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E0321

Sustainable Development

– The biggest challenge today?

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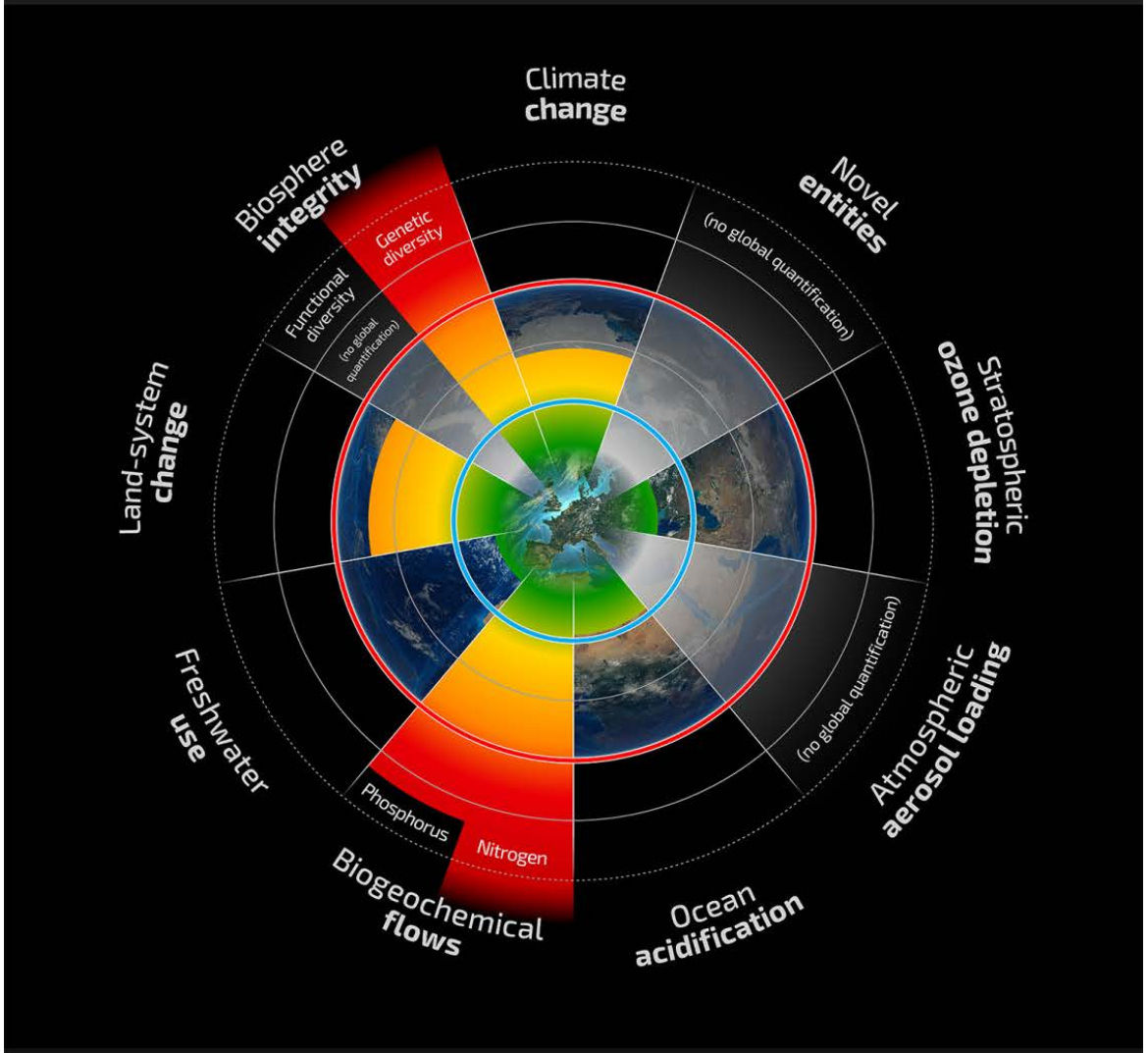
Planetary Boundaries

A safe operating space for humanity



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

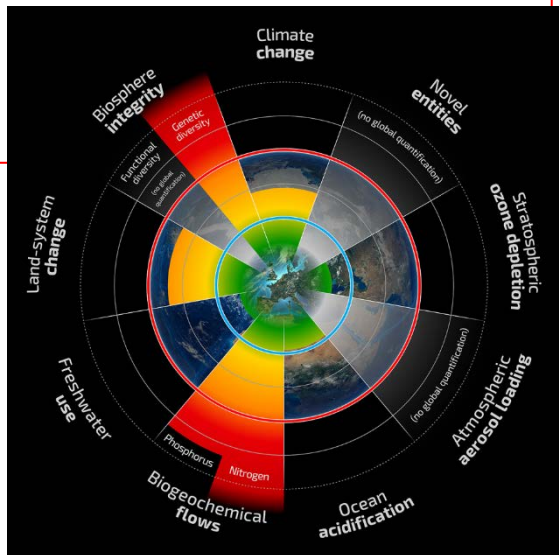
Source: Steffen et al. Planetary Boundaries: Guiding human development on a changing planet, *Science*, 16 January 2015.
Design: Globaia

III. Stratospheric Ozone Depletion

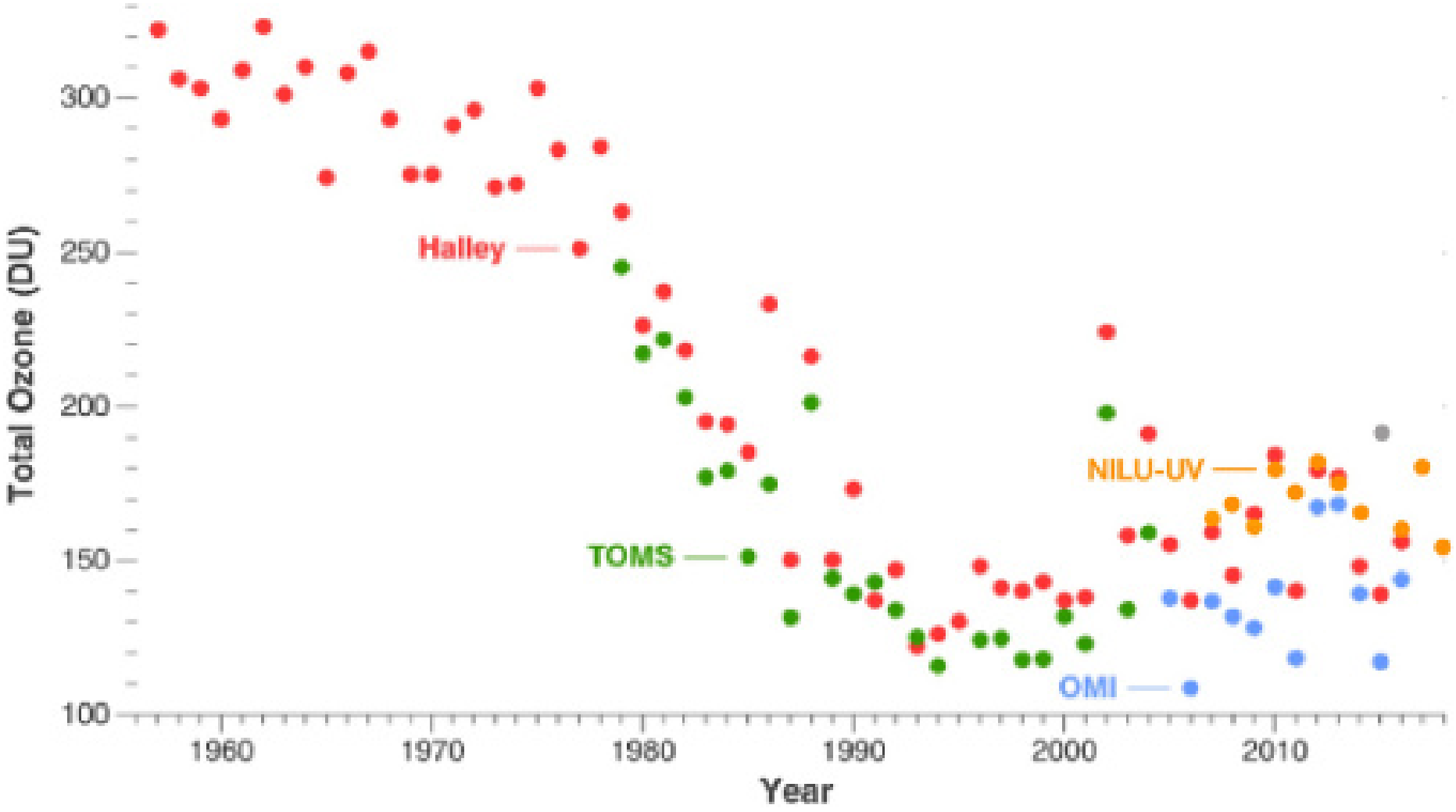
Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Stratospheric ozone depletion (R2009: same)	Stratospheric O_3 concentration, DU	<5% reduction from pre-industrial level of 290 DU (5%–10%), assessed by latitude	Only transgressed over Antarctica in Austral spring (~200 DU)

Boundary: Average conc. of stratospheric O_3 no lower than 276 Dobson units
Current level: 283 Dobson units

Diagnosis: Safe, and improving



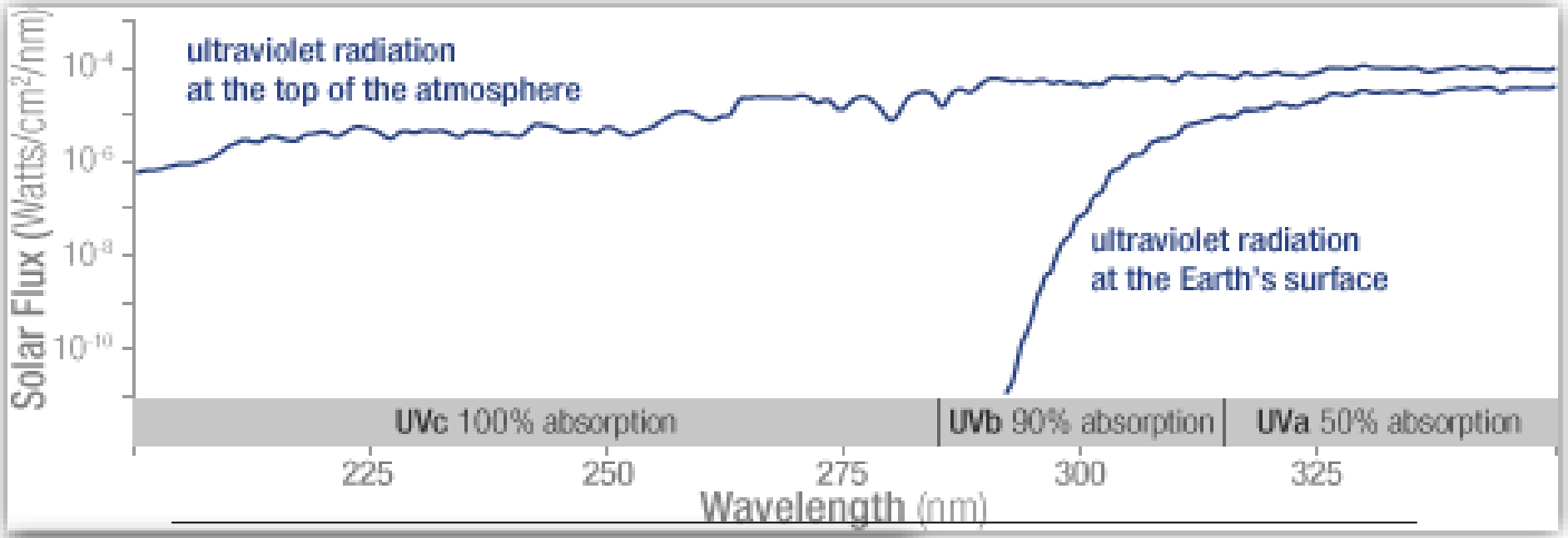
Stratospheric ozone above Antarctica

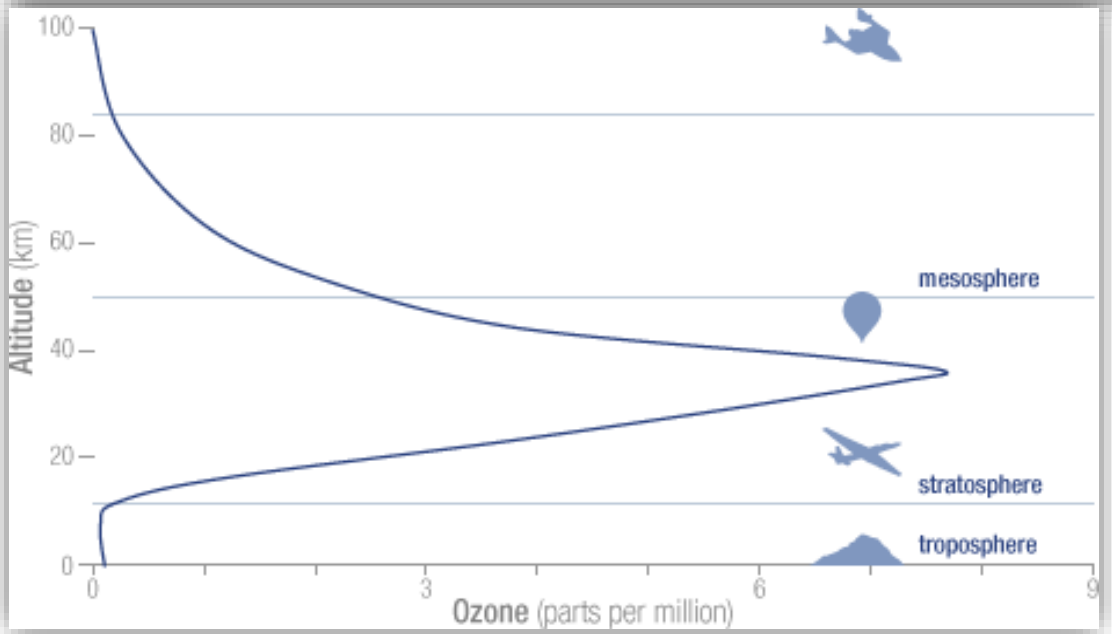


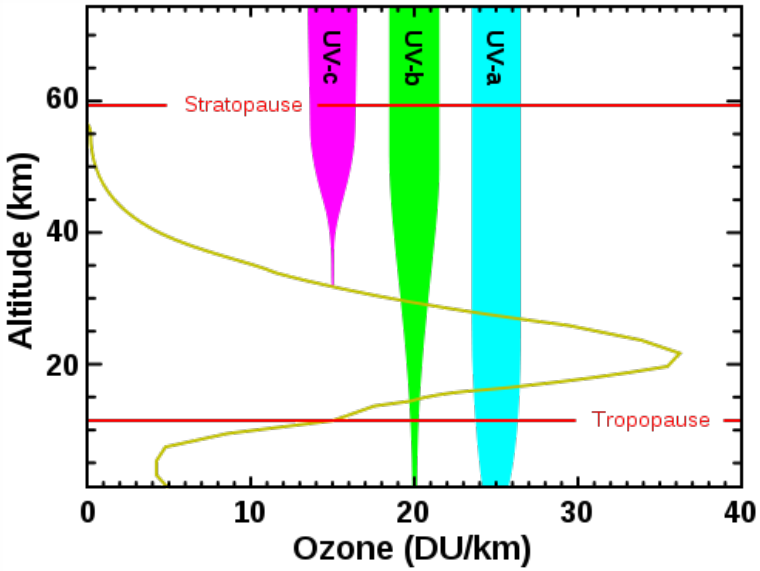
Stratospheric O3 depletion - is it only the one environmental/health issue linked to O3?

Significance of the Ozone Depletion

O_3 – protection of biosphere against harmful UVB radiation

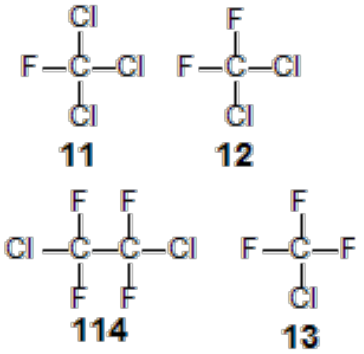






Degradation of O_3 layer

- Cl· radicals from Chloro-fluoro-carbons (CFC, Freon)
- Br· radicals from Bromo-fluoro-carbons (BFC, Halon)



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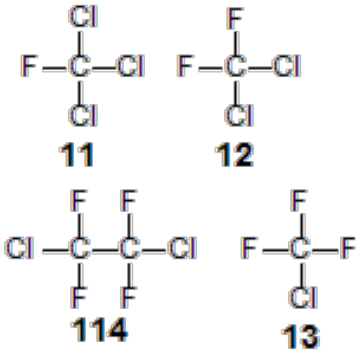
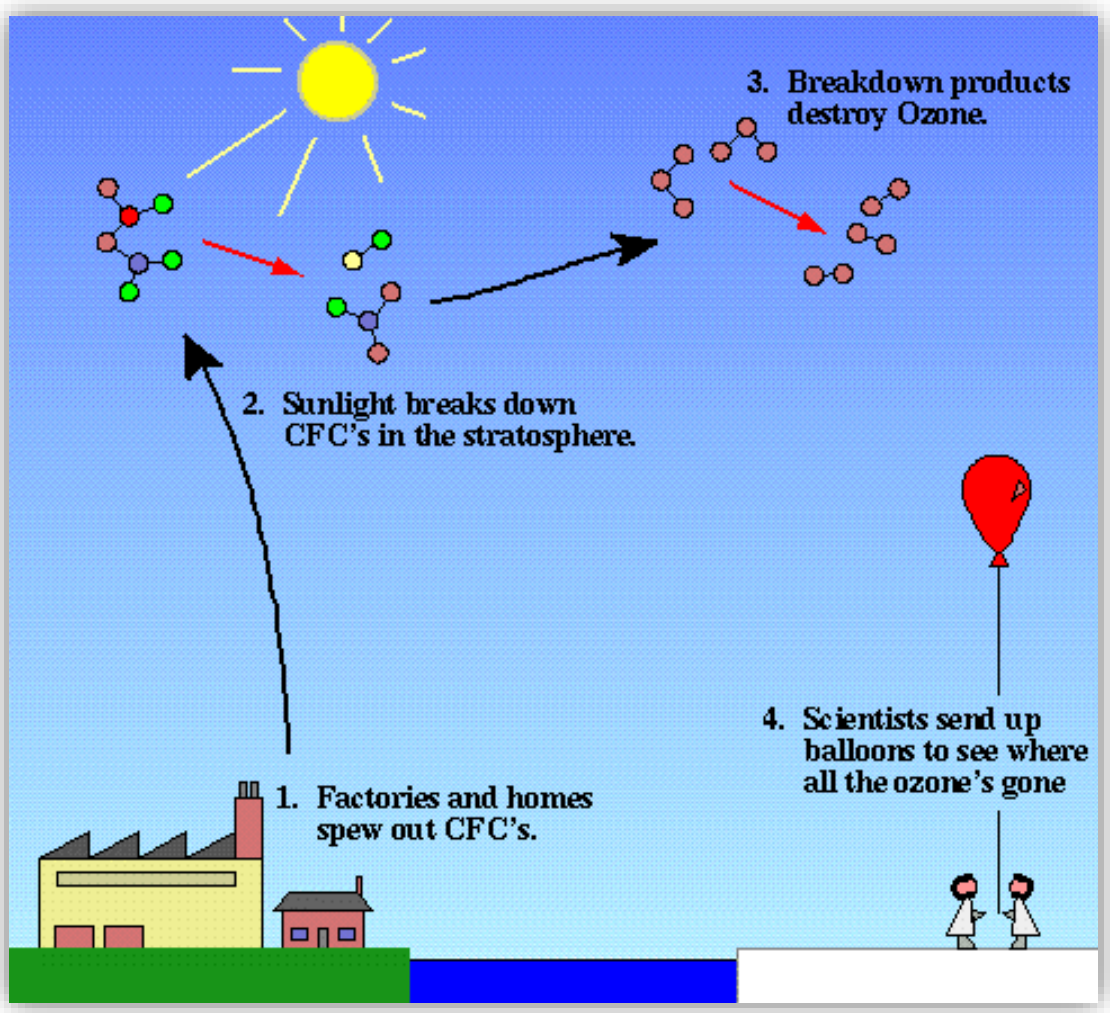
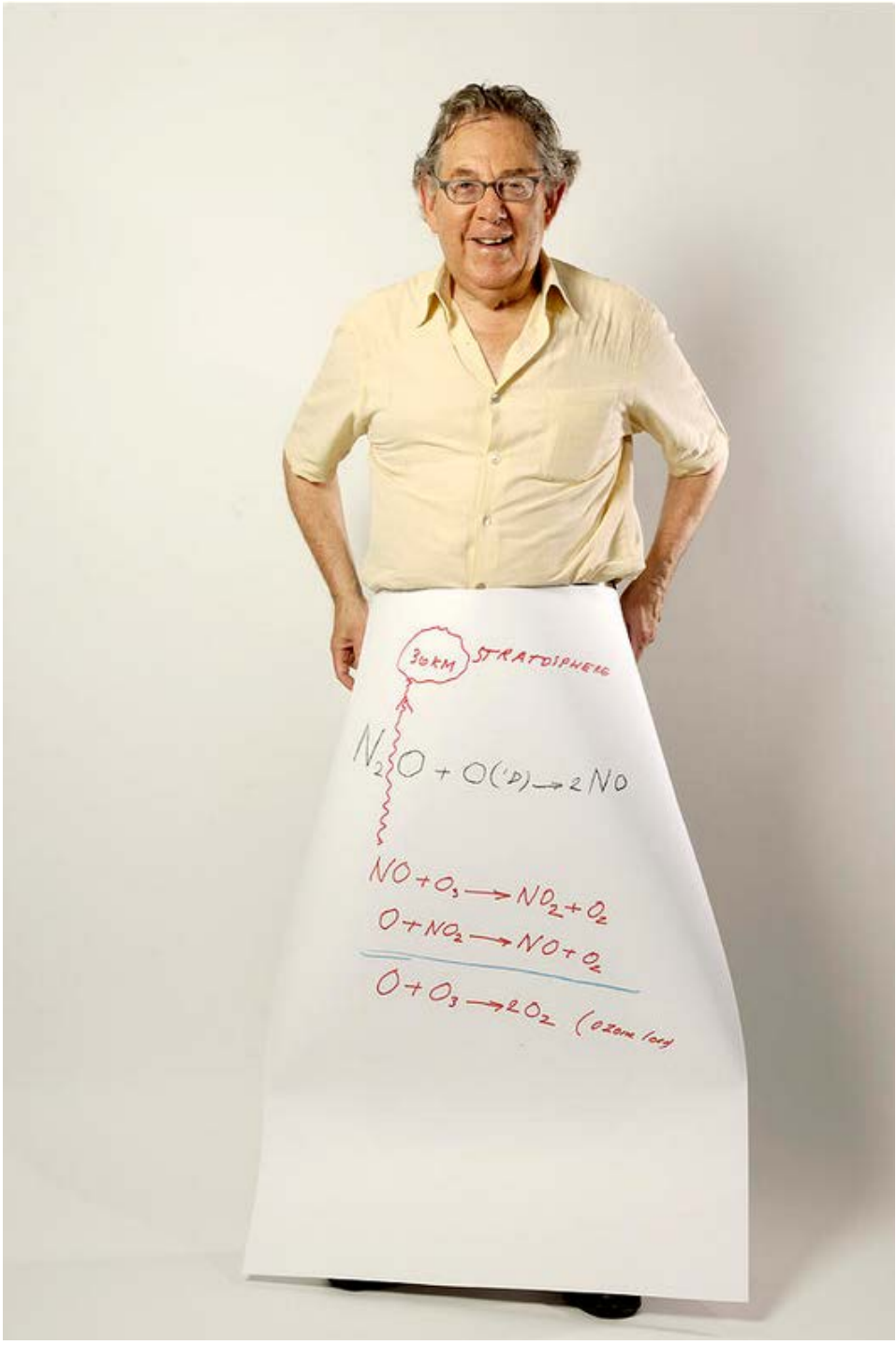




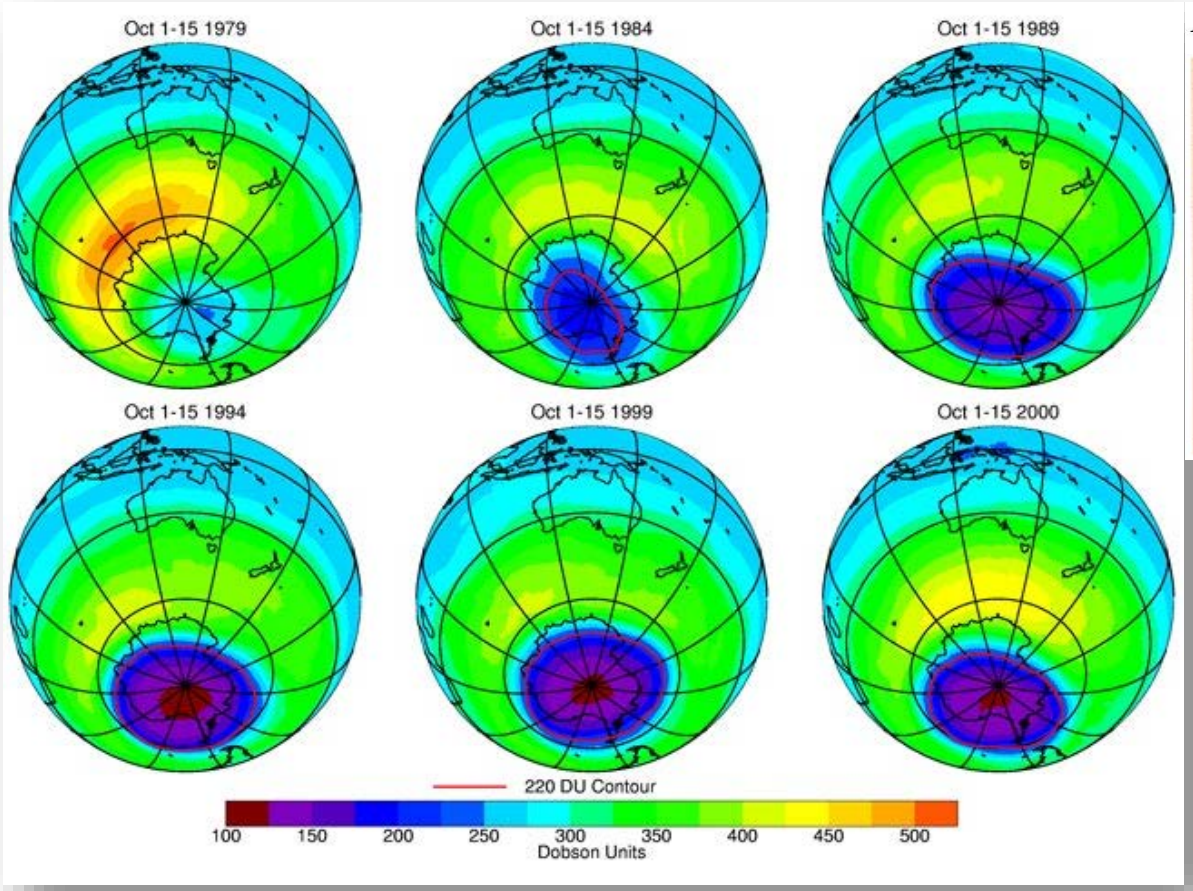
Degradation of O_3 layer

- N_2O from fertilizers

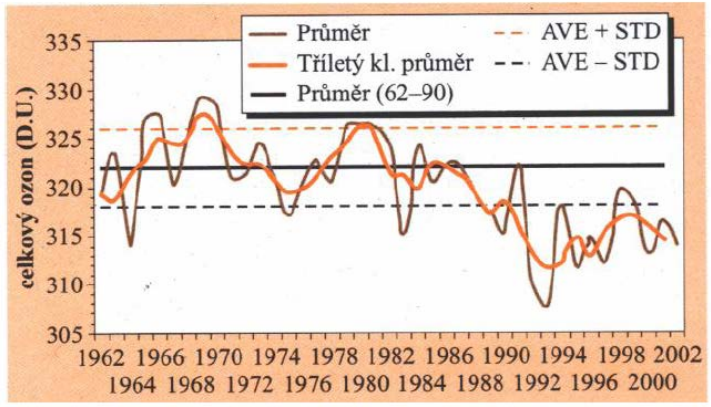


Ozone hole

- ozone depletion primarily over the South pole area
- however, significant O_3 depletion observed everywhere



Průměrné množství ozónu, ČR, 1962–2002

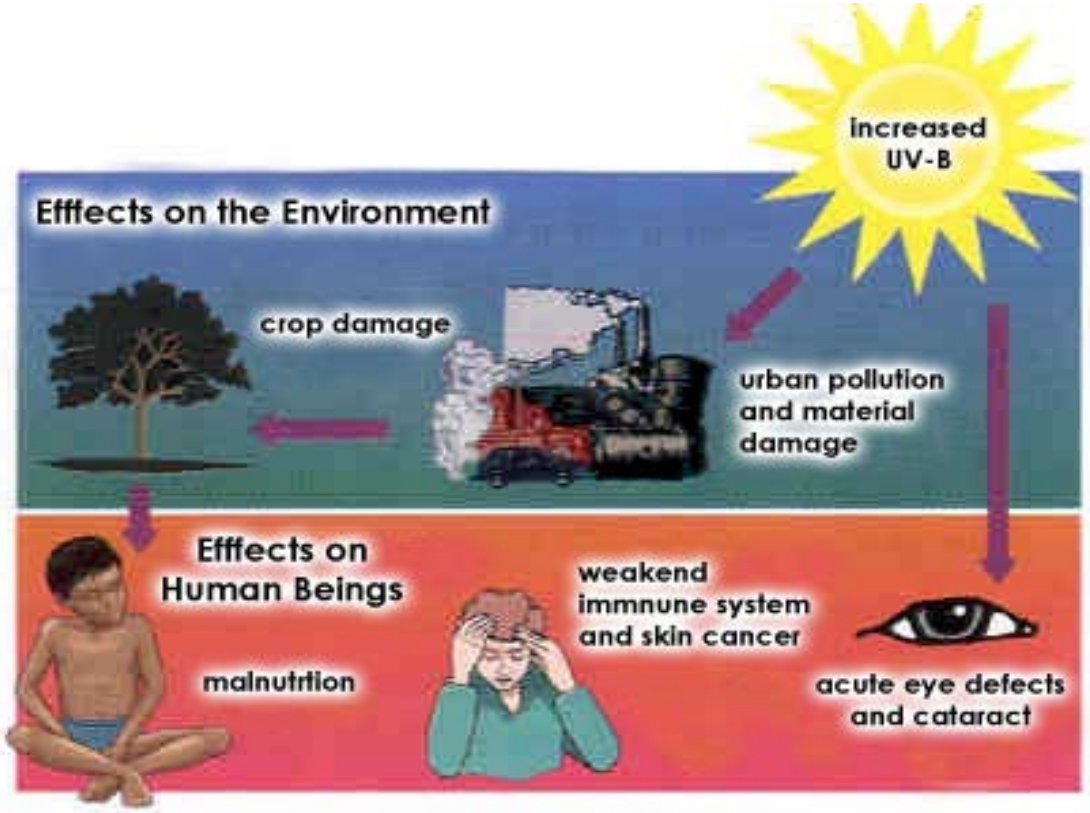


Consequences of O_3 depletion

What are the consequences of the stratospheric ozone depletion?

Less O_3 = more cancer

1% ↓ conc. O_3 ≈ 2% ↑ intensity UVB ≈ 4% ↑ skin cancer hazard



- majority of melanoms are on sunlit parts of the skin
- greatest incidence in Australia

Impact of increased UVB irradiaton on crop

Possible changes in plant characteristics	Consequences	Selected sensitive crops
■ Reduced **photosynthesis** ■ Reduced **water-use efficiency** ■ Enhanced **drought stress sensitivity** ■ Reduced **leaf area** ■ Reduced **leaf conductance** ■ Modified **flowering** (either inhibited or stimulated) ■ Reduced **dry matter production**	Enhanced plant fragility Growth limitation Yield reduction	Rice Oats Sorghum Soybeans Beans

NB: Summary conclusions from artificial exposure studies.

Source: modified from Krupa and Kickert (1989) by Runeckles and Krupa (1994) in: Fakhri Bazzaz, Wim Sombroek, *Global Climate Change and Agricultural Production*, FAO, Rome,1996.

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Ozone hole

- solution

Whta can we do with a stratospheric ozone depletion?

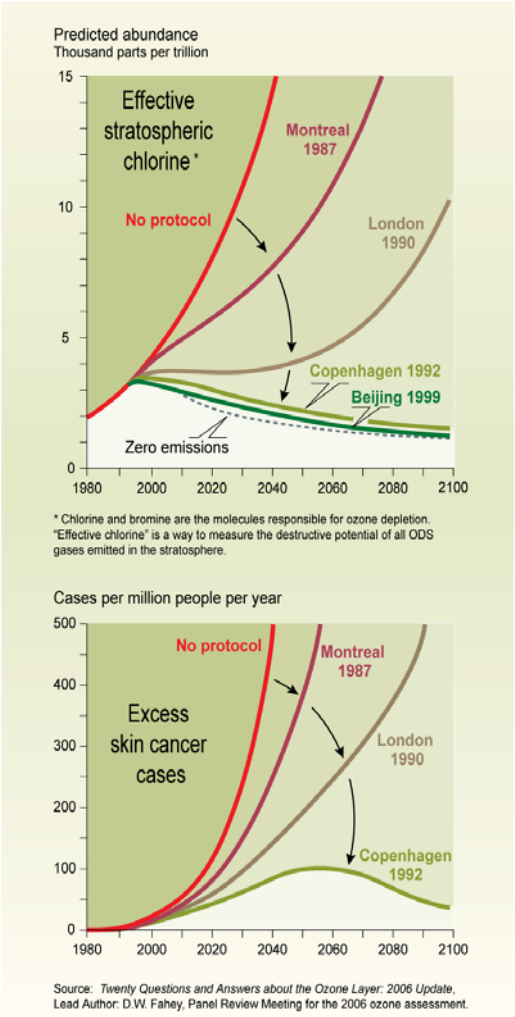
Top

Effect of accepted solutions

1985 – Vienna Convention for the Protection of the Ozone Layer

1987 – Montreal protocol + amendments

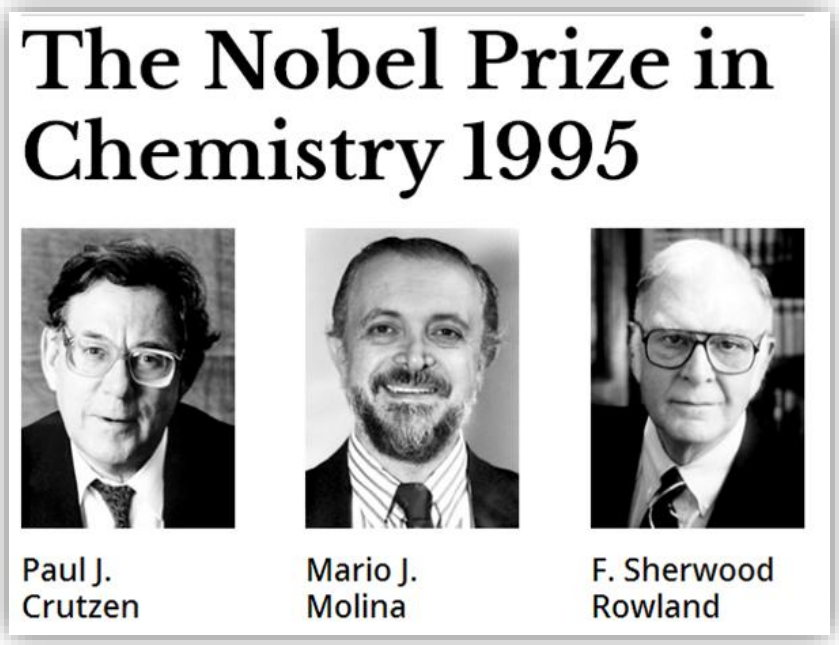
THE EFFECTS OF THE MONTREAL PROTOCOL AMENDMENTS AND THEIR PHASE-OUT SCHEDULES



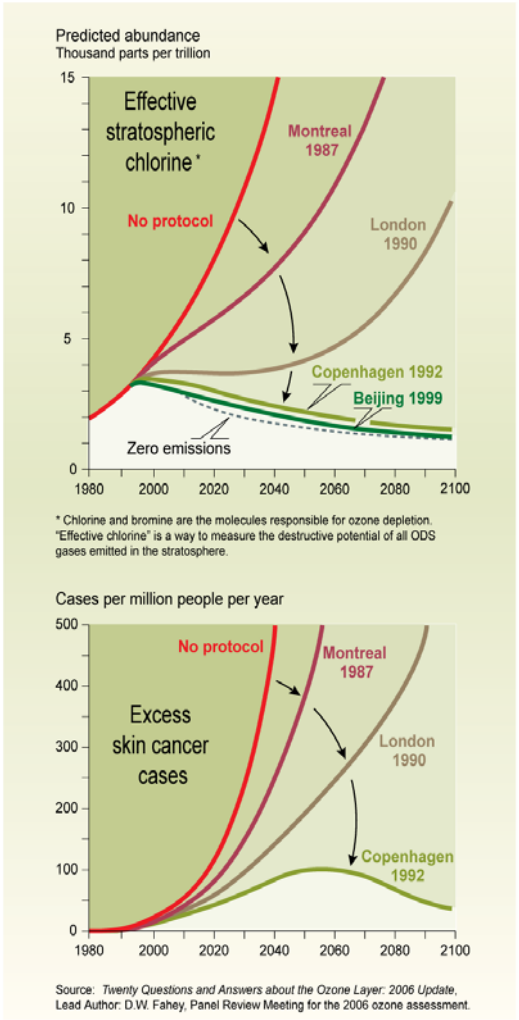
Solutions and consequences

1985 – Vienna Convention for the Protection of the Ozone Layer

1987 – Montreal protocol + amendments



„for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.“



Effect of accepted solutions

1985 – Vienna Convention for the Protection of the Ozone Layer
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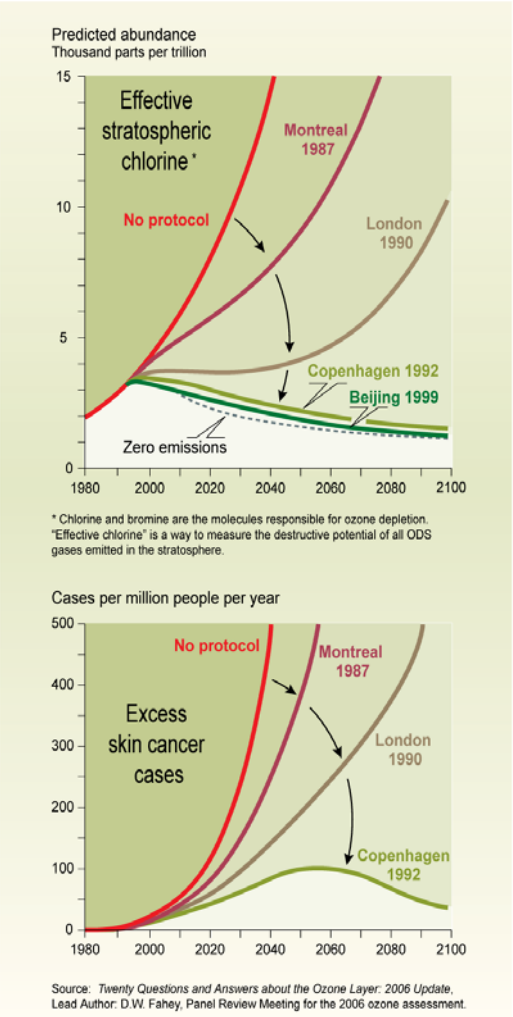
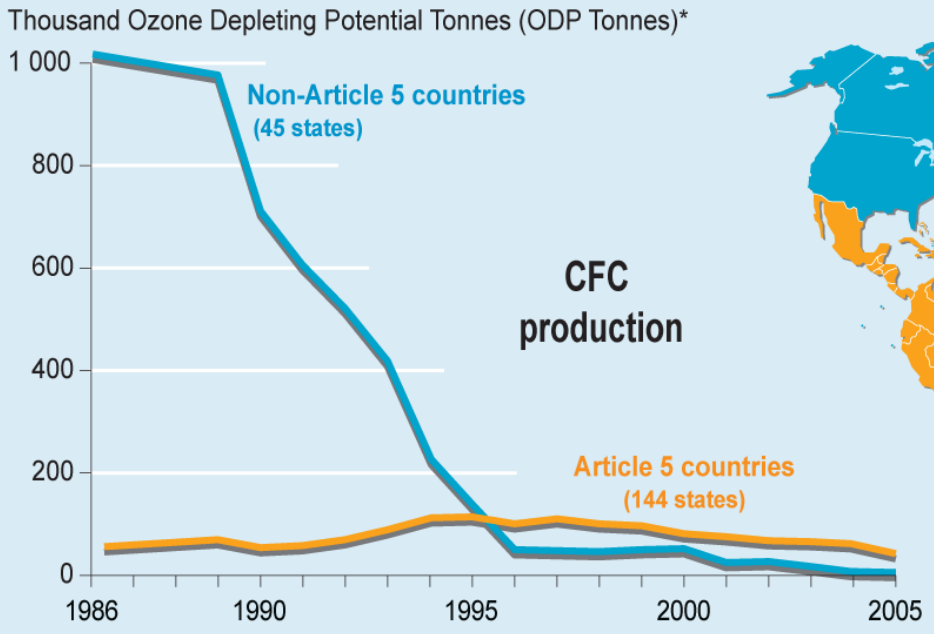
Costs of CFC abandonment

- 1988-2000 – product. decreased for 90%
- overal costs of abandonment - 40 bil. $
- no job losses
- 1/3 simply not necessary
- new HFC in cars increased car price for 50-150 $ (prognosed 1000-1500 $)
- CH_3Br for soil sterilisation replaced e.g. with crop rotation
- CH_3Br for stores fumigation replaced with CO_2

THE EFFECTS OF THE MONTREAL PROTOCOL AMENDMENTS AND THEIR PHASE-OUT SCHEDULES



A common but differentiated responsibility



* Tonnes multiplied by the ozone depleting potential of the considered gas.

Source: United Nations Environment Programme Ozone Secretariat

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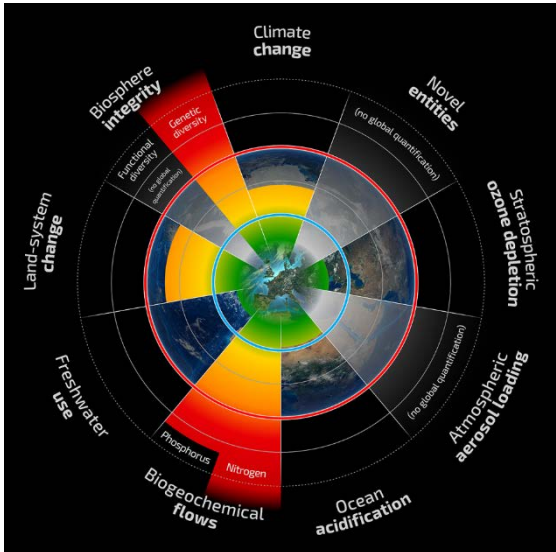
Lesson from successful solution of global issue

- cooperation of all the following stakeholders:

- scientific discoveries and monitoring – **problem notification**
- UNEP – **international coordinator of legal measures**
- environemntal activists – **pressure to solve the issue**
- responsible consuments – **purchasing according to env. info**
- technical experts - **developing env.-friendly alternatives**
- flexible and responsible industry

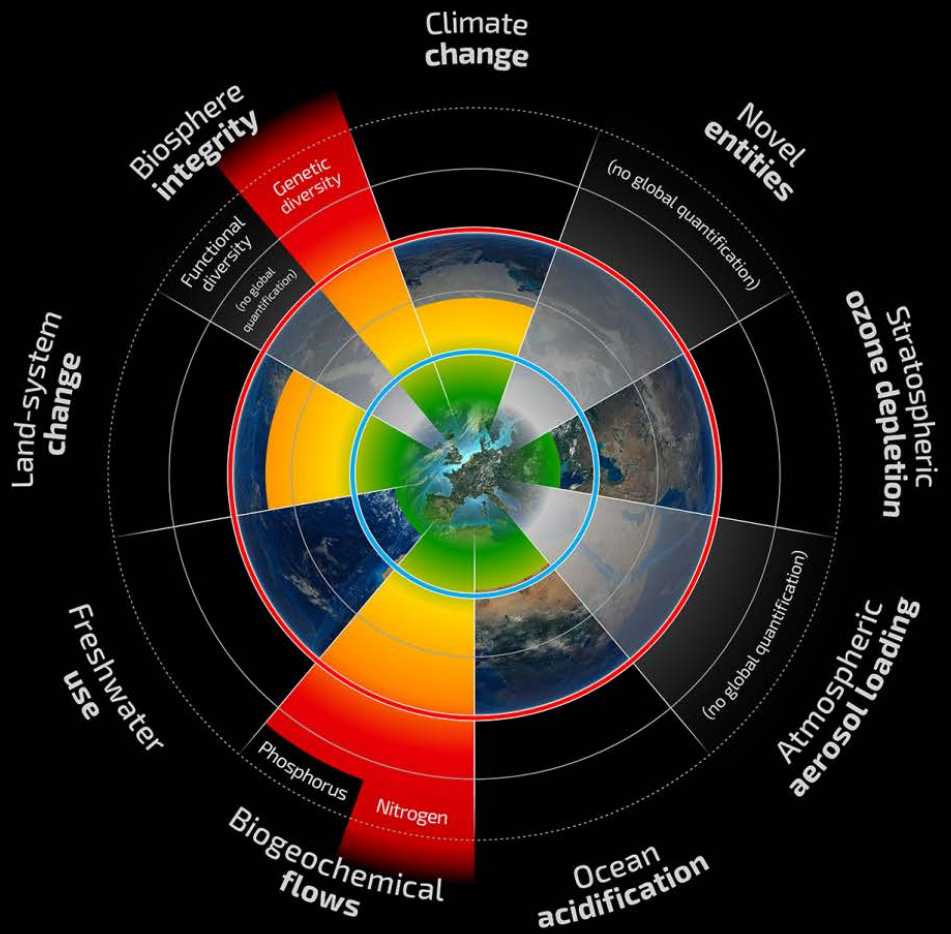
IV. Ocean acidification

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Ocean acidification (R2009: same)	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	≥80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80%– ≥70%)	~84% of the pre-industrial aragonite saturation state



Planetary Boundaries

A safe operating space for humanity



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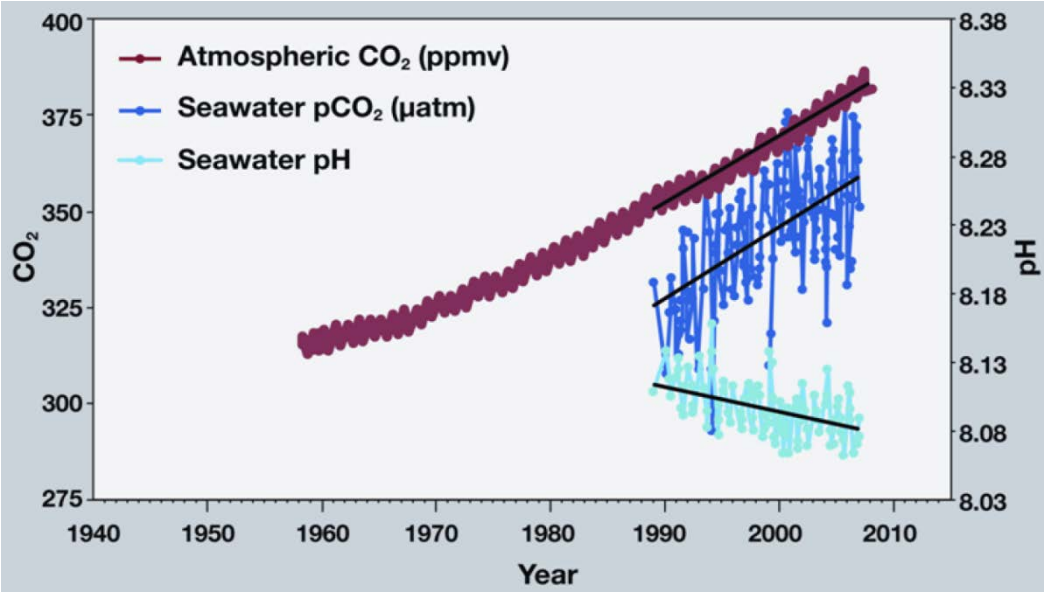
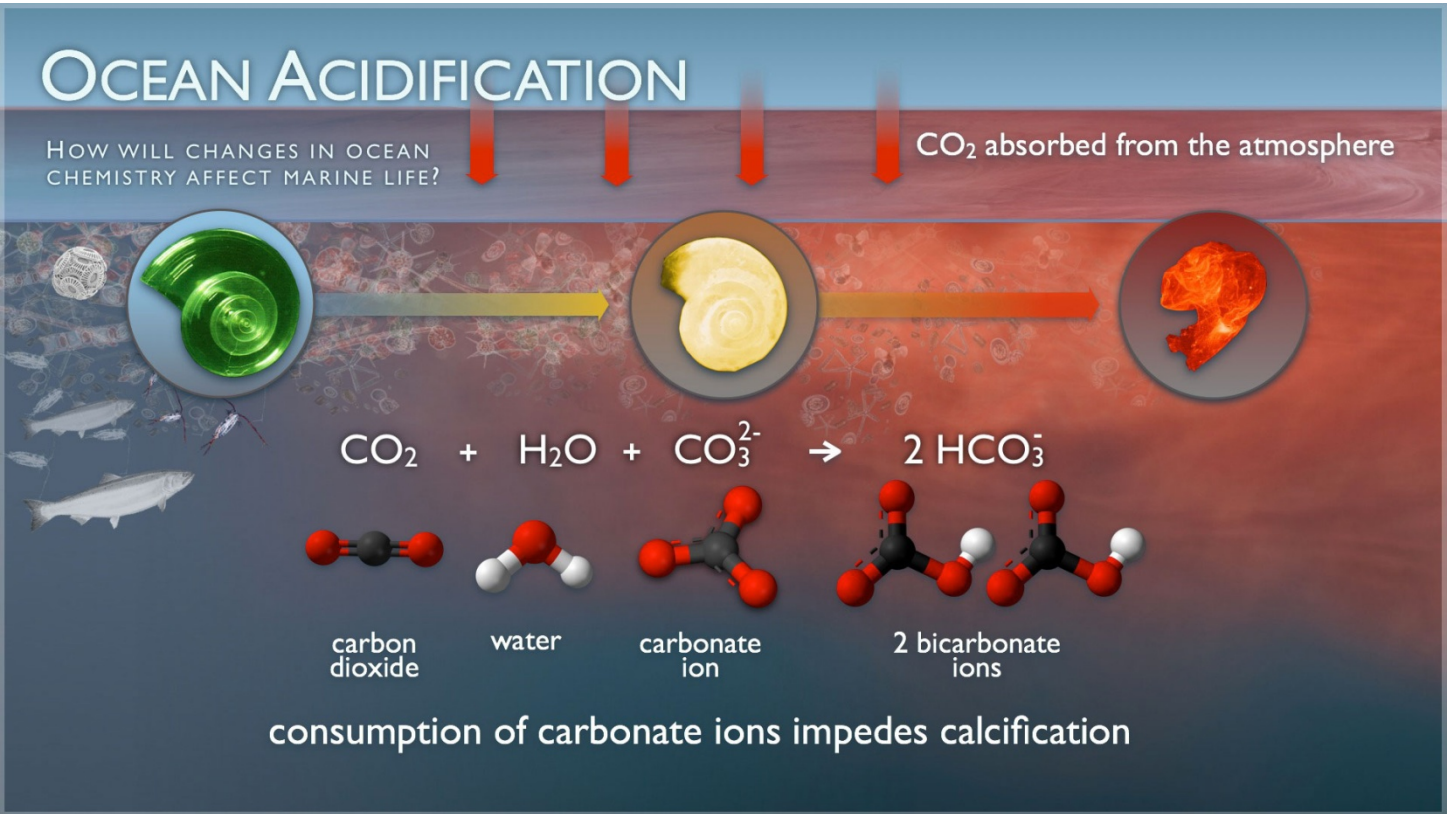
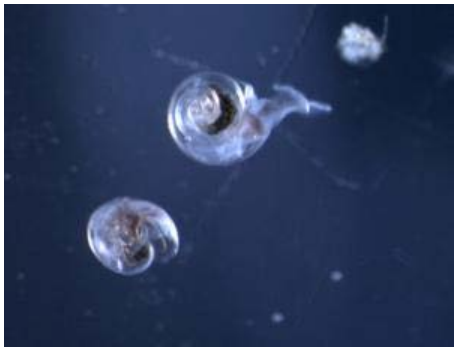
Design: Globaia

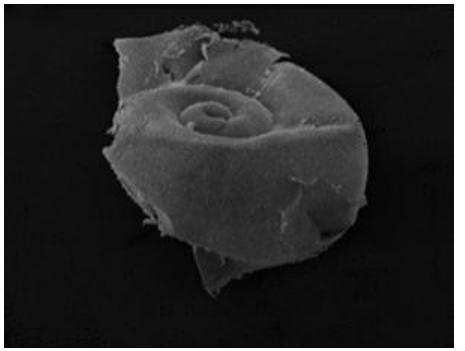
Ocean acidification

- what is the cause?

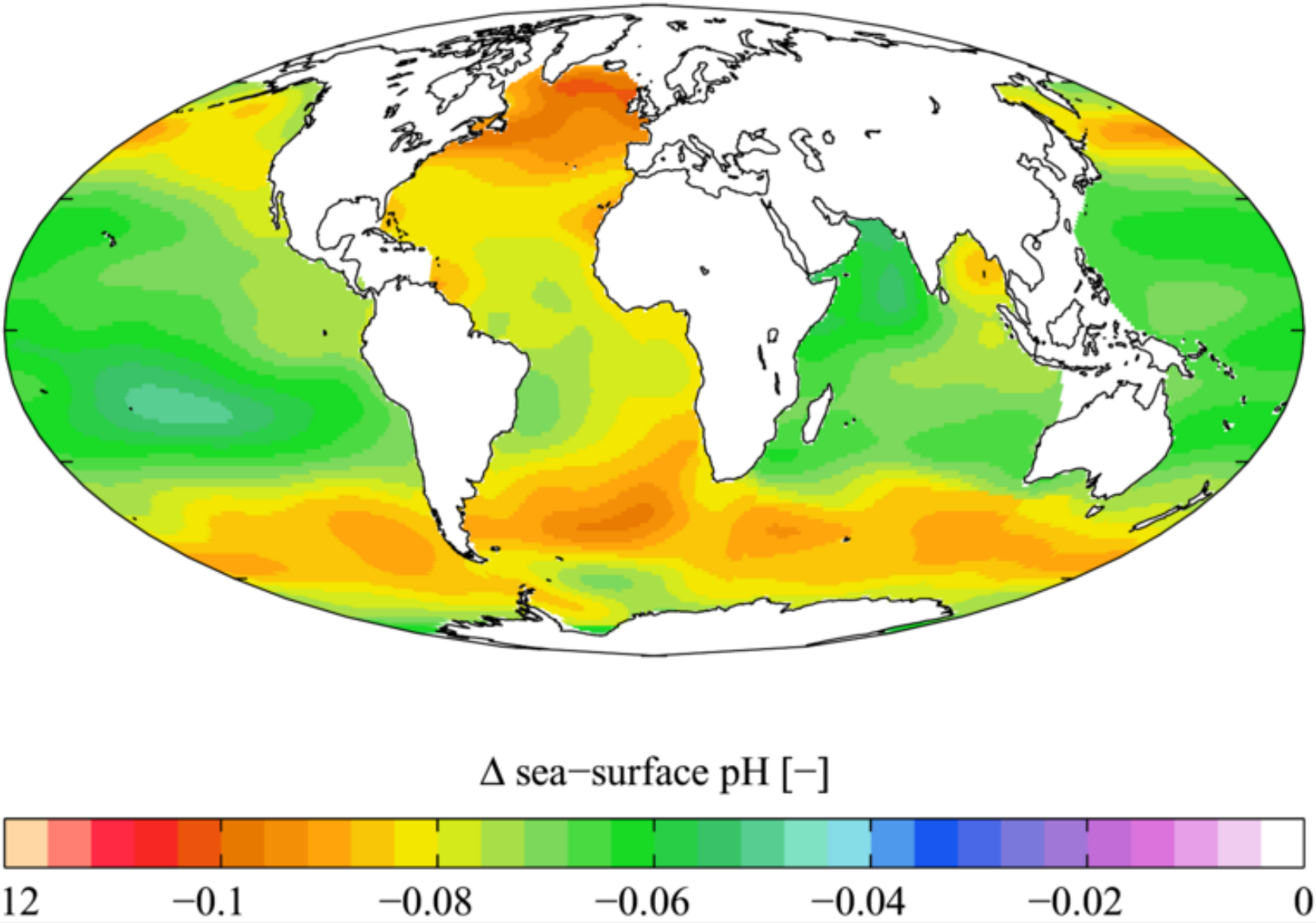








Change in pH of oceans 1700-2000



„Natural laboratory“

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Natural lab shows sea's acid path

By Richard Black
Environment correspondent, BBC News website

Scientists study conditions at the bottom of the Mediterranean Sea

Natural carbon dioxide vents on the sea floor are showing scientists how carbon emissions will affect marine life.

Dissolved CO2 makes water more acidic, and around the vents, researchers saw a fall in species numbers, and snails with their

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26 March 2014 Last updated at 23:03 GMT Share

How climate change will acidify the oceans

By Roger Harrabin
BBC environment analyst, Normanby Island

Off the remote eastern tip of Papua New Guinea a natural phenomenon offers an alarming glimpse into the future of the oceans, as increasing concentrations of CO2 in the atmosphere make sea water more acidic.

Streams of volcanic CO2 bubbles emerge from deep under the seabed here, like a giant jacuzzi.

As the bubbles of carbon dioxide dissolve into the water, carbonic acid is

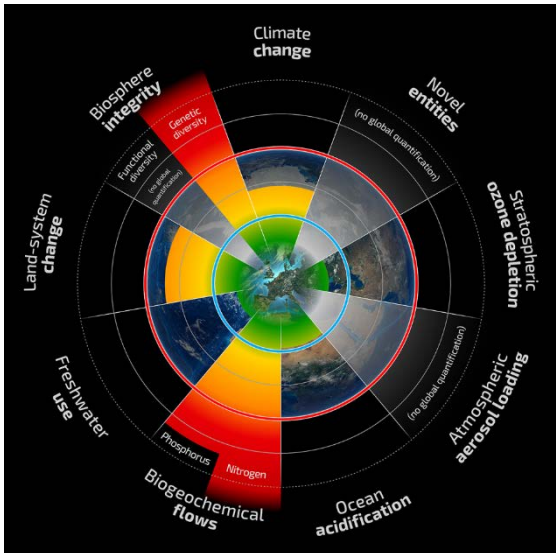
In today's Magazine

One lonely man and his hoard of Nazi art

Malaysia plane: 10 questions that are

V and VI. Biogeochemical flows of P and N

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Biogeochemical flows: (P and N cycles) (R2009: Biogeochemical flows: (interference with P and N cycles))	*P Global*: P flow from freshwater systems into the ocean	11 Tg P yr^{-1} (11–100 Tg P yr^{-1})	~22 Tg P yr^{-1}
	P Regional: P flow from fertilizers to erodible soils	6.2 Tg yr^{-1} mined and applied to erodible (agricultural) soils (6.2-11.2 Tg yr^{-1}). Boundary is a global average but regional distribution is critical for impacts.	~14 Tg P yr^{-1}
	N Global: Industrial and intentional biological fixation of N	62 Tg N yr^{-1} (62–82 Tg N yr^{-1}). Boundary acts as a global 'valve' limiting introduction of new reactive N to Earth System, but regional distribution of fertilizer N is critical for impacts.	~150 Tg N yr^{-1}



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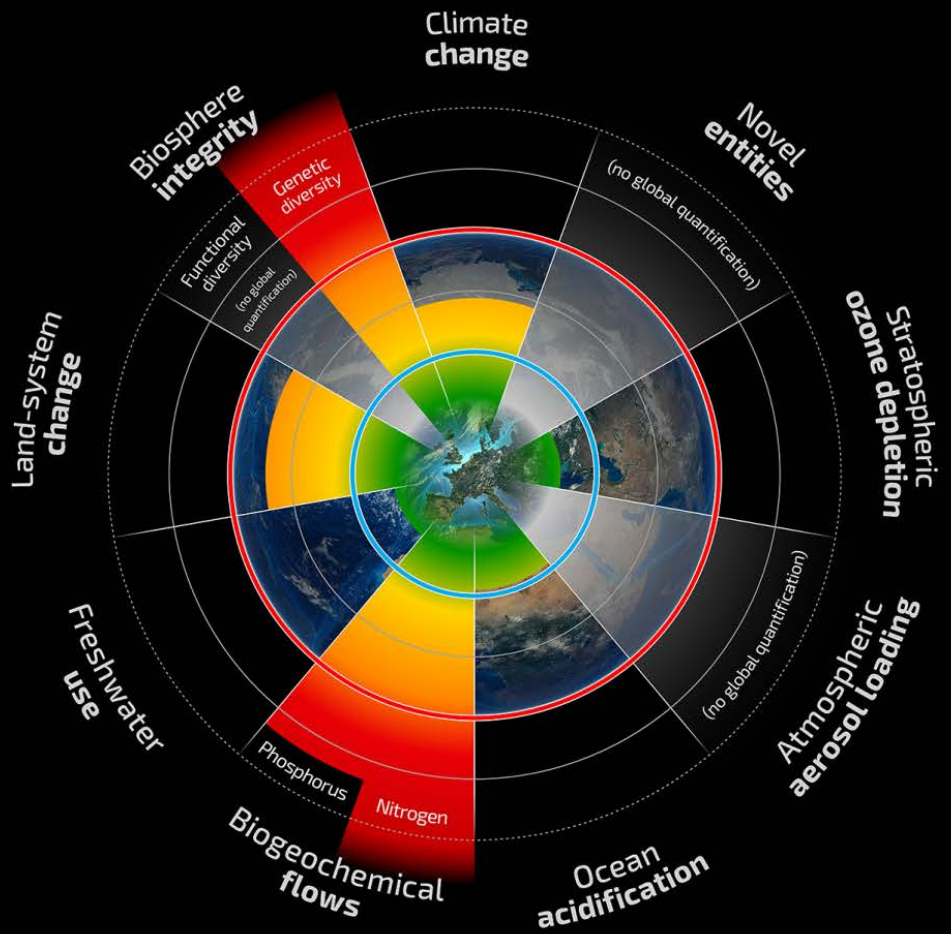

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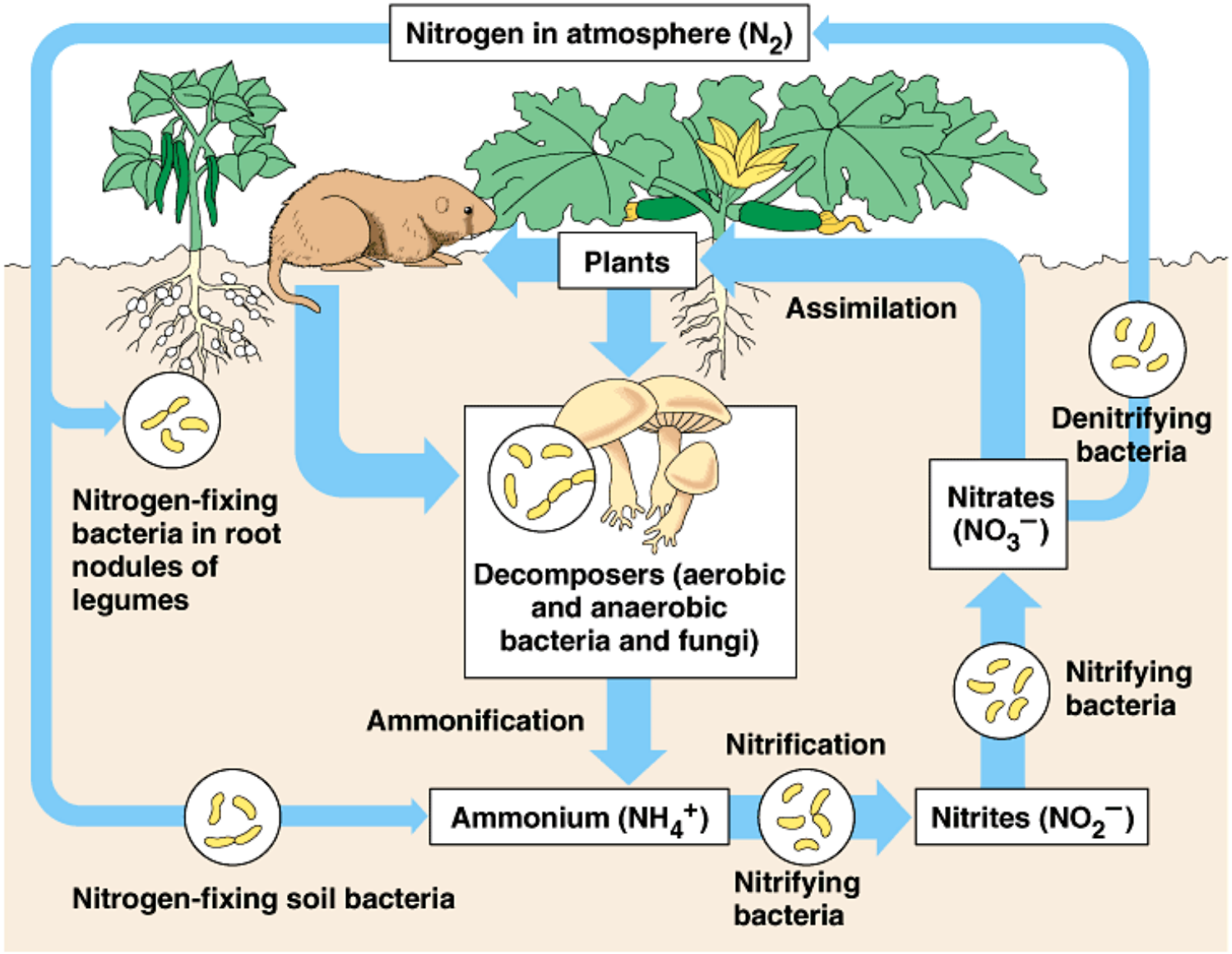
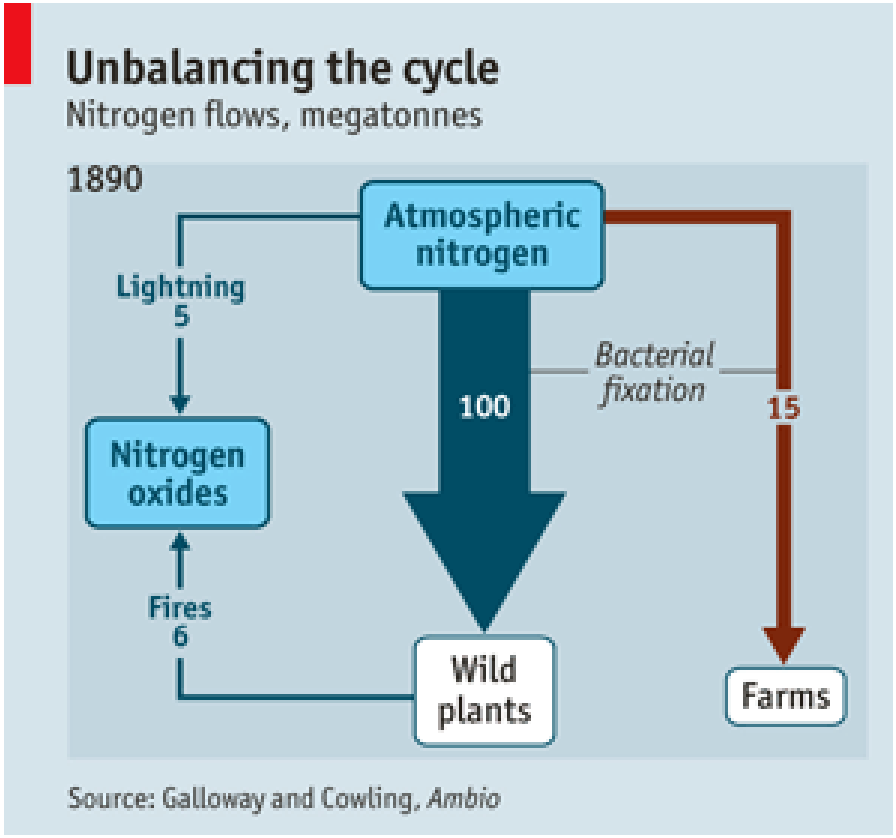
Design: Globaia

N - Nitrogen – natural geochemical cycle

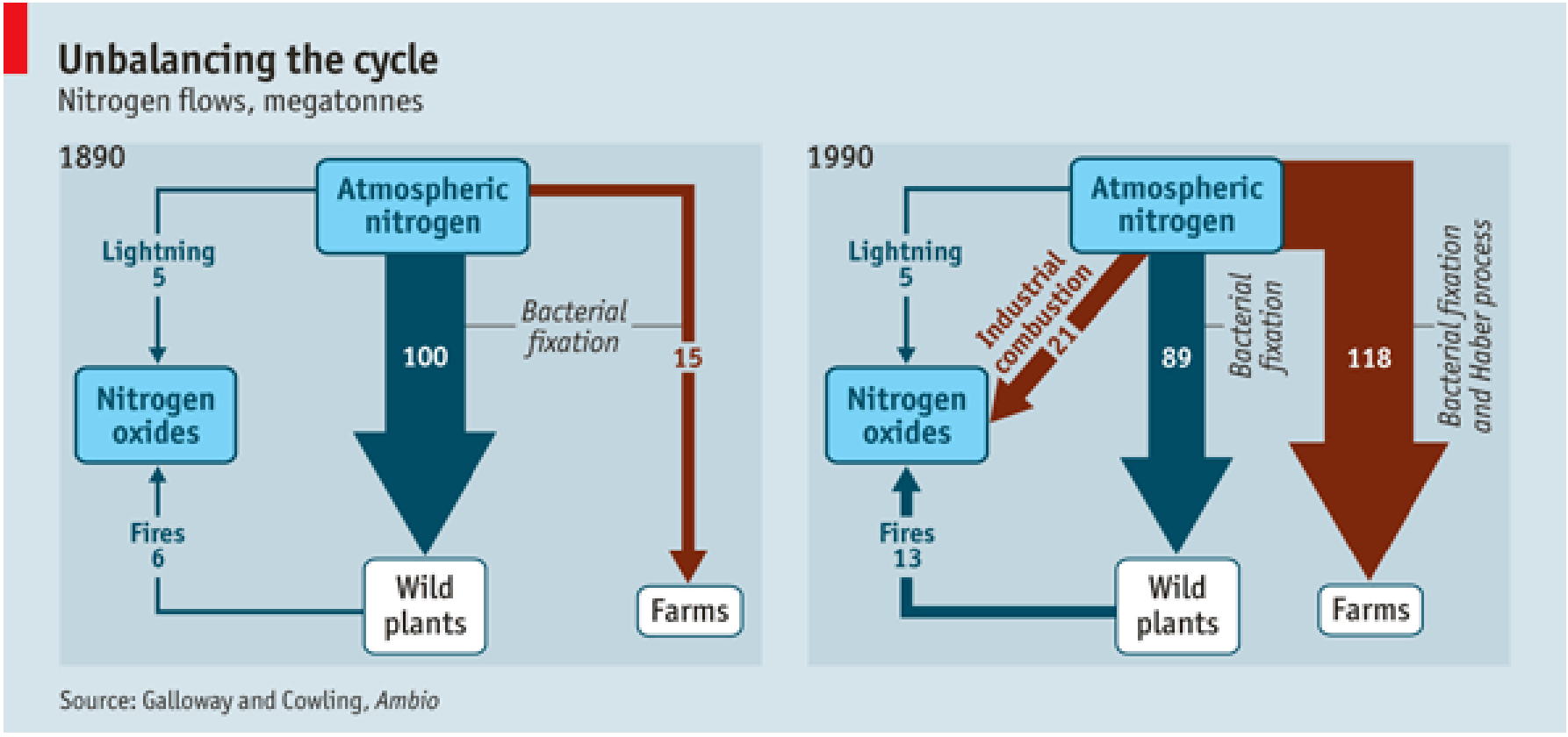


N - Nitrogen


Unbalancing the cycle
Nitrogen flows, megatonnes
1890
Atmospheric nitrogen
Lightning 5
Nitrogen oxides
Fires 6
100
Bacterial fixation
15
Wild plants
Farms
Source: Galloway and Cowling, Ambio

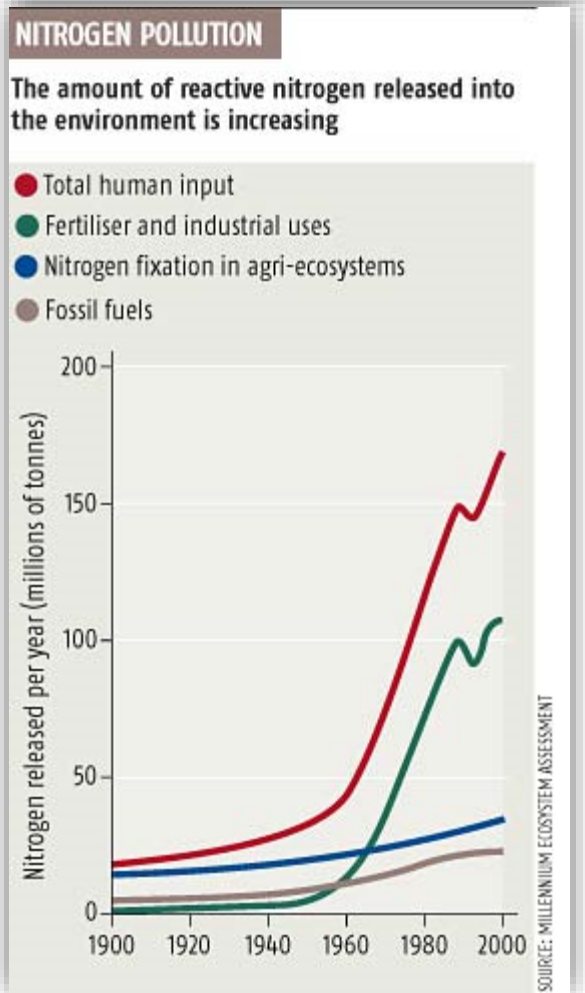
N - Nitrogen

- today, human activity changes more N_2 to reactive forms of N than all terestrial processes together
- Haber-Bosch 80 Mt_N/yr, leguminosis 40 Mt_N/yr, fossil fuels combustion 20 Mt_N/yr, biomass combustion10 Mt_N/yr



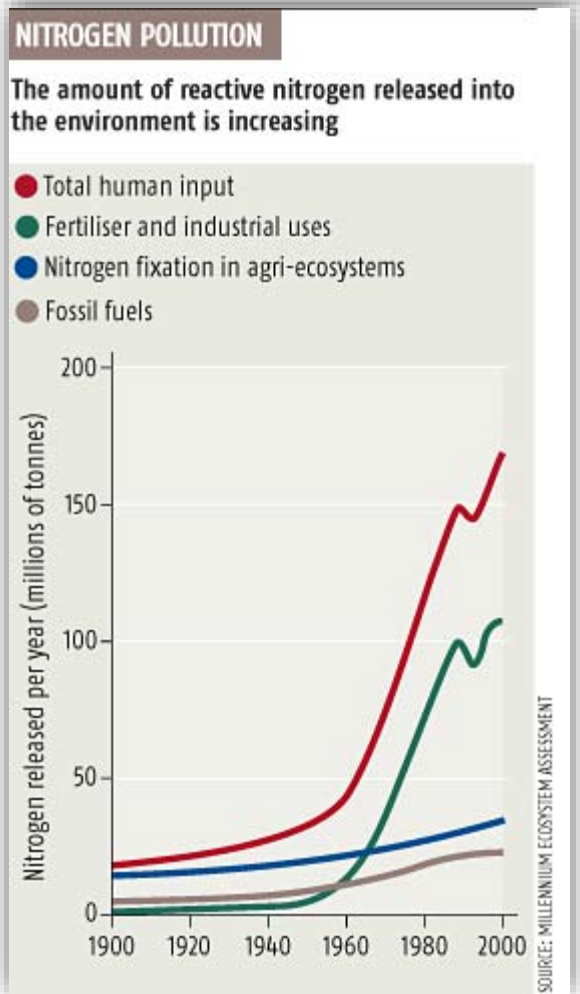
N - Nitrogen

- major reason of N_2 fixation ?

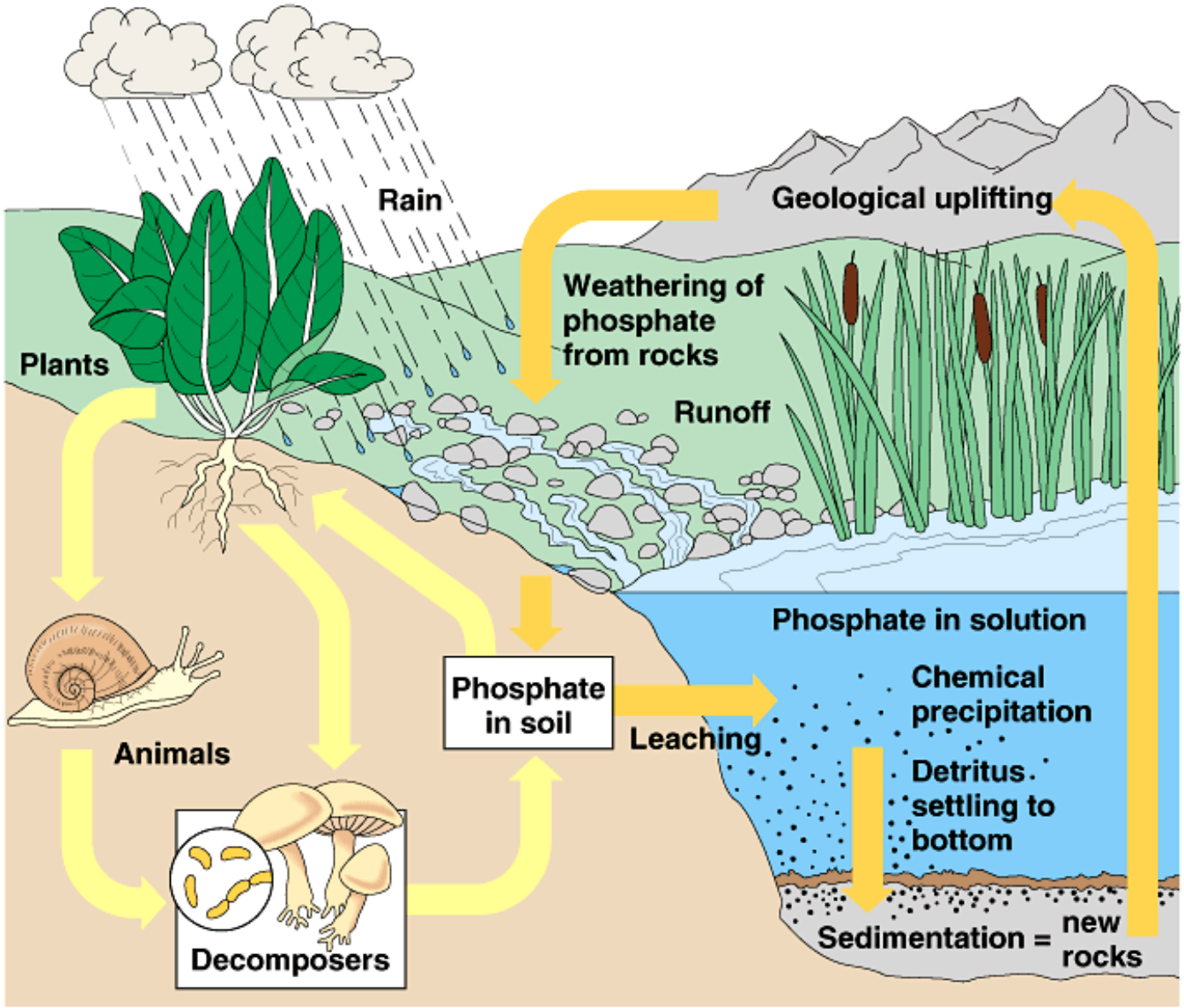


N - Nitrogen

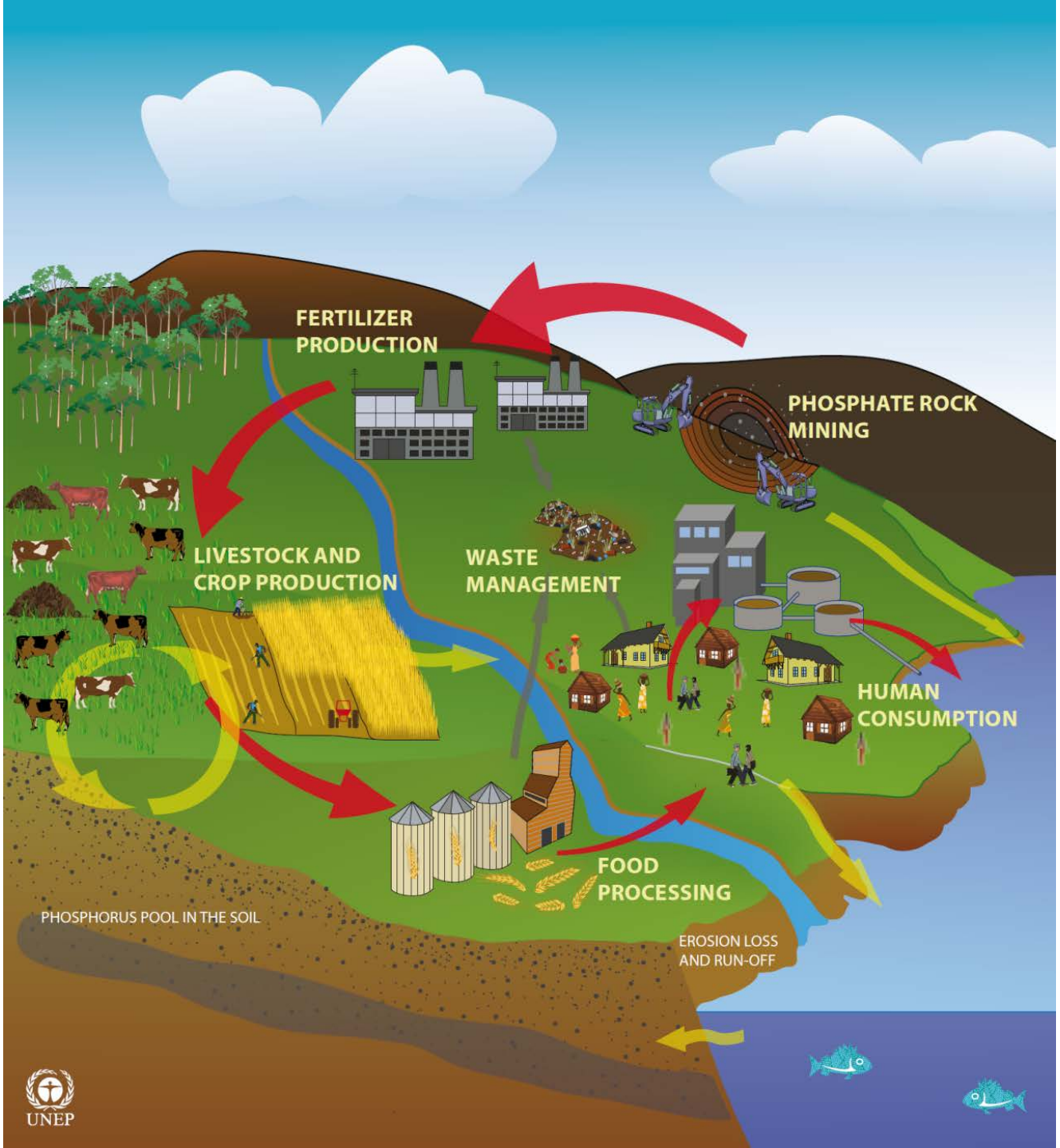
- major reason of N_2 fixation ?
- N-fertilizers
- significant part ends in water – eutrofication and nitrates issue
- significant part ends in atmosphere N_2O is GHG and O_3 decomp.
- owerall decrease of resilience of planetary systems thanks to high input of reactive nitrogen molecules



P – phosphorus – natural geochemical cycle

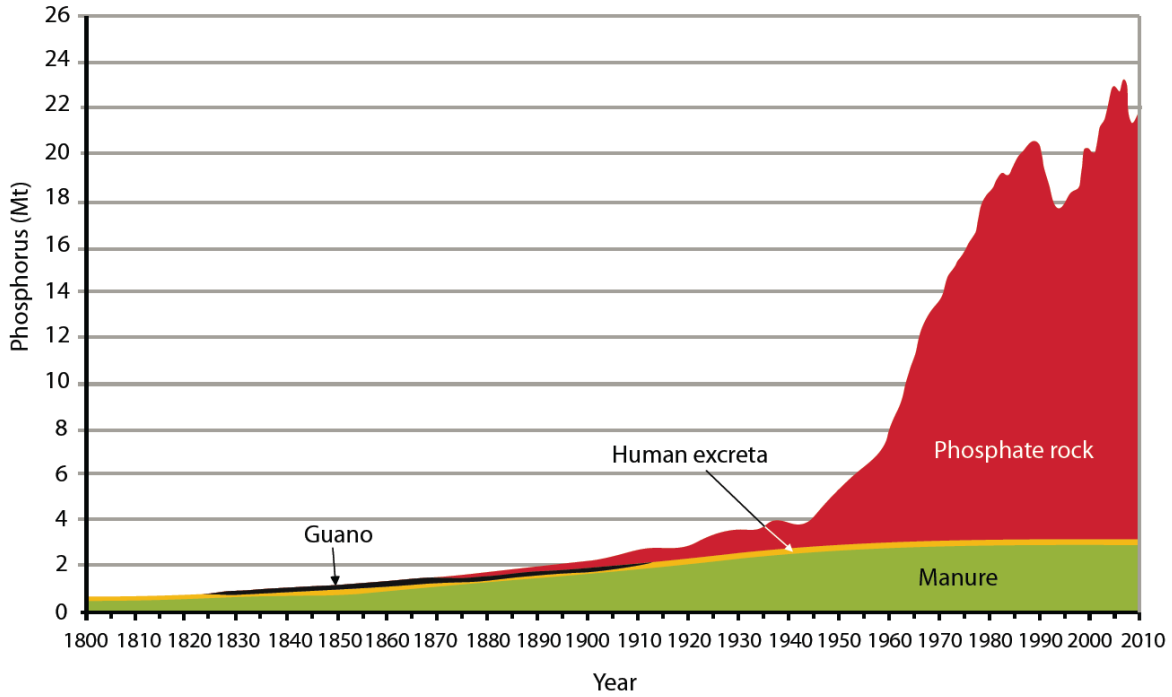


Human intervention to P cycle

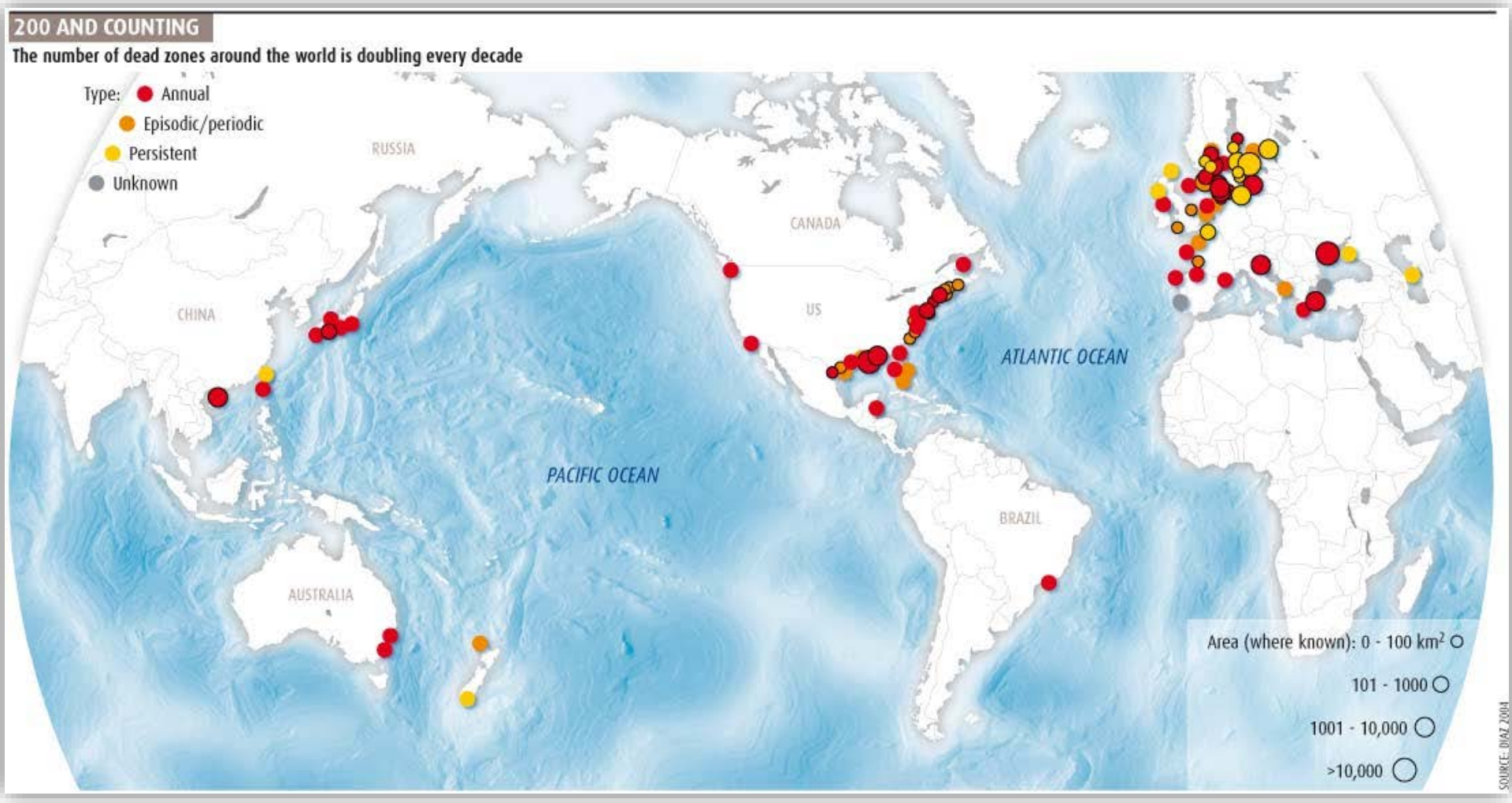


P - phosphorus

- primary source - weathering or apatite mining
- anthropogenic flow to oceans - 8-9x higher amount
- from 20 Mt_N/yr industr. P – half ends in oceans
- higher risk of anoxic events



P + N = anoxic zones in oceans



Deadly Trio in the oceans

My New Scientist

The oceans are heating, acidifying and choking

› 19:58 04 October 2013 by **Fred Pearce**
› For similar stories, visit the **Climate Change** Topic Guide

We know the oceans are warming. We know they are acidifying. And now, to cap it all, it turns out they are suffocating, too. A new health check on the state of the oceans warns that they will have lost as much as 7 per cent of their oxygen by the end of the century.

The cascade of chemical and biological changes now under way could see coral reefs irreversibly destroyed in 50 to 100 years, with marine ecosystems increasingly taken over by jellyfish and toxic algal blooms.

The review is a repeat of a study two years ago by the International Programme on the State of the Ocean (IPSO), a coalition of scientists. It concludes that things have become worse since the first study.

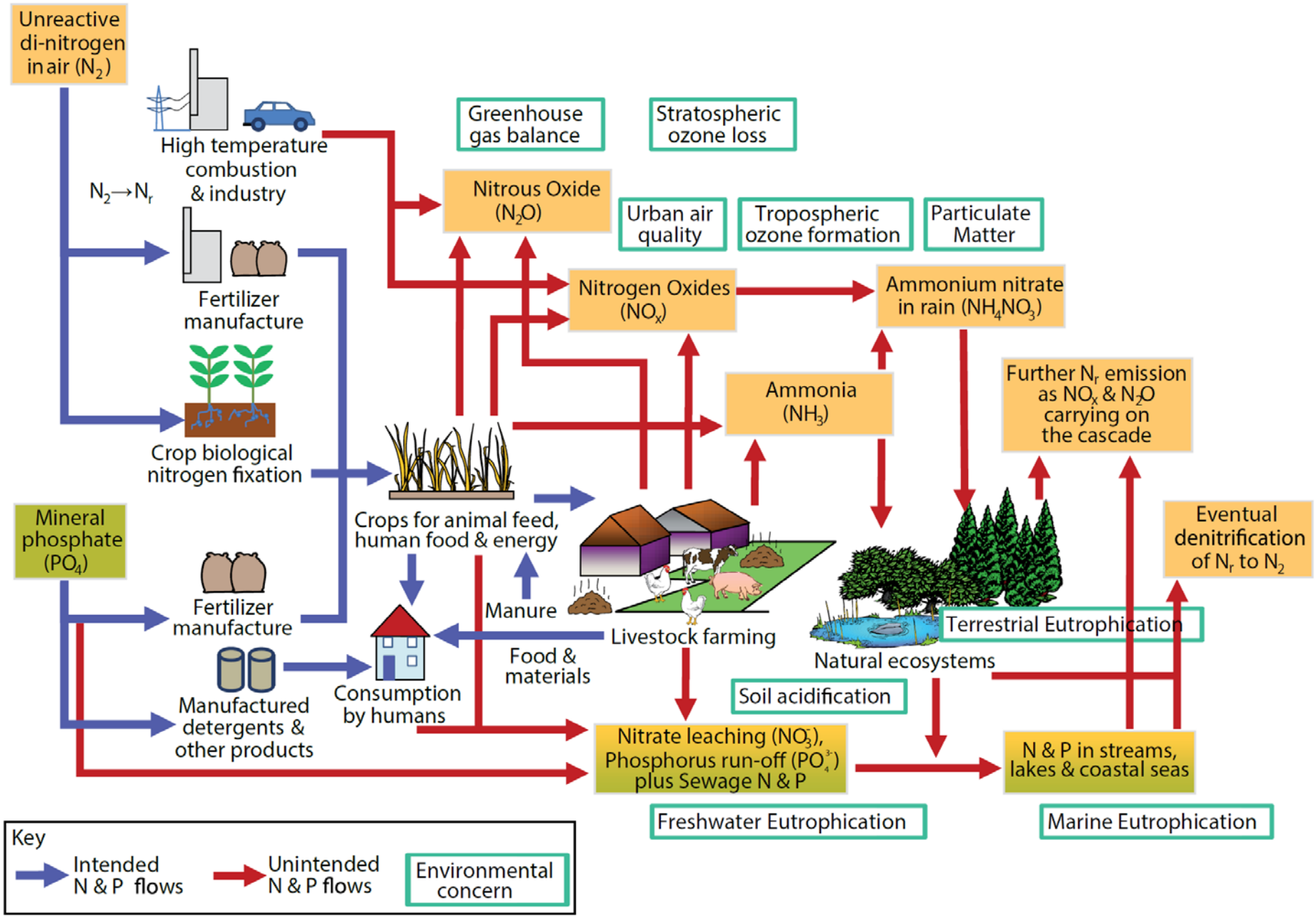
"The health of the oceans is spiralling downwards far more rapidly than we had thought, exposing organisms to intolerable and unpredictable evolutionary pressure," says Alex Rogers at the University of Oxford, the scientific director of IPSO.

Deadly trio

Rogers describes a "deadly trio" of linked global threats. The first is global warming: surface sea water has been warming almost as fast as the atmosphere. The second is acidification – a result of the water absorbing ever more CO_2 from the atmosphere. The third is deoxygenation.

Getting harder to breathe underwater *(Image: Incredible Features/Barcroft Media)*

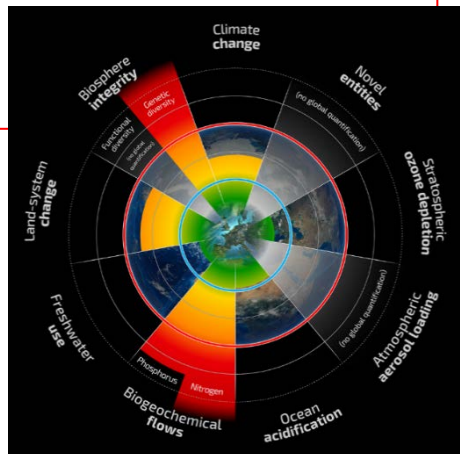
Simplified view of the nitrogen and phosphate cascade



VII. Global freshwater consumption

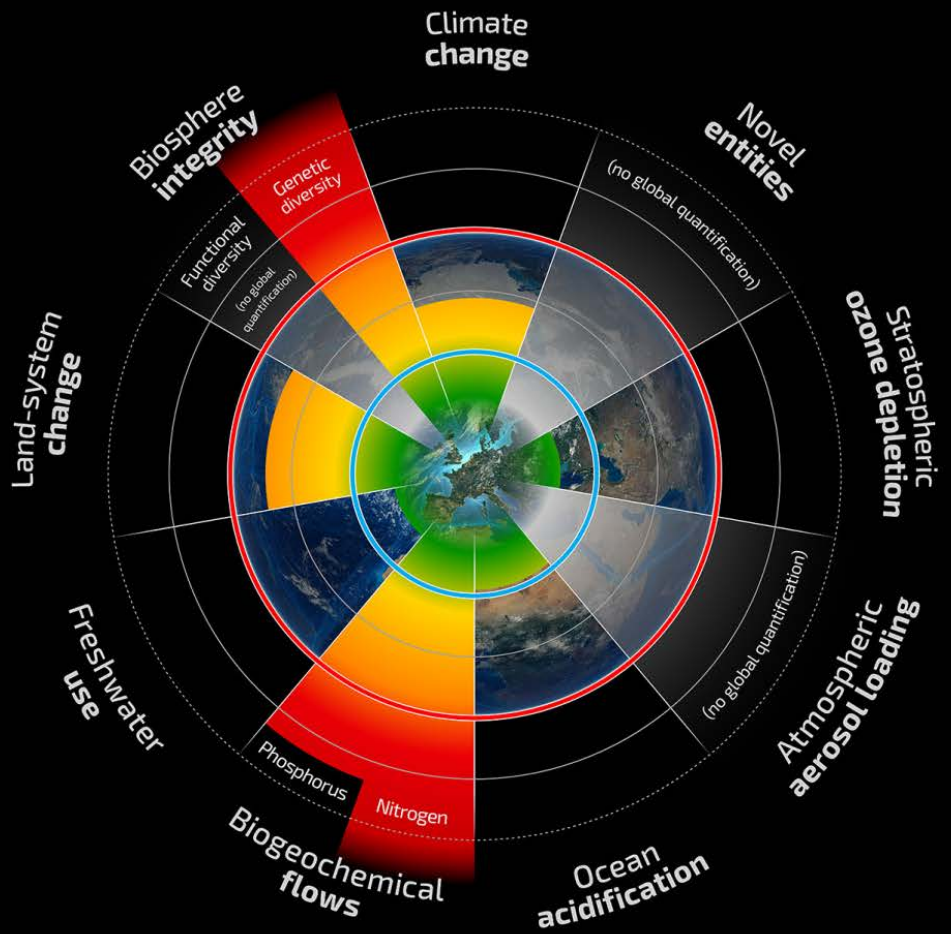
Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Freshwater use (R2009: Global freshwater use)	*Global:* Maximum amount of consumptive blue water use ($km^3 yr^{-1}$)	*Global:* 4000 $km^3 yr^{-1}$ (4000–6000 $km^3 yr^{-1}$)	~2600 $km^3 yr^{-1}$
	Basin: Blue water withdrawal as % of mean monthly river flow	*Basin:* Maximum monthly withdrawal as a percentage of mean monthly river flow. For low-flow months: 25% (25–55%); for intermediate-flow months: 30% (30–60%); for high-flow months: 55% (55–85%)	

Boundary: No more than 4000 km^3 of fresh water consumed per year
Current level: 2600 km^3 per year
Diagnosis: Boundary will be approached by mid-century



Planetary Boundaries

A safe operating space for humanity



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

Source: Steffen et al. Planetary Boundaries: Guiding human development on a changing planet, *Science*, 16 January 2015.
Design: Globaia

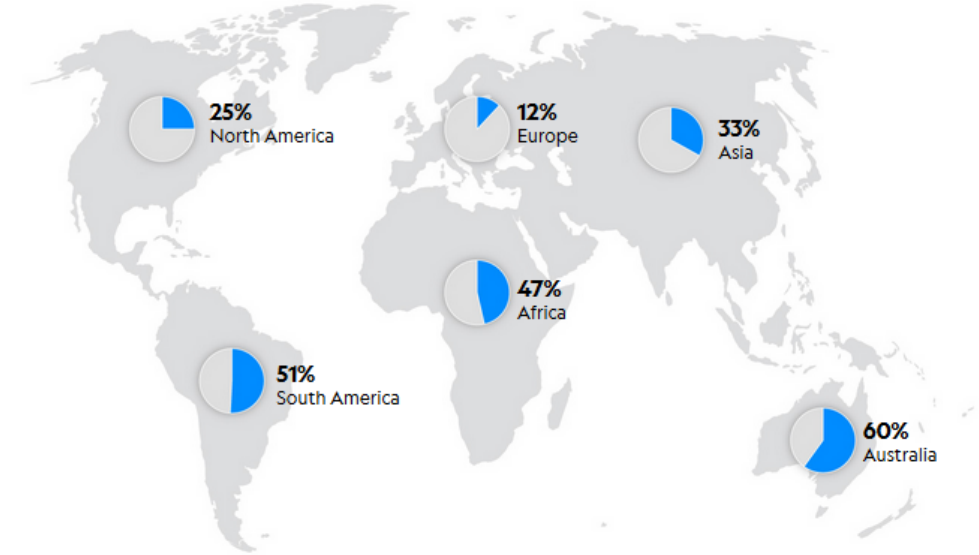
FW issue

- People are a dominant force changing flow of water in rivers
- cca 25 % water does not reach the ocean
- consequences for the biodiversity, nutrition, aquatic and terestrail ecosystems

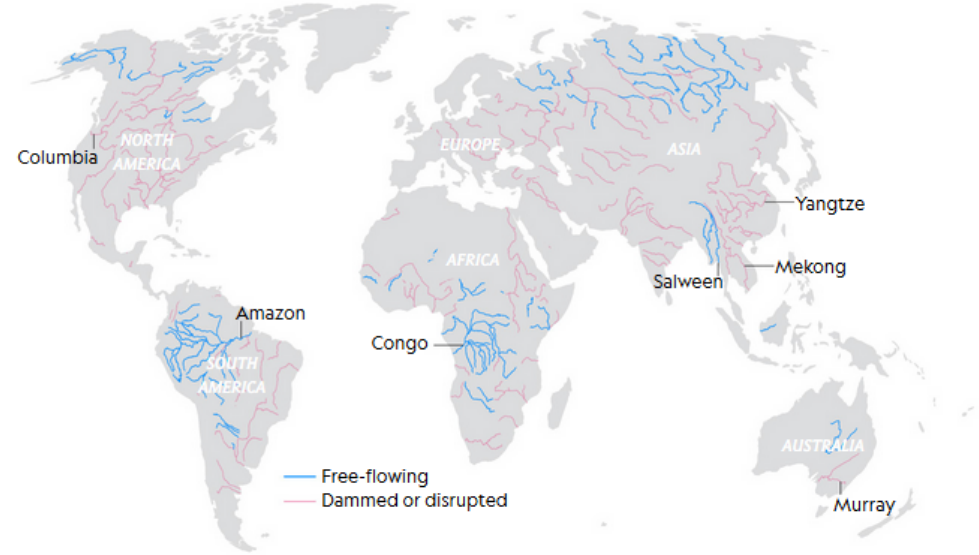
The world's remaining free-flowing rivers

Only 37 percent of world's largest rivers are free of dams or other disruptions. Free-flowing rivers are found primarily in the Amazon and Congo Basins, and in the Arctic.

Percentage of very large rivers (longer than 1,000 km) that remain free-flowing, by continent

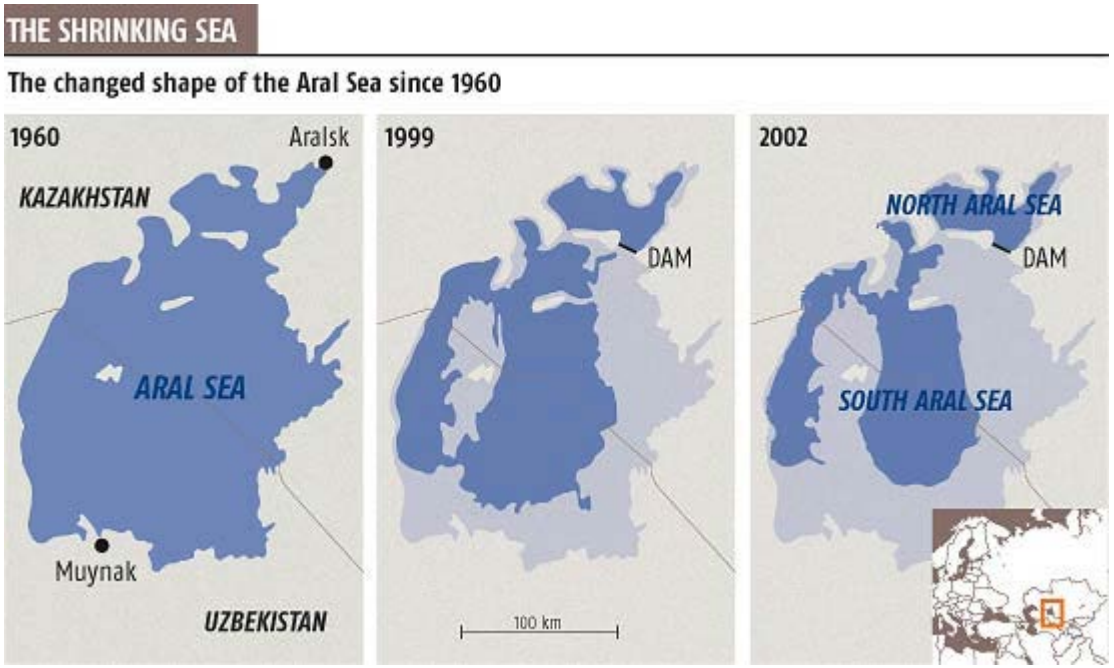


Distribution of very large rivers

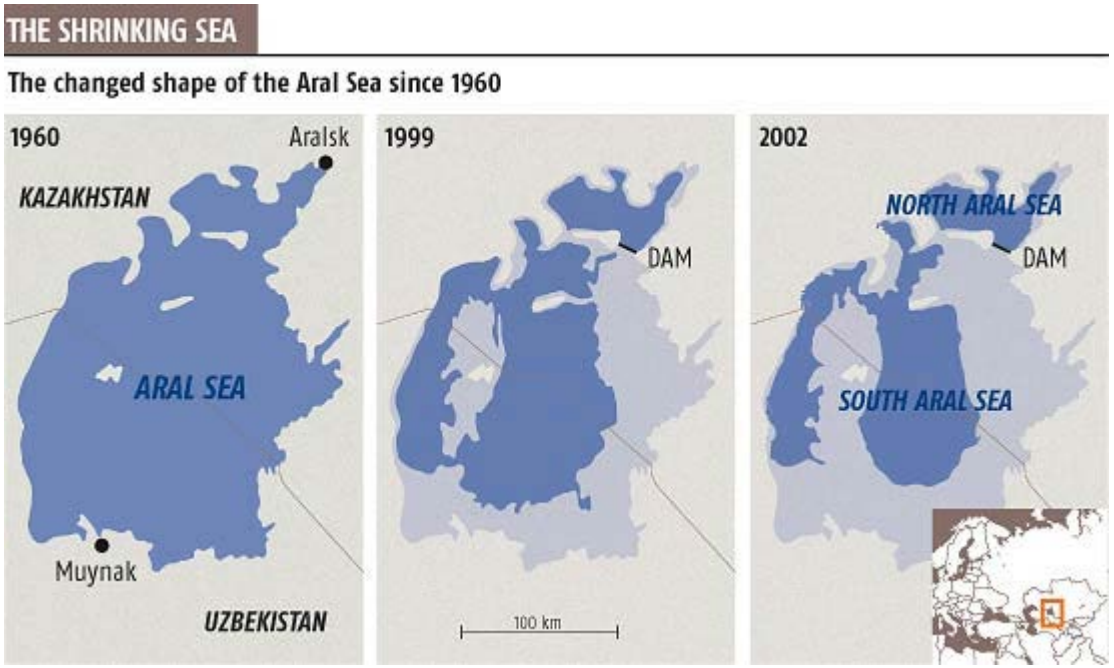


THEODORE SICKLEY AND RYAN MORRIS, NG STAFF
SOURCE: *NATURE*

Aral See
- Kazachstan, Uzbekistan



- 2005 – a dam between N and South part was constructed
- what has happened?



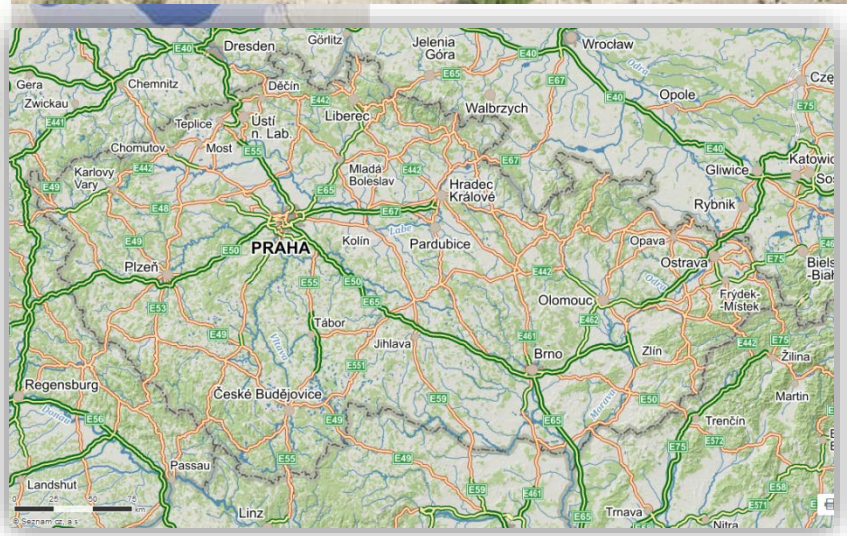
- 2005 – a dam between N and South part was constructed
- what has happened?

An original area of the Aral sea (1960) was:

Bigger than Czechia	Of similar size to Czechia	Smaler than Czechia

THE SHRINKING SEA

The changed shape of the Aral Sea since 1960



THE SHRINKING SEA

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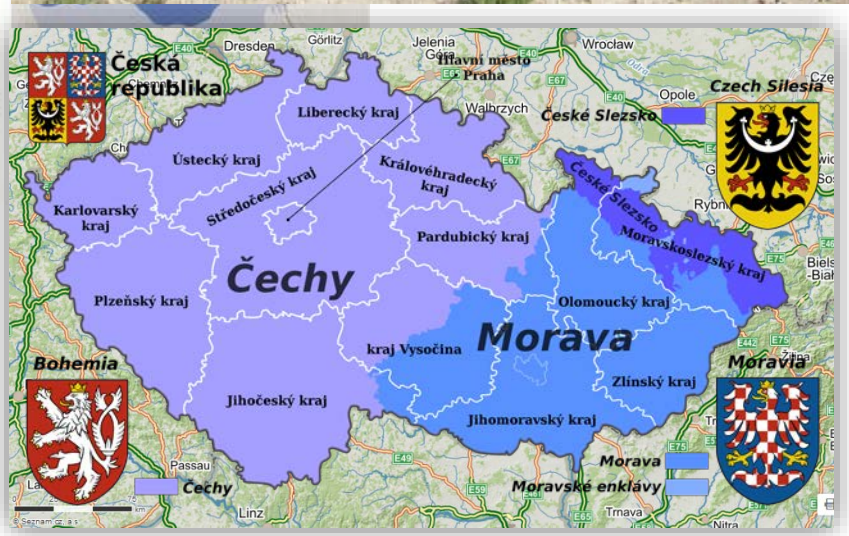
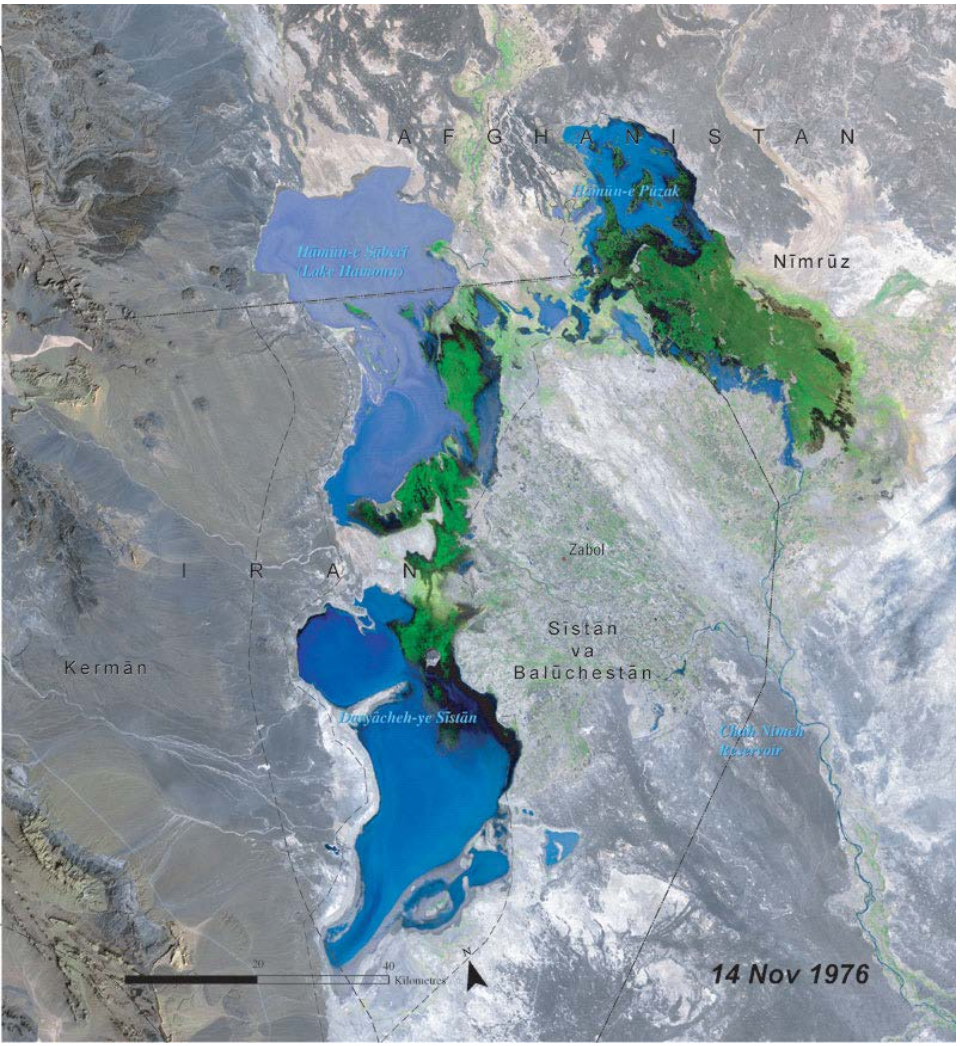
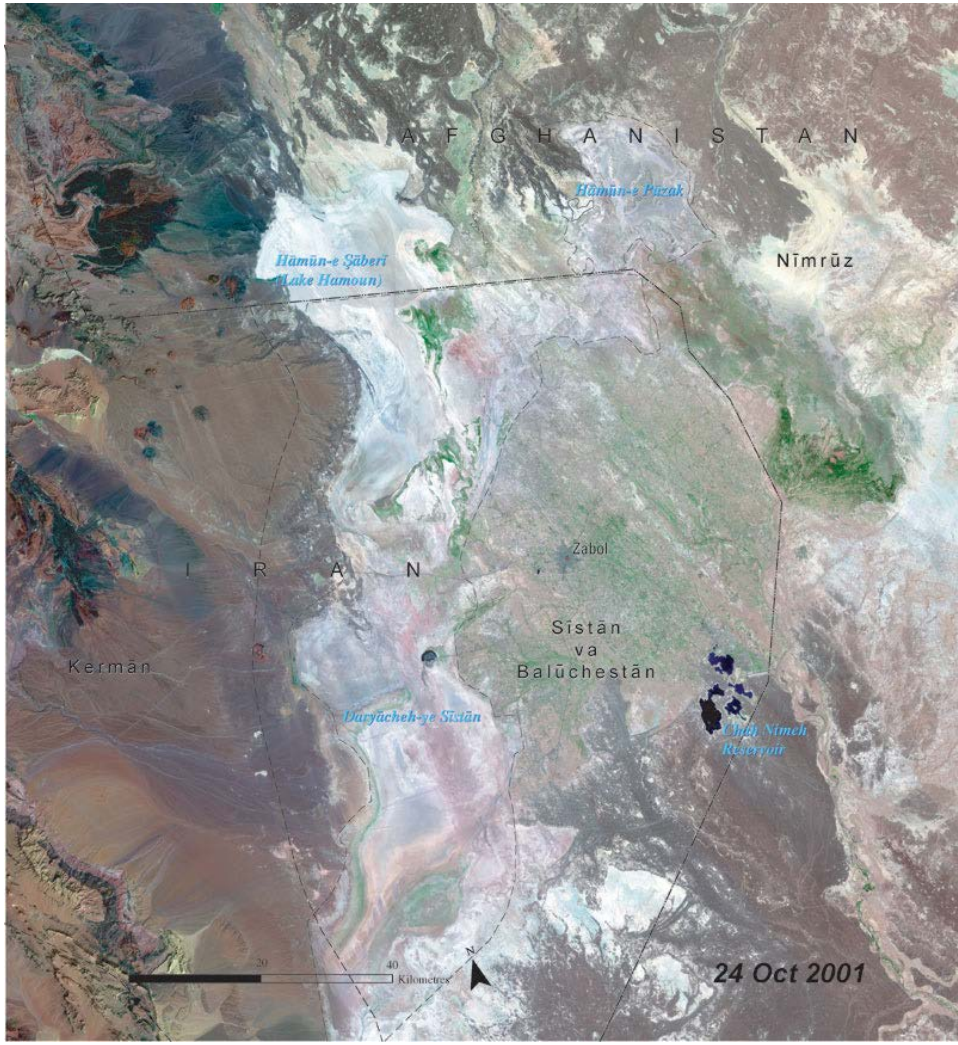
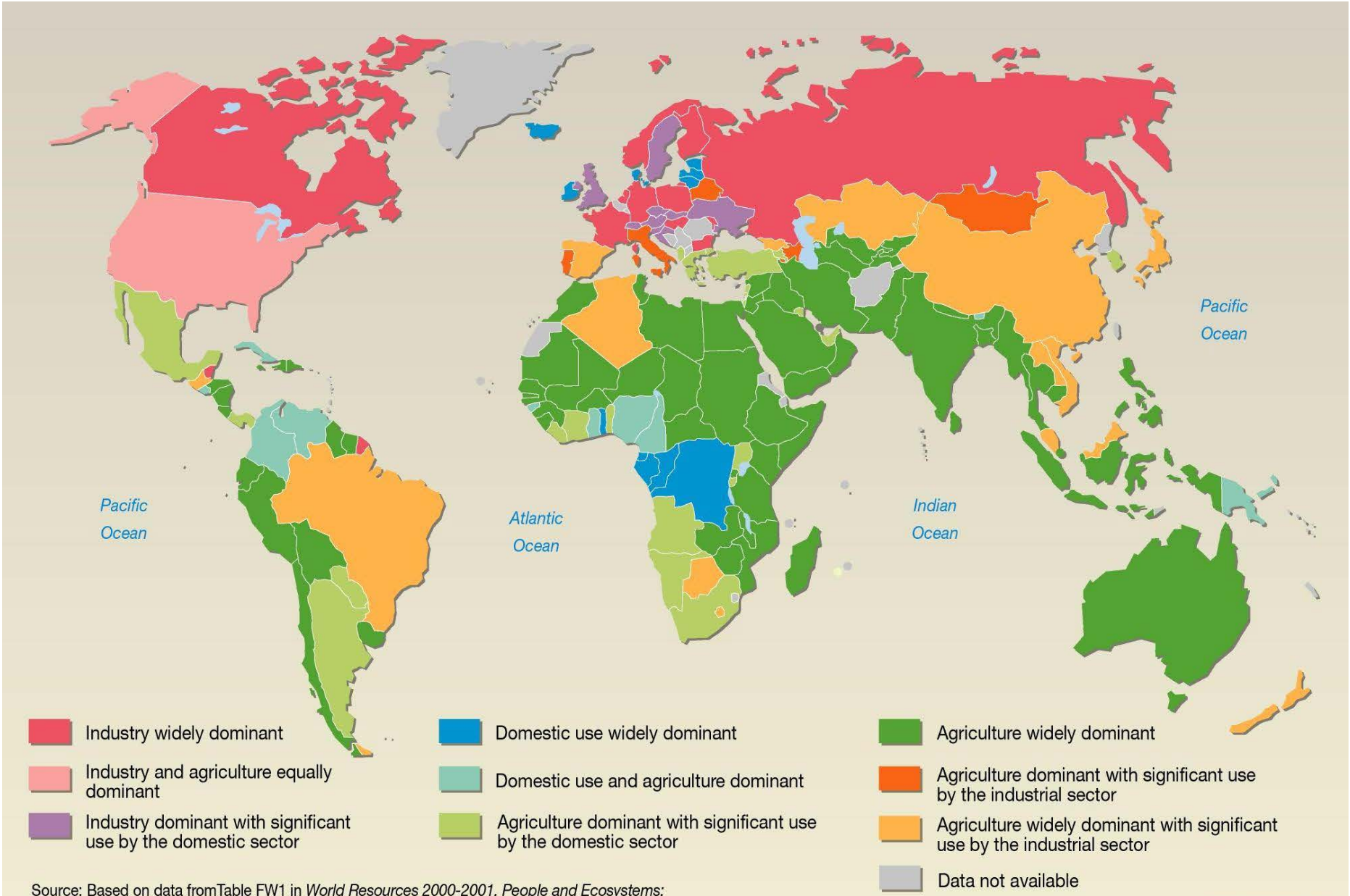


Lake Hamoun – Iran, Afghanistan





Areas and types of water consumption

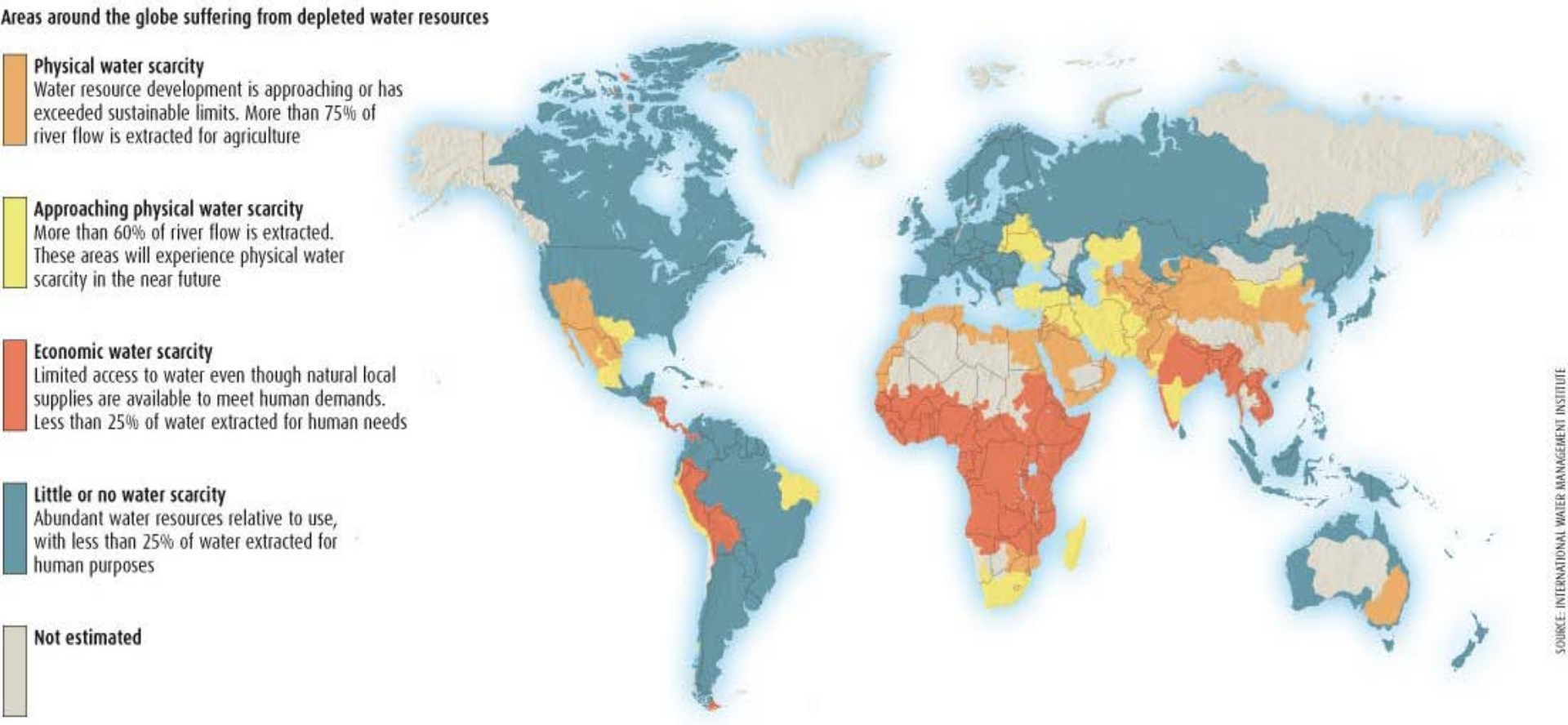


Source: Based on data fromTable FW1 in *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

PHILIPPE REKACEWICZ
MARCH 2002

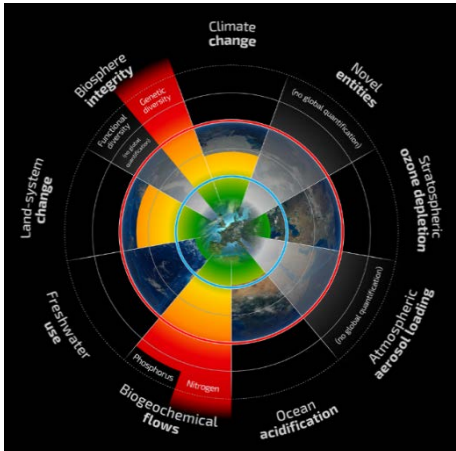
Water consumption - what does it mean?

Areas and types of water scarcity



VIII. Land use

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Land-system change (R2009: same)	*Global:* Area of forested land as % of original forest cover	*Global:* 75% (75–54%) Values are a weighted average of the three individual biome boundaries and their uncertainty zones	62%
	Biome: Area of forested land as % of potential forest	*Biome*: Tropical: 85% (85–60%) Temperate: 50% (50–30%) Boreal: 85% (85–60%)	



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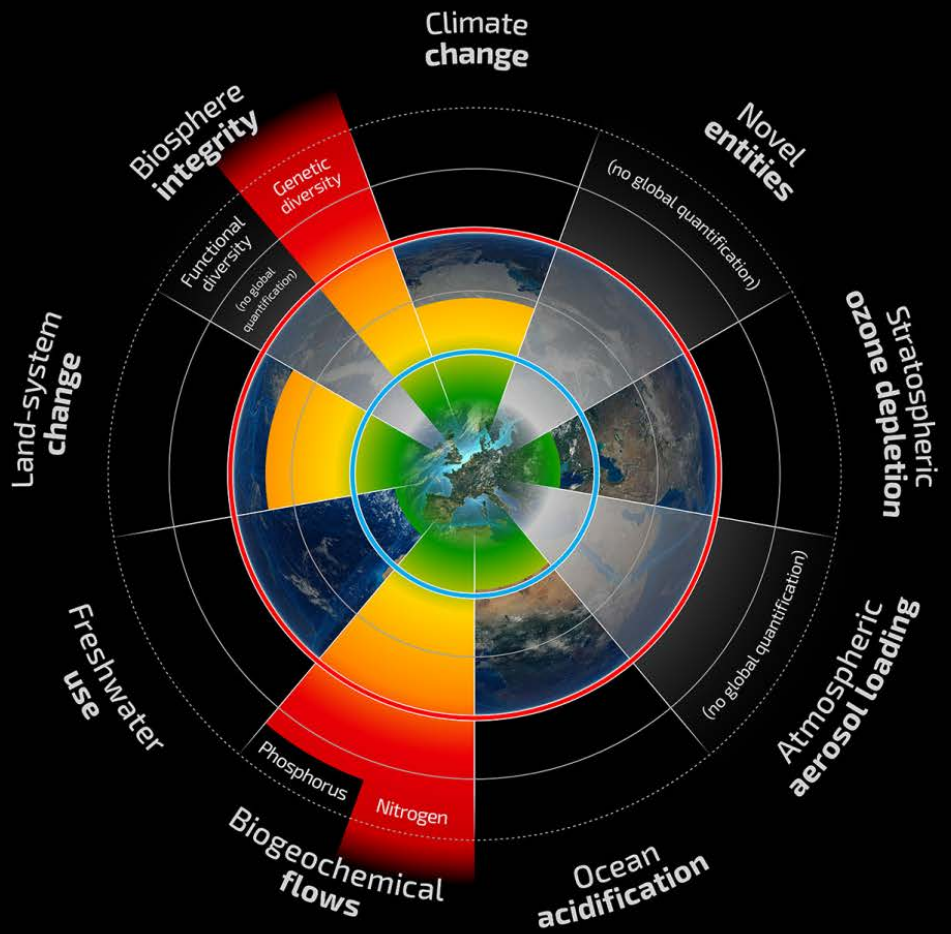

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Design: Globaia

Santa Cruz, Bolívia

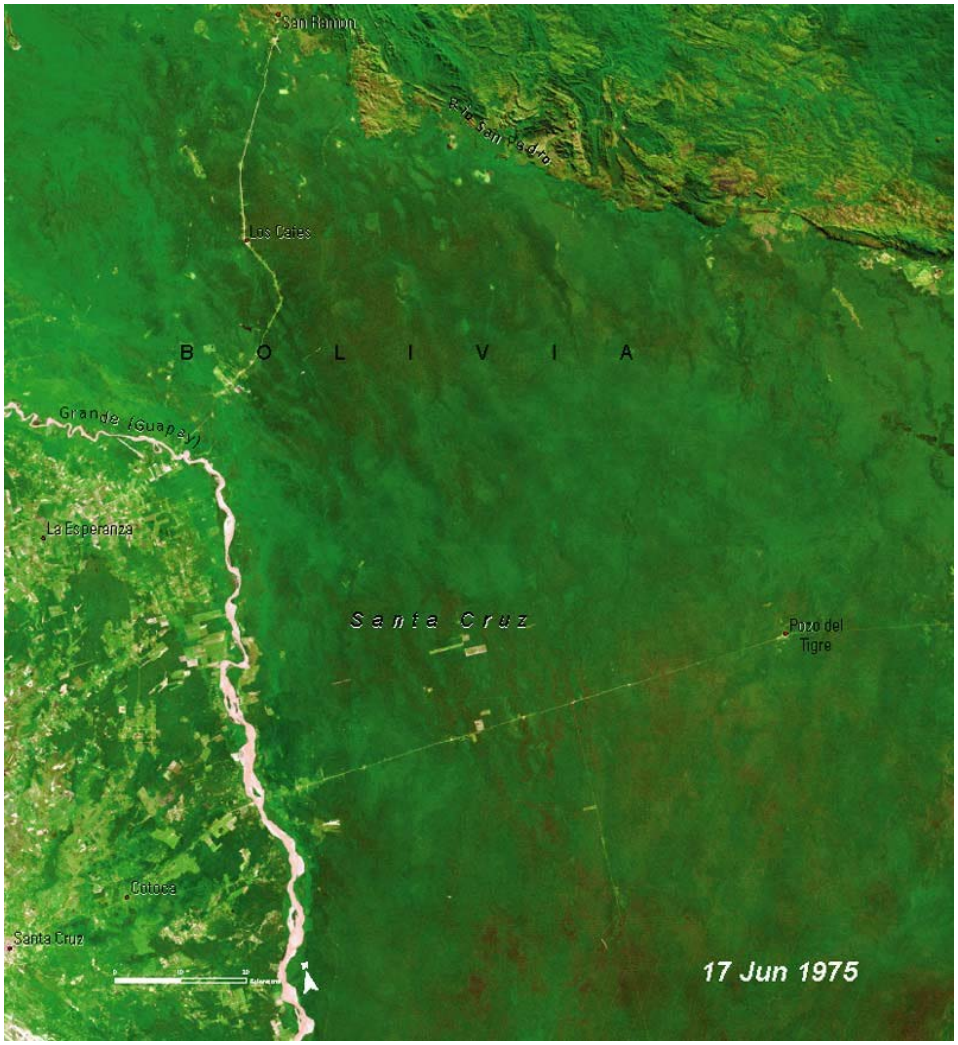
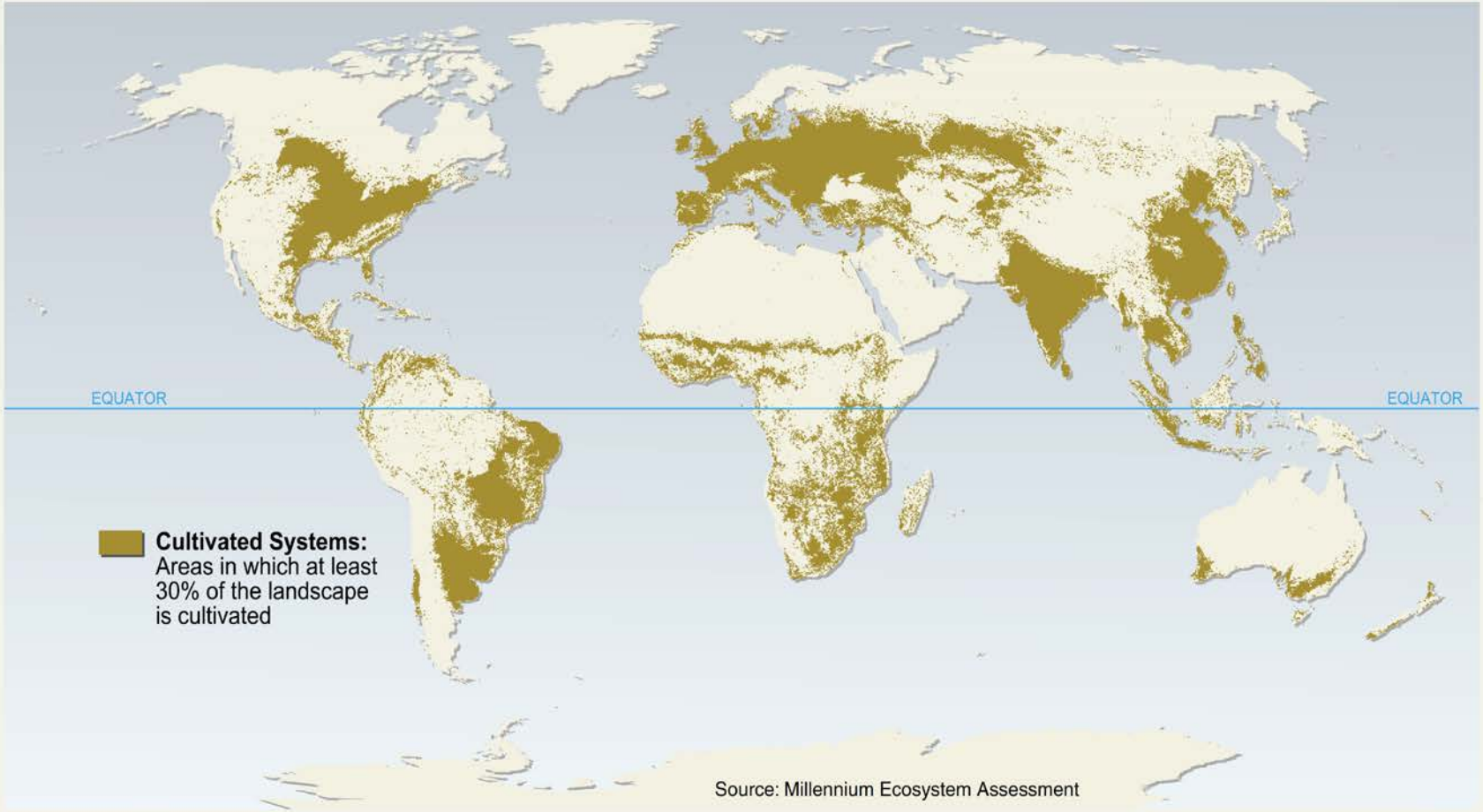


Figure 1. Extent of Cultivated Systems, 2000. Cultivated systems cover 24% of the terrestrial surface.



Change in land system

- agriculture (main driver)

- In the last 50 years, change of the ice-free land to the agriculture land circa 0.8% per year
- main force of the changes of ecosystem services and functions (e.g. food production, water cleaning, etc.),
- habitat loss is a main force of biodiversity loss
- it undermines human well-being and sustainability

- exceeding the safe level of a land system change in a certain region can lead to a sudden change in the character of the landscape

Change in land system

- agriculture (main driver)

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Parts of Amazon close to tipping point

› 13:52 05 March 2009 by Catherine Brahic
› For similar stories, visit the Endangered Species Topic Guide

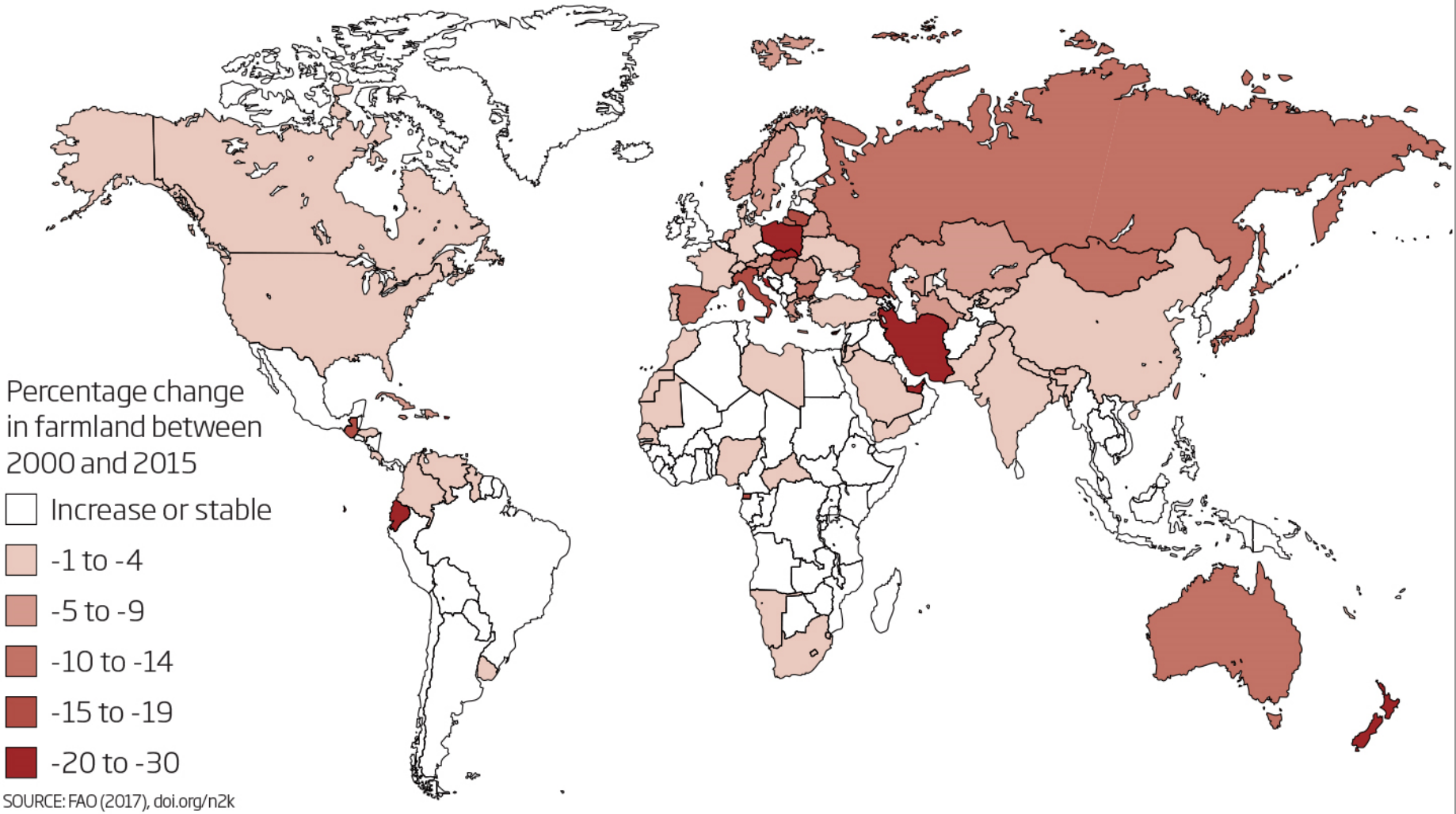
The Mato Grosso, the most scarred region of the Amazon rainforest, is teetering on a deforestation "tipping point", and may soon be on a one-way route to becoming a dry and relatively barren savannah.

Mônica Carneiro Alves Senna and colleagues at the Federal University of Viçosa, Brazil, used computer models to simulate how the Amazon would recover from various amounts of deforestation. Their simulations ranged from a complete wipe-out of the entire forest to a situation where just one fifth of the forest would be removed.

Optimistic future?

Shrinking farmland

For the first time, more land is being left to return to nature than is being cleared for agriculture



SOURCE: FAO (2017), doi.org/n2k