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COMMENTARY

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Charting a Transformational Course Toward a Safe and Just Future: The Earth Commission's Contribution

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Key Points:

- Human activity has pushed the planet beyond safe and just limits, endangering stability and the well-being of billions
- A just and rapid transformation is needed to shift toward a liveable future for both people and the planet
- The Earth Commission provides a science-based framework to guide systemic change across scales and sectors

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Abstract Humans are now operating well outside the planetary conditions under which social and economic development has been possible. A precondition for securing equitable access to this prosperity is to safeguard the stability of the Earth system. The situation is urgent—we need a swift and profound shift in direction—a collective transformation. In response, the Earth Commission has developed a science-based framework that integrates biophysical limits with justice considerations, aiming to enable human wellbeing for all. The Earth Commission's first assessment showed that multiple safe and just Earth system boundaries have already been transgressed, threatening the resilience of the planet and the well-being of billions. This paper

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outlines the vision and scientific strategy for the Earth Commission's second phase (2024–2027), which focuses on advancing this framework and translating it into actionable budgets and exploring transformation pathways toward a safe and just future. Key components include expanding the safe and just boundary assessment to currently under-assessed Earth system processes (e.g., novel entities and ocean change), integrating justice more deeply into the framework, modeling interactions between boundaries and tipping points, and developing practical approaches to cross-scale translation and transformation. Special attention is given to the structural inequalities and power dynamics that shape both environmental degradation and our capacity to act. Through coordinated research, interdisciplinary collaboration, and stakeholder engagement, the Earth Commission seeks to provide knowledge to guide collective efforts toward transforming to a safe and just space for both people and the planet.

Plain Language Summary People around the world are already feeling the effects of a planet under pressure-from climate change and biodiversity loss to rising inequality. Scientists are warning that we are pushing Earth's life-support systems beyond their safe limits, putting both nature and human well-being at serious risk. In response, the Earth Commission has created a new science-based framework that brings together environmental limits and fairness. This helps define what a "safe and just" future looks like-one where the planet remains stable, and the well-being of all people is promoted. The next phase of work focuses on improving our understanding of under-explored threats like pollution and novel types of pollution, deepening the role of justice in our analysis, and identifying fair ways to share responsibility for staying within Earth's limits. It also looks at how big changes to systems like energy and food can help move us toward a safe and just future. The goal is to support faster, fairer action that protects both people and the planet.

1. Introduction

We are living in the Anthropocene—a proposed epoch fundamentally distinct from the Holocene, characterized by human activities' profound and accelerating influence on Earth's geology and ecosystems (Ellis et al., 2021; Folke et al., 2021; Skelton & Noone, 2025; Steffen et al., 2018). The drivers, pressures, and impacts have intensified dramatically since the mid-20th century, a period that can be characterized as the Great Acceleration, marked by exponential growth in resource consumption, pollution, biodiversity loss, and climate change (Steffen et al., 2015). These pressures have pushed several planetary processes beyond their safe limits, placing both human societies and the biosphere at growing risk (Gupta et al., 2024; Richardson et al., 2023; Rockström, Gupta, et al., 2023). The situation is urgent—incremental adjustments are no longer sufficient. Rapid, coordinated transformations are needed to steer the Earth system back toward a safe and just operating space.

The emerging risk landscape of the Anthropocene is characterized not only by escalating biophysical change but also by increasing systemic connectivity and unevenly distributed impacts (Crona et al., 2021; Keys et al., 2019; Lam et al., 2020; Rockström, Norström, et al., 2023). Crises such as pandemics, financial collapse, and synchronized food shocks now propagate more rapidly and with greater geographic reach, often exacerbating pre-existing inequalities (Frank et al., 2014; Homer-Dixon et al., 2015). Meanwhile, seven of the nine planetary boundaries that define a safe operating space for humans have already been breached, including those related to climate change, biosphere integrity, land system change, freshwater change, biogeochemical flows (nitrogen and phosphorus), and novel entities (e.g., synthetic chemicals, plastics) (Planetary Boundaries Science, 2025; Richardson et al., 2023). Signs of weakening carbon sinks and growing Earth system instability indicate that key biogeochemical and physical processes may be approaching saturation or tipping points (Abrams et al., 2023; Armstrong McKay et al., 2022; Ke et al., 2024; Lee et al., 2025). Crossing these thresholds would risk large-scale, potentially irreversible changes in conditions that have supported human societies for millennia (Steffen et al., 2018).

These planetary-scale dynamics have unfolded alongside long-standing inequalities rooted in uneven development pathways. Industrialization and resource extraction have historically been geographically concentrated, creating disproportionate contributions to greenhouse gas emissions and material use (Heede, 2014; Hickel et al., 2022; Rammelt et al., 2023; Wiedmann et al., 2020). These historical patterns—and the institutions that have sustained them—continue to shape contemporary environmental and economic outcomes (Acemoglu

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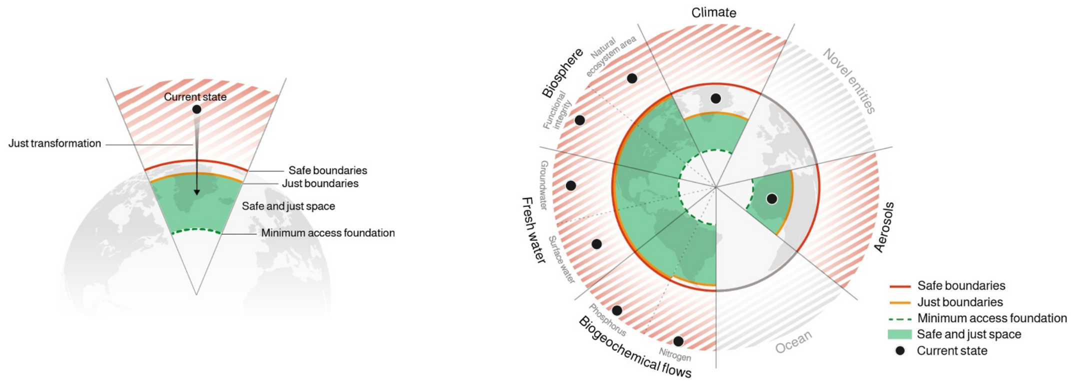

Figure 1. The Earth Commission defines the ceiling of the safe and just space through the joint quantification of safe boundaries, which safeguard Earth system resilience, and just boundaries, which aim to minimize harm and deprivation to people and ecosystems. The Commission also introduced the concept of just access, defining minimum resource thresholds required for a dignified life and forming the foundation of the safe and just space. Current conditions indicate that humanity operates well outside this space, suggesting that incremental responses are unlikely to be sufficient. Addressing this challenge will require rapid, large-scale systemic transformations across governance, economic, and social systems. In its next phase, the Earth Commission will expand the framework to include two additional Earth system processes not yet assessed: novel entities and ocean change.

et al., 2001; Rempel & Gupta, 2020). Today, extreme disparities persist. Large segments of the global population struggle to meet basic needs, while others consume resources at excessive and unsustainable levels (Zimm et al., 2022). The wealthiest individuals and nations exert enormous pressure on the Earth system (Rammelt et al., 2023). High-income countries, which comprise just 16% of the global population, are responsible for 74% of global resource consumption, underscoring the extreme disparities in material footprints (Hickel et al., 2022). Such inequalities extend beyond income and wealth to political voice, environmental exposure, and access to knowledge and institutions. They undermine social cohesion, trust, and cooperation—factors essential for enabling collective action and effective governance responses (Barone & Mocetti, 2016; Cardenas, 2003; Gür-oğlu et al., 2010, 2014). In short, inequalities interact with biophysical destabilization to erode the foundations for resilience and transformation.

2. The Earth Commission 2019–2023: A First Quantitative Assessment of the Safe and Just Space

The Earth Commission (EC) was founded in 2019. Its first assessment focused on identifying a safe and just space for humans, assessing the resource implications of meeting basic needs, developing frameworks for translating the safe and just boundaries into action by a diversity of actors, and proposing an Earth system justice framework to guide equitable transformations (Figure 1; Bai et al., 2024; Gupta et al., 2024, 2023; Rammelt et al., 2023; Rockström, Gupta, et al., 2023; Stewart-Koster et al., 2023). This work is now informing the next generation of science-based targets and practices, helping business leaders and policymakers access the opportunities offered by a safe and just space by better managing the planet's finite resources (Box 1). It has led to an improved understanding of global systemic risks, what it takes to meet the minimum material living standards for all, and pathways to a safe and just future.

Box 1.

The Earth Commission—establishment, mandate, and impact

The Earth Commission was established in 2019 as the scientific cornerstone of the Global Commons Alliance. Its mandate is to define a "safe and just space" for humanity by integrating biophysical limits with justice considerations and to translate these insights into actionable targets for decision-makers across scales.

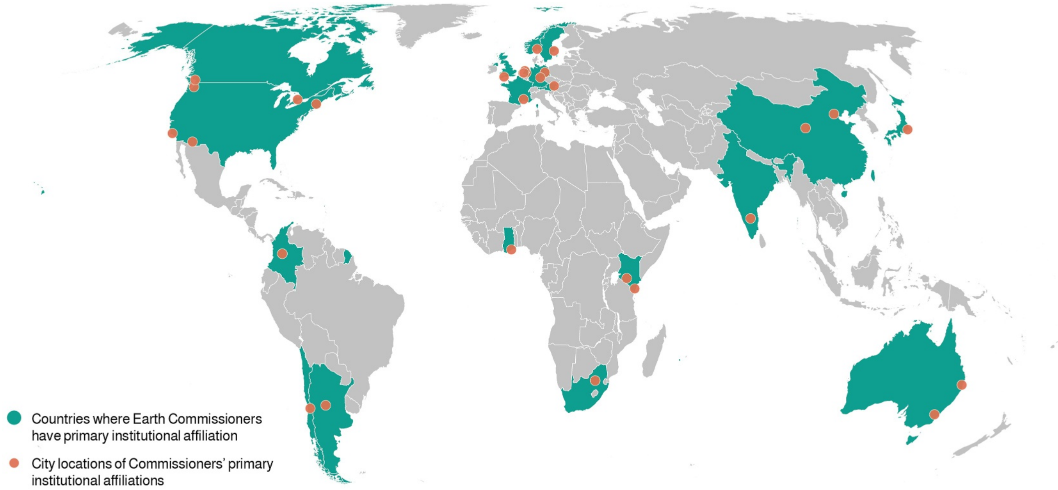

Figure 2. Global distribution of Earth Commission members by primary institutional affiliation. Countries with at least one Commissioner are shaded, and dots indicate the city of their main affiliation.

The Commission currently comprises 23 leading scientists from diverse disciplines and regions (Figure 2). Appointments are honorary and unpaid, typically for 3 years. Selection for the second phase combined an open call with targeted outreach to ensure expertise in novel entities, transformation pathways, and governance. Candidates were evaluated on scientific excellence, international collaboration experience, and commitment to the Commission's goals, with attention to diversity in geography, gender, discipline, and career stage.

To deliver its objectives, the Commission operates through four interlinked workstreams supported by a scientific secretariat hosted by Future Earth. Each workstream addresses a core thematic area and ensures coordination across disciplines and scales. Workstreams are led by designated Commissioners (workstream Leads) who organize activities in consultation with the Science Director and co-chairs, supervise supporting researchers, and maintain collaboration with other workstreams and the secretariat. Each workstream convenes approximately 12–15 experts, including Commissioners and specialists from partner networks such as Future Earth and the Science Based Targets Network (SBTN). Additional contributors may join for short-term tasks such as workshops. Dedicated researchers and technical staff provide assessment and synthesis support, funded by the Commission or through in-kind contributions from host institutions. A liaison from the core secretariat ensures integration across workstreams and alignment with overall goals. Since its inception, nearly 100 scientists from over 35 countries have contributed to the work of the Earth Commission, with active involvement of early- and mid-career researchers.

The Commission's influence extends well beyond academia. Its research informs science-based targets for businesses and cities and has been cited by multilateral organizations, including the UN, World Bank, and EU. Commissioners engage regularly in high-level policy processes such as UN climate and biodiversity COPs, the World Economic Forum, and New York Climate Week, and serve on expert panels and advisory boards at the UN, IPCC, EU, and other bodies. Media coverage amplifies this impact: in 2023, Carbon Brief ranked two Earth Commission papers among the 10 most influential climate publications worldwide. To date, the Commission's work has generated over 20 peer-reviewed papers, 4,500+ citations, and 2,300+ media stories, reflecting its wide-reaching impact on science, policy, and practice.

A key feature of the Commission's framework is Earth system justice (ESJ), which acknowledges that, while safe biophysical boundaries are a guardrail to protect the stability of the Earth system, this is not necessarily enough to avoid levels of environmental change that harm people or perpetuate deprivation (Gupta et al., 2023, 2025). This perspective provides an important lens for understanding how inequalities shape exposure to risks and capacities for transformation. The EC's integration of justice, therefore, complements its biophysical assessments, helping to identify boundary conditions that are both safe for the planet and just for people.

The concept of a safe and just space was originally introduced by Kate Raworth (2017) in a conceptual framework that has become known as Donut or well-being economics. Donut economics argues that human development in the Anthropocene should occur within a donut-shaped space where resource use is below the level that carries a substantial risk of crossing planetary boundaries (i.e., a “safe” environmental ceiling), but above the level required to meet people's basic needs (i.e., a “just” social foundation). In short, if there is a biophysical ceiling on Earth (the safe operating space defined by boundaries), then there must be a social floor, defined by human needs and rights. The EC advanced this concept by incorporating justice into a quantified assessment of the ceiling and by using comparable units to assess biophysical and social indicators. The EC's approach thus also enabled a more integrated analysis of sustainability challenges (Rockström, Beringer, et al., 2021; Rockström, Beringer, et al., 2021).

The EC quantified the ceiling of the safe and just space by assessing safe and just Earth system boundaries (Rockström, Gupta, et al., 2023). This work was the first to quantify just boundaries to avoid significant deprivation and harm to humans and other living beings, which, together with the safe boundaries, were integrated into a scientific assessment of the state of the planet. In short, the Earth Commission assessment allows for a combined quantification of “safe” and “just” boundaries aimed, respectively, at protecting Earth's resilience and minimizing harm and deprivation to people and ecosystems. Staying within the safe and just boundaries would reduce the risk of crossing dangerous tipping points in the Earth system, minimize human and nature's exposure to widespread significant harm from Earth system change, and safeguard the Earth system conditions that we know can support human development. Through modeling and literature assessment, safe and just boundaries were quantified at both global and sub-global scales for: biosphere (functional integrity and ecosystem area), climate change, nutrient cycles (phosphorus and nitrogen), freshwater (surface and groundwater), and aerosols. Globally, safe and just boundaries for the biosphere, climate, nutrient cycles, and freshwater were found to be breached, while the boundaries for aerosol loading were found to be violated at local levels in many parts of the world. Two or more safe and just sub-global ESBs were found to be transgressed in over 52% of the world's land area, affecting 86% of the global population (Rockström, Gupta, et al., 2023). Through the use of consistent units across safe boundaries and just boundaries, the Commission found that three just boundaries (climate, nitrogen, and aerosols) were stricter than their corresponding safe boundaries.

In addition to defining the ceiling, the EC introduced the concept of “just access” to establish minimum resource thresholds needed for a dignified life, and quantify the foundation of a safe and just space. Ensuring minimum access to resources necessary for a dignified life is central to ESJ. Aligning with the Sustainable Development Goals (SDGs) and human rights frameworks, this approach prioritizes access to critical resources such as water, food, energy, and infrastructure for all, including the most marginalized populations. The Commission established two tiers of minimum access: one ensuring basic dignity and another enabling the capability to escape from poverty. These thresholds were then transcribed into biophysical pressures on the Earth system to evaluate the environmental impact of providing universal minimum access. Under existing inequalities and technologies (ceteris paribus), it was shown that ensuring minimum access for the poorest would cause further transgressions of the safe and just (harm) boundaries (Rammelt et al., 2023). Additional projections for 2050 provided further evidence that, without systemic and just transformation, achieving universal minimum access (i.e., everybody in the world living with minimum access to resources and nothing more) will result in substantially deeper breaches of the safe and just ceiling (Bodirsky et al., 2022; Gupta et al., 2024).

As part of its mission to address critical knowledge gaps, the EC also incubated and helped develop the Tipping Points Modeling Intercomparison Project (TIPMIP). TIPMIP is an international collaboration that systematically advances our understanding of tipping dynamics in key Earth system components, while assessing the associated uncertainties. By connecting and evaluating multiple models, TIPMIP fills crucial gaps in Earth system and climate modeling—particularly in relation to long-term

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commitments and irreversibilities—by improving the representation of anthropogenic forcing. It also facilitates interdisciplinary knowledge exchange and enhances understanding of critical feedback processes that are currently underrepresented in Earth system models and assessments through the interrogation and comparison of multiple models from across the community.

A specific feature of the safe and just boundaries is that the selected control variables are, in principle, translatable across scales in order to make them actionable. Operationalization requires the boundaries to be translated into context-specific targets for cities, businesses, and policymakers. The EC has identified knowledge gaps (Bai et al., 2022), and developed guiding principles to support this process, ensuring that these translations are scientifically robust, fair, and transparent (Bai et al., 2024). A structured protocol provides decision-makers with high-level guidance on key questions, such as the appropriate spatial scale for implementation, the current state of boundary transgressions, the regenerative capacity of Earth system processes and systems, and fairness in resource-sharing or allocation.

Currently, we are far outside the safe and just space, and incremental solutions will not suffice. The challenge now lies in the speed and scale of implementing systemic transformations. The EC highlighted the need for deep structural transformations in governance, economics, and society (Gupta et al., 2024). This requires embedding planetary safety and justice into all decision-making, improving real-time monitoring of Earth system risks and social justice metrics, and fostering stronger collaborations among policymakers, nation states, businesses, scientists, and civil society.

The EC's second phase (2024–2027) now focuses on filling critical knowledge gaps, updating boundaries as evidence advances, and charting pathways for the deep societal transformations required to live within a safe and just operating space. This involves synthesizing inter- and transdisciplinary insights on governance, power, political economy, technological innovation, and societal change. A holistic safe and just approach recognizes that Earth system resilience and human equity are deeply interconnected—and that neglecting either risks destabilizing both.

3. The Earth Commission 2024–2027: Charting a Course Toward a Safe and Just Future

3.1. Safe and Just Boundaries: Addressing the Whole Earth System and Interactions

In the next phase of work, the EC aims to provide safe and just boundary quantifications for two additional critical Earth system processes not yet assessed—namely novel entities and ocean change. The broader objective is to establish a global science assessment mechanism for safety and justice across all biophysical processes and systems that regulate the function, state, and life-support capacity of the planet (Box 2).

Box 2.

Toward a Global Framework for Safe and Just Boundaries

The Planetary Boundary framework has identified the nine critical biophysical processes and systems that regulate the stability and resilience of the Earth system, defining a "Safe Operating Space" for humanity. The nine planetary boundary processes are Climate Change; Introduction of Novel Entities; Stratospheric Ozone Depletion; Atmospheric Aerosol Loading; Ocean Acidification; Modification of Biogeochemical Flows; Freshwater Change; Land System Change; Change in Biosphere Integrity. For each of the planetary boundary processes, one or more control variables are identified. A quantitative assessment is made for each of these control variables, quantifying the boundary level within which there is a high chance of maintaining Earth system functions and the state of the planet within Holocene-like inter-glacial conditions. Together, these quantifications provide a safe operating space for human development on Earth.

The Earth Commission takes these nine Earth system processes and systems as the entry point for its assessment of a safe and just space. It extends the PB framework by also integrating justice considerations, aiming to minimize harm to people and ecosystems while safeguarding Earth's resilience. In its first assessment cycle, the Earth Commission quantified safe and just boundaries for five planetary boundary processes—climate change, aerosol loading, biosphere integrity, freshwater use, and biogeochemical flows—and plans to expand this work to all nine processes in its future assessments. The control variables chosen by the Earth Commission assessment allow for a combined 'safe" (i.e., aimed at protecting Earth's resilience) and 'just", (i.e., aimed at minimizing significant harm to people and ecosystems using the 3 I approach—interspecies justice and Earth system stability, intergenerational justice, and intragenerational justice) assessment. The control variables are further chosen to enable actors across sectors and scales to set targets, generating and implementing transformative pathways that are consistent with a safe and just Earth system. Where possible, the control variables are spatially explicit; many of the first assessment's boundaries were already expressed at the scales of operations of the Earth system processes, as small as one square kilometer in the case of the functional integrity, as this is the scale at which relevant local ecosystem services are produced. Spatially explicit control variables allow justice dimensions to be included as they provide insight into the spatial distribution and (in)equality in access of different actors. In the second assessment, we will extend this approach across other boundaries.

A novel contribution of this phase will be the development of "burning ember" diagrams—visual tools adapted from the IPCC—to illustrate how risks to both biophysical and human systems escalate across thresholds (Zommers et al., 2020). These diagrams will help enhance cross-boundary consistency and serve as powerful communication tools to convey how environmental and social risks increase with proximity to or transgression of key safe and just boundaries. Another important advancement will be the introduction of more rigorous criteria for defining just boundaries and assessing their interconnections. This includes specifying standards for minimum, medium, and limitarian levels of access and impact; clarifying the interdependencies between different minimum living standards; and identifying guiding principles for just transformations. These developments will be informed by emerging work on distributive justice, particularly the drivers of "acceptable" and "unacceptable" inequalities.

3.1.1. Safe and Just Boundaries for Novel Entities

Since the mid-20th century, novel entities such as manufactured chemicals and materials have proliferated, profoundly reshaping societies. However, the balance between their benefits and risks is increasingly uncertain at a global scale, with scientific and regulatory oversight diminishing. Scholars argue that the planetary boundary for novel entities (formerly known as the planetary boundary for "chemical pollution") has already been exceeded, citing the exponential growth in chemical production and releases, the increasing number of registered chemicals and their potential to cause multifaceted effects on the environment, ecosystems and humans, and critical data gaps to capture the complexity of this boundary (Persson et al., 2022).

The EC aims to assess and define safe and just boundaries for novel entities. A starting point will be on novel entities for which sufficient data is available, using existing regulatory safety thresholds as benchmarks, and taking into account diverse impacts across different geographical and time scales. This analysis of "known knowns" will provide the basis for exploring boundaries that reflect the latest understanding of the maximum cumulative loading of novel entities that the Earth systems can tolerate, before irreversibly shifting in their function, stability, and life-support. The careful distinction between the safe and the just novel entities boundaries will be made. For the safe boundary, we are setting thresholds for avoiding risks of causing changes (potentially irreversible) in the functioning of the Earth system, for example, through the accumulation of novel entities and/or novel entities that once loaded into the Earth system, never disappear. The just boundary will focus on the impacts of novel entities on human health, livelihoods, and well-being. A life-cycle approach will be employed, assessing a selection of novel entities from extraction to disposal.

Additionally, a horizon-scanning analysis, building upon expert evaluation and advanced data technologies such as large language models and machine learning, will help identify previously overlooked or emerging novel entities that need to be taken into consideration ("unknown knowns"), as well as explore how future trends

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(e.g., climate change) may exacerbate the impacts of novel entities to provide a more comprehensive and forward-looking assessment of novel entities.

3.1.2. Safe and Just Boundaries for Ocean Change

The ocean covers more than 70% of the planet and plays a central role in regulating Earth system functions, including carbon sequestration and heat absorption (Cheng et al., 2022; Siegel et al., 2023). It is home to some of the most biodiverse ecosystems, such as coral reefs, as well as some of the least explored habitats and undiscovered species in the deep sea (Amon et al., 2016). Blue or aquatic foods (derived from wild and farmed ocean animals and plants) are central to the diets and nutritional security of billions of people worldwide, and underpin the livelihoods, economies, and cultural identities of many coastal and riparian communities (Cisneros-Montemayor et al., 2016; Srinivasan et al., 2010; Tigchelaar et al., 2022).

Yet the ocean is undergoing unprecedented change. Fisheries collapse, eutrophication, sea level rise, intensified storm surges, and coastal flooding are compounding risks for billions of people, threatening both livelihoods and critical coastal ecosystems. Small Island Developing States (SIDS) and coastal Least Developed Countries (LDCs) are expected to be disproportionately affected (Lam et al., 2020; Sumaila et al., 2019). Simultaneously, a surge in global competition for ocean resources—referred to as the "blue acceleration"—is generating complex ecological, economic, and equity challenges (Jouffray et al., 2020; Sumaila & Villasante, 2025).

Ongoing climate change, unprecedented ocean warming, and acidification further compromise the ocean's capacity to sustain key Earth system functions, such as absorption of carbon dioxide. The risk of crossing tipping points—such as a shutdown of the Atlantic Meridional Overturning Circulation (AMOC) or collapse of fish populations—is growing (Lee et al., 2025; Rocha et al., 2014). In parallel, an emerging literature on ocean or "blue" justice highlights the need to define what just boundaries might entail from a marine perspective (Bennett et al., 2021; Blythe et al., 2023).

The EC's assessment of safe and just boundaries for the ocean will focus on identifying key control variables—such as marine biogeochemical cycles, ocean acidification and deoxygenation, marine biomass, and fisheries—that can represent oceanic dynamics within the planetary boundaries framework. By integrating insights from both social and natural sciences, this assessment aims to identify appropriate control variables and assess thresholds that safeguard Earth system resilience while ensuring equitable access to marine resources.

The EC has launched a collaborative and interdisciplinary process to refine these control variables. Candidates include ocean deoxygenation, sea surface temperature (SST), marine biodiversity and habitat loss, trophic structure, fish biomass and catch data, and justice-related indicators such as access to fish for small-scale fisheries and nutritional reliance on marine foods. Emphasis is placed on selecting variables that capture critical biophysical thresholds while also reflecting ecosystem functionality and wellbeing. Interlinkages—such as how habitat degradation affects biodiversity, trophic dynamics, and ecosystem service delivery—are being systematically explored. A conceptual framework has been developed to represent these interactions and guide the design of integrated modeling approaches. Ongoing efforts focus on refining variable definitions, assessing data availability and policy relevance, and developing methodologies to support the operationalization of safe and just boundaries for the ocean.

3.1.3. Interacting Boundaries: Understanding Cross-System Feedbacks and Risks

The Earth system operates as an interconnected whole; approaching or crossing one safe and just boundary can add pressure to others and amplify systemic risks. For example, climate change weakens the biosphere's resilience, making ecosystems more vulnerable to additional stressors, and reduces the capacity of nature to sequester carbon under stress. These cascading effects can trigger abrupt shocks, posing severe risks to present and future generations. These interactions can effectively shrink the safe operating space for humans (Lade et al., 2020). On the other hand, a stronger grasp of these interactions offers substantial scope for better designing transformation pathways and informing decision-making. In some cases, there are opportunities to benefit from synergies between different Earth system processes: if impacts on one safe and just boundary are decreased, impacts on other boundaries may also lessen. An example is the alignment between biosphere stewardship and climate goals (Rockström, Beringer, et al., 2021; Rockström, Beringer, et al., 2021) through modest reforestation projects that are adapted to the local socio-ecological contexts (Pörtner et al., 2021). The opposite is also possible: measures to

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improve performance on one boundary might impact negatively on another one. For example, where large-scale cultivation of biofuel crops or increased forest harvesting for biofuels might have positive impacts on reduced CO_2 emissions, it might have a tradeoff on ecosystem intactness and integrity (Tudge et al., 2021). Quantifying these interactions remains a critical challenge to better understand the safe and just operating space as a whole and to find effective transformation pathways. In its second phase, the EC will systematically assess interdependencies among safe and just "ceilings" as well as between the Earth system "ceilings" and justice (minimum access) "foundations" across different boundaries. This work includes reviewing empirical evidence, modeling cross-boundary interactions, and evaluating their governance implications with respect to setting science-based targets, identifying the target space for transformation, minimizing harm, promoting just access, and mitigating systemic risks.

4. Minimum Access and the Foundations of a Safe and Just Space

In its second phase, the EC will expand its concept of just foundations to include a broader set of basic human needs—such as education, healthcare, digital connectivity, and clothing—that are fundamental to human well-being. While these needs are widely recognized in global human rights frameworks and the Sustainable Development Goals (SDGs), they were not fully integrated into the research and synthesis of the Commission's first phase (Gupta et al., 2024; Rammelt et al., 2023).

The environmental implications of meeting these needs, across the multiple Earth system processes, will be systematically assessed at three levels of access. The first level combines the concepts of dignity and poverty alleviation, reflecting the minimum resources required for individuals to escape poverty and live with dignity. The second level is inspired by the Decent Living Standards (DLS) framework (Rao & Min, 2018), which includes access to nutritious food, sanitation, clean water, modern energy, adequate housing, communication, education, and healthcare. This level represents a socially and environmentally viable foundation for most people to lead flourishing lives with a limited ecological footprint. The third level addresses the upper bound of consumption, building on emerging frameworks such as limitarianism and sufficiency, which propose maximum thresholds for individual environmental impact (Robeyns, 2019; Ziegler, 2021). This assessment will map and evaluate such frameworks in terms of their scientific basis, feasibility, and potential contributions to Earth system stability.

Achieving just access to resources within safe and just boundaries presents significant challenges due to entrenched global inequalities (Chancel et al., 2026; Chancel & Piketty, 2021). In its second phase, the EC will quantify minimum, medium, and maximum levels of consumption and resource use—aligned with justice and Earth system stability—to assess what levels of inequality are acceptable without undermining the trust and cooperation needed for collective action (Barone & Mocetti, 2016). The Commission will evaluate approaches to equitable resource distribution as a strategy to remain within the safe operating space while ensuring universal access to basic needs (Gupta et al., 2023).

This includes assessing existing frameworks for sharing resources equitably—such as in water governance (Bayu et al., 2020; Fukuda et al., 2019)—as well as legal and ethical fair-sharing principles like "polluter pays," "ability to pay," "no significant harm," and "historical responsibility." Concepts such as carbon debt, linked to historical emissions and resource extraction, will be examined for their relevance in allocating differentiated responsibilities across regions and sectors.

The EC will also analyze how power dynamics shape unjust outcomes—highlighting the use of legal, financial, or institutional instruments that entrench inequities—and identify ways to counterbalance these. Mechanisms for redistribution that simultaneously curb overconsumption and meet essential needs—what has been called "saving two birds with one stone" (Sumaila et al., 2024)—will be explored. This includes assessing literature on systemic redistribution, technological innovation, shifts in global power, and structural change aimed at decoupling human well-being from environmental harm.

5. Operationalizing Earth System Justice: Addressing Power and Inequality

The EC introduced Earth system justice (ESJ) as a systemic approach to addressing the intertwined environmental and social injustices of the Anthropocene. Unlike environmental justice, which focuses on local inequities, or planetary justice, which emphasizes global fairness, ESJ integrates biophysical and social thresholds into a unified framework, as well as the means to achieve these thresholds. It embeds justice in defining and

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operationalizing safe and just boundaries and incorporates intragenerational, interspecies, and intergenerational responsibility, recognizing the rights of future generations to a stable Earth system.

The framework bridges local and global justice concerns by combining recognition and epistemic justice—valuing diverse knowledge systems—with procedural and substantive justice, ensuring fair decision-making and equitable outcomes. It also addresses structural justice by confronting systemic drivers of inequality, including skewed power relations, GDP-driven economic models, and environmental harm without accountability. ESJ emphasizes equitable distribution of planetary resources, shared responsibilities for mitigating environmental risks, and liability for causing harm. Justice is not a normative add-on but a structural and strategic condition for planetary stability and resilience.

In its next phase, the Earth Commission will deepen and operationalize ESJ by addressing critical gaps. This includes exploring how ESJ principles can inform global governance structures and multilateral agreements, and developing accountability tools such as litigation. For example, the IPCC could expand its burning ember diagrams to include social risk dimensions, visualizing how harm escalates for vulnerable populations as biophysical thresholds are crossed. Financial institutions such as the IMF could adopt "just transition conditionalities" in debt restructuring and lending programs, linking concessional finance to commitments that safeguard minimum social floors while curbing ecological overshoot. Corporate frameworks like the Science-Based Targets Network could incorporate ESJ checks to ensure biodiversity and water targets do not exacerbate inequities. These pathways leverage existing governance architectures, making ESJ actionable without creating new institutions, while reinforcing accountability and fairness across scales. It will also link ESJ to economic and financial systems through mechanisms such as fair access to green finance, debt-for-nature swaps, tax justice, and trade conditionalities that promote equity. A key advance will be integrating analysis of entrenched political and economic systems that shape environmental outcomes and reinforce inequalities that block transformative change. This requires moving beyond ex-post outcomes, such as emissions disparities or risk exposure, to their ex-ante origins in histories of extraction, marginalization, and epistemic exclusion.

The framework will also expand its analytical depth by introducing indicators for assessing just boundaries, including attention to local harms, spatial distributions, poverty linkages, and root causes of vulnerability. Principles for defining minimum, medium, and maximum needs will be refined, drawing on human rights, decent living standards, sufficiency, and limitarian approaches, while addressing poverty and overconsumption traps. Finally, the operationalization of risk and responsibility will be sharpened, clarifying how responsibilities should be allocated among actors and how harm can be fairly prevented, compensated, or redistributed. Taken together, these developments position ESJ as a cornerstone for guiding transformations toward a safe and just future—embedding justice as a structural condition for planetary resilience rather than a normative aspiration.

6. Modeling Tipping Points: The TIPMIP Initiative

The risk of transgressing critical thresholds triggering abrupt or nonlinear changes in the Earth system increases with continued human pressure (i.e., via the emission of greenhouse gases, land-use change, etc.). Key components of the Earth system, including the Greenland and Antarctic ice sheets, permafrost, the Atlantic Meridional Overturning Circulation (AMOC), and boreal and tropical forests as well as mountain glaciers, terrestrial hydrological systems and the Sahel region, have been identified as possibly containing self-amplifying feedbacks, wherein transgressing critical thresholds would threaten the health and livelihoods of billions of people. While there is agreement on the possibility of nonlinear and irreversible responses of parts of the climate system, the nature and characteristics of tipping dynamics are not well-constrained, such that critical knowledge gaps remain (Armstrong McKay et al., 2022; Kopp et al., 2025; Stocker et al., 2025; Wunderling et al., 2024). Furthermore, many of the underlying feedbacks and interactions between different processes in the Earth system are not fully understood. Additionally, they are not always included (or are inadequately represented) in models (Jones et al., 2024). And there is a paucity of observational data for model input and validation, particularly on long timescales (Loriani et al., 2025).

Despite these uncertainties, scientific assessments increasingly highlight the risks associated with tipping dynamics, as tipping points must be taken into consideration when setting both safe and just boundaries. The most recent Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) highlights the potential high risks posed by tipping dynamics as well as the substantial uncertainties associated with them. It presses the need for additional and more robust lines of evidence, such that an entire chapter of the upcoming IPCC report will be devoted to this topic. The Tipping Points Modeling Intercomparison Project (TIPMIP), an international community effort to address the critical knowledge gaps regarding tipping dynamics, has been organized to work toward a multi-model assessment of the associated likelihoods and biophysical impacts. No such systematic approach to investigate tipping point risks in a standardized way across biophysical domains exists as of yet. TIPMIP aims to provide a systematic analysis for key Earth system components, including the ice-sheets, ocean, permafrost, and different biomes, based on state-of-the-art Earth System Models as well as stand-alone domain models. Numerical process-based modeling will advance the understanding of crucial feedbacks and quantify uncertainty ranges for critical thresholds based on ensembles of scenarios, parameters, and other modeling choices. Multi-model assessments and Model Intercomparison Projects (MIPs) are a well-established and widely used means of improving and consolidating scientific understanding, thereby supporting and informing climate policy, and, in particular, will help constrain safe (planetary) boundaries by identifying the critical temperature thresholds at which tipping points may be triggered. Furthermore, TIPMIP will provide the data crucially needed for robust assessments of expected tipping impacts, to inform harm assessments.

7. Operationalizing Boundaries: Actors, Agency, and Translation

The EC will continue to advance the conceptualization and synthesis of methodological approaches for cross-scale translation of safe and just boundaries for operationalization by actors, building on the general principles, allocation approaches, and a protocol developed during the previous phase. Specifically, the aim is to begin testing and applying these in selected case study locations to operationalize specific safe and just boundaries. Such applications will allow further refinement of cross-scale translation methodologies to better reflect socio-economic and ecological contexts, as well as Earth system justice. As previously articulated (Bai et al., 2024; Gupta et al., 2024), the first step in cross-scale translation is transcription, which refers to a process of determining the maximum level of aggregate pressure that does not lead to transgressing safe and just boundaries, to define environmental "budgets" using pressure variables that are relatable to and actionable by actors. The second step involves determining how these budgets of environmental resources and the relevant pressure reduction burdens (for transgressed boundaries) should be shared among actors. In this second phase, the EC will focus on reviewing transcription methods from the peer-reviewed literature for each boundary. This review will help clarify how different methods align with the principles of Earth system justice, and which approaches risk reinforcing existing injustices.

Another focal area in this round of assessment centers around actors' agency. Here, we seek to identify key actors who have the potential to initiate and sustain rapid positive changes. Key actors could be those with high environmental footprints and capacities to alter production processes or consumption patterns toward low-impact alternatives. Opportunities for collaborations between actors such as city-company and public-private partnerships (Kılkış et al., 2025) will also be explored in this phase. Developments in corporate reporting and disclosures, science-based target setting, and other sustainability practices will further inform our synthesis of translation methods, acknowledging the important link between translation and city-level and business-level reporting, benchmarking, risk management, and strategic planning (Gupta et al., 2024).

The outcomes of this work will contribute toward the development of methods that can be used to scale the safe and just boundaries from global and sub-global scales to actionable, quantitative pressure or impact targets for different sectors (cities, companies, regions, and countries). As part of the Global Commons Alliance (https://globalcommonsalliance.org/), the EC assessment informs the development of science-based targets for business and cities by the Science-Based Targets Network (SBTN). As of May 2025, SBTN has, in addition to existing methods for climate, released methods for target setting for water (including nitrogen and phosphorus), land, and the ocean. Companies and cities can apply these methods to identify their individual targets.

8. Transformation Pathways to a Safe and Just Future

In its second phase, the EC will generate a set of qualitative and quantitative time-bound transformation pathways toward a safe and just space, as well as identify appropriate policy instruments and measures to enhance governance. This is essential to increase the policy relevance of the EC by not only providing diagnostics on the current situation but also providing insights into the conditions needed for shifting societies toward a safe and just future. These pathways aim to explore the feasibility and needed conditions for alternative strategies to simultaneously reduce aggregate environmental pressures and ensure that everyone can have access to resources for decent living. This work builds on a strong interdisciplinary approach that combines integrated assessment modeling (IAM) expertise, social and natural sciences knowledge, reflecting the work of the EC on PBs and justice. The work will be structured around several interconnected activities that include developing alternative global narratives that describe what a safe and just space could look like and what pathways could take us to these futures, considering diverse governance, economics, justice, technology, and societal changes. Subsequently, these pathways are formalized in IAMs, capturing the interactions between the boundaries and the relevant human consumption and production patterns and their distribution. This helps to make the pathways transparent in terms of required changes, while also testing the feasibility.

While some scenarios have explored how to meet multiple SDGs (Soergel et al., 2024; Vuuren et al., 2022), or the planetary boundaries (van Vuuren et al., 2025), no scenarios have yet been developed that look into what is needed to live within the safe and just space assessed and quantified by the EC. This means that the scenarios will have to look into transformative outcomes of what “could be.” As well as creating a set of global pathways that cut across multiple dimensions, there will also be parallel ‘bottom up” research at sub-global, local, and social-ecological system scale on narratives to provide more nuanced, contextually relevant inputs as expertise and funding become available. Addressing the structural power imbalances that shape transformation pathways is central to this work.

An operational modeling protocol will be developed to formalize these storylines, incorporating various transformation elements. Modeling will be conducted using integrated assessment (IAMs), with a focus on intercomparison. Participatory processes, including workshops, will ensure inclusivity and diverse perspectives. The pathways can also be used to provide insights into short-term actions consistent with reaching long-term goals. The EC will therefore place particular emphasis on how governance and political-economic systems mediate the distribution of environmental burdens and benefits, and what this implies for designing equitable and effective pathways to a safe and just future.

9. Conclusion

The planet is undergoing accelerating biophysical destabilization alongside deepening social inequalities. Remaining on our current trajectory risks irreversible harm to Earth's life-support systems and widespread human suffering. The scientific evidence is clear: the window for meaningful action is rapidly closing, and urgent course correction is essential.

Incremental change is no longer sufficient. Addressing these intertwined crises demands rapid and systemic transformation—of our energy and food systems, governance structures, economic models, and underlying societal values. These transformations must not only be technically feasible but also socially just, ensuring that solutions do not reproduce or exacerbate existing inequities.

The Earth Commission provides a science-based framework to guide such transformation. By integrating cutting-edge interdisciplinary research, modeling, and expert deliberation, the Commission identifies and quantifies a safe and just space for humans. It will continue to refine this framework, assess risks and interactions across Earth system processes, and offer robust diagnostics and propose concrete transformative pathways to inform decision-making.

Achieving a safe and just future requires coordinated and immediate action across all levels of society. No single actor—whether government, business, or civil society—can meet this challenge alone. The Commission's work supports the translation of safe and just boundaries into concrete targets for countries, cities, companies, and communities. By fostering accountability, strengthening science-policy interfaces, and co-developing transformative pathways, we aim to empower decision-makers to act in line with principles of Earth system justice.

Ultimately, securing a safe and just future is not only a scientific and technical challenge—it is a moral and political imperative. The Earth Commission's second phase marks a critical step toward building the tools, narratives, and coalitions needed to meet this challenge with the urgency, clarity, and courage it demands.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Availability Statement

Data were not used, nor created, for this research.

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Erratum

The originally published version of this article contained an error. The first affiliation for coauthor Zhanyun Wang has been removed. This may be considered the authoritative version of record.