”What types of data do we need to manage the environment at the global level?”.

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At the Sustainable Development Summit on 25 September 2015, UN Member States will adopt the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and tackle climate change by 2030.

The SDGs, otherwise known as the Global Goals, build on the Millennium Development Goals (MDGs), eight anti-poverty targets that the world committed to achieving by 2015. The MDGs, adopted in 2000, aimed at an array of issues that included slashing poverty, hunger, disease, gender inequality, and access to water and sanitation. Enormous progress has been made on the MDGs, showing the value of a unifying agenda underpinned by

THE GREAT ACCELERATION

SOCIO-ECONOMIC TRENDS

REFERENCE: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig (2015), The Trajectory of the Anthropocene: the Great Acceleration, Submitted to *The Anthropocene Review.*

MAP & DESIGN: Félix Pharand-Deschênes / Globaïa

To manage environmental resources at the global level, we need a ”framework”, i.e. *to define a ”safe operating space”*

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

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years[1,2]. 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[3], in which human actions have become the main driver of global environmental change[4]. 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[4]. Without pressure from humans, the Holocene is expected to continue for at least several thousands of years[5].

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[6,7].

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

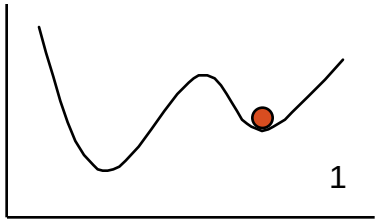
Research

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/

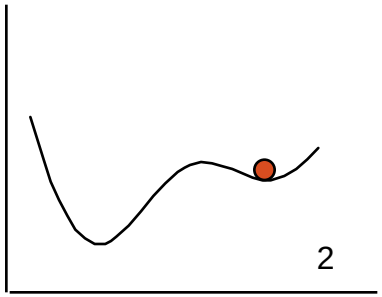
Valuable Ecosystem Services (Desirable) → **Loss of ecosystem services (Undesirable)**



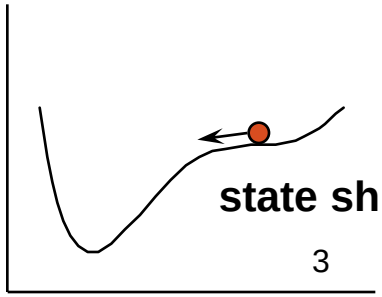
coral dominance

clear water

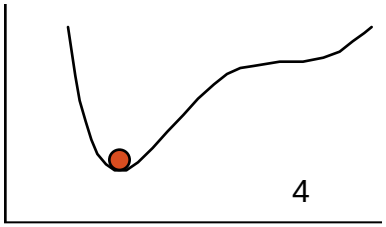
grassland



- 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

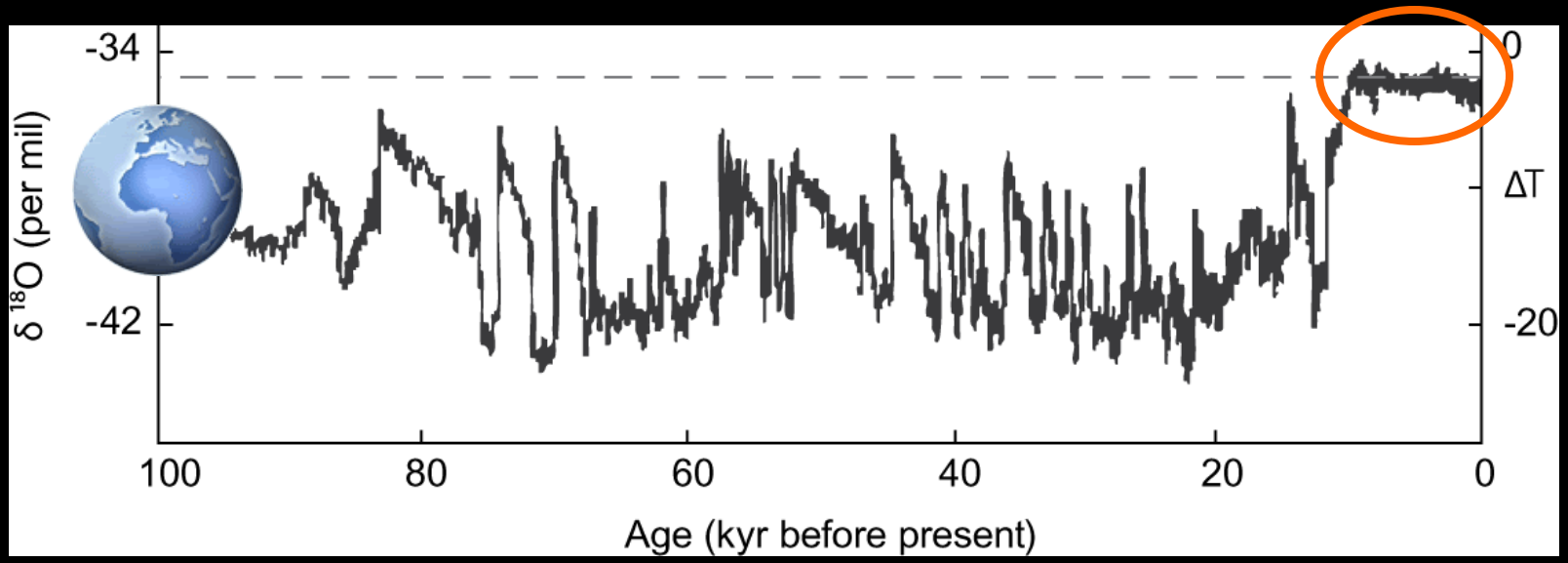


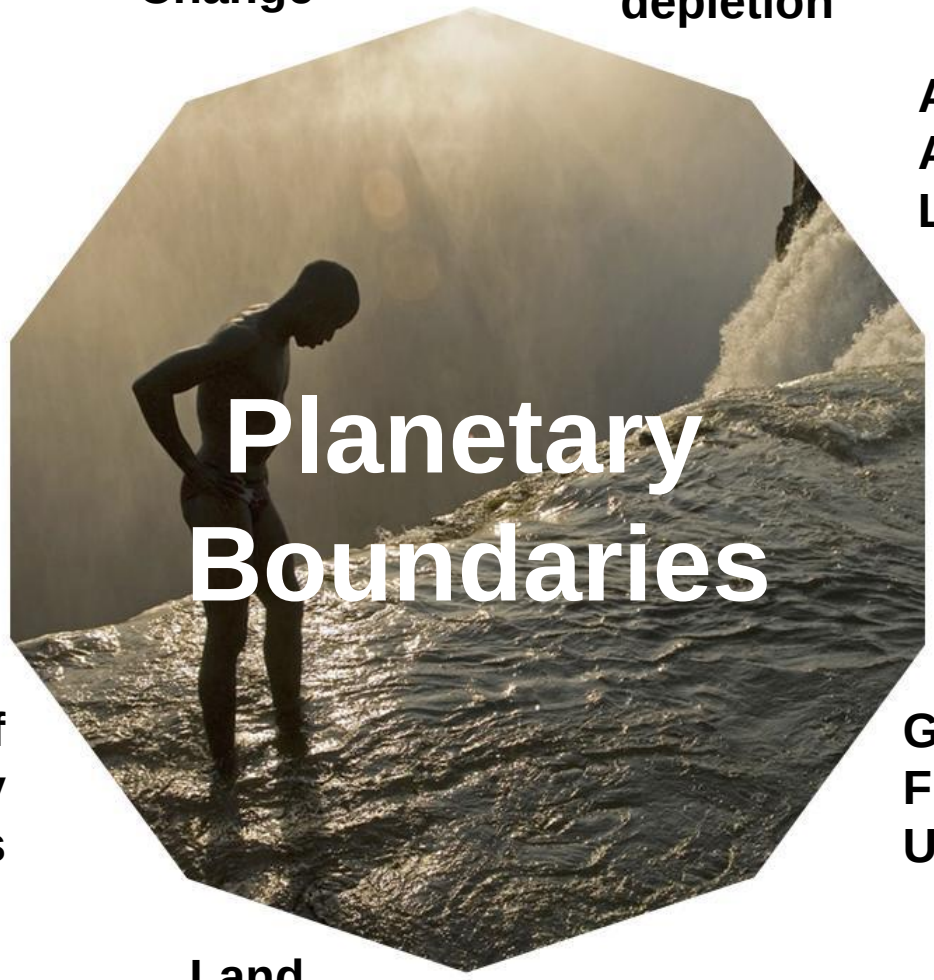
algal dominance

turbid water

shrub-bushland

Humanity's 12,000 years of grace




Climate Change
Ozone depletion
Atmospheric Aerosol Loading
Biogeochemical loading: Global N & P Cycles
Planetary Boundaries
Ocean acidification
Rate of Biodiversity Loss
Global Freshwater Use
Land System Change
Chemical Pollution

Planetary Boundaries:

a potentially valuable framework for guiding policy directed at achieving sustainable development

- **OECD Environmental Outlook 2012**
- **Global Energy Assessment 2012**
- **UNEP 2012**
- **UN High-level Panel on Global Sustainability (GSP) 2012**
- **UN Sustainable Development Solutions Network**
- **World Economic Forum 2013**
- **…**

”Planetary Boundaries 2.0”

Sciencexpress Research Articles

Planetary boundaries: Guiding human development on a changing planet

Will Steffen,[1,2*] Katherine Richardson,[3] Johan Rockström,[1] Sarah E. Cornell,[1] Ingo Fetzer,[1] Elena M. Bennett,[4] R. Biggs,[1,5] Stephen R. Carpenter,[6] Wim de Vries,[7,8] Cynthia A. de Wit,[9] Carl Folke,[1,10] Dieter Gerten,[11] Jens Heinke,[11,12,13] Georgina M. Mace,[14] Linn M. Persson,[15] Veerabhadran Ramanathan,[16,17] B. Reyers,[1,18] Sverker Sörlin[19]

(ii) updating the quantification of most of the PBs; (iii) identifying two core boundaries; and (iv) proposing a regional-level quantitative boundary for one of the two that were not quantified earlier (*1*).

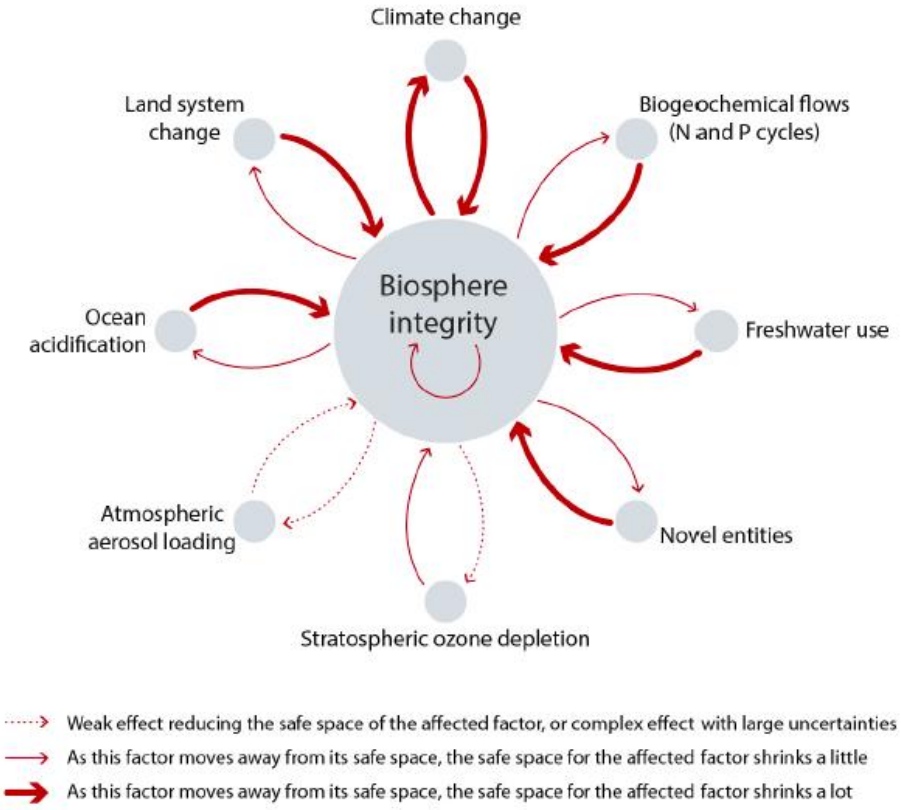
The basic framework: Defining a safe operating space

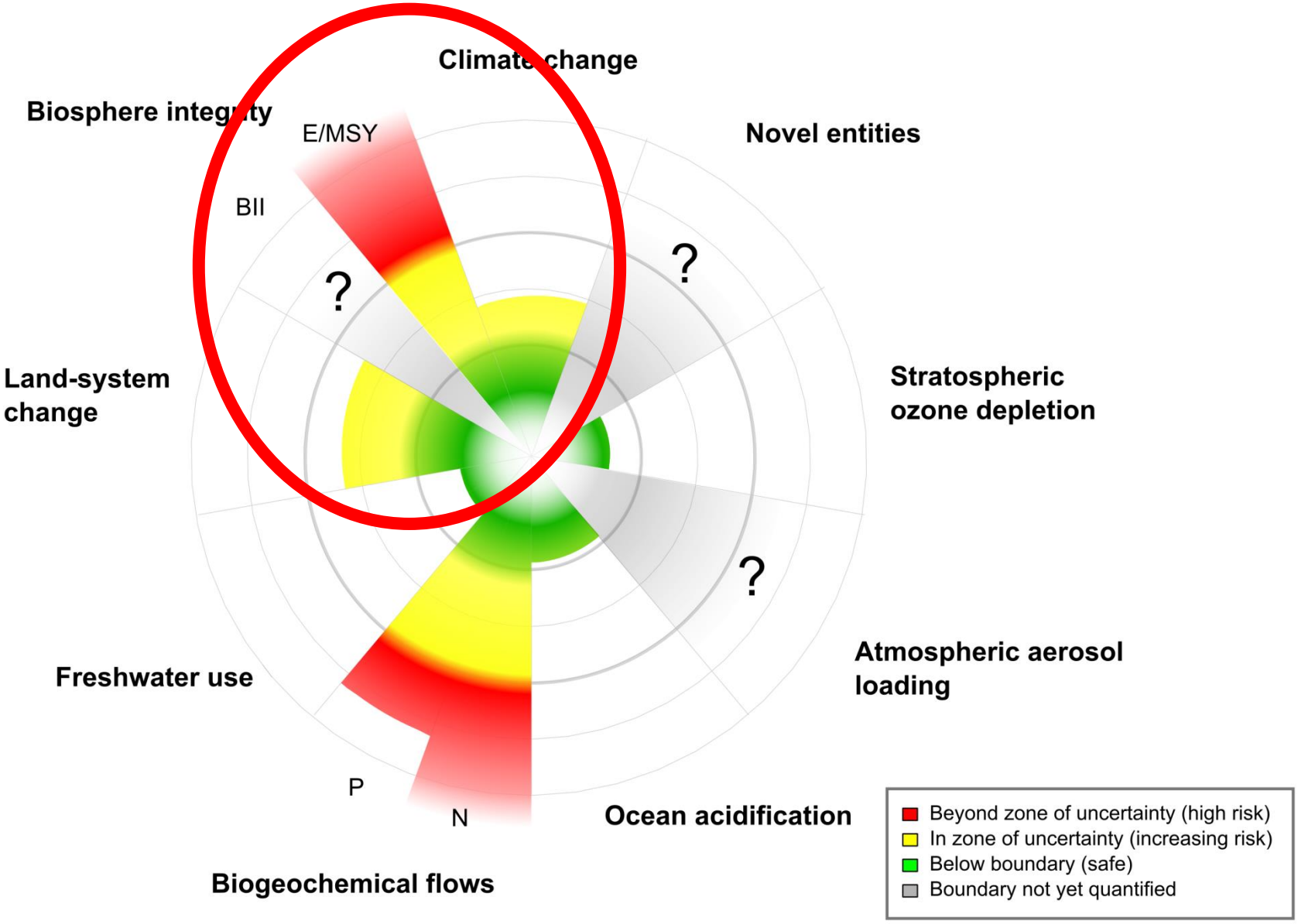
Throughout history, humanity has faced environmental constraints at local and regional

15 January 2015

Two ”CORE” boundaries:

Climate **Biosphere Integrity**




Climate change
Biosphere integrity
E/MSY
BII
Novel entities
?
?
Land-system change
Stratospheric ozone depletion
?
Atmospheric aerosol loading
Freshwater use
P
N
Ocean acidification
Biogeochemical flows
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified

Biosphere/Biodiversity data:

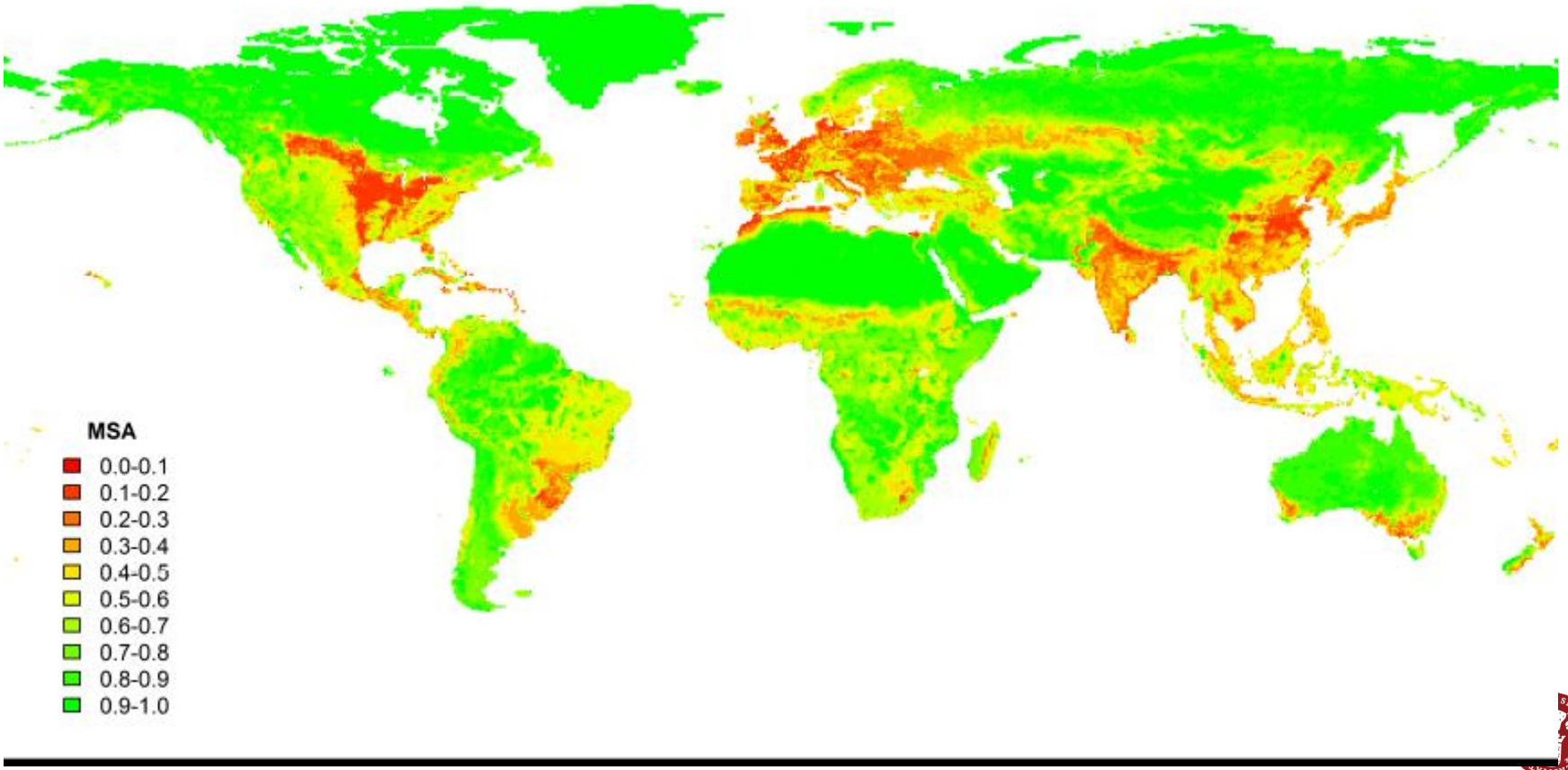
”Loss of genetic diversity (resilience)”

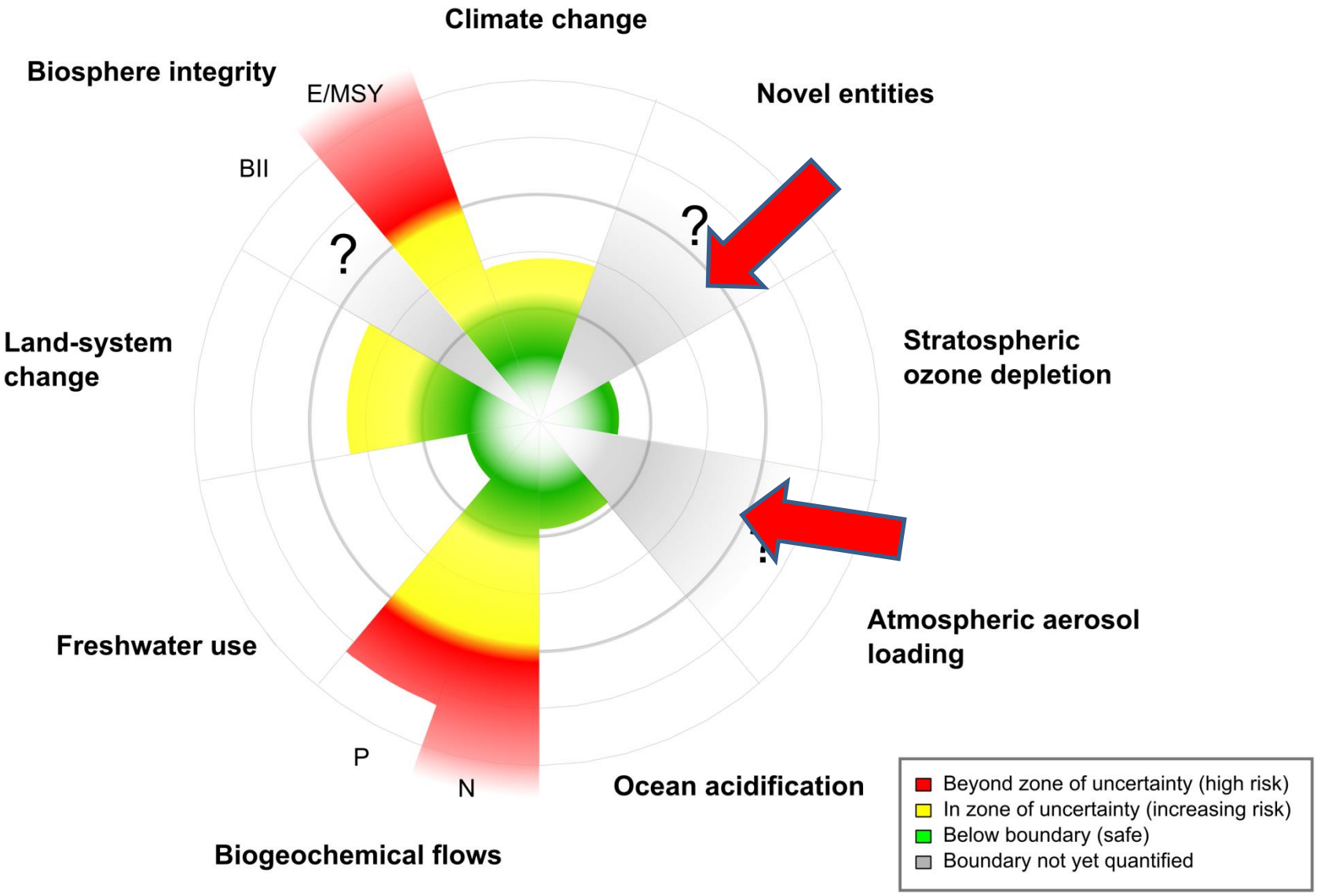
- **Need data that better indicates changes in genetic diversity!**
- *Phylogenetic Species Variability (PSV)?*
- *”Red list” approach is not very interesting in an ES context!*

”Biosphere function”

- **Need indicator(s) of value, range, distribution and relative abundance of functional traits in an ecosystem or biota**
- ? à la Biodiveristy Intactness Indicator ”BII” Scholes and Biggs, 20015, Nature 434)

Biosphere integrity:




Climate change
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P
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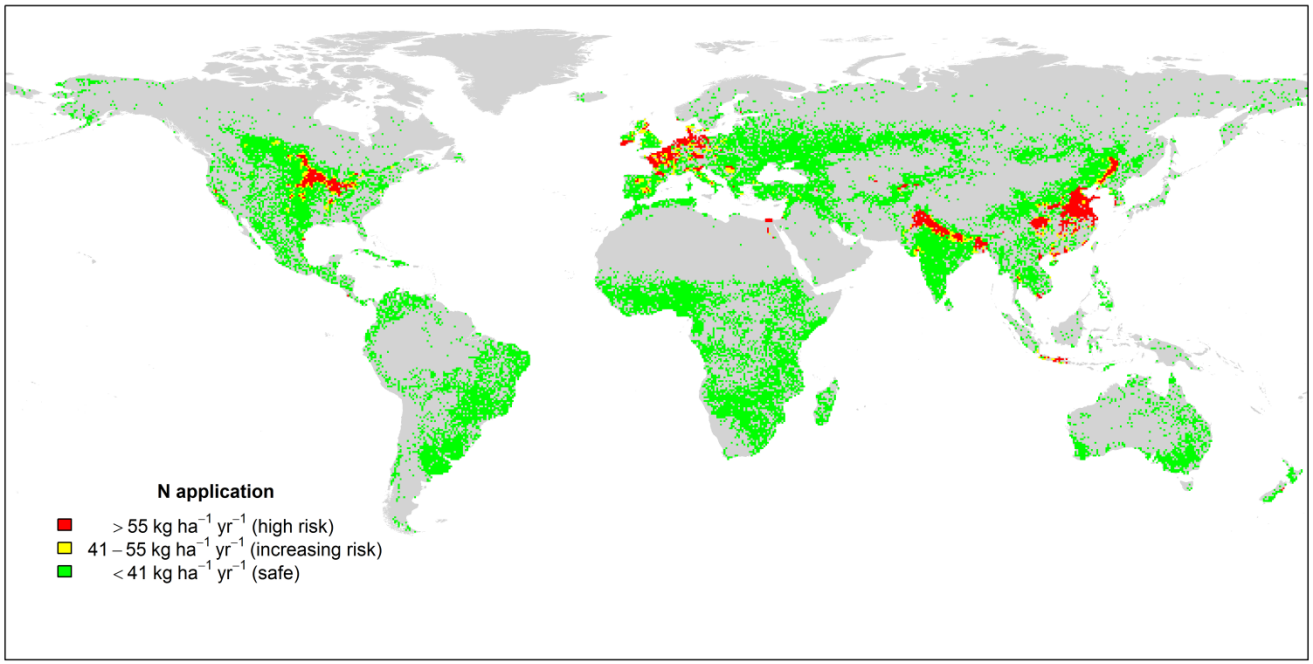
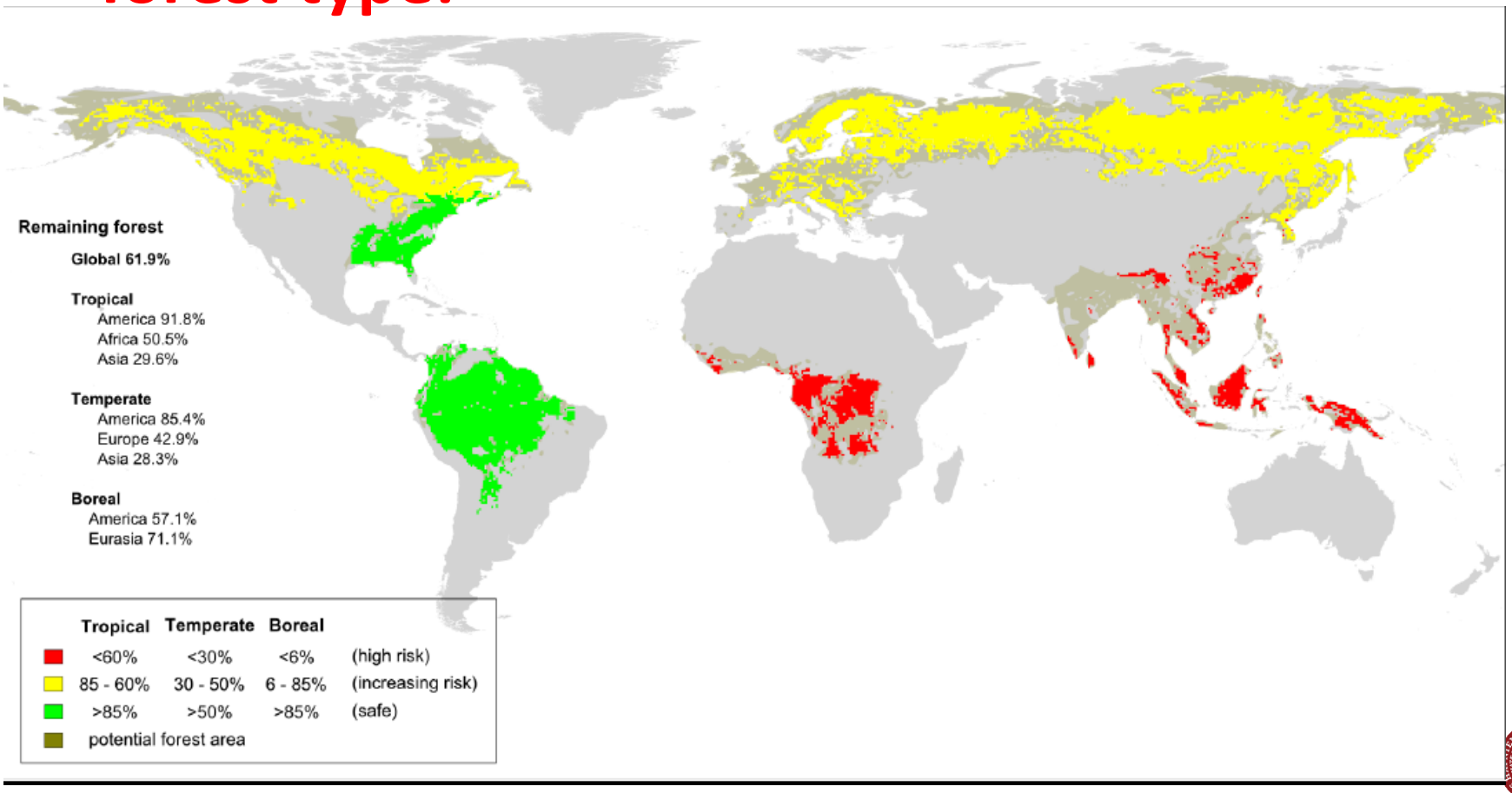
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified

We need better data on the *release of reactive N + P* to the environment

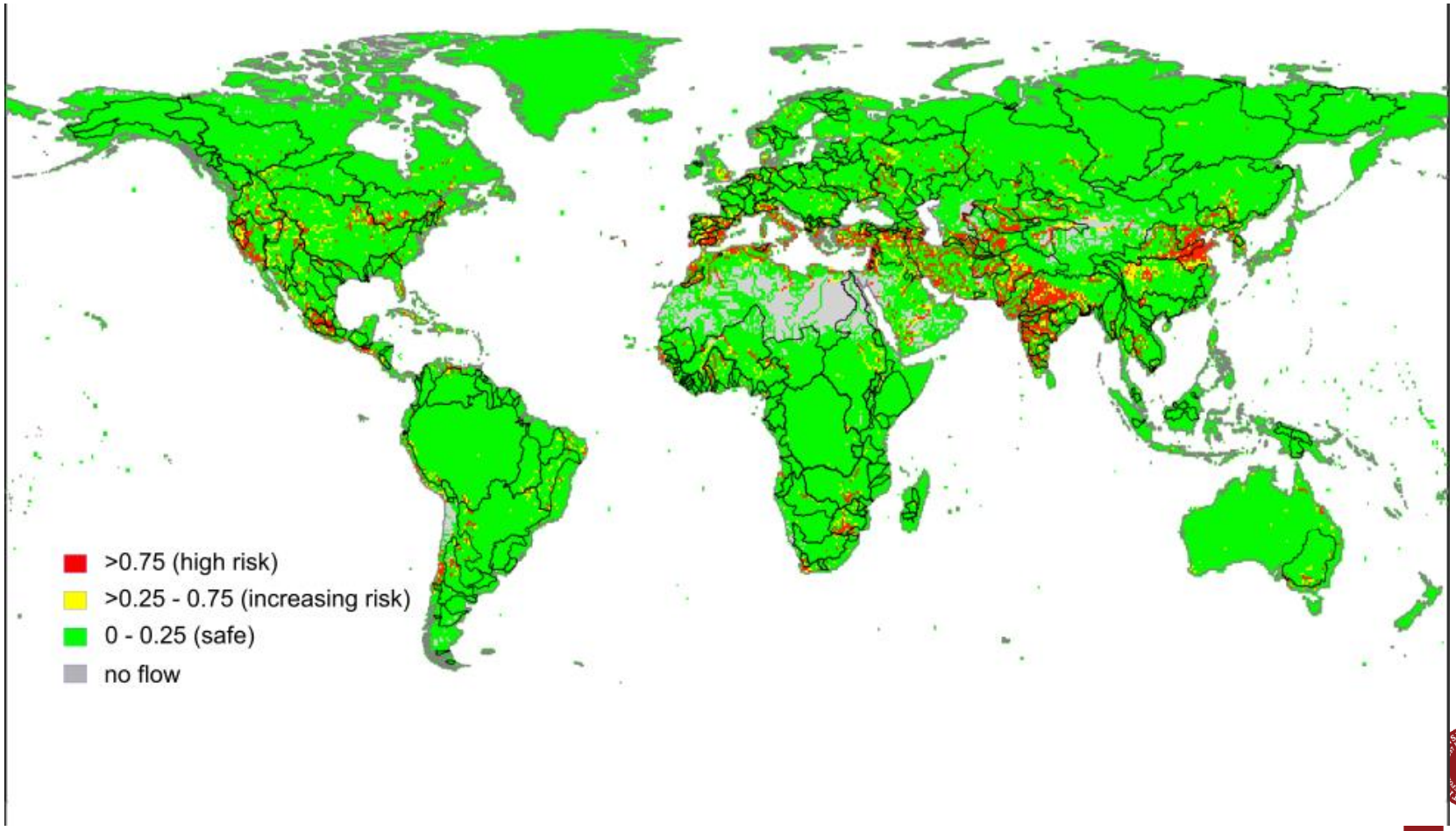
Nitrogen application:



We need monitoring of forest loss by forest type:



We need monitoring of river water removal as a function of natural flow:



- **We need a better understanding of the behaviour of system ”behaviour”:**
  - **Identification of ”thresholds”**

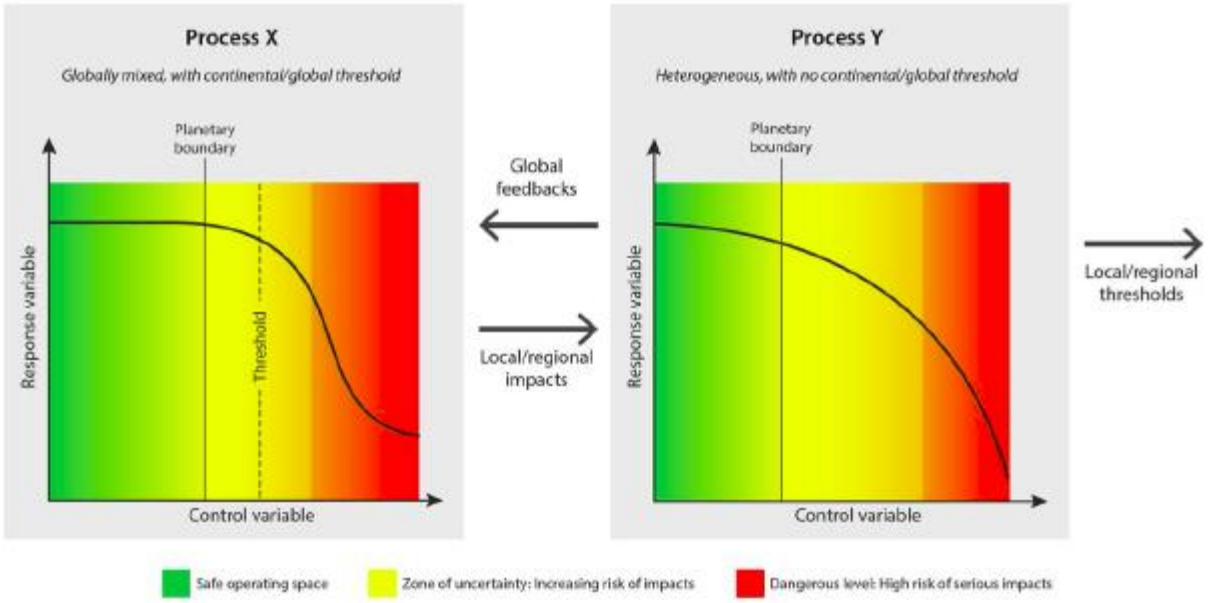
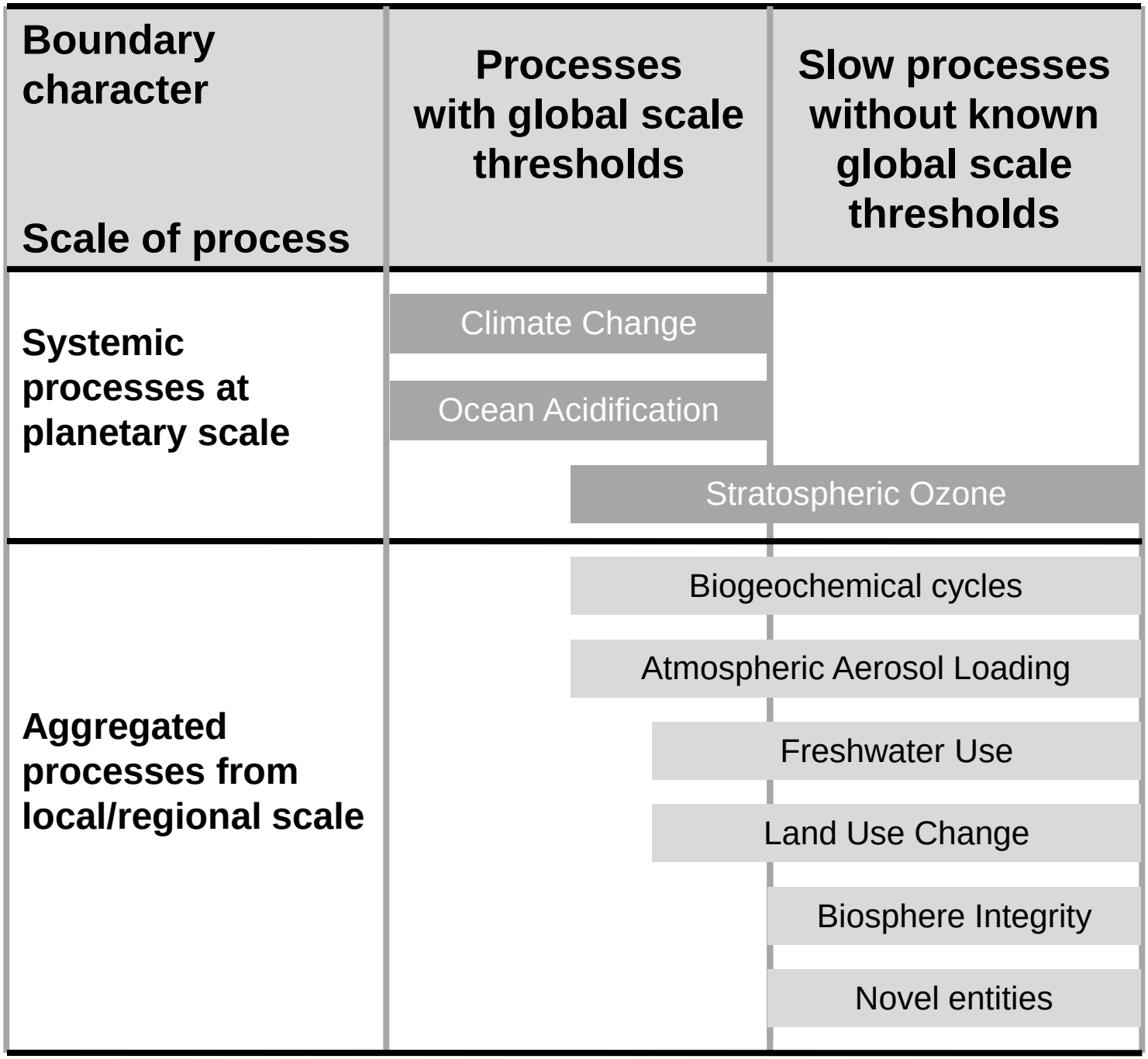


Fig. 1. The conceptual framework for the planetary boundaries approach, showing the safe operating space, the zone of uncertainty, the position of the threshold (where one is likely to exist) and the area of high risk. Modified from (*1*).


Boundary character
Scale of process
Processes with global scale thresholds
Slow processes without known global scale thresholds
Systemic processes at planetary scale
Climate Change
Ocean Acidification
Stratospheric Ozone
Aggregated processes from local/regional scale
Biogeochemical cycles
Atmospheric Aerosol Loading
Freshwater Use
Land Use Change
Biosphere Integrity
Novel entities

SUSTAINABILITY SCIENCE CENTER

- **We need a better understanding of the behaviour of system ”behaviour”:**
  - **Identification of ”thresholds”**
  - **Understanding of interactions between processes**
  - **Better understanding of ranges of variability in the Holocene.**

PBs are scientifically-based levels of human perturbation of the ES beyond which ES functioning may be significantly altered.

The PB framework does not dictate how societies should develop.

By identifying a safe operating space for humanity on Earth, the PB framework can make a valuable contribution to decision-makers in charting desirable courses for societal development and they (or something like them) are essential for SDGs.

”Global Environmental Management”?

Continued development requires that we become stewards of the Earth system and that cannot be be done without science