Environment and humanity: How humans affect the environment?

ZA311 Environmental geography

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Intro

– The biosphere has sustained itself for billions of years using solar radiation as an energy source
– Our lives and society depend completely on ecosystem services (natural capital) provided by the planet Earth
– Human activities and non-human processes interact to shape the world around us

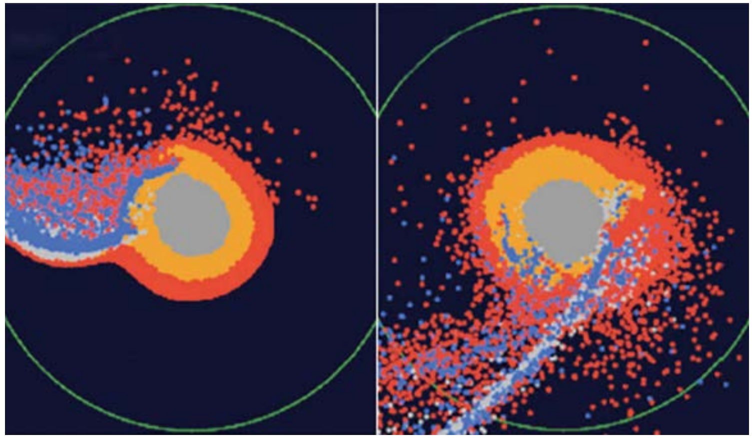
The brief history of the Earth

Before the life on Earth

Ga = billion of years (10^9 years)
Ma = million of years (10^6 years)
ka = thousand of years (10^3 years)
BP = before present

- The age of the Earth is 4.57 Ga
- The Earth-Moon system originited 4.533 Ga ago by collision of the proto-Earth with the planet Theia

The mass of the planet Theia was 11–14% of the mass of Earth



Blue: material of impacting planet
Red: terrestrial material (magma)

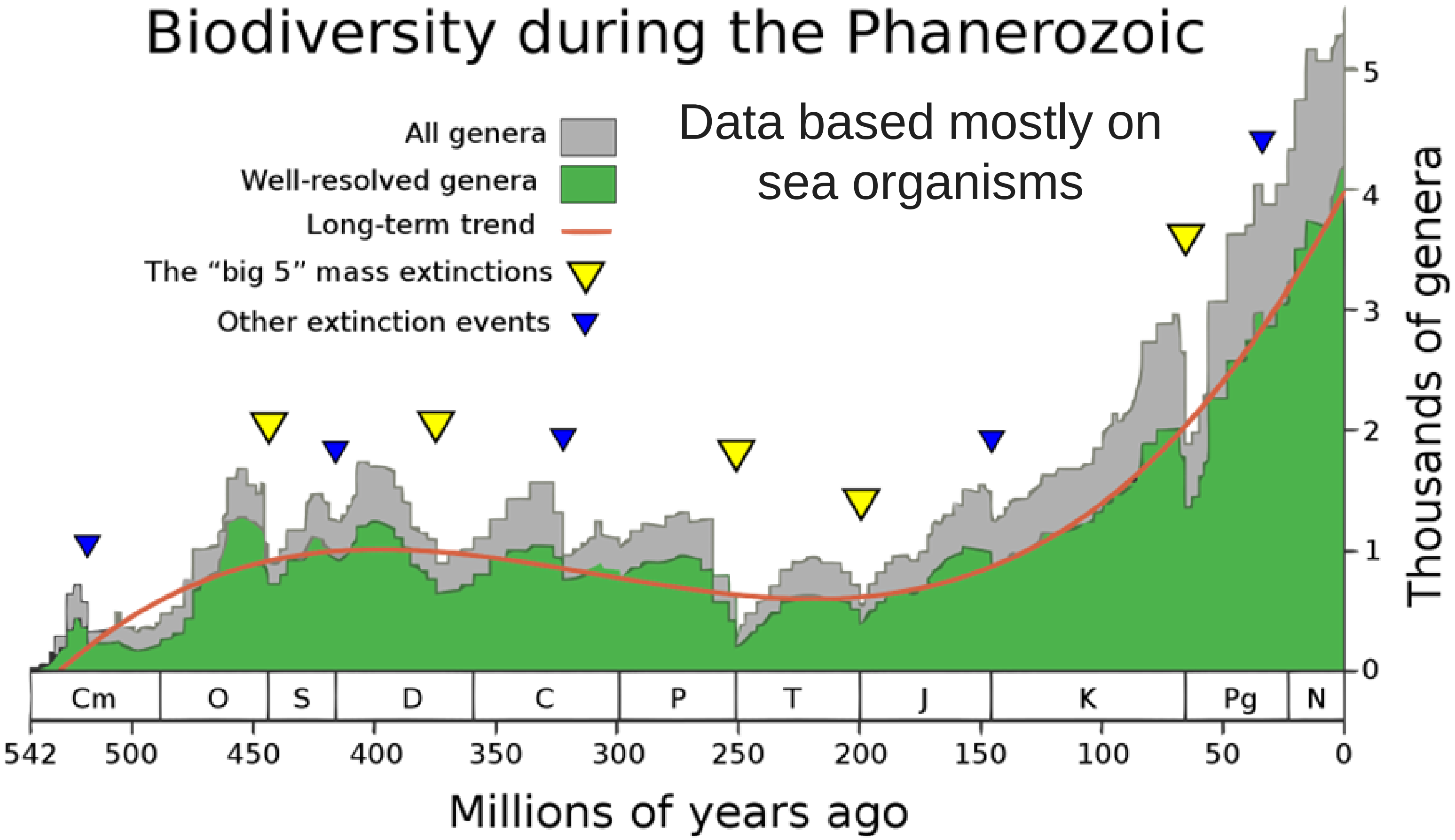
Life on Earth: an origin of the biosphere

- First organisms on Earth (Archean, 4–2.5 Ga)
  - Chemical evidence of life in rocks (Issua Greenstone Belt, Greenland): 3.8 Ga
  - The first cellular organisms were bacteria and cyanobacteria
  - Photosynthesizing cyanobacteria formed biofilms – stromatolites (Pilbara, Australia): 3.5 Ga
- Phanerozoic – the period of the “visible life”(540 Ga–present)
  - Explosive evolution of life, abundant animal and plant life has diversified and colonized the Earth surface

Fossil stromatolites

Mass extinctions: the evidence of the past environmental change

The life has never been easy on this planet



Rohde & Muller (2005)

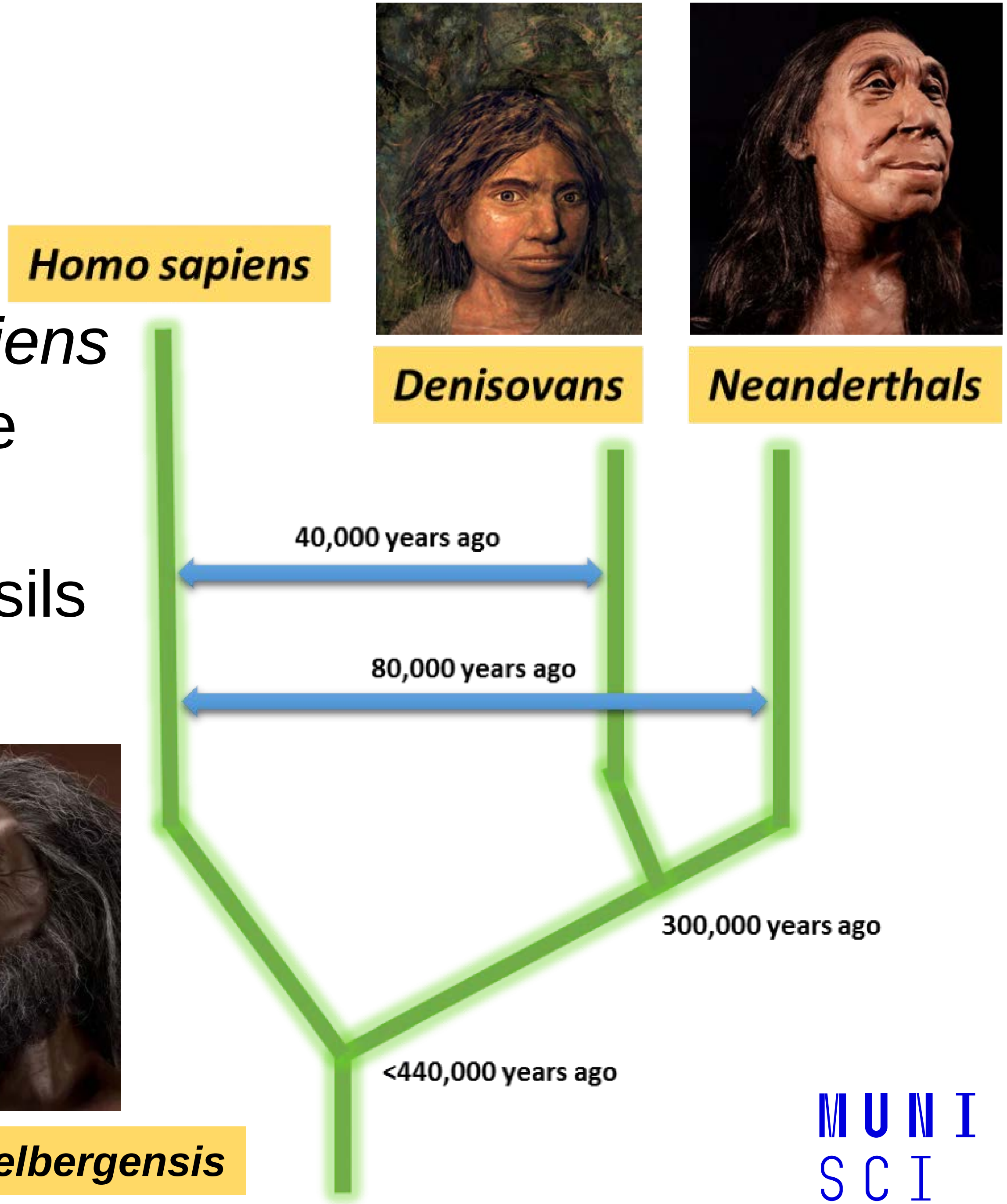
- Five *mass extinctions* in the Earth history
- Causes of extinctions:
  - Volcanism
  - Asteroid impact (C/T boundary)
- Extinction followed by *evolutionary radiation*
- Recent sixth mass extinction is caused by humans

Humans on Earth

The origin of modern humans

- The anatomically modern *Homo sapiens* evolved in Africa and spread over the globe (Out of Africa)
- The oldest known *Homo sapiens* fossils date back <u>300,000 years</u> (found in Morocco)

Common ancister of Sapiens, Denisovans and Neanderthals



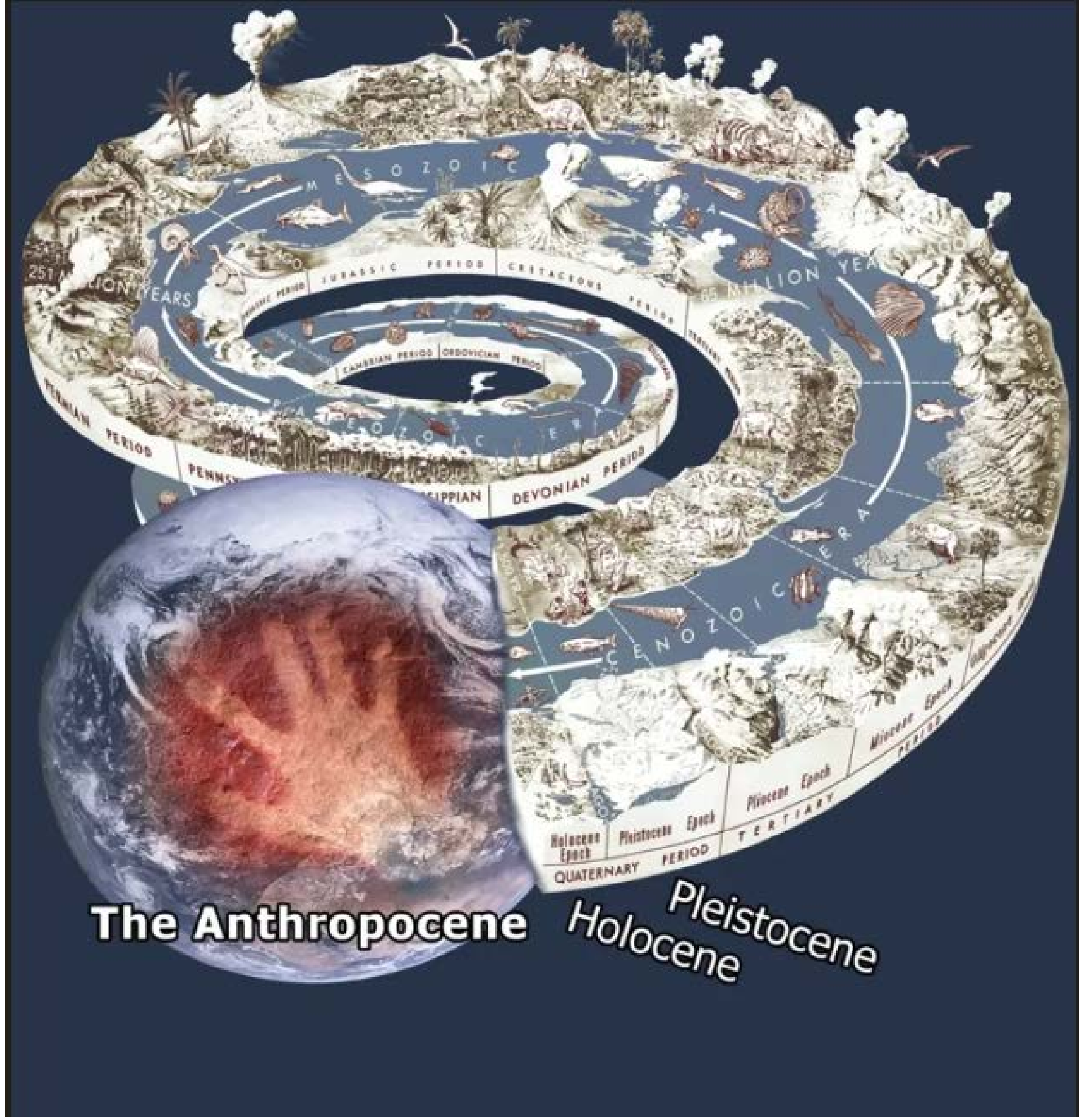
A world in crisis: environmental impacts of human activities

Discussion question

Do we really face the environmental crisis caused by human actions? Or is it just a fiction? In other words: Are you an alarmist or a sceptic?

The Anthropocene: the age of humans

- The existence of Earth
  4,600 Ma = 100% of geological time
- The existence of biosphere
  3,800 Ma = 83%
- The existence of modern humans
  0.3 Ma = 0.007%
- The Anthropocene
  0.0,003 Ma = 0.000,007%
  An epoch in which humans have become the major driver of environmental change



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The Anthropocene

- …is a proposed geological epoch dating from the commencement of significant human impact on geology, ecosystems and climate

- Origin of the concept comes from atmospheric chemists Paul J. Crutzen who regards the influence of human behavior on Earth's atmosphere in recent centuries as so significant as to constitute a new geological epoch

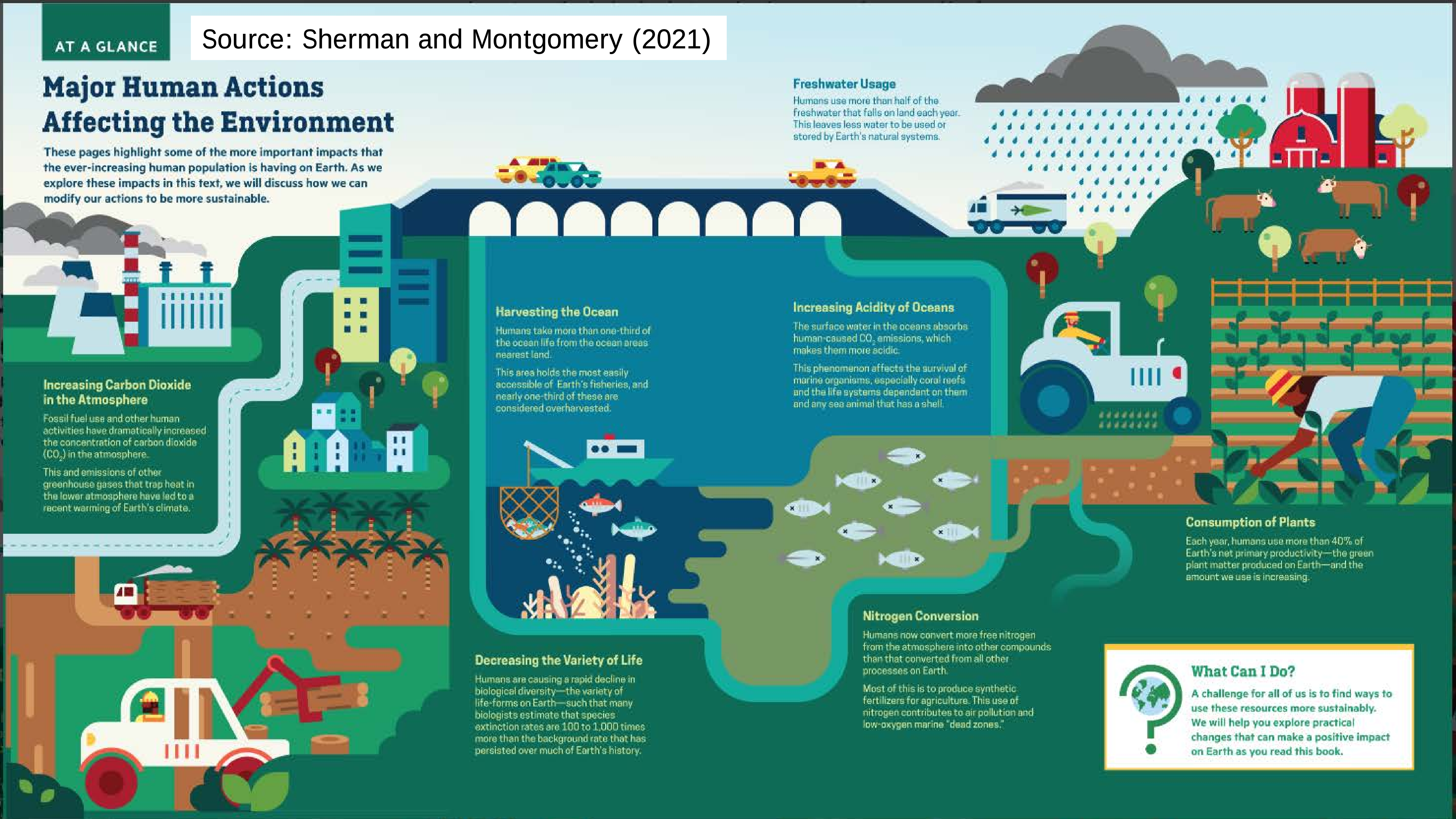
When did the Anthropocene begin?

- Neolithic (agricultural) revolution (12–15 ka BP)
- Industrial revolution (ca. 1780 AD)
- Atomic age (Trinity nuclear test, 1945)

- Lewis & Maslin (2015)
  - 1610 AD; "Orbis spike" drop in carbon dioxide (CO_2) observed in two core records from the Antarctic Ice Sheet; extermination of 50 mil. people in New World (Latin America) mostly due to smallpox, measles and typhus deseases → decline in farming → afforestation → dip in CO_2 atmospheric concentrations; repeated, cross-ocean exchange of species is without precedent in Earth's history
  - 1964 AD; maximum production of ^{14}C from tests of atomic bombs
- Foley et al. (2013)
  - Palaeoanthropocene (time of human presence on Earth, local and regional impacts)
  - proper Anthropocene (post 1780 AD, human-induced changes started to significantly influence global climate)

Discussion question

Which are the human actions most damaging to the environment? Create a list of six human actions which are the most devastating to the environment according to your opinion.



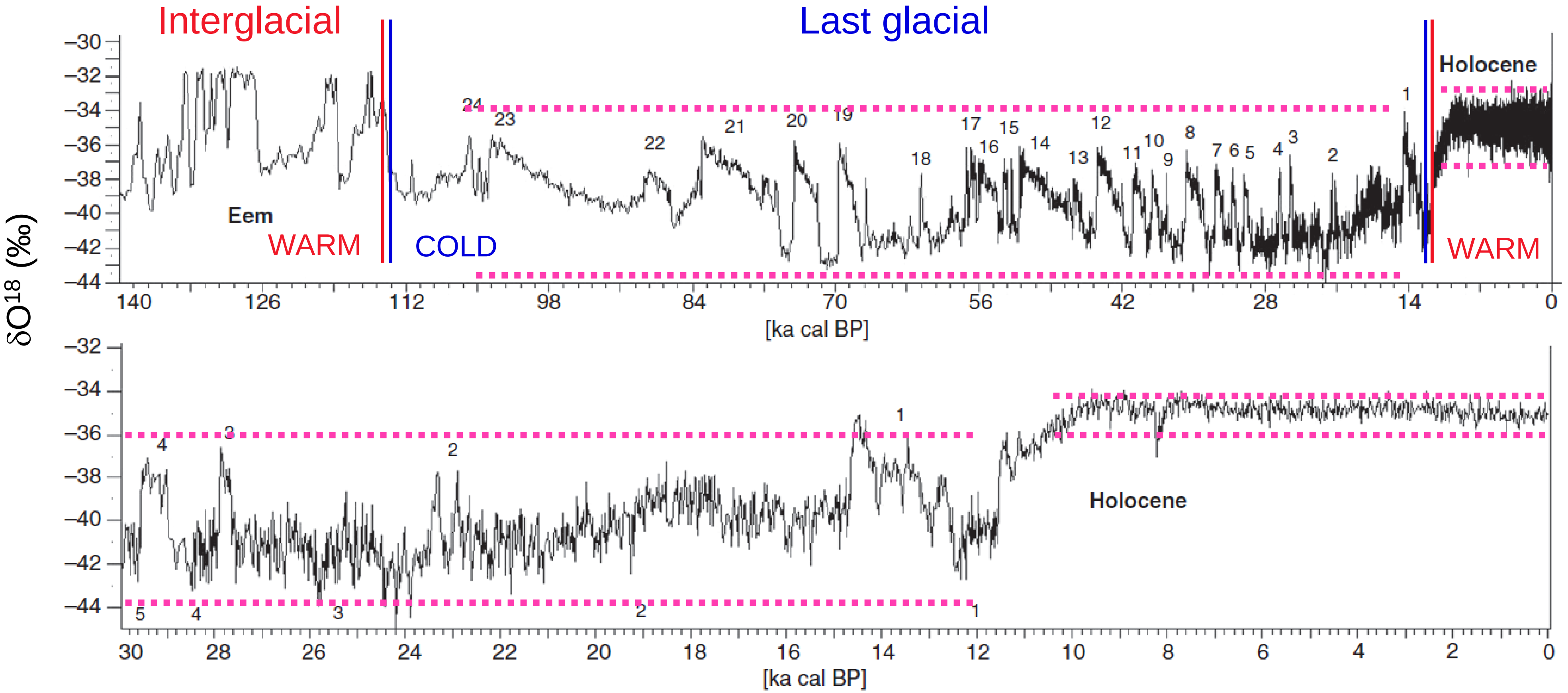
Source: Sherman and Montgomery (2021)

Earth's planetary boundaries (Rockström et al., 2009)

- Regular temperatures, freshwater availability and biogeochemical flows all stayed within a relatively narrow range during the Holocene geological epoch
- It seems that human activities push the Earth system outside the stable environmental state of the Holocene to less habitable state
- Planetary boundaries define the safe operating space for humanity with respect to the Earth system and are associated with the planet's bio-physical subsystems or processes

The Holocene: geological epoch when modern civilization arose

- The planet's environment was unusually stable during ca. 11 ka
- This period of stability is known as the Holocene (11.7 ka–present)



The natural range of variability

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Processes for which it is necessary to define planetary boundaries

Planetary boundaries are critical values of control variables for the nine bio-physical processes

1. Climate change
2. Change in biosphere integrity
3. Stratospheric ozone depletion
4. Ocean acidification
5. Biogeochemical flows: the nitrogen and phosphorus cycles
6. Change in land use (now “Land-system change)
7. Global freshwater use
8. Atmospheric aerosol loading
9. Chemical pollution (now “Novel entities”)

How are planetary boundaries defined?

Earth system process	Control variable(s)	Planetary boundary	Preindustrial Holocene base value	Upper end of zone of increasing risk	Current value of control variable
Change in biosphere integrity	Genetic diversity: E/MSY	<10 E/MSY but with an aspirational goal of ca. 1 E/MSY (assumed background rate of extinction loss)	1 E/MSY	100 E/MSY	>100 E/MSY (*24–26*)
	Functional integrity: measured as energy available to ecosystems (NPP) (% HANPP)	HANPP (in billion tonnes of C $year^{-1}$) <10% of preindustrial Holocene NPP, i.e., >90% remaining for supporting biosphere function	1.9% (2σ variability of preindustrial Holocene century-mean NPP)	20% HANPP	30% HANPP (see the Supplementary Materials)
Land system change	*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)	*Global: 75%* values are a weighted average of the three individual biome boundaries; *biomes*: tropical, 85%; temperate, 50%; boreal: 85%	100%	*Global*: 54%; *biomes*: tropical, 60%; temperate, 30%; boreal: 60%	*Global*: 60% [(*72*, *97*) and see the Supplementary Materials]; *tropical*: Americas, 83.9%; Africa, 54.3%; Asia, 37.5%; *temperate*: Americas, 51.2%; Europe, 34.2%; Asia, 37.9%; *boreal*: Americas, 56.6%; Eurasia: 70.3%

How are planetary boundaries defined?

Earth system process	Control variable(s)	Planetary boundary	Preindustrial Holocene base value	Upper end of zone of increasing risk	Current value of control variable
Climate change	Atmospheric CO_2 concentration (ppm CO_2)	350 ppm CO_2	280 ppm CO_2	450 ppm CO_2	417 ppm CO_2 *(41)*
	Total anthropogenic radiative forcing at top-of-atmosphere ($W\ m^{-2}$)	$+1.0\ W\ m^{-2}$	$0\ W\ m^{-2}$	$+1.5\ W\ m^{-2}$	$+2.91\ W\ m^{-2}$ *(41)*
Stratospheric ozone depletion	Stratospheric O_3 concentration, (global average) (DU)	<5% reduction from preindustrial level assessed by latitude (~276 DU)	290 DU	261 DU	284.6 DU *(96)*
Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	≥80% Ω_{arag} of mean preindustrial aragonite saturation state of surface ocean, including natural diel and seasonal variability	3.44 Ω_{arag}	2.75 Ω_{arag}	2.8 Ω_{arag} *(71)*

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How are planetary boundaries defined?

Earth system process	Control variable(s)	Planetary boundary	Preindustrial Holocene base value	Upper end of zone of increasing risk	Current value of control variable
Biogeochemical flows: P and N cycles	Phosphate *global:* P flow from freshwater systems into the ocean; *regional*: P flow from fertilizers to erodible soils (Tg of P year^{-1})	Phosphate *global:* 11 Tg of P year^{-1}; *regional:* 6.2 Tg of P year^{-1} mined and applied to erodible (agricultural) soils. Boundary is a global average, but regional distribution is critical for impacts.	0 Tg of P year^{-1}	*Global*: 100 Tg of P year^{-1}; *regional*: 11.2 Tg of P year^{-1}	*Global*: 22.6 Tg of P year^{-1} (*75*); *regional*: 17.5 Tg of P year^{-1} (*76*)
	Nitrogen *global:* industrial and intentional fixation of N (Tg of N year^{-1})	Nitrogen *global:* 62 Tg of N year^{-1}. Boundary is a global average. Anthropogenic biological N fixation on agriculture areas highly uncertain but estimates in range of ~30 to 70 Tg of N year^{-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.	0 Tg of N year^{-1}	82 Tg of N year^{-1}	190 Tg of N year^{-1} (*84*)

How are planetary boundaries defined?

Earth system process	Control variable(s)	Planetary boundary	Preindustrial Holocene base value	Upper end of zone of increasing risk	Current value of control variable
Freshwater change	Blue water: human induced disturbance of blue water flow	Upper limit (95th percentile) of global land area with deviations greater than during preindustrial, Blue water: 10.2%	9.4% (median of preindustrial conditions)	50% (provisional)	18.2% (*46*)
	Green water: human induced disturbance of water available to plants (% land area with deviations from preindustrial variability)	Green water: 11.1%	9.8% (median of preindustrial conditions)	50% (provisional)	15.8% (*46*)

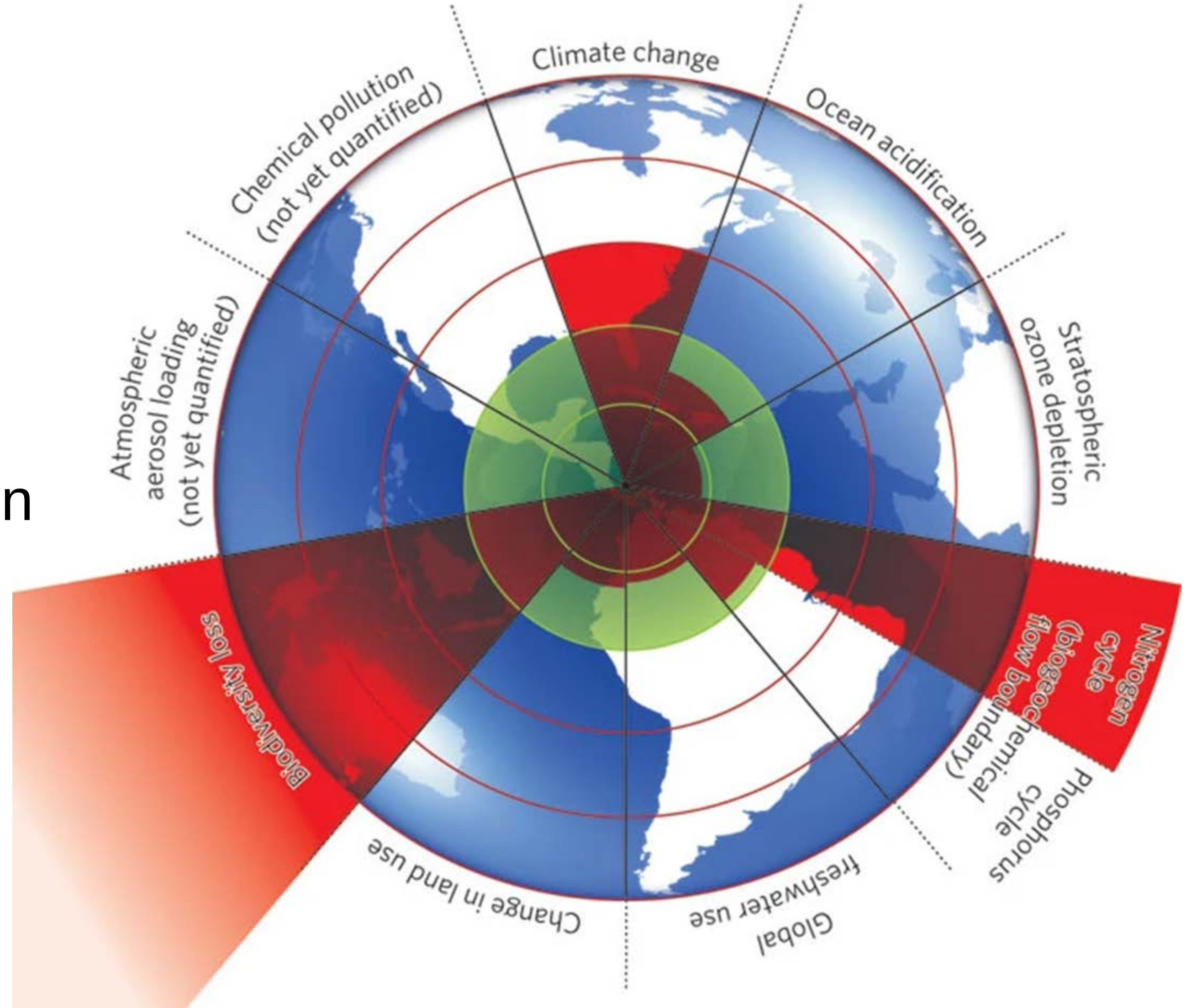
How are planetary boundaries defined?

Earth system process	Control variable(s)	Planetary boundary	Preindustrial Holocene base value	Upper end of zone of increasing risk	Current value of control variable
Atmospheric aerosol loading	Interhemispheric difference in AOD	0.1 (mean annual interhemispheric difference)	0.03	0.25	0.076 (*55*, *57*, *68*)
Novel entities	Percentage of synthetic chemicals released to the environment without adequate safety testing	0	0	NA	Transgressed

Beyond the boundary

The boundaries in three systems have already been exceeded in the year 2009

- The rate of biodiversity loss
- Climate change
- Human interference with the nitrogen cycle



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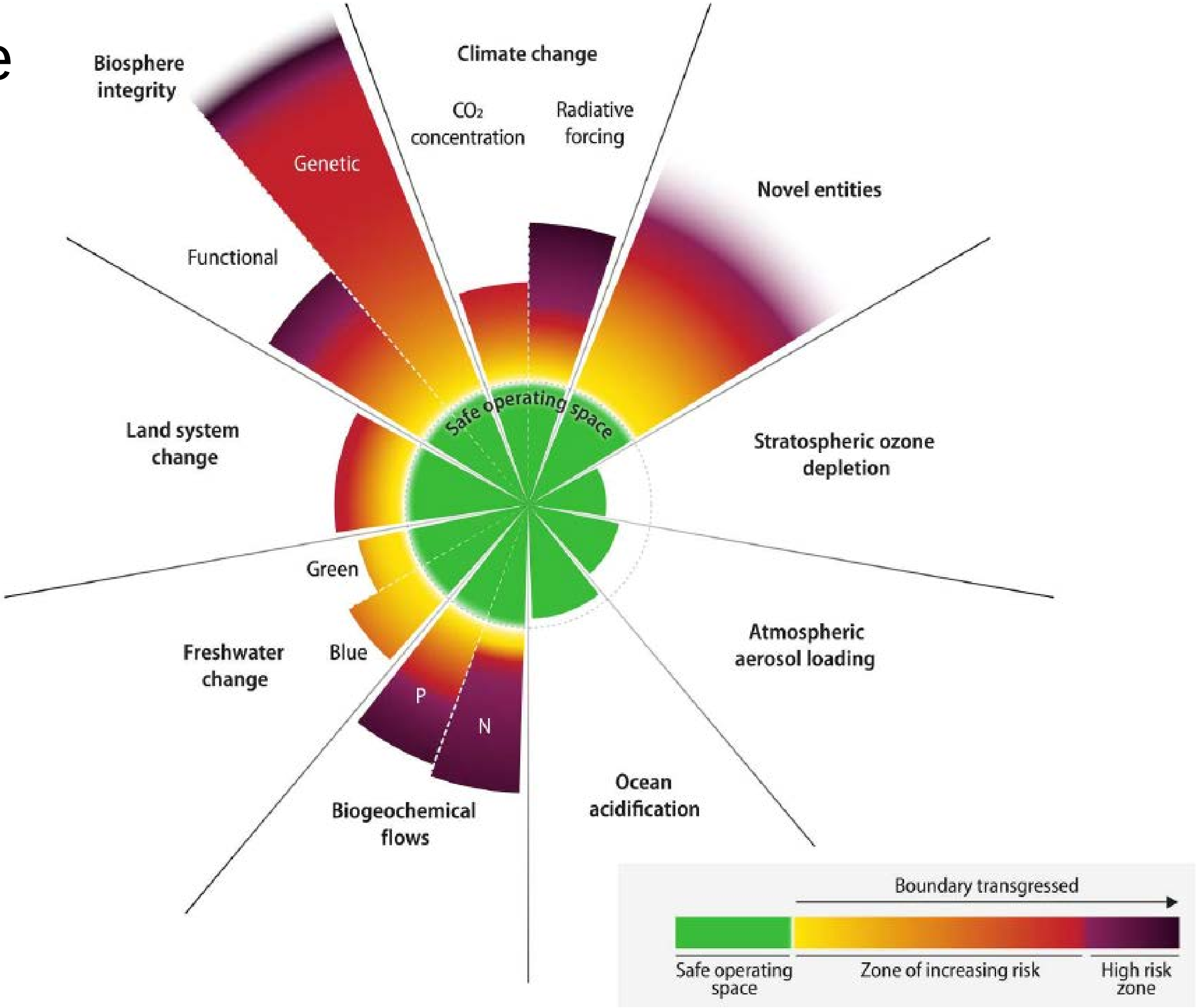
Planetary boundaries – the 2023 update

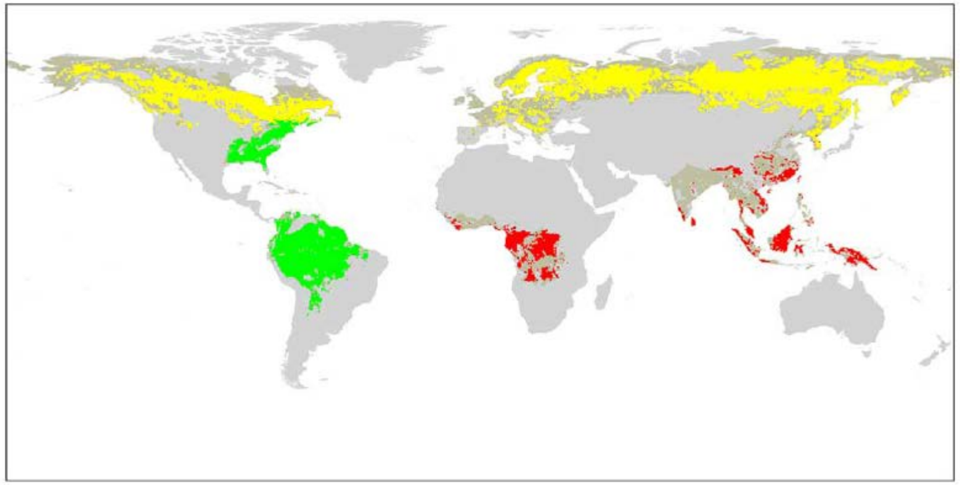
Six out of nine boundaries are now transgressed!



The subglobal distributions and current status of the control variables

Example: LAND-SYSTEM CHANGE

C Land-system change



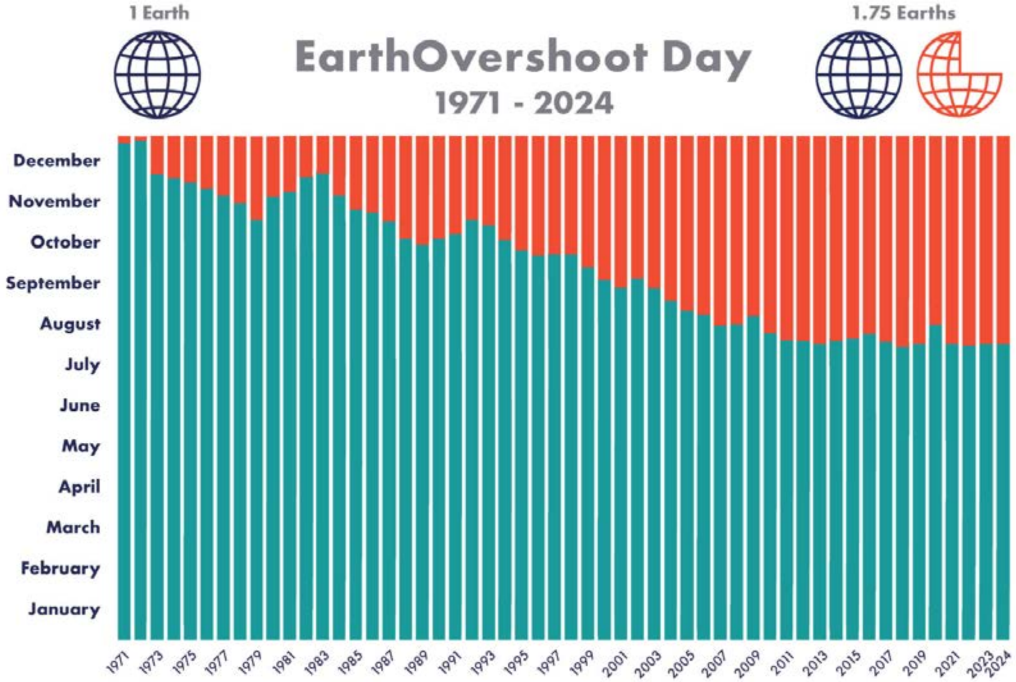
Beyond zone of uncertainty (high risk) In zone of uncertainty (increasing risk) Below boundary (safe)

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%)	

Why are human actions so devastating to the environment?

Earth overshoot day

- Earth overshoot day marks the date when humanity’s demand for ecological resources and services in a given year exceeds what Earth can regenerate in that year
- 2024: 1st August
- Humans use as much ecological resources as if we lived on 1.7 Earths

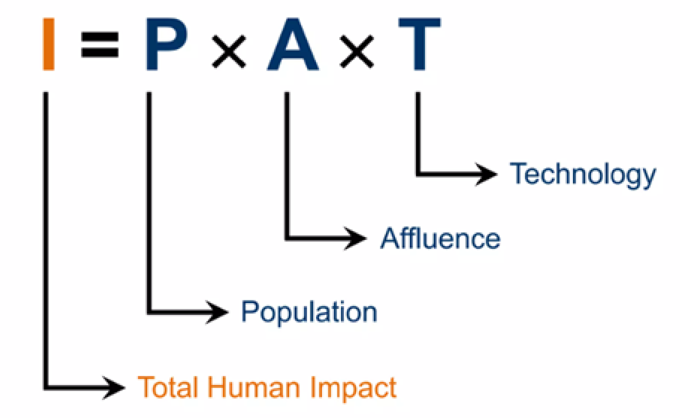


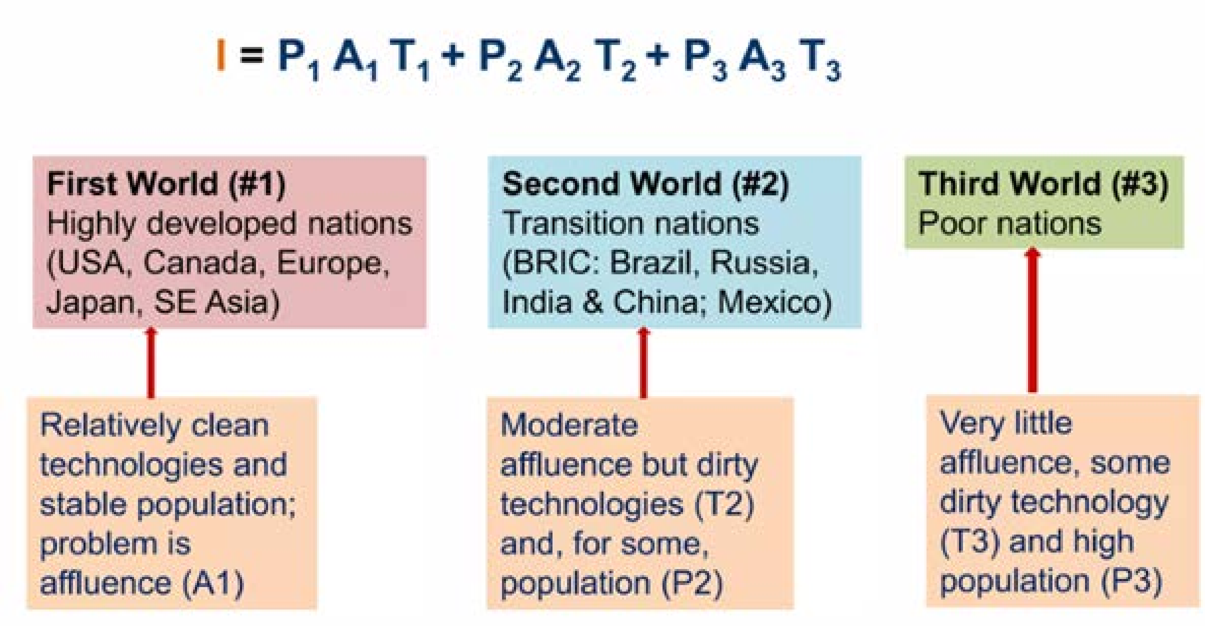
Causes of environmental crisis

- Population growth
- Unsustainable resource use
- Poverty
- Excluding environmental costs from market prices
- Increasing isolation from nature

The IPAT equation (Ehrlich and Holdren, 1970s)

The IPAT equation determines the environmental impact of human activities





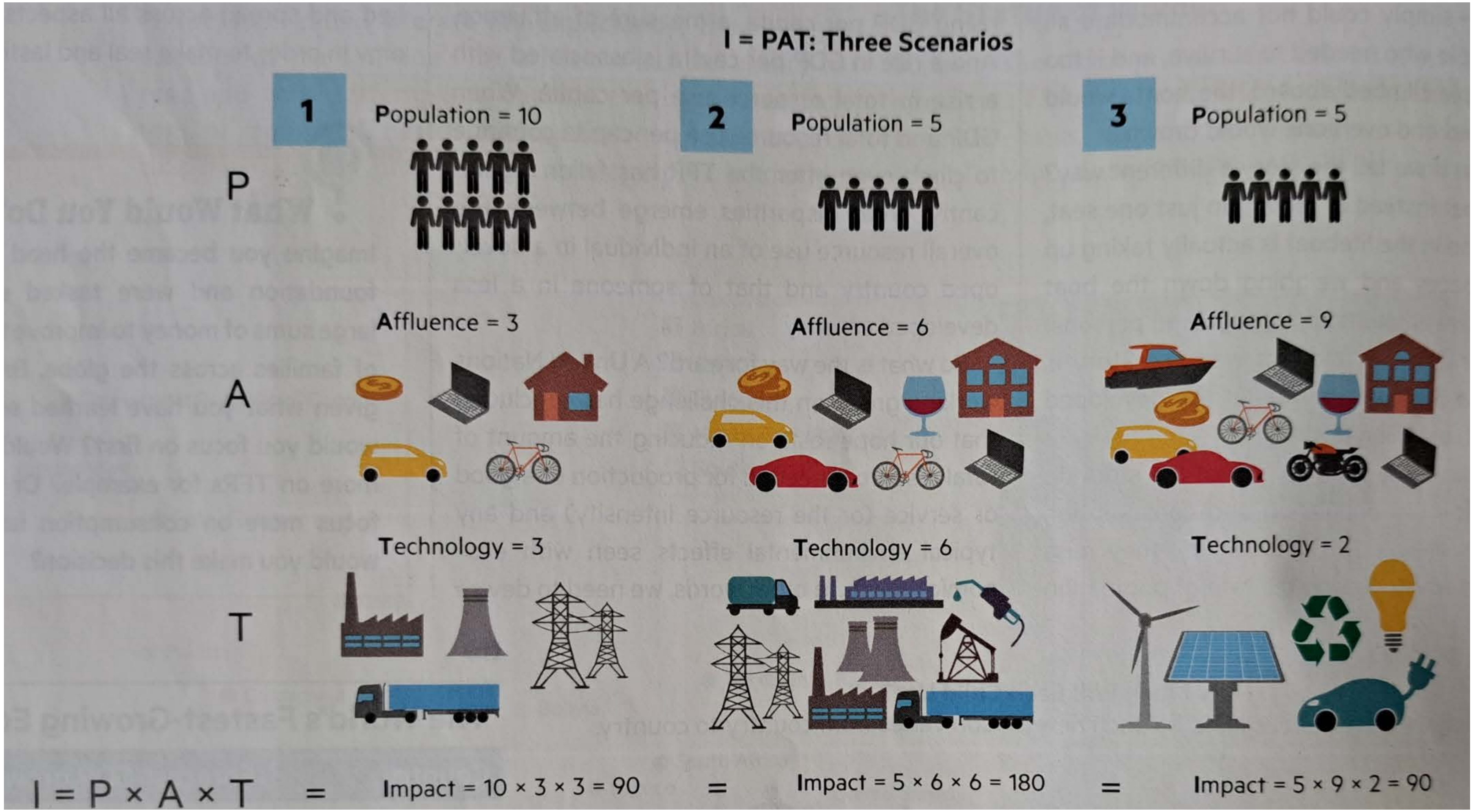
Human impact: may be expressed in terms of resource depletion or waste accumulation

Population: size of human population

Affluence: level of consumption by population (usually measured as GDP per person in a country)

Technology: processes used to obtain resources and transform them to useful goods and waste

The IPAT scenarios



Ecological footprint

– Considering consumption not every human on this planet has an equal impact
– Ecological footprint analysis: a technique that attempts to calculate the area of land (and water) required for different categories of consumption and waste, i.e. “global hectar”
– Global hectar: the measure of land and sea required to provide the resources for the goods humns consume and the waste that must be absored from human activity
– The resources and services the Earth provides devided equally amon human population → 1.59 ha per person

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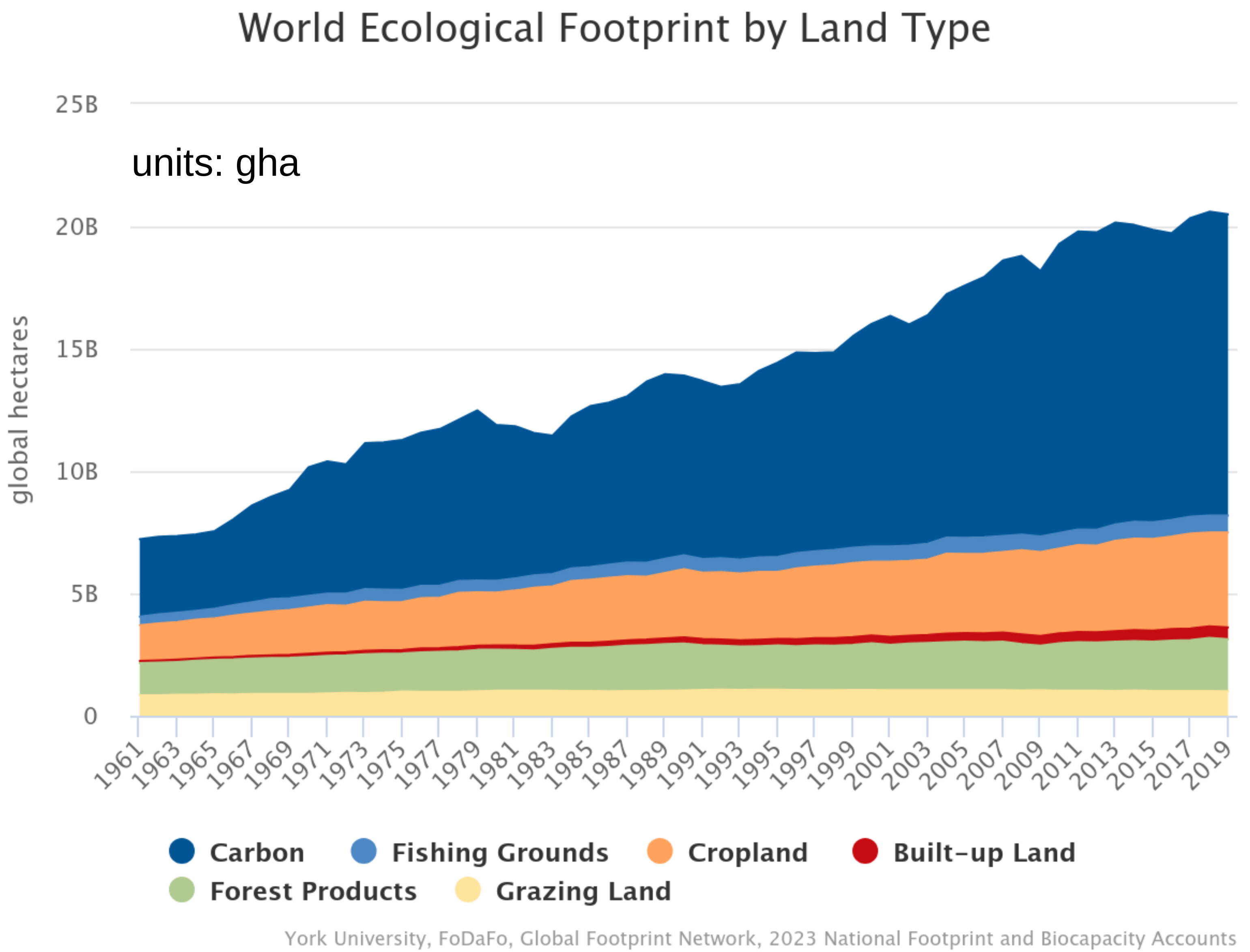
World ecological footprint by land type



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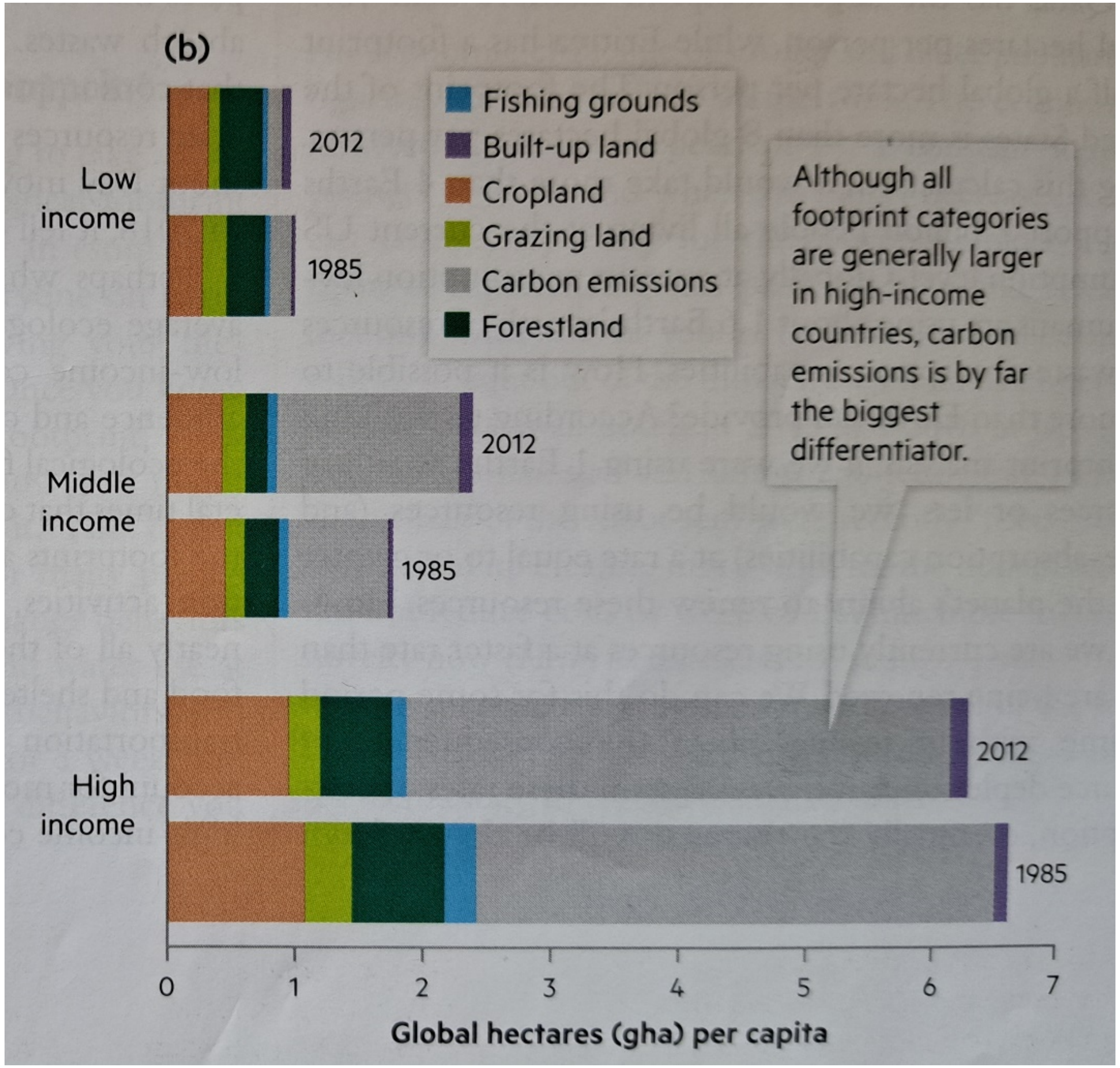
Countries ranked by ecological footprint per capita

COUNTRY	Ecological footprint (global ha)	COUNTRY	Ecological footprint (global ha)
Nauru	62.1	Malawi	0.8
Faroe Islands	35.8	Congo DR	0.7
Micronesia	25.0	Bangladesh	0.7
Iceland	24.4	Pakistan	0.7
Kiribati	19.1	Burundi	0.6
St. Kitts and Nevis	16.3	Yemen	0.6
Marshall Islands	16.1	Haiti	0.6
Seychelles	12.3	Rwanda	0.6
Luxembourg	12.3	Timor-Leste	0.5
Qatar	12.0	Puerto Rico	0.1

Ecological footprint of countries according to income

- Low-income countries
  EF stable
- Middle-income countries
  EF rising
- High-income countries
  EF slowly declining



Toward a sustainable world

What is sustainability?

- ... is the management of natural resources in ways that do not diminish or degrade Earth's ability to provide them in the future
- ... is the capacity of the Earth's natural systems and human cultural systems to survive, flourish, and adapt into the very long-term future
- "Sustainable development" first defined in the "Our Common Future" report elaborated by the UN World Commission on Environment and Development (WCED) (published in 1987)

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Millenium Development Goals

UN Millenium Summit (2000, New York)

UN Millenium Declaration:

Millenium Development Goals

The goals were to be achieved by 2015

1. Eradicate extreme poverty
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership

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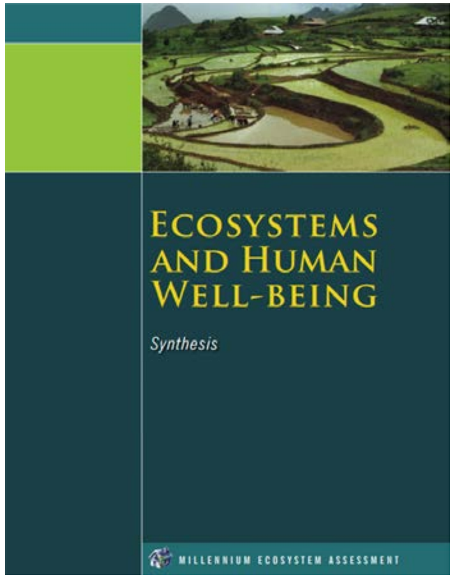
The Millennium ecosystem assessment

– Collaborative effort to assess the consequences of ecosystem change for human well-being, involving more than 1,360 experts worldwide
– 2001–2005
– Main findings:



– The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals.
– The challenge of reversing the degradation of ecosystem while meeting increasing demands for services can be partially met under some scenarios considered by the MA, but will involve significant changes in policies, institutions and practices that are not currently under way.

The Sustainable Development Goals (SDGs)

Transforming our World: The 2030 Agenda for Sustainable Development (2015, New York)

SUSTAINABLE DEVELOPMENT GOALS

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