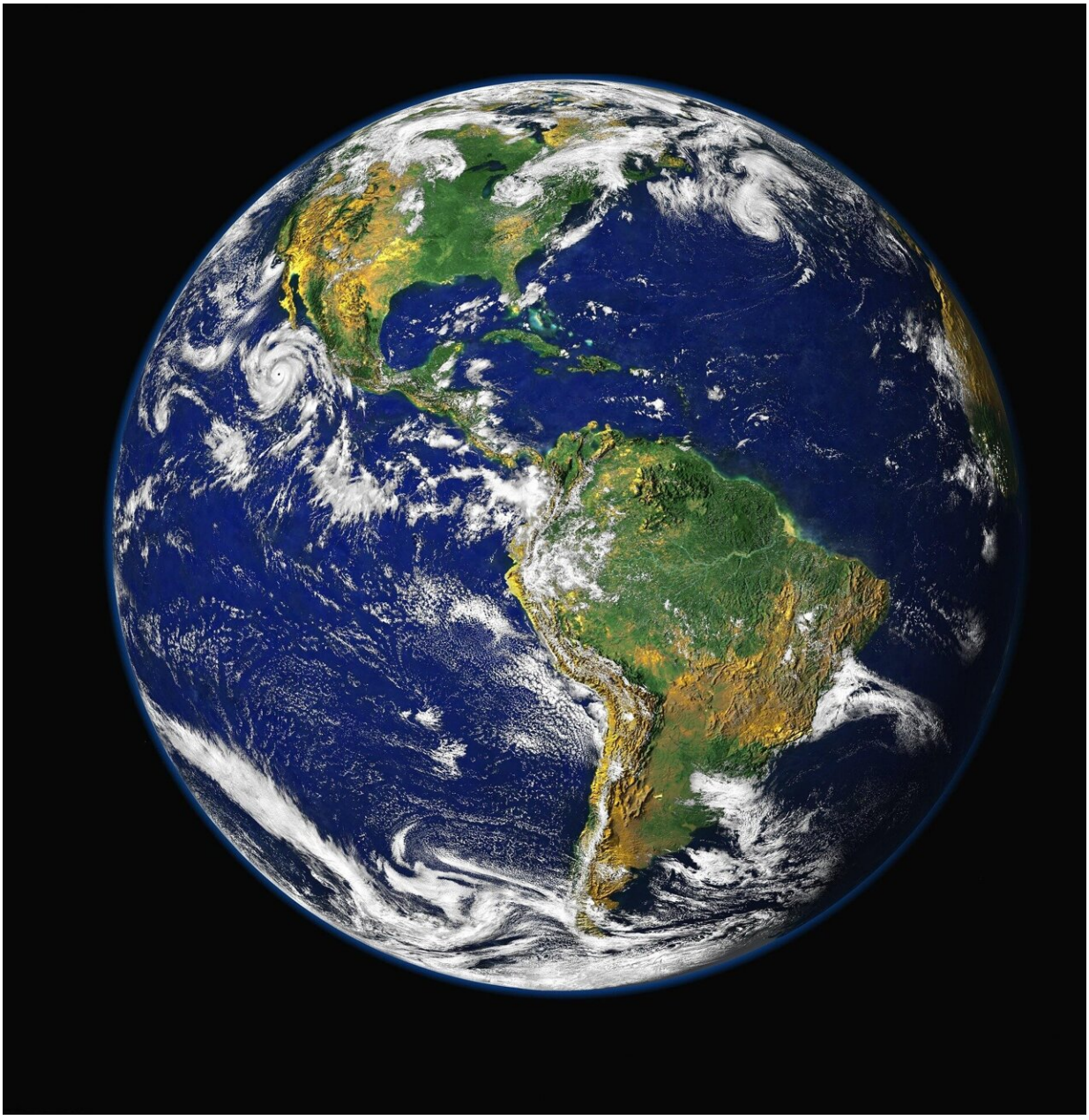
A just world on a safe planet: First study quantifying Earth system boundaries

May 31 2023



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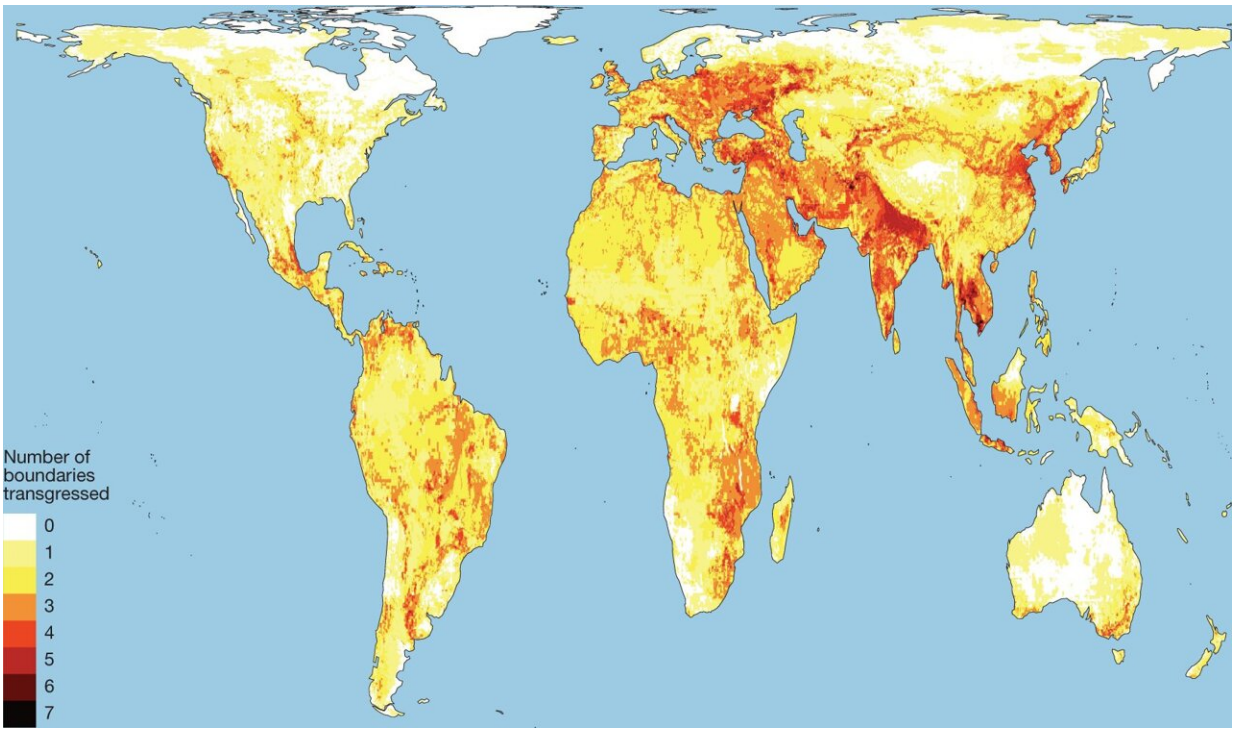
Humans are taking colossal risks with the future of civilization and everything that lives on Earth, a new study published in the journal *Nature* shows. Developed by an international science commission engaging more than 40 researchers from across the globe, the scientists deliver the first quantification 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 well-being and equity / justice," said Prof. Johan Rockström, Earth Commission Co-Chair, lead author and Director of the Potsdam Institute for Climate Impact Research.



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 emphasize 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' Credit: Credit: FutureEarth / Earth Commission / Lade et al., 2023

"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.

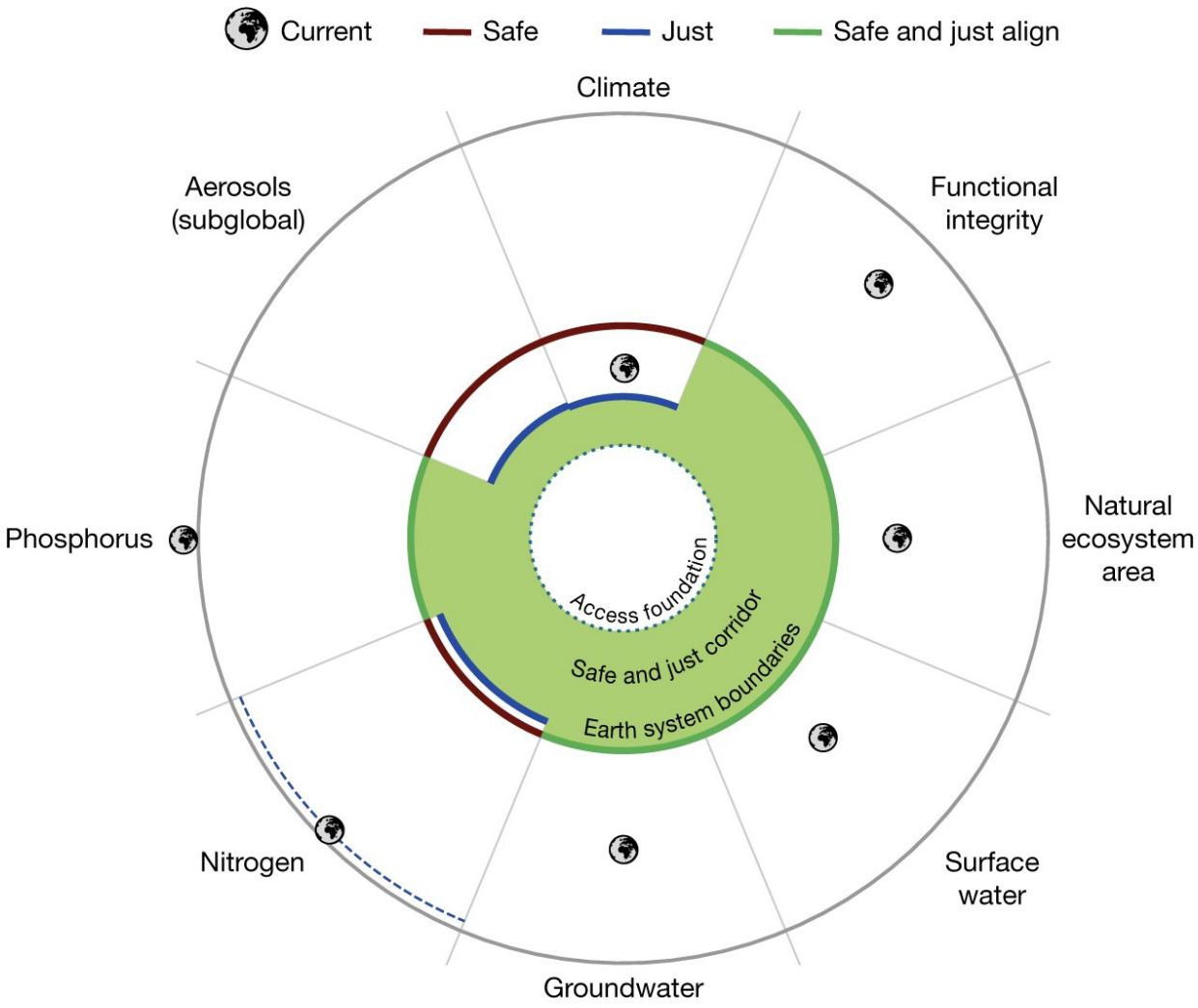
Health indicators for people and planet

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.

"The results of our health check 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 well being 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.



Visualization of safe ESBs (dark red), just (NSH) ESBs (blue), cases where safe axnd just (NSH) boundaries align (green), and current global states (Earth icons).

Radial axes are normalized to safe ESBs. Headline or central estimate global boundaries (Table 1) are plotted, to support comparison with current global state, but we emphasize 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. Credit: FutureEarth / Earth Commission / Lade et al., 2023

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 minimize 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.

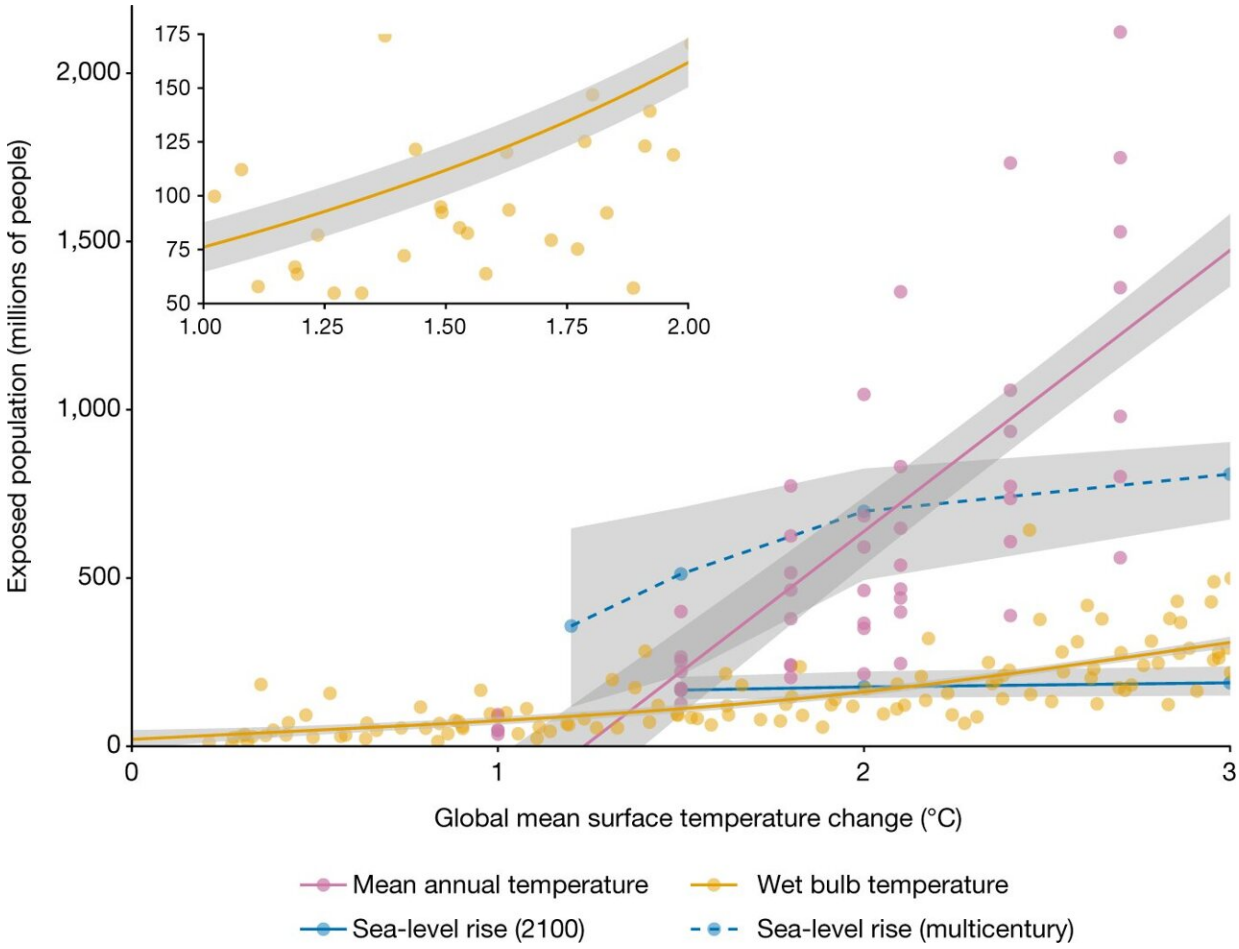
Safe boundaries ensure stable and resilient conditions on Earth, and use an interglacial Holocene-like Earth system functioning as a reference point for a healthy planet. A stable and resilient Earth is dominated by balancing feedbacks that cope with buffer and dampen disturbances. Cutting edge science 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.



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

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 fertilizer 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 km^2.

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):