

Press Release

Nature Article: *“Safe and just Earth System Boundaries”*

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A just world on a safe planet: First study quantifying Earth System Boundaries

Humans are taking colossal risks with the future of civilization and everything that lives on Earth, a new study published in the journal *Nature* shows. Developed by an international science commission engaging more than 40 researchers from across the globe, the scientists deliver the first quantification of safe and just Earth system boundaries on a global and local level for several biophysical processes and systems that regulate the state of the Earth system.

For the first time, safety and justice for humanity on Earth is assessed and quantified for the same control variables regulating life support and Earth stability. Justice, assessed based on avoiding significant harm to people across the world, tightens the Earth system boundaries, providing even less available space for humans on Earth. This is extremely challenging, as the Earth Commission concludes that numerous of the safe boundaries are already crossed today.

Convened by [Future Earth](#), the [Earth Commission](#) is the scientific cornerstone of the [Global Commons Alliance](#).

“We are in the Anthropocene, putting the stability and resilience of the entire planet at risk. This is why, for the first time, we present quantifiable numbers and a solid scientific foundation to assess the state of our planetary health not only in terms of Earth System stability and resilience but also in terms of human wellbeing and equity / justice.” said Prof. Johan Rockström, Earth Commission Co-Chair, lead author and Director of the Potsdam Institute for Climate Impact Research.

“Justice is a necessity for humanity to live within planetary limits. This is a conclusion seen across the scientific community in multiple heavyweight environmental assessments. It is not a political choice. Overwhelming evidence shows that a just and equitable approach is essential to planetary stability. We cannot have a biophysically safe planet without justice. This includes setting just targets to prevent significant harm and guarantee access to resources to people and for as well as just transformations to achieve those targets” said co-author Prof. Joyeeta Gupta, Co-Chair of the Earth Commission, Professor of Environment and Development in the Global South at the University of Amsterdam and Professor of Law and Policy in Water Resources and Environment at IHE Delft Institute for Water Education.

Health indicators for people and planet

The Earth Commission has quantified safe and just boundaries for climate, biodiversity, freshwater and different kinds of pollution to air, soil and water - and most have been breached. For example, human activities are altering water flows, excessive amounts of nutrients are released into waterways from fertilizer use, and limited natural areas are left. This poses existential threats for a stable planet, to ecosystems and their vital contributions to people. The world has already passed the safe and just climate boundary, which is set at 1°C above pre industrial temperature levels, as tens of millions of people are already harmed by the current level of climate change.

“Our results are quite concerning: Within the five analyzed domains, several boundaries, on a global and local scale, are already transgressed. This means that unless a timely transformation occurs, it is most likely that irreversible tipping points and widespread impacts on human wellbeing will be unavoidable. Avoiding that scenario is crucial if we want to secure a safe and just future for current and future generations,” continued Rockström.

“The Earth system is in danger, as many tipping elements are about to cross their tipping points. So far, seventeen tipping elements are identified in scientific literature, among them,

nine are cryosphere-related. The Asia High Mountain Cryosphere (AHMC) is fast changing and close to becoming a new tipping element, which can impact the regional social-economy.” explained Prof. Dahe Qin, Co-Chair of the Earth Commission and Director of the Academic Committee, Chinese Academy of Sciences.

For a safe future, the world needs global targets beyond climate

Global target setting has focused on climate change and limiting global warming well below 2°C and aiming at 1.5°C according to the Paris Agreement. Science also clearly shows there is a need to manage all the other biophysical systems and processes on Earth that determine the livability on the planet.

“The Earth system is an interconnected set of biophysical processes that operate across regions and scales. Interference in one part of the world can have enormous impacts in other regions. Using Earth Systems Boundaries as an entry point for holistic and transformative action will support impactful and just progression towards a safe and just world.” said Wendy Broadgate, Earth Commission Executive Director and Future Earth, Global Hub Director, Sweden

Justice tightens the available space for humans on Earth

The new study builds on authoritative scientific evidence defining the biophysical conditions to maintain a stable planet to underpin life on Earth (“safe”) as well as assessing how significant harm can be avoided to humans and other species. Past scientific attempts to define environmental boundaries, such as the Planetary Boundary framework, have looked at the global conditions needed to maintain a stable planet and safeguard life on Earth.

“The new research provides safe and just earth system boundaries for five critical domains that play a key role in life support and Earth stability. It also explores what’s needed to minimise significant harm to humans as a result of changes in the Earth system and sets boundaries at scales relevant for assessment and management of the conditions of biophysical systems such as the biosphere and freshwater. ” explained Steven Lade, Lead author and Research Scientist, Earth Commission Secretariat at Future Earth, Australian National University and Stockholm Resilience Centre.

Safe boundaries ensure stable and resilient conditions on Earth, and use an interglacial Holocene-like Earth system functioning as a reference point for a healthy planet. A stable and resilient Earth is dominated by balancing feedbacks that cope with buffer and dampen disturbances. Cutting edge science on climate tipping points feature as one major line of evidence to set safe boundaries.

Just boundaries minimize human exposure to significant harm. The Commission defines significant harm as: widespread severe existential or irreversible negative impacts on countries, communities and individuals from Earth system change, such as loss of lives, livelihoods or incomes, displacement, loss of food, water or nutritional security, chronic disease, injury or malnutrition.

“Our safe and just boundaries will guide target setting, but must also be realized through just transformation processes that ensure minimum access to resources for people. adds Gupta.

The Safe and Just boundaries take the stricter of the two quantified levels to identify the Safe and Just Earth System Boundary.

Science for real world application

The Earth Systems Boundaries will underpin the setting of new science-based targets for businesses, cities and governments to address the polycrises of: increasing human exposure to the climate emergency, biodiversity decline, water shortages, ecosystem damage from fertiliser overuse in some parts of the world coupled with lack of access elsewhere, and health damage from air pollution. In a time of increasing scrutiny and expectations, the resilience and success of businesses, cities and governments will depend on their ability to accurately measure and improve their impact on people and planet - and target opportunities within the finite limits of the planet.

“A safe and just transformation to a manageable planet, requires urgent, collective action by multiple actors, especially in government and business to act within Earth system boundaries to keep our life support system of the planet intact. Stewardship of the global commons has never been more urgent or important.” continued Wendy Broadgate, Earth Commission Executive Director, and Global Hub Director (Sweden), Future Earth.

“With this global scientific assessment, we provide all stakeholders with scientific boundaries that can enable a prosperous and equitable world development on a stable planet, a better future for people and planet. This new science functions as input to the development of science-based targets. These can be adopted by cities, businesses and countries to address the systemic global crises of climate change, biodiversity loss, nutrient overloading, overuse of water, and air pollution.” concludes Rockström.

SAFE AND JUST EARTH SYSTEM BOUNDARIES

CLIMATE

- Safe: 1.5°C to avoid high likelihood of multiple climate tipping points. NOT YET BREACHED
- Just: 1°C to avoid high exposure to significant harm from climate change. BREACHED AT 1.2°C
- **Safe and Just: 1°C**

BIOSPHERE

- Global Intact Nature: at least 50-60% natural ecosystem area (safe and just). BREACHED AT 45-50%
- Local Managed nature: at least 20-25% natural ecosystems in every square kilometer (safe and just). BREACHED FOR TWO-THIRDS OF HUMAN-DOMINATED LAND AREA
- **Safe and Just (global intact nature):** >50-60% natural ecosystem area
- **Safe and Just (local managed nature):** >20-25% natural ecosystems in every km²

WATER

- Surface water: 20% monthly flow alteration (safe and just). BREACHED FOR 34% OF GLOBAL AREA
- Groundwater: Annual drawdown less than recharge (safe and just). BREACHED FOR 47% OF GLOBAL AREA
- **Safe and Just (surface water):** <20% monthly flow alteration
- **Safe and Just (groundwater):** Drawdown ≤ Recharge

NUTRIENT CYCLES (Fertilizers)

- Nitrogen:
 - Safe: <2.5 mgN/L in surface water & <5-20 kgN/ha/yr land deposition (local); 61 TgN/yr surplus (global) - BREACHED AT 119 TgN/yr
 - Just: same as Safe, plus drinking water <11.3 mgNO₃-N/L (local); 57 TgN/yr surplus (global). BREACHED AT 119 TgN/yr
- Phosphorus:
 - Safe: 50-100 mgP/m³ (local freshwater concentration); 4.5-9 TgP/yr (global surplus). BREACHED AT 10 TgP/yr

- Just: same as Safe, plus any additional local standards.

BREACHED AT 10 TgP/yr

- **Safe and Just (nitrogen):** <57 TgN/yr (global)
- **Safe and Just (phosphorus):** Surplus <4.5-9.0 TgP/yr (global)

AEROSOL POLLUTANTS

- **Global:** 0.15 annual mean interhemispheric AOD difference (safe). NOT BREACHED AT 0.05
- **Local:** 0.25 aerosol optical depth (AOD) to avoid changes to monsoons (safe). 15 µg/m³ PM_{2.5} to avoid high likelihood of harm to human health (just).
- **Safe and Just (global):** 0.15 annual mean interhemispheric AOD difference (safe)
- **Safe and Just (local):** 15 µg/m³ PM_{2.5}

- ENDS -

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NOTES TO EDITORS

[The Earth Commission](#) has scientifically defined and quantified a safe and just corridor for people and planet at local and global scales, avoiding crossing irreversible tipping points and avoiding significant harm to humans and ensuring access to resources for a dignified life and freedom from poverty for everyone. The Commission is hosted by [Future Earth](#), the world's largest network of sustainability scientists, and is the scientific cornerstone of the [Global Commons Alliance](#), a sponsored project of Rockefeller Philanthropy Advisors with support from Oak Foundation, MAVA, Porticus, Gordon and Betty Moore Foundation, Tiina and Antti Herlin Foundation, the Global Environment Facility and Generation Foundation and the William and Flora Hewlett Foundation. The Commission is also supported by the Global Challenges Foundation and the Frontiers Foundation.

The Commission is chaired by Prof. Johan Rockström (Potsdam Institute for Climate Impact Research, Germany), Prof. Dahe Qin (Chinese Academy of Sciences, China), Prof. Joyeeta Gupta (University of Amsterdam, Netherlands).

[Future Earth](#) is a global network of scientists with a mission to advance research in support of transformations to global sustainability. Future Earth hosts the Earth Commission and its scientific secretariat.

Press conferences

Online press briefing

Title: Safe and Just Earth System Boundaries, Online

Date: Tuesday 30 May

Time: 15:00 GMT (16:00 CEST /17:00 EAT /19:30 IST /22:00 CST)

Login details: Go To Webinar. Contact Press@nature.com for more information

- **Chaired** by Lisa Boucher, Nature Press Manager
- **Opening speakers:** Prof. Johan Rockstrom, Prof. Joyeeta Gupta, Dr. Wendy Broadgate,
- **Q&A Speakers:** Prof. Qin Dahe, Dr. David Obura, Prof. Xuemei Bai, Prof. Stuart Bunn,

Explainers

Glossary of terms

[Earth Commission glossary - press resource](#)

explainer Briefs

- [Climate](#)
- [Biosphere](#)
- [Freshwater](#)
- [Nutrients](#)
- [Aerosols](#)
- [All explainer briefs \(one file\)](#)

Additional Quotes

“Evidence from 1990 stated that a 1°C temperature limit minimizes harm to ecosystems, and by implication to humans too. By setting our climate Earth System Boundary at 1°C we are not advocating that the world should adopt this ambitious target, but we are exposing the injustice inherent in current world targets”. explains **Prof. Joyeeta Gupta, Co-Chair of the Earth Commission, Professor of Environment and Development in the Global South at the University of Amsterdam and Professor of Law and Policy in Water Resources and Environment at IHE Delft Institute for Water Education.**

“Potential future tipping points are not the only risks we consider, damage is already happening to millions of people at 1°C of climate warming. Our climate Earth System Boundary exposes the injustice in current targets and underscores the urgency of immediately phasing out fossil fuels and accelerating work from all directions to meet Paris Agreement Goals”. said **Gupta.**

“While we know that there are 9 biophysical processes and systems that regulate the state of the Earth system - the Planetary Boundaries – the Earth Commission took 5 of these and scientifically quantified them with safe and Just Earth System Boundaries. This is a major advancement of the Planetary Boundaries framework, by quantifying safety and justice”. explains **Prof. Johan Rockström, Earth Commission Co-Chair, lead author and Director of the Potsdam Institute for Climate Impact Research.**

“Climate is only one of many different Earth sub-systems on which we depend for a stable planet. Others - such as the biosphere, nutrient and hydrological cycles - are just as fundamental to our societies, but much less acted on. The Earth Commission findings are a scientific breakthrough. Not only do we go beyond climate, we also provide quantifications

along the same metrics for multiple Earth system boundaries for both safety and justice ". explains **Wendy Broadgate, Earth Commission Executive Director and Global Hub Director (Sweden), Future Earth.**

"It's shocking to see how far into the danger zone we are for so many areas that we rely on for our safety and stability. At the same time, it's reassuring to see - in clear, quantified terms - the contours of a safe and just space that would allow people and planet to thrive. I am committed to making sure, that through the Global Commons Alliance, these Earth System Boundaries will inform and spark the urgent action necessary, across all sectors and scales." said **Jane Madgwick, Executive Director of the Global Commons Alliance**

"The science is clear: we need urgent action right now across climate and nature because our Earth system is fundamentally interconnected. At the Science Based Targets Network we're helping companies with the critical "how" and the "what can we do about it" questions. We now have clear guidance that companies can use today to set integrated climate and nature targets - with an initial focus on freshwater and land - based on science, so that they can play their part in ensuring an equitable, net zero, nature positive future". said **Erin Billman, Executive Director of the Science Based Targets Network**

"We are in a race to net zero and a race to resilience for our climate. We also need to be in a race to nature if we want to secure a safe and just future for all people. These Earth System boundaries provide an important scientific underpinning for that race, and provide multiple different entry points for businesses to strengthen their climate action. Urgent, integrated action is key and the time to start is now". said **Razan al Mubarak, President of the International Union for Conservation of Nature (IUCN)**

"This science is critically important for business. It connects climate to nature, freshwater, clean air and other global commons and defines what is needed to secure our collective future. It highlights how the current trajectory is untenable for the global economy and society. Businesses will face interacting crises and escalating risks in their operations and supply chains, which will destroy value. This new research will become the scientific underpinning for how businesses can and should build strategy, set targets and implement action to mitigate the risks and exercise leadership to safeguard the conditions for their continued success." said **Gim Huay, Managing Director, Centre for Nature and Climate at the World Economic Forum**

"This robust and comprehensive science will allow governments and industry to understand and improve – for the first time – their impact on our Earth against human boundaries as well

as biophysical, planetary boundaries. In practice, for CEOs, taking this people-centric approach is going to mean more ambitious and urgent targets and actions. Following the research, as we should, will mean setting the bar higher, but ultimately setting it where it belongs, with human-beings at the heart of our collective efforts to build a better and safer future for all.” said **Paul Polman, business leader and co-author of ‘Net Positive: how courageous companies thrive by giving more than they take’ and former CEO of Unilever**

Additional context

Earth System Boundaries or Planetary Boundaries?

This new research builds on the well-known Planetary Boundaries framework, which identifies the nine processes that regulate the stability and resilience of the Earth system. The Earth Commission explores five of these processes (Climate, Biodiversity, Freshwater, Nutrient cycles, Aerosol pollutants) and quantifies minimum access and harm considerations (justice) into the assessment.

Sub-level boundaries were quantified for water and biodiversity, resulting in **eight** Earth System Boundaries that expand on **six** of the **nine** Planetary Boundaries by considering minimum access to resources and where significant harm to humans occurs from Earth system change. In upcoming assessments, the Earth Commission will tackle additional Planetary Boundaries, with an imminent focus on Novel Entities and Ocean Acidification.

Figures and captions from the paper

Figure 1.

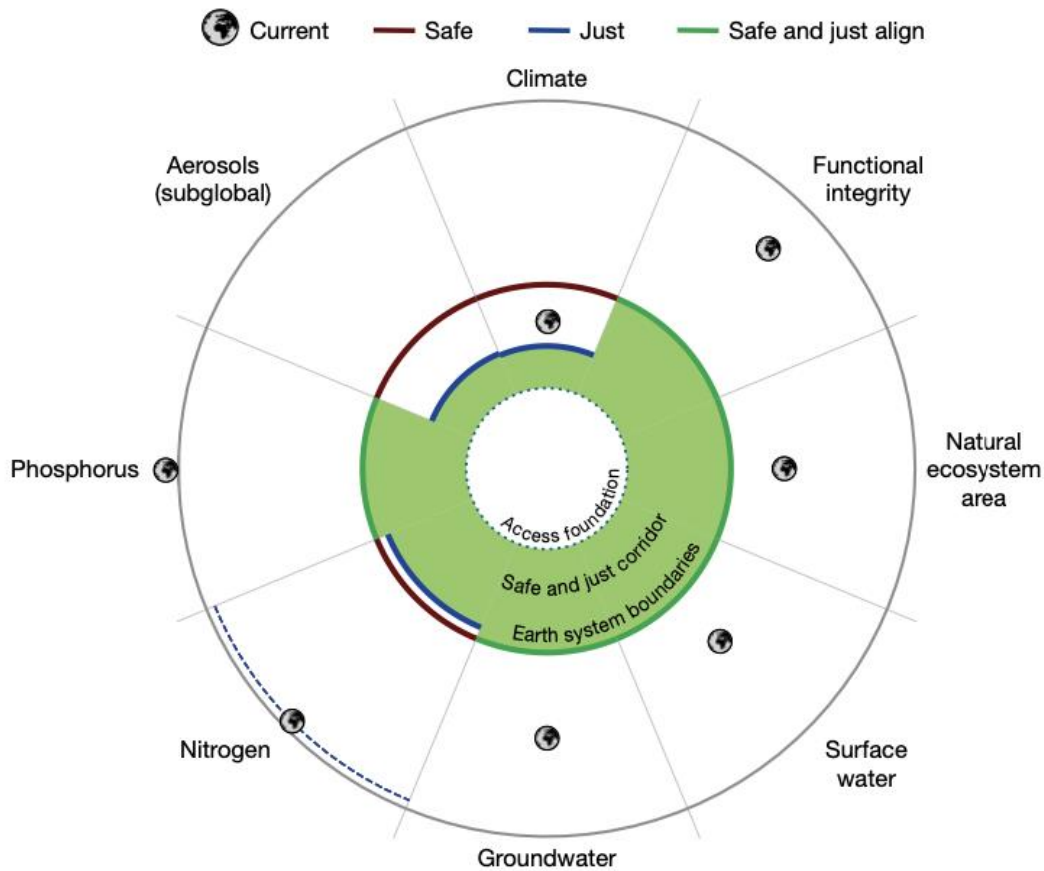


Figure 1. Proposed safe and just (NSH) Earth system boundaries. Visualisation of safe ESBs (dark red), just (NSH) ESBs (blue), cases where safe and just (NSH) boundaries align (green), and current global states (Earth icons). Radial axes are normalised to safe ESBs. Headline or central estimate global boundaries (Table 1) are plotted, to support comparison with current global state, but we emphasise that we have also defined sub-global boundaries and multiple likelihood levels for many domains (Table 1). For aerosols, however, we display the sub-global boundaries to compare safe and just boundaries. For nitrogen, we plot with a dashed blue line the boundary quantification for harm from nitrate in groundwater, while noting that the just boundary must also incorporate safe considerations via eutrophication leading to a more stringent safe and just boundary. Minimum access to water, food, energy and infrastructure for all humans (dotted green line) could constitute the foundation of a safe and just ‘corridor’ (green filled area), but we do not quantify this foundation here. Alternative visualisations are presented in Extended Data Figure 1.

Figure 2.

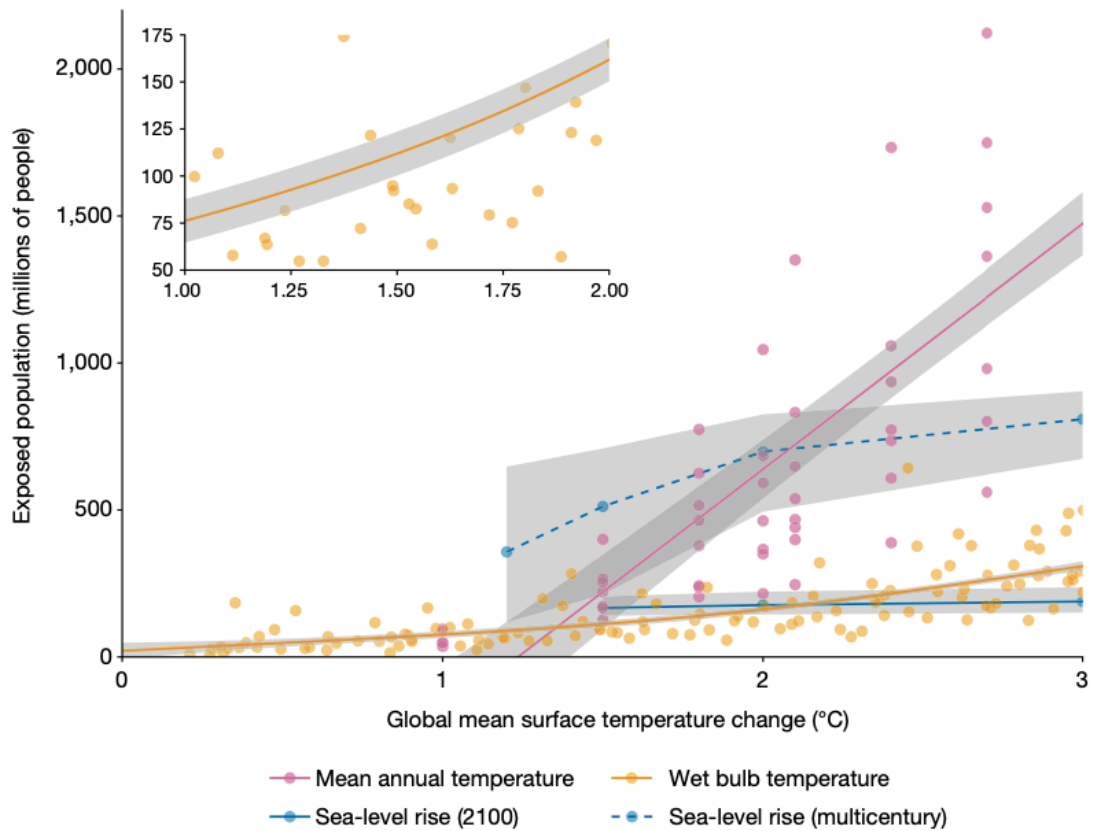


Figure 2: Exposure to significant harm from climate change at different levels of warming. We examine exposure of the 2010 global population to: mean annual temperatures above 29°C (purple, linear fit, $p < 0.01$); wet bulb temperatures of 35°C for an average of at least one day per year (orange, quadratic fit, $p < 0.01$); and future sea level rise (SLR) (blue, linear interpolation). Sea level rise is calculated for 2100 (blue solid) and multi-centennial (blue dashed, linear interpolation) responses to a given temperature stabilisation by 2100, representing near-term impacts and long-term equilibria, respectively. Inset shows magnification of wet bulb temperature in the range 1-2°C. Shading indicates one standard error.

Figure 3.

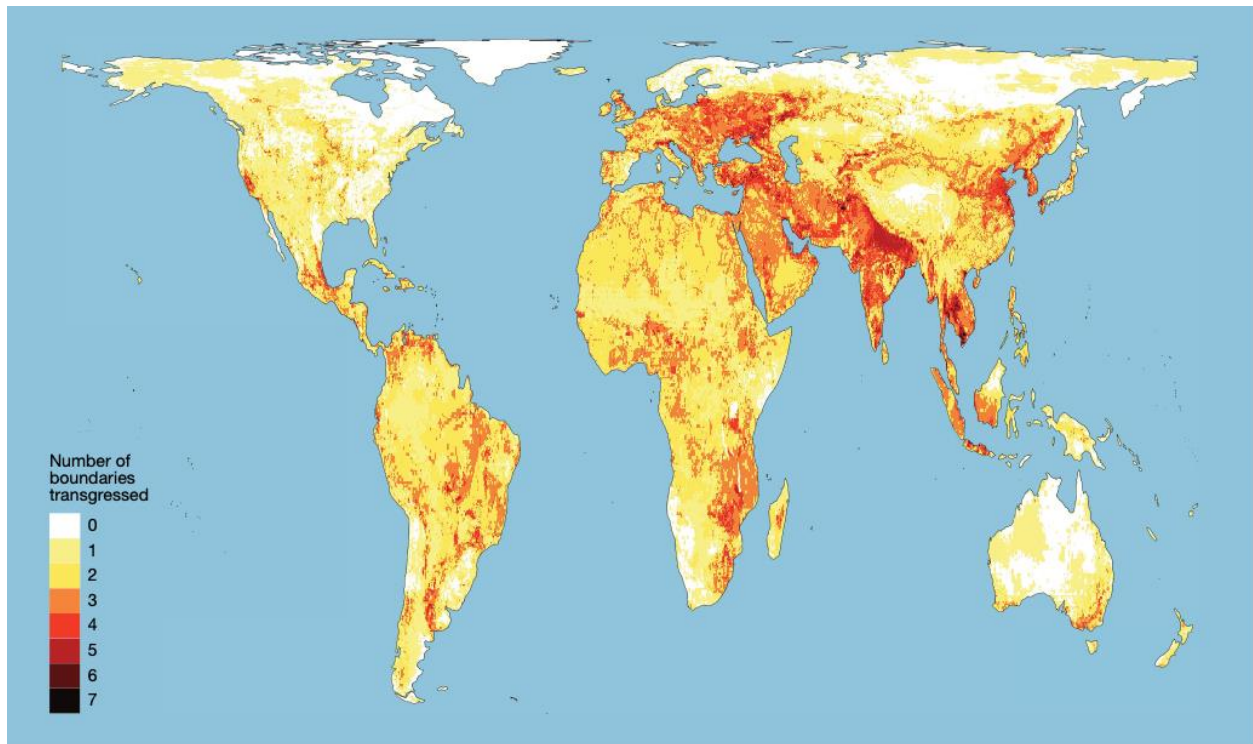
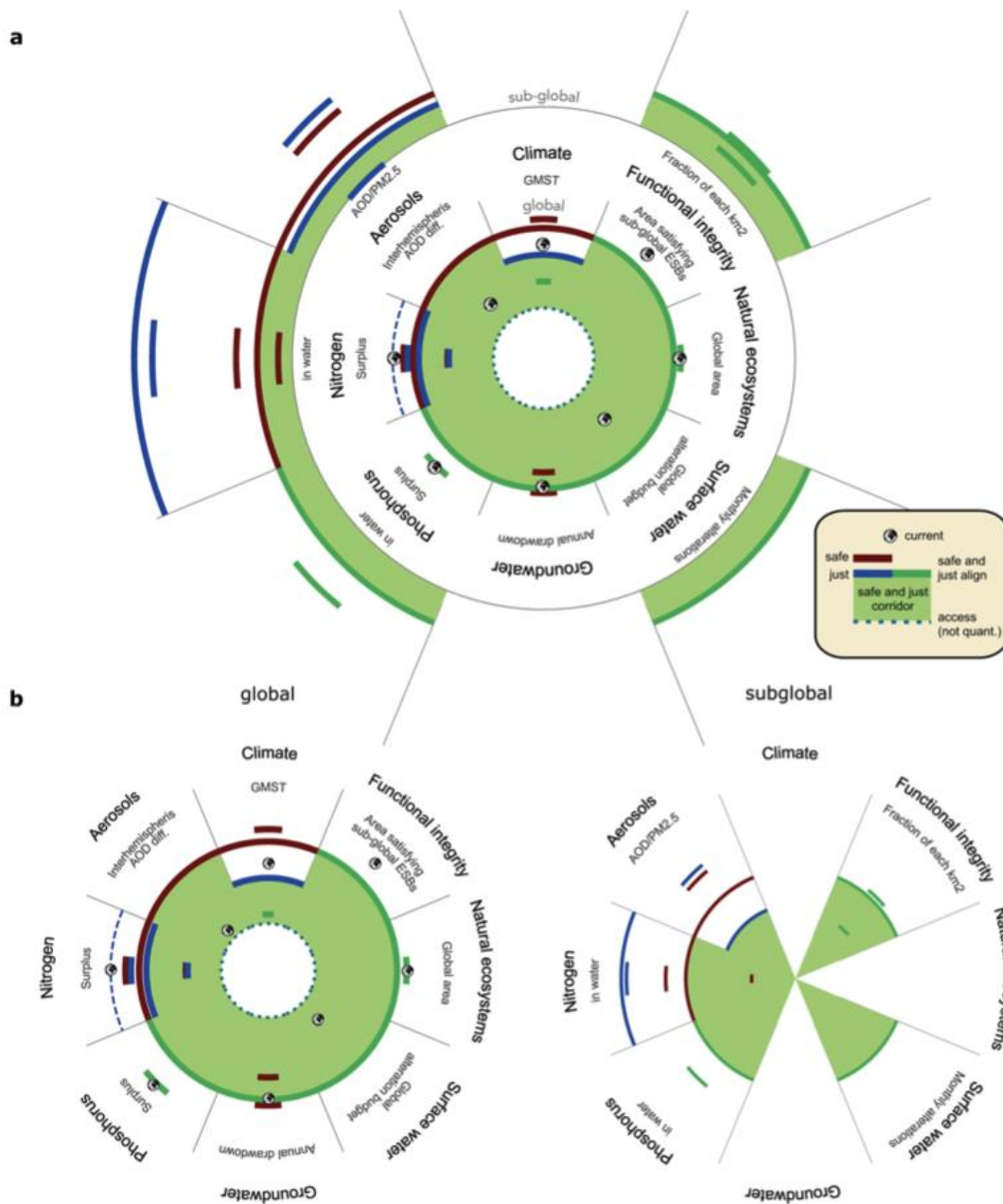


Figure 3. Hotspots of current ESB transgressions. The number of sub-global climate (two local exposure boundaries), functional integrity, surface water, groundwater, nitrogen, phosphorus and aerosol safe and just ESBs currently transgressed by location. No more than 7 of these 8 metrics have their ESBs transgressed in any one pixel. Since climate is a globally defined ESB, we use wet bulb temperatures of over 35°C for at least one day per year and low-elevation coastal zones (less than 5 m) exposed to sea level rise as proxies for local climate transgression, while acknowledging that the impacts of climate change are far more diverse. We also emphasise that exposure of a location does not necessarily imply responsibility for causing or addressing these environmental impacts. We invite the reader to investigate the consequences of different boundary values using the code available at ‘Code Availability’.

Extended Data Figure 1.



Extended Data Figure 1: Alternative visualisations of safe and just Earth system boundaries (Fig 1). Concentric (a) and parallel (b) visualisations of global (a, inner circle; b, left circle) and sub-global (a, outer circle; b, right circle) safe and just ESBs. Colours are as in Fig 1. Global rings (a, inner circle; b, left circle) show current global states; a single current state cannot be defined sub-globally. Short concentric lines (that extend across less than the full width of a wedge) represent alternative likelihood levels (safe) or levels of exposure (just NSH) (Table 1).

Extended Data Table 1.

Earth system domain	Overall confidence	Robustness of evidence base	Degree of scientific agreement
Climate	<i>High confidence</i>	Given the uncertainty on some evidence streams, for example, paleoclimate reconstructions of Holocene or Eemian maximum temperatures ^{107,108,118} , or on the assessment of climate tipping points in the 1-2°C range, overall this is taken as a <i>medium evidence robustness</i> .	There is <i>high evidence consistency and agreement</i> in the scientific literature of the Earth system being fundamentally altered with respect to climate change between 1 and 2°C.
Biosphere: natural ecosystem area	<i>Medium confidence</i>	There is <i>limited evidence</i> in the scientific literature addressing the relationship between area of natural ecosystems and Earth system functions and services (the majority of studies use the same method, and the range of estimates remains similar), with several conservation planning studies that relate largely intact natural area to extinction risks.	Among experts the <i>level of agreement is high</i> regarding the proposed ranges.
Biosphere: Functional integrity	<i>Medium confidence</i>	Highly variable robustness of the evidence across NCP: <i>robust evidence</i> for pollination, pest and disease control and water quality regulation, <i>medium evidence</i> for soil protection, <i>limited evidence</i> for natural hazards (variable quantity of studies, generally diverse methods used, and high consistency in findings).	<i>Medium degree of scientific agreement</i> in the literature.
Water: surface and ground	<i>Medium confidence</i> in the sub-global safe ESB for surface water flow. <i>High confidence</i> on the globally aggregated surface water and groundwater volumes.	The underlying flow data used in this analysis is derived from a well-documented and verified water balance model ^{132,133} . Output flow results are shown to be consistent with global discharge estimates and agricultural water consumption found in the scientific literature for both similar models and observed datasets (Table S3). Taken together, these suggest a <i>robust evidence base</i> .	<i>Scientific agreement</i> is considered <i>high</i> , based on the assessed literature and opinion of working group experts. The sub-global safe surface water flow boundary is recognised as a suitable boundary in the absence of detailed flow-ecology relationships ⁵⁹ and it has been adopted elsewhere in global-scale assessments (Supplementary Methods).
Nutrients	<i>Medium confidence</i> with respect to terrestrial systems. Due to substantial literature uncertainty and limited global modelling, there is <i>low confidence</i> for a nutrients ESB on ocean systems and hence none provided in this assessment.	<i>Medium-to-limited evidence robustness</i> due to a modest quantity of papers.	<i>Medium-to-high evidence consistency and agreement</i> in the literature on proposed global N/P boundary values.
Aerosols	<i>Low confidence</i>	There is high confidence in the physical mechanism by which the aerosol emissions from NH would influence the tropical monsoons ⁸⁴ . However, the uncertainty in the quantification of the interhemispheric AOD difference could be large due to aerosol-cloud interactions. Therefore, we assess <i>low level of evidence</i> , in terms of quantity and consistency in findings.	<i>Medium degree of scientific agreement</i> in the scientific literature assessed and among working group experts

Extended Data Table 1: Assessment of levels of confidence in each domain's safe Earth system boundaries. For more information see Methods. The robustness of evidence and degree of agreement of all ESB quantifications are based on the assessment of available literature and working group experts' views.