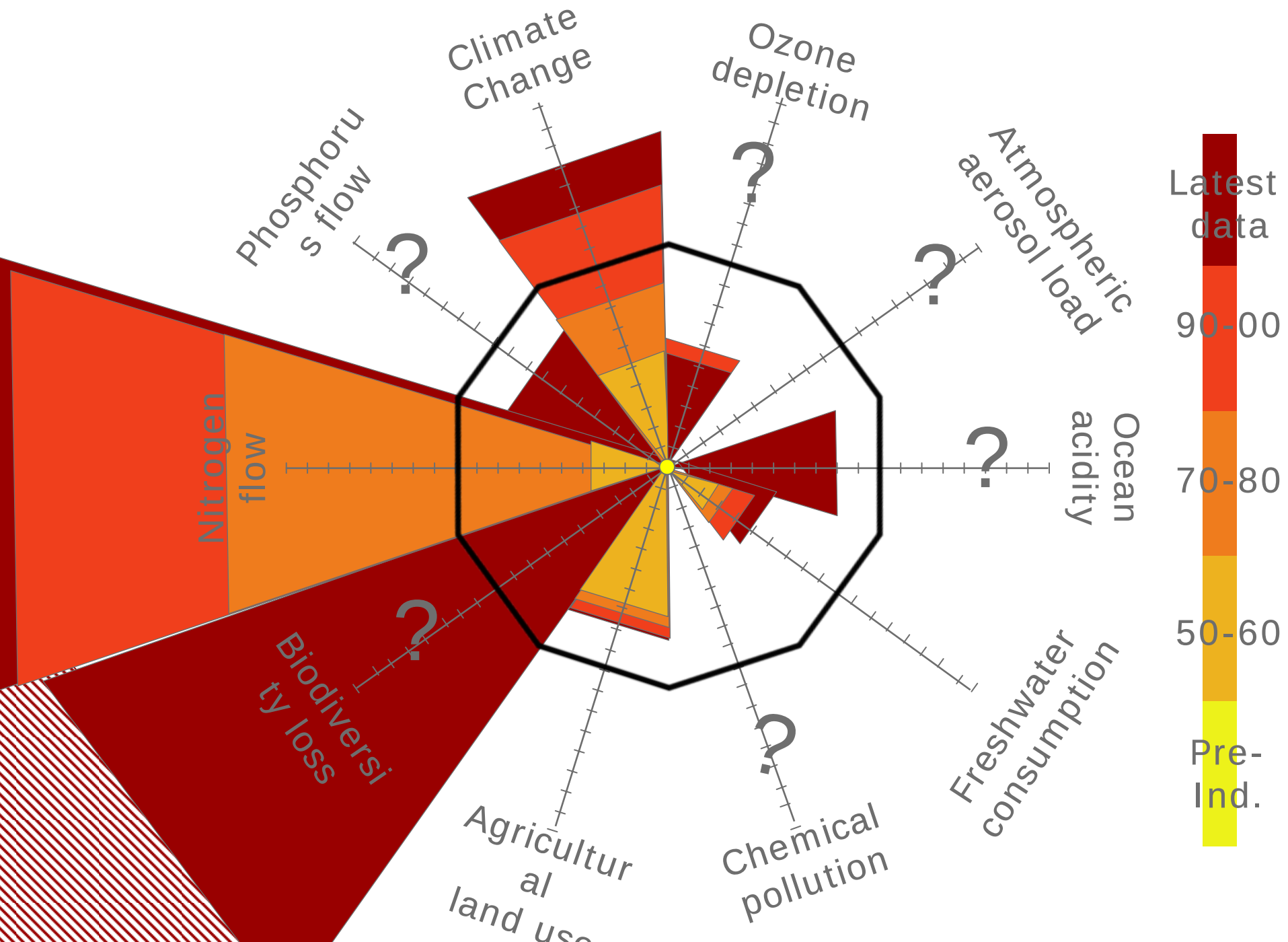
Ocean acidification
Aragonite saturation ratio > 80 % above pre-industrial levels
(> 80% - > 70 %)

Rate of Biodiversity Loss
< 10 E/MSY
(< 10 - < 1000 E/MSY)

Global Freshwater Use
<4000 km^3/yr
(4000 – 6000 km^3/yr)

Land System Change
≤15 % of land under crops
(15-20%)

Chemical Pollution
Plastics, Endocrine Desruptors, Nuclear Waste Emitted globally
To be determined


Climate Change
Ozone depletion
Atmospheric aerosol load
Ocean acidity
Freshwater consumption
Chemical pollution
Agricultural land use
Biodiversity loss
Nitrogen flow
Phosphorus flow
?
Latest data
90-00
70-80
50-60
Pre-Ind.

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:

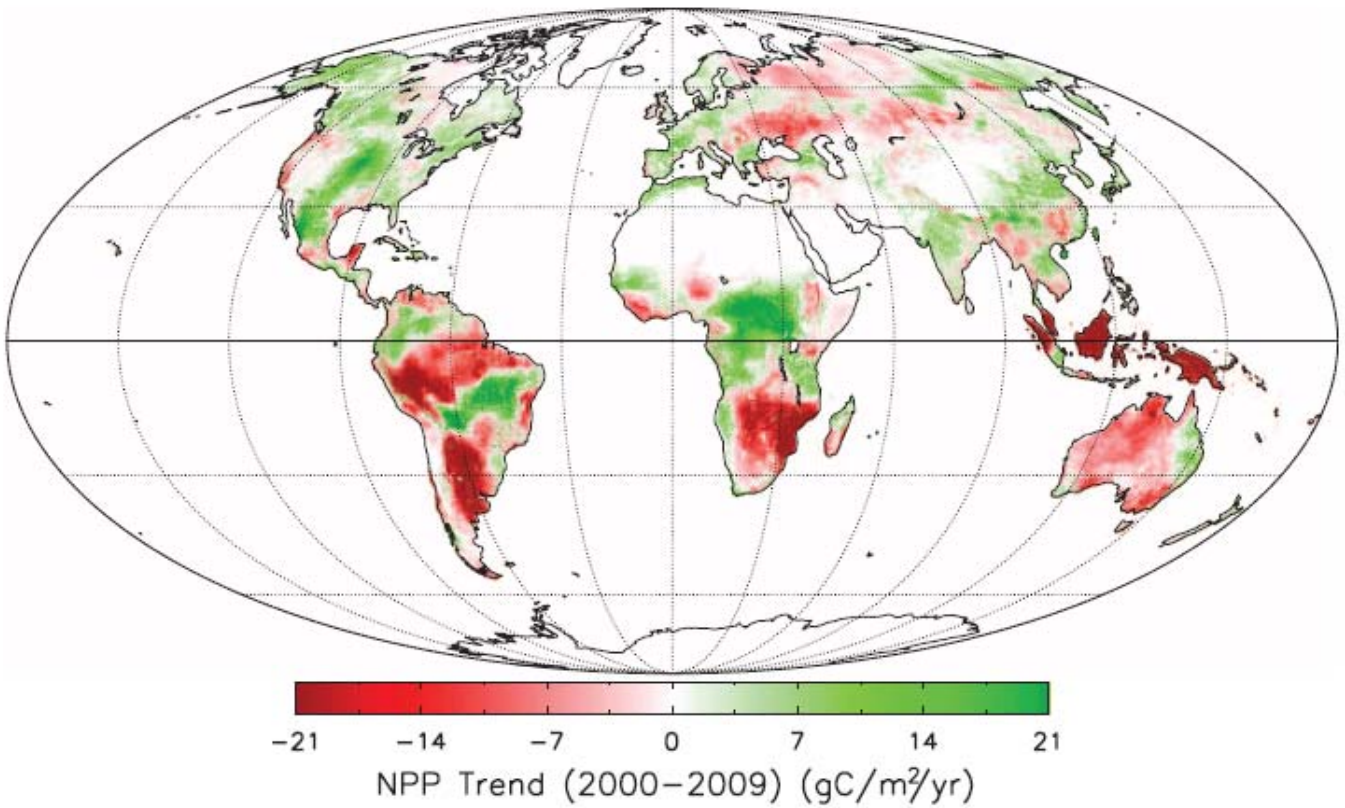


Fig. 2. Spatial pattern of terrestrial NPP linear trends from 2000 through 2009 (SOM text S1) (*8*, *10*).

Bottom line?

(Also) for agriculture…

Business as usual is dead!

The challenge is to feed 9 billion while staying within the Planetary boundaries!

Rate of Biodiversity Loss

Avoid large scale irreversible loss of functional diversity and ecological resilience

The current and projected rate of biodiversity loss constitutes the sixth major extinction event in the history of life on Earth – the first to be driven by human activities on the planet

Humans have increased the rate of species extinction by 100-1,000 times the background rates that were typical over Earth's history

Average global extinction rate projected to increase another 10-fold, to 1,000-10,000 E/MSY during the current century

Suggesting a safe planetary boundary (here placed at 10 E/MSY) of an extinction rate within an order of magnitude of the natural background rate