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Thresholds of significant harm at global level: The journey of the Earth Commission

Joyeeta Gupta [a,b], Jesse F. Abrams [c], David Armstrong McKay [c,d,e], Xuemei Bai [f], Kristi L. Ebi [g], Paola Fezzigna [a], Giuliana Gentile [a], Lauren Gifford [h], Syezlin Hasan [i], Lisa Jacobson [j], Aljoscha Karg [a,*], Steven Lade [d,f,j], Tim Lenton [c], Diana Liverman [h], Awaz Mohamed [k], Nebojsa Nakicenovic [l], David Obura [m], Johan Rockström [n,o], Ben Stewart-Koster [i], Detlef van Vuuren [p,q], Peter Verburg [r,s], Raimon C. Ylla-Català [a], Caroline Zimm [l]

[a] Amsterdam Institute for Social Science Research, University of Amsterdam, Amsterdam, the Netherlands
[b] IHE-Delft Institute for Water Education, Delft, the Netherlands
[c] Global Systems Institute, University of Exeter, Exeter, UK
[d] Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden
[e] Georesilience Analytics, Leatherhead, UK
[f] Fenner School of Environment & Society, Australian National University, Canberra, ACT, Australia
[g] Center for Health & the Global Environment, University of Washington, Seattle, WA, USA
[h] School of Geography, Development and Environment, University of Arizona, Tucson, AZ, USA
[i] Australian Rivers Institute, Griffith University, Brisbane, QLD, Australia
[j] Future Earth Secretariat, Stockholm, Sweden
[k] Functional Forest Ecology, University of Hamburg, Hamburg, Germany
[l] International Institute for Applied Systems Analysis, Laxenburg, Austria
[m] Coastal Oceans Research and Development in the Indian Ocean East Africa, Mombasa, Kenya
[n] Potsdam Institute for Climate Impact Research, Leibniz Association, Potsdam, Germany
[o] Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany
[p] Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, the Netherlands
[q] PBL Netherlands Environmental Assessment Agency, The Hague, the Netherlands
[r] Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland
[s] Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

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ABSTRACT

The planetary boundary framework proposes 'safe' boundaries, but these boundaries are not necessarily 'just'. Hence, we ask: How has the Earth Commission defined just boundaries building on the concept of minimizing significant harm and how many people are currently exposed to harm above the safe and just threshold? We document the work of the Earth Commission to address these questions using our Earth System Justice framework. We conclude that: (a) from a justice perspective, nine criteria need to be considered when defining just boundaries; (b) the proportions of populations exposed to harm from exceeding safe and just boundaries today range from 14 to 85 % for the five domains studied (climate, biosphere, water, nutrients, aerosols); and (c) argue that the absolute upper limit for significant harm is possibly harm to 1 % of the population, which although not stringent enough to leave no one behind, would require radical transformations, given the populations currently already above the threshold.

1. Introduction

In the Anthropocene, six out of nine planetary boundaries have been crossed (Richardson et al., 2023). Planetary boundaries are thresholds defined to stabilize the Earth system in a Holocene-like state or to ensure that critical tipping points are not crossed. While some boundaries aim to protect ecosystems and species, they were not explicitly set to prevent harm to humans, instead focusing on protecting the critical Earth system processes supporting life. However, our hypothesis is that long before a

* Corresponding author. GPIO Governance and Inclusive Development, University of Amsterdam, Nieuwe Achtergracht 166, 1018 WV Amsterdam, the Netherlands
E-mail address: a.a.k.karg@uva.nl (A. Karg).

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Abbreviations

EC	Earth Commission
ESBs	Earth System Boundaries
ICJ	International Court of Justice
IPCC	Intergovernmental Panel on Climate Change
NSH	No significant harm
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change

planetary boundary is reached, there may be significant harm to humans. Recent extreme weather events, many attributed to climate change, have caused significant loss of life, spread of infectious disease, damage to property, land, and infrastructure, and displacement. For example, one third of Pakistan was inundated following extreme rainfall in 2022, where 33 million people were harmed (NDMA, 2024). People have thus been harmed by climate variability and change, although moral philosophy, medicine and law call for not causing harm to others. Moreover, international law initially aimed at not causing significant harm to the environment of others. Yet, this principle was omitted in the 1992 Climate Convention and other treaties. Thus currently, human activities that are not forbidden by international law in one area are causing significant transboundary harm to both humans and the environment globally (e.g. climate) and locally (e.g. upstream dams) across borders. This indicates that the global community has neglected to define a threshold for significant harm.

The Earth Commission[1] (EC) set out to identify safe *and just* Earth System Boundaries (ESBs) (from here on boundaries), where *safe* focuses on avoiding tipping points and loss of Earth system stability and function, and *just* focuses on avoiding significant harm to people, communities and countries (and other species), now and in the future. Indeed, the justice implications of safe boundaries require systematic investigation (Häyhä et al., 2016; O'Neill et al., 2018). First, a safe boundary may not inherently embody justice; while safeguarding Earth system functionality, it could still allow significant harm to the environment and people. Second, a safe boundary remains neutral regarding the allocation of the limited ecospace within the boundary (environmental utilization space), thereby overlooking vast disparities in resource utilization and responsibility for ecospace degradation. Third, establishing a safe boundary offers no direction on how human activities should be regulated to prevent breaches of these boundaries. Therefore we have proposed just boundaries to prevent "significant harm". However, such boundaries also need to be met in a 'just' manner.

We had many debates in defining and operationalizing what no significant harm (NSH) means in terms of just boundaries as it is a subjective, normative and difficult exercise. But, "the systemic and structural injustices involved (in Earth system governance) require interrogating who was and is involved, how so, (and) with what consequences" (Sultana, 2023: 3). In response, we open the 'black-box' of our research on safe and just boundaries and communicate our working process to the outside in an accountable, comprehensible and transparent way: How has the Earth Commission defined just boundaries building on the concept of minimizing significant harm and how many people are currently exposed to harm above the safe threshold?

Here we provide the context of our work on significant harm building on an exploration of the concept in different philosophies and cultures, and how it has or has not been institutionalized in international law (see Section 2). We explain how this influenced the 'just boundaries' and analyse the discussions within the EC on NSH by reviewing the literature on NSH (see Section 3). We then apply our method to the five domains covered – water, climate, biosphere, aerosols and nutrients on a domain-by-domain basis. This led to the proposal of safe and just boundary levels for eight indicators across five domains, where the ESB is the more stringent of the safe and just boundaries. We also develop a methodology to calculate the number of people currently exposed from crossing the safe and just boundaries (see Section 4). Finally, we conclude that an inductive approach is needed to answer the question on significant harm (see Section 5).

2. Literature review

2.1. No harm in different worldviews

The Western notion of doing no harm can be traced back to Stoic philosophers – such as Cicero – who deemed harm to other people as unjustifiable (Linklater, 2006). Western philosophy of harm is largely anthropocentric (Aristarkhova, 2012), and foregrounds harm avoidance rather than proactive acts of solidarity (Linklater, 2006). Harm avoidance is dictated by empathy limited to one's circle of individuals: the infliction of harm therefore occurs "either out of sheer unconcern with the damage so inflicted, or even out of a positive taste for the infliction of damage on persons or groups outside the circle of one's sympathies" (Warnock, 2020: 80). Only if one recognizes the capacity of suffering shared among all living beings, can the duty to avoid harm be extended to people outside one's circle of sympathies and the more-than-human world (Warnock, 2020). Adam Smith argued that "the violation of justice is injury" as "it does real and positive hurt to some particular persons" (Smith, 2025: 79). Consequently, justice in an organized society required avoiding harm, which includes positive duties beyond merely avoiding negative harm (Linklater, 2006).

The need to integrate the no-harm principle with an ethic of rescue – the idea that people have a duty to save others in danger of death or serious harm, even if it's costly - has sparked further debate. American author Joel Feinberg (1984) reflected on 'Bad Samaritanism', and claimed that "in some circumstances, acts of omission should be punished because they do not differ qualitatively from deliberate attempts to injure. […] In this domain, inaction which might reflect sheer indifference to a person's suffering, as opposed to cruel dispositions, can cause death" (Linklater, 2006: 340). Such perspectives were cited in the literature regarding the Holocaust, where the bystander exhibited "mortal indifference to […] human dignity" (Gay, 1998: 185). This was evident in Primo Levi's (1959) concept of the demolition of man caused by the refusal to recognize basic human claims, and Horwitz's (1990) analysis of the people residing in proximity to the Mauthausen camp, who chose to ignore the obvious atrocities occurring inside, proving how such indifference was ultimately correlated to a lack of human recognition. Norman Geras (1999:58) sums up: "practical indifference to the calamities and suffering of others is taken to be a legitimate mode of personal conduct. Living side by side with them, not regarding them as one's own responsibility […] is not widely seen as a form of moral depravity." He claims that a "legal and moral culture of rights and obligations largely structured around the notion that one should refrain from harming others […] [is] plainly inadequate" (Geras, 1999: 58) due to its neglect to aid the victims of human rights abuse.

Such a perspective of the no-harm principle – entrenched in solidarity and proactive assistance – has also been part of Eastern philosophy and theology, crucially extended to the more-than-human world (Linklater, 2006; Aristarkhova, 2012). "Confucianism stresses the duty of *ren* or benevolence which forbids harm to others (as well as positive obligations of benevolence). The concept of *pu jen* links the duty not to cause harm with duties to relieve human and animal suffering" (Linklater, 2006: 334). In Jainism avoiding and amending harm are closely related: "Jain philosophy is founded on the ethical premise […]

[1] The Earth Commission was set up by Future Earth and the Global Commons Alliance to assess such thresholds, how these can be downscaled to actors and how transformation pathways can be created.

that "doing nothing" about the already done harm to another living being itself constitutes doing harm. Jain ethics demands that one be attentive to harmed living beings and also that one should help them" (Aristarkhova, 2012: 640). The Jain concept of Ahimsa means "non-harm" or "nonviolence" towards all living beings. In early translations of the Akaranga Sutra, a foundational text of Jainism, the word "himsa" – meaning harm – has been translated as a form of "injury" or "sin", in the Christian sense (Aristarkhova, 2012). This difference in translation shows how the concept of no harm within the inherently anthropocentric Christian moral code loses its connection to all living beings and becomes limited to the human world (Aristarkhova, 2012). The term ahimsa is also critical in Hinduism and Buddhism. Importantly, a concept missing in Western views of no harm is the Jain concept of the *jiva*, an essential soul or force that "connects and is common to all living things and creatures" (Aristarkhova, 2012), which implies that harming any living being implies harming one's self. Such a perspective contrasts with the conception of no harm illustrated by Geoffrey Warnock and criticized by Holocaust authors, as it rejects any hierarchic selection of individuals worthy of respect, and entails respect for all life as an extension of one's life itself. Thus, the no harm principle includes not causing harm to others in one's own circle to not causing harm to any living being anywhere; to assist when others are harmed; and to recognize that harming others might imply harming oneself.

2.2. No harm in international law

We now focus only on not causing harm in one's own circle and to any living being anywhere else rather than solidarity principles in law. The causing no harm principle was institutionalized in international law through a series of landmark cases (McIntyre, 2020; Tignino and Bréthaut, 2020). Between 1938 and 1941 the judgement on the Trail Smelter transboundary air pollution case between the US and Canada set the foundation for the obligation not to cause serious injury to the territory of other states thereby limiting state sovereignty[2]. In 1972, the Stockholm Conference on the Human Environment (UNGA, 1972) adopted Principle 21: countries may use their sovereignty to exploit their own resources pursuant to national environmental policies, international law, and the Charter of the United Nations, but they must not cause damage to the environment of other States. This concept was reiterated in the 1992 Rio Declaration on Environment and Development, Principle 2 (UNGA, 1992: 1). Thus, not causing harm or damage to the environment of others is a cornerstone of several international conventions aimed at protecting transboundary resources (Tignino and Bréthaut, 2020). A state's failure to prevent activities within its jurisdiction from causing environmental damage across boundaries carries international responsibility (Mayer, 2016).

In transboundary water law, upstream countries claimed absolute territorial sovereignty. This was modified by the demand for absolute integrity of state territory – which required upstream countries not to reduce the quality and quantity of water a downstream nation received. In 1957, the Lake Lanoux Tribunal between France and Spain called for extensive consultations among the interested parties to prevent harm. In 1966, the International Law Association included in its Helsinki Rules the requirement not to cause harm to each other. In 1997, this concept of not causing significant harm was included in the UN Watercourses Convention.

In 1997, the International Court of Justice (ICJ) ruled on the Gabcikovo–Nagymaros case between Hungary and the Czech Republic that the state had the duty to ensure vigilance to minimize environmental damage as long as it did not affect the equitable and reasonable use of surface water (ICJ, 1997). In 2010, the court ruled in the Pulp Mills case (Argentina and Ururguay) that states must undertake Environmental Impact Assessments and demonstrate due diligence in preventing transboundary harm, including through consultations with local populations (ICJ, 2010). In the 2013 Kishenganga (India and Pakistan) case the court promoted the duty to ensure a minimum environmental flow (Permanent Court of Arbitration, 2013); and in 2015, the San Juan River (Costa Rica and Nicaragua) case culminated with a historical ICJ ruling that proclaimed environmental damage as compensable under international law (ICJ, 2015). Thus, in water law, the NSH principle includes requirements for environmental impact assessments, due diligence, the duty of care, public consultation, maintaining minimum flows, preventing negligence and in some cases the payment of compensation.

2.3. Omission of the no harm principle in climate and other agreements

Despite legal consensus on the no harm principle, the United Nations Climate Convention (UNFCCC, 1992), the Convention on Biological Diversity (UNEP, 1992), and Agenda 2030 (UNGA, 2015) omitted this principle, ignoring the harm in these global environmental regimes, although the Climate Convention referred to the concept in the Preamble. The Climate Convention includes in its long-term objective (Article 2) the goal to avoid anthropogenic interference with the climate system but *not* to avoid causing significant harm to the environment of other countries and hence to their people (Gupta et al., 2024b). The absence of the no-harm principle in the subsequent climate negotiations results from denial by the most influential countries who also happen to be the largest greenhouse gas emitters (Mayer, 2016) and who wish to avoid liability and compensation (Gupta, 1997). This is countered by the social movements and countries that have increasingly been demanding action including loss and damage from the harm they have faced (Sultana, 2022). As this paper goes to press, Vanuatu has convinced the UN General Assembly members to request an advisory opinion from the International Court of Justice on the responsibilities of states to reduce harm caused and to prevent climate change (ICJ, 2023).

Progress in the no harm principle on water continues, while it appears to have stalled in other legal areas such as climate. The no-harm rule in water is operationalized (Gupta and Schmeier, 2020; McIntyre, 2020; Tignino and Bréthaut, 2020), and is seen as complementary to the principle of common but differentiated responsibility (CBDR), and the Duty of Care (Tignino and Bréthaut, 2020). The CBDR principle has so far merely led to ad hoc state initiatives, and would therefore be improved by the adequate placement of responsibility on high-emitters ensured by the no-harm rule. On the other hand, the no-harm rule does not entail liability beyond the prevention of negligence – which results in the failure to address historical emissions. This could, in turn, be improved by the responsibilities warranted by the Duty of Care (Tignino and Bréthaut, 2020), which provides an all-encompassing standard of care for the environment (Gunningham, 2017).

The principle of NSH within the Anthropocene needs further refinement. Gupta and Schmeier (2020) expound upon different dimensions of harm that need to be addressed such as the multidirectional nature of harm (where victim-perpetrator is difficult to define), direct and indirect; and immediate and future harm. Spatial dimensions further complicate matters and the definition of 'significant' harm, and their potential evolution over time introduce additional layers of complexity. These dimensions show the challenges inherent in understanding and addressing harm, necessitating ongoing refinement of the NSH principle and its operationalization.

While the UN Human Rights Council has generally focused on promoting human rights and preventing damage to human rights, it has only recently expanded to focus on loss and damage from climate change. In August 2024, it stated:

> "Loss and damage, referring to harm from the adverse impacts of climate change, can affect the full enjoyment of human rights. Respecting, protecting and fulfilling human rights amid the climate crisis require taking effective action to address harm to human rights from loss and damage, including economic and non-economic loss

[2] See Trail Smelter Arbitration (1941)

and damage. The impact of loss and damage on human rights can be both direct and indirect, with cascading implications for different interconnected rights" (Human Rights Council, 2024: 2).

The Council suggests that most fossil emissions since the Industrial Revolution have been caused by 78 producers who should be held accountable and that, as of 2024, the US state of Vermont holds fossil producing companies accountable for paying damages. The report concludes: "Averting, minimizing and addressing loss and damage require immediate, effective and fair mitigation, adaptation and remedies for climate change-related harms as a legal, moral, development and economic imperative" (Human Rights Council, 2024: 2).

2.4. Inferences

We have argued that the no harm principle exists across cultures and in philosophical and theological works and that there is a moral obligation to go beyond the mere avoidance of harm, and also aid those affected by it, regardless of direct responsibility. This has been institutionalized in national and international legal systems. In international water law, it has been operationalized through procedural mechanisms - EIA, the duty of care, due process, etc.

In climate change, this principle was excluded, leading to a countermovement from youth, social movements, indigenous people's groups, small island states, demanding respect for nature and humans. Courts are recognizing the rights of rivers, and social movements are demanding the adoption of the concept of ecocide – or the crime of damaging nature (see the website of Stop Ecocide International[3]). Since the 1990s governments have been avoiding including the no harm principle in transboundary environmental treaties because of the implications for liability, for development trajectories, and because it challenges many people's way of life. For example, the UN's Law Commission ceased work on harm caused by activities not forbidden by international law. Thus, today this principle is not specifically applied in climate change and biodiversity loss, although it is still applied in transboundary water. Hence, harm continues unabated with impunity without recognition and compensation. One of the main concerns with the loss and damage funding agreed upon at the UNFCCC is that historically such commitments never materialize—the Global North repeatedly fails to pay its climate debt (Uri et al., 2024). In fact, the demand for loss and damage by developing countries and the inclusion of relevant clauses in recent UNFCCC Conferences of the Parties shows that those harmed are reverting to basic principles of relationships between people and countries. In August 2028, the UN Human Rights Council will once more look at how climate change causes harm to the rights of humans and would benefit from more interdisciplinary academic thought on how this principle can be operationalized in practice. If countries do not wish to compensate for harm caused, they need to avoid causing harm.

3. The Earth Commission's approach: towards No significant harm

3.1. Introduction

Building on the philosophical and cultural understanding of harm and the legal discussion on NSH (see Section 2), social scientists within the EC argued for the need to integrate not causing harm into planetary boundaries. Natural scientists have been honing their methods on defining safe boundaries since the 1980s, culminating in concepts such as the planetary boundaries (e.g. Rockström et al., 2009). However, social science engagement with such concepts has been limited (see Raworth, 2017 as an exception). There is debate about whether social scientists should engage with concepts such as the planetary boundaries framework and from what perspective (e.g. Biermann and Kim, 2020), because many scientists reject the idea of shortage and boundaries as a neo-Malthusian idea. Such perspectives called for new and creative thinking to unify planetary limits with a framework of justice for people. We argued that social scientists should engage with the concept of planetary limits since these did not adequately consider justice issues, while being very influential in international discussions (Gupta et al., 2021). Within the first year, there was growing consensus in the entire team of Earth Commission scholars that we would try to find an inter-if not transdisciplinary way to engage with boundaries.

3.2. Defining No significant harm

The EC employed a multi-faceted approach to assess the concept of NSH. A special issue on the NSH concept in water law helped to introduce some elements of the concept in 2020 (Schmeier and Gupta, 2020). After considerable debate if and how to quantify 'acceptable' harm - considering the existing understanding of harm in different worldviews (see Section 2.1.), the use of NSH in international water law (see Section 2.2.) and the omission of it in the climate change regime (see Section 2.3.) - the EC eventually converged on the following definition:

> "**Harm**: negative impact on humans, communities and countries from Earth system change additional to background rates and to changes in vulnerability. […]
>
> **Significant harm**: What constitutes significant harm is difficult to quantify. […] Within the Earth Commission we decided not to define on a cut off point for significant harm and instead define significant harm as: Existential and/or irreversible negative impact on countries, communities or people, such as substantial loss of life, livelihood and income, loss of access to resources and Nature's Contributions to People, loss of land, chronic disease, injury, malnutrition and displacement.
>
> **NSH Principle** - States and other actors responsible for anthropogenic Earth system change have a duty to refrain from causing significant harm; to prevent, reduce, and control the risk of causing significant harm; and to repair or compensate for the significant harm already inflicted.
>
> **Just (NSH) ESB** - Earth system state that minimizes risk of significant harm to present and future generations, countries, communities, and people." (Rockström et al., 2023, SI: 2)

We initially focused on harm to humans, as harm to nature was presumably accounted for in the safe boundaries which aimed at maintaining a Holocene like state which would preserve space for nature. However, in a later paper we found that the safe boundary for climate change did not protect nature and species - long before tipping points were crossed there was extensive damage to nature (Gupta et al., 2024b).

3.3. The role of vulnerability

The Intergovernmental Panel on Climate Change (IPCC) has made it clear that the impacts and associated harm from climate change depend not only on the exposure to physical changes in climate but also on the vulnerability of exposed populations. For example, in regions where there are no human populations or where wealth, technology and governance buffer people against a changing climate, the social impacts and harm from physical climate changes are much less than in regions that are poor, densely populated or lack funds for adaptation and disaster relief. Thus, the degree of significant harm can be reduced by reducing vulnerabilities through poverty alleviation, government warning and relief programmes, health systems, and good regulations (Adger, 2006; Liverman, 2024). But would it not be simpler to reduce

[3] Stop Ecocide International.

the harm itself? Afterall, why should the ability to spend resources on adaptation or adaptive capacity determine vulnerability; why should people be subjected to harm that requires such adaptation in the first place? Vulnerability is not innate, it is created.

3.4. Harm from not meeting minimum needs

It can be debated whether the social Sustainable Development Goals (SDGs) should be included and/or referred to in relation to boundaries, also drawing on inspiration from Doughnut Economics (Raworth, 2017). Raworth has argued that meeting basic needs is as critical as identifying boundaries. Some members of the EC argued that introducing the SDGs into the Earth System Boundaries science could mean integrating a normative, policy-oriented framework that could weaken the scientific analysis of boundaries. Others argued that the SDGs give a mandate for such research. Eventually, going beyond Raworth, by analysing what meeting basic needs means for the environmental domains using the same units for access and boundaries, we showed that meeting only four basic social rights of people could have a powerful impact on the domains (Rammelt et al., 2023). Thus, the harm caused by not meeting minimum needs was seen as part of the 'just access' discussion (e.g. Rammelt et al., 2023; Gupta et al., 2024a).

A second question was how to differentiate between harm caused by the overuse of resources (i.e. harm caused by transgressing the boundaries) and harm caused by not meeting minimum needs. We concluded that if boundaries are crossed for all by some people, this can affect the access to resources for others. Thus, avoiding NSH from Earth system change would imply harm caused to others in terms of irreversible damage to their lives and livelihoods and include damage to their access.

3.5. Embedding the approach in a justice framework: Earth System Justice

The concept of not causing harm (see Section 2) was elaborated in terms of harm to whom (recognition justice); using whose knowledge (epistemic justice); balancing interspecies justice and/or earth system stability (I1), intergenerational (I2) and intragenerational justice (I3); procedural justice (access to information, decision-making, civic space and courts); and substantive justice (which includes addressing who and what causes the structural direct and indirect harm *and* the vulnerability; who should be held responsible for harm caused; how should the ecospace be shared between people, communities and countries; and how should responsibilities be allocated). This led to the conceptualization of Earth System Justice (Gupta et al., 2023).

The above development occurred because the justice frameworks developed could not simply complement the planetary boundary research ad hoc, necessitating further integrations. We undertook an extensive literature review on justice and analysed the 'Assessment of Assessments' – the Making Peace with Nature report from the United Nations Environment Programme (UNEP, 2021). We concluded that the latter identified injustices and called for justice, suggested ideas for what constitutes justice, but did not provide a justice framework (Gupta et al., 2024c). Hence, we developed the above-mentioned concept of Earth System Justice (Gupta et al., 2023). Earth System Justice takes an ideal perspective – aiming to leave no one behind, as mandated by the UN 2030 Agenda.

While intergenerational and intragenerational justice have a long pedigree in scholarship and policy, the work on interspecies/multi-species justice is more scattered. For example, Stone (2010) discusses if trees have 'standing' and the right to defend themselves. The rights of nature and rivers have also been discussed by Nash (1989) or O'Donnell and Talbot-Jones (2018). There is considerable work on intersectional justice (how poverty and vulnerability accumulate through lack of recognition across aspects of ethnocultural heritage), intercommunity justice, and inter-individual justice. This work was simplified into the 3I's of justice. Our definition of interspecies justices (I1) includes equity between human and non-human species and Earth System Stability, which would imply transitioning from an exploitative relationship to one of symbiotic coexistence; and recognizing the intrinsic value of nature and its contributions to people. This goes beyond much of the scholarship on interspecies and multi-species justice (see Box 1), in that it presents quantitative limits to our exploitation of nature. Intergenerational justice (I2) includes equity between present and future generations, and sustainable use of natural resources. Intragenerational justice (I3) includes an intersectional lens and covers justice between countries, communities and individuals, equity among present generations, equitable access to minimum resources and equitable sharing of the remaining natural resources (once resources for nature, and for meeting minimum needs were excluded) and responsibility and accountability in terms of mitigation. Drawing on the 3I's, we evaluated based on the existing scholarship, whether the safe boundaries sufficiently protect humans, species and ecosystems from significant harm.

Our notion of procedural justice builds on the vast existing literature on the subject. Substantive justice is defined in terms of *access* to a minimum and *allocation* of the remaining resources, risks/harm and responsibilities. Our *access and allocation* framework built on a decade of work within the Earth System Governance community that culminated in a special issue on the topic (Gupta and Lebel, 2020). We chose to operationalize justice in terms of ends (boundaries; access floors) and means (the transformation needed to meet the ends in a just manner) (see Fig. 1). Over four years, the concepts were developed, polished and revised in response to feedback at international conferences and workshops, and the extensive comments of reviewers before final publication (see Gupta et al., 2023; Gupta et al., 2024c; Appendix A Table A.1).

3.6. Literature on harm in specific earth system domains

An exhaustive literature review was conducted to explore what kind of harms are covered in the literature across the five key domains, climate, biosphere, nutrients, water, and aerosols and whether the literature discusses specific levels of harm. We found limited discussion of what would constitute significant harm although there was research on the different kinds of harm or damage that is being caused to people, communities and countries from existing Earth system changes and pollution levels - much of which we scholars saw as unacceptable. We sought insights into whether the literature identified thresholds of avoidable harm, where, for whom (including other species) and at what scale from the local to the global level.

3.7. Methods for estimating no significant harm

We considered different methods to identify NSH thresholds such as in terms of percentage of population harmed. We identified several ways of thinking about harm.

a) global social collapse from environmental changes – which can lead to significant harm for all (as in the film 'Don't Look Up'),
b) Noah's Ark – where only a few survive or thrive and the remaining 90 % suffer harm, (a Kingsman film deals with this scenario)
c) just for average humanity – injustice to bottom 50 %,
d) just for many – injustice to bottom 10 %,
e) just for almost all - injustice for bottom 1 %
g) leave no one behind or just for all (as in the 2030 Agenda).

For each configuration, we tried to calculate the number of people who could be harmed. We debated considerably about how many deaths from an Earth system change perspective were avoidable and how significant harm was viewed from the perspective of disasters. For example, the World Disaster Report (IFRC, 2023) proposes that a disaster occurs when 10 people die and 100 are displaced. The IPCC appears to take a more lenient approach. The risks estimates of the Sixth Assessment Report (IPCC, 2022) include.

Box 1
Interspecies justice and EC approach

Is the EC approach too anthropocentric? Interspecies justice entails aiming beyond the well-being of humans, to protect nature for the sake of nature, as humans are – in fact – nature themselves (Tschakert, 2022). Trade-offs between human and more-than-human wellbeing would therefore be problematic (Celermajer et al., 2020). Feminist ethics scholar Josephine Donovan (2006: 310) proposes an ethics of care towards all species including 'caring about what they are telling us'. These ethical justice approaches cannot, however, lead to an understanding of how this balance is to be quantified.

The EC has used different approaches: in surface water we have used pre-industrial alterations to water flow to enable freshwater species to flourish. For biosphere, we propose to reserve more than half the Earth for nature and the people living there in mutual respect. We have used functional integrity in managed areas to enable a balance between species in managed areas and humans. For climate change, safe boundaries focused on tipping points and harm to the biosphere with the just boundary also having positive impacts on nature. The differences in approaches depends on the existing scholarship. Despite the inherent anthropocentrism to the EC approach, it goes a long way towards quantifying interspecies justice.

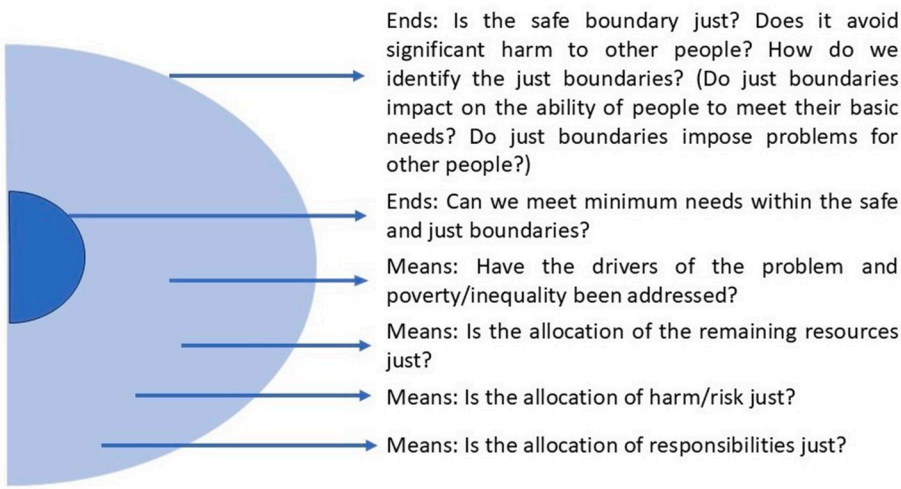

Fig. 1. Justice in relation to the boundary, foundation framework
Note: Authors' conceptualization.

- For health, severe risks as a mortality of 2–5 % over the background rate (add specific cites)
- For food security, any increase in undernourishment above 10 million people.
- For water, severe risk as an additional 1 billion people experiencing scarcity or 100 million affected by flooding.

Within IPCC's scientific community there is hence a much greater tolerance for harm than in the disaster community. These two extremes were discussed. While one billion people experiencing scarcity was seen as unacceptably high as a threshold – in particular, given that this one billion are probably the world's poorest - 10 deaths was regarded as a low number to be termed "significant harm" at a global population level in our debates. On the other hand, a car driver who kills one person in an accident is held accountable and hence, from a leave no one behind perspective, even 10 deaths would be unacceptable. Ultimately, the EC did not agree on a quantitative universal description of what significant harm is. Instead, the EC took a more pragmatic, inductive approach.

Our method developed not only through a literature review but also through a process of reasoning. Social scientists within the EC asked: how (in)justice impacted planetary-scale boundaries (#1), proposed justice criteria against which to assess planetary-scale boundaries and elaborated diverse aspects of justice based on a rich literature review (Gupta et al., 2023) (#2), elaborated on justice criteria (#3), discussed drivers, actors, and levers of transformation (#4), quantified just boundaries (#5), and elaborated on just transformations (#6). Workshops with participants from different parts of the world, from different disciplines and expertise on justice debated the issues raised in specially prepared background documents (see Appendix A; Table A.1 and A.2) and discussed how justice can be applied to boundaries. Through this process, many issues were debated, some settled and some postponed.

3.8. Adoption of a domain-by-domain inductive approach drawing on nine justice criteria

We decided to assess the safe boundary proposals, and to determine whether and how just they were in terms of NSH. Embracing a bottom-up approach, we analysed each safe boundary proposal using the 3I's to state whether we thought it was just or not and under what conditions and whether the quantifications should be more nuanced.

Retrospectively, we implicitly and explicitly adopted nine justice criteria.

1. The boundaries are mostly quantitative and do not include qualitative justice issues. For example, the safe water boundaries only consider water flows, not if the water is clean. Hence, we suggested that boundaries should be complemented with local boundaries building on existing quality standards. This was possible as WHO and other international bodies have existing standards for water and air quality.

2. In some domains, local harm is not accounted for (e.g. local air pollution), implying that local harm needs to be accounted for in global boundaries, which we subsequently implemented.
3. Many boundaries are abstract and not relatable at local levels, implying that some kind of translation and contextualization is needed. This led to boundaries ranging from 1 cu metre for air pollution to 1 square kilometre for biosphere integrity, through fluvial to global boundaries. This also led to a refined process of translation.
4. Spatial analysis can reveal that harm is not evenly distributed. Hence, we used maps to illustrate how harm is spread through the world to contextualize global boundaries.
5. In order to show how harm and poverty are connected, we decided to make maps showing how harm and poverty or other indicators overlay on each other (Gupta et al., 2024a).
6. Boundaries do not tell us who is causing the problem. This was to be addressed through our Means of Earth System Justice that focuses on the structural and root causes of harm and what causes inequality/vulnerability.
7. Just boundaries are necessary but not sufficient, in that the boundaries also have to be achieved in a just manner. For example, in a follow-up project financed by the Netherlands Science Foundation, we assessed the justice implications of implementing the biosphere functional integrity targets at the local level, focusing on cities like Lagos (Nigeria) and Rotterdam (Netherlands). Our results show that greening cities almost always exacerbates gentrification, increases house prices, pushing local people out of those areas (Gupta et al., in review); limited greening funds and subsidies are spent mostly or accessed mostly in rich areas; and the quality of green differs in different localities. Implementing this boundary needs to take these challenges into account in order to be just.
8. A just boundary needs to be accompanied by a discussion of what it can do and what it cannot do; a boundary is not in itself just.
9. Finally, procedural justice requires that any proposals we make are debated and discussed to refine and improve these proposed just boundaries.

3.9. The limits to our approach

We identified a number of limits to our approach. First, a systematic method to calculating just boundaries was not possible as the domain specific literature varied so much. Second, this is a first attempt at identifying just boundaries and there will undoubtedly many refinements that can be made both scientifically and through a procedural justice approach. Third, we were able to collectively identify three just boundaries for climate, nitrogen and aerosols. For climate, we had enough data and for nitrogen and aerosols there was considerable information about harms to health. We are still debating the just boundaries for the remaining domains. Fourth, so far just boundaries have been more stringent than safe boundaries and the EC's decision to take the more stringent of the two boundaries implies that we have chosen the more just boundary. However, in future, just boundaries could be less stringent than safe ones. This could be the case in relation to surface and ground water boundaries which we are currently researching. Fifth, our NSH boundaries do not meet the leave no one behind principle and can be critiqued for inadequately implementing recognition and inter-species justice. Nevertheless, we have tried to use a domain-by-domain approach to identify safe and just boundaries, noting that just boundaries may also need to be implemented justly. Although delineating boundaries may not entirely prevent harm, it serves to propose strong mitigation which could potentially have the effect of not creating vulnerability, emphasizing the ongoing necessity for ethical and equitable decision-making.

3.10. Inferences

Building on the philosophic and legal approaches to the no-harm principle (see Section 2), this section has defined significant harm (see Section 3.2), has examined whether and how the vulnerability of people should be accounted for in defining harm (see Section 3.3), has explained how the boundaries relate to the concept of minimum needs and that just boundaries cause harm to humans and may affect access (see Section 3.4). This notion of significant harm was then incorporated in a comprehensive Earth System Justice narrative (see Section 3.5), operationalized by analysing the harm in the literature (see Section 3.6) and through methods for estimating harm (see Section 3.7). We then identified nine justice criteria to assess safe boundaries (see Section 3.8) and five limits to our approach (see Section 3.9). While we first tried to take a comprehensive deductive approach to identify just boundaries, we later rejected it in favour of a domain-by-domain literature based safe boundary approach subjected to a justice analysis.

4. The Earth Commission's operationalization of No significant harm

As described earlier, we tried to take a deductive approach to identify the amount of acceptable significant harm. The deductive approach failed as we could not agree on what was an acceptable level of harm in terms of the number of people to die/be sick/displaced etc. Thus, we tried to inductively assess how harm has been implicitly defined in each domain.

4.1. Just boundaries

Some of the just boundaries differ from the safe boundaries (Rockström et al., 2023). For climate change, the proposed just boundary was identified as 1 °C, as at that level about 70 million people are exposed to very high wet bulb temperatures. If we were to include those affected by forest fires, extreme weather events such as floods and drought, the risk of shifting disease patterns and so on, the number of people who suffer now and into the future would rise. In a subsequent paper, we examined the politics of the 1 °C objective in the climate regime thus complementing our quantitative analysis with a political one (Gupta et al., 2024b). For aerosols, the global safe boundary which prevents the collapse of the monsoon system was found to not relate to the existing 7 million deaths from air pollution annually (WHO, 2024). This led to the addition of regional and local air quality standards within the aerosol boundary. For nitrogen, the existing safe boundary, set in terms of surplus nitrogen limits in agriculture before critical eutrophication thresholds are reached in surface waters and terrestrial ecosystems, only captured the harms resulting from eutrophication, to which the tighter just boundary added WHO drinking water limits for groundwater to also capture the problem of drinking water pollution.

We then examined the safe boundaries for the biosphere. The boundary for natural ecosystem area calls for 50–60 % of global land to be left intact (although this does not exclude local and indigenous people from living in these areas). This is in line with the call for half Earth for nature (Wilson, 2016). Today around 45 % of ice free land is largely intact. Area-efficient restoration priorities overlap to some extent with places where the poorest communities currently depend on local land resources for subsistence. Therefore, there has been considerable criticism of half Earth arguing that this could displace local people and indigenous communities especially from the poorest countries (Schleicher et al., 2019). While biodiversity conservation is possible without harming those communities dependent on local land resources, it would require more area for the same biodiversity benefits. Therefore, the safe and just boundary is likely close to 60 % of global area. This would imply that the richer countries and global North would have to take the responsibility for making land available for biodiversity. Alternatively, rich countries could financially support poorer countries

in maintaining their biodiversity. The second safe boundary in the biosphere domain is that every square kilometre of managed land (cities and farms) should maintain 20–25 % natural or semi-natural ecosystems. The boundary is based on the notion that access to ecosystem services should be guaranteed everywhere, and hence every square kilometre should have the conditions that support ecological functions providing these services (Venier-Cambron et al., 2024).

On water, the safe groundwater boundary of average annual groundwater drawdown, from both anthropogenic withdrawals and natural declines (being more or less the same as average annual recharge), was preliminarily accepted as just because excess withdrawals have major impacts on ground water availability in the future and can lead to land subsidence. The surface water boundary (which probably violates many river basin agreements) calls for limiting alterations of surface water flows to no more than 20 % on a monthly basis. This is very stringent, which led us to agree to this as a possibly just boundary. Initial conclusions indicate that this could ensure that downstream regions have enough water (a major problem in international water basins), that fisheries are protected (given the massive decline in coastal and fresh water fisheries, often related to flow alteration), and that dams need to be constructed and maintained to allow fish to go upstream. We are currently working on refining these two blue water boundaries.

4.2. The number of people currently exposed and spared from crossing the safe and just boundaries

Our assessment showed that we have crossed safe and just boundaries in four of the five domains (and seven of the eight indicators) affecting 52 % of the land area and potentially harming 86 % of the global population (Rockström et al., 2023). As mentioned earlier, we developed a methodology to examine how many people are currently exposed to harm from currently transgressing the proposed safe and just boundaries.

We investigated population exposure to harm when a local boundary is crossed and created spatially explicit transgression layers for each domain identifying areas where the boundary is transgressed (see Rockström et al., 2023; Gupta et al., 2024a for details). This is calculated for sub-global climate (two local exposure boundaries), functional integrity, surface water, groundwater, nitrogen, phosphorus and aerosol boundaries. While climate is a globally defined boundary, we used local climate transgressions to integrate wet bulb temperatures of over 35 °C for at least 1 day per year and low-elevation coastal zones (<5 m) exposed to sea-level rise as proxies. We acknowledge that the impacts of climate change (and other Earth system changes) are far more diverse than the two local exposure metrics used here (such as displacement from extreme weather events, or the impacts of glacial melt). In a next step, we overlay these boundary transgression layers with spatially explicit 2020 population data to extract the population of each grid cell where a boundary is transgressed (Gupta et al., 2024a). We use the Gridded Population of the World (GWP) UN WPP-Adjusted Population Count v.4.11 which has a 30 arc-second (~1 km at the equator) resolution. We then sum up the total population to derive the globally exposed population. It is important to note that the transgressions are calculated only based on the population in each grid cell and do not consider the broader impact that a boundary transgression may have for a local area or region (e.g. Stewart-Koster et al., 2024), either through telecoupling or displacement of impacts. Transgression of boundaries is spatially widespread, with most of the global population exposed to local transgressions in one or more domains.

Our results show that globally, 1 billion people (14 %) are currently exposed to transgressions of the climate boundary, 6.7 billion people (85 %) are exposed to transgressions of the aerosol boundary, 3.7 billion people (47 %) are exposed to transgressions of the functional integrity boundary, 2.5 billion people (33 %) are exposed to transgressions of the surface water boundary, 3.8 billion people (49 %) are exposed to transgressions of the groundwater boundary, 1.9 billion people (24 %) are exposed to transgressions of the nitrogen boundary, and 5.3 billion people (68 %) are exposed to transgressions of the phosphorus boundary (see Fig. 2 and Table 1). We also include the exposure of people to a lack of biosphere intactness. These calculations rely on data from Fedele et al. (2021). The biosphere intactness boundary is set globally. However, recent work has shown that certain populations are more "nature-dependent" – meaning that they are directly dependent on natural resources for the provisioning of their basic human needs. For these people, nature is a direct source of food, clean water, and energy. These peoples account for approximately 17 % of the global population. Thus, not exceeding the boundaries is critical to reduce harm to people. While aerosol, phosphorus and water boundaries are crossed and cause most harm, crossing the safe and just climate boundary increases the harm substantially over time because of the long-term impacts of climate change.

Our safe and just boundaries do not avoid all harm. As a proposal, we argue that the safe and just harm boundary should not harm more than 1 % of the global population above the background levels as the absolute upper limit. This will be further assessed in the ongoing second phase of the Earth Commission. Our 1 °C proposal for climate change would cause harm to at least 70 million people, a little less than 1 % of the global population. In addition to quantitative boundaries, it is also critical to have qualitative boundaries for ambient air and water quality. Our air pollution boundary causes harm to much less than 1 % of the global population based on WHO standards. There is thus a range in the way we have defined significant harm.

4.3. Justice considerations for just transformations required to meet the safe and just boundaries

Having presented our just boundaries and shown how many people are exposed to transgressions of the boundaries, we now examine additional justice issues in meeting these boundaries (see Table 1). Implementing the safe and just boundaries may also lead to harm/injustices if not implemented via just and fundamental social

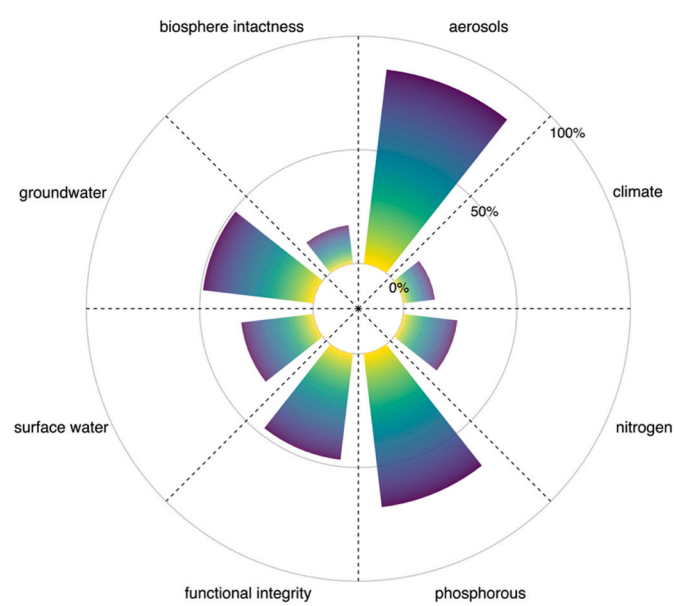

Fig. 2. The percentage of the 2020 global population exposed to transgressions of the safe and just ESBs.
Note: These are calculated for sub-global climate (measured by three local exposure boundaries – exposure to mean annual temperature (MAT), extreme wet bulb temperature, and sea level rise), biosphere functional integrity, surface water, groundwater, nitrogen, phosphorus and aerosol currently transgressed by location.

Table 1
Justice considerations for just transformations required to meet the safe and just boundaries and the number of people currently exposed and spared from crossing the safe and just ESBs.

Domain	Justice challenges in meeting the boundary (building on our nine justice criteria)	Safe and Just Earth System Boundaries	Percentage of global population currently exposed to harm	Hence % of people not exposed from crossing the boundary today
Climate change[a]	The distribution of who is allowed to use fossil fuels (the question of carbon budget allocation), or who is allowed to use the fossil fuels within their own territory (the question of stranded resources and assets) The effectiveness and equity of market-based mechanisms The distribution of who has to stop deforesting and begin afforestation. The distribution of technologies that enable a circular economy, socially sustainable renewable energy, and nature-based solution The availability of low-cost finance to enable the just transformation Issues of power and agency in transition/transformation		>14 %	<86 %
Biosphere functional integrity	The distribution of greening within managed lands; the risk of gentrification (Wolch et al., 2014) and good/bad green The ability to change existing green planning to accommodate biosphere integrity The ability to finance green planning in to be built up areas to accommodate biosphere integrity Security of food provisioning locally (and access to recent/current services), issues of power and agency in transition/transformation		47 %	53 %
Biosphere intactness	Who has to give up land rights for protected areas? Conservation is most effectively done in species rich areas, but these often overlap with livelihoods depending on subsistence agriculture or that are industrialized. For example, Schleicher et al. (2019) argue that achieving half Earth may imply moving half a billion people; while at the same time such conflict could be resolved by careful spatial planning of conservation (Venier Cambron et al., 2023, 2024)		17 %	83 %
Surface water	Who decides to allocate water; to whom and for which uses is water allocated under what conditions; How is water to be reused? How does the surface water boundary relate to historical and treaty rights to use the water? Who pollutes the water? Who needs to reduce their discharges to reduce water pollution? Who is responsible for maintaining the ambient quality of surface water? How does power and agency influence implementation?		32 %	68 %
Ground water	Who decides to allocate water; to whom and for which uses is water allocated under what conditions; How is water to be reused? How difficult is it for farmers and other users to reduce their groundwater use and implement just water sharing? Who pollutes the water? Who needs to reduce their discharges to reduce water pollution? Who is responsible for maintaining the ambient quality of ground water? How does power and agency influence implementation?		49 %	51 %
Phosphorous	Who has access to phosphorous (in the form of mineral deposits)? Who is harmed by the extraction of phosphorus? Who overuses phosphorous? How can future supplies of phosphorous be guaranteed? Who has the responsibility to remove phosphorous from the water system? How is phosphorus to be recycled?		68 %	32 %
Nitrogen	Who has access to nitrogen (in the form of energy to fix atmospheric nitrogen)? Who overuses nitrogen? Who has the responsibility to remove nitrogen from the water system? How is nitrogen to be recycled?		24 %	76 %
Aerosols	Who must reduce their aerosol pollution and by how much and where? What does this mean for standards for factories, transport, energy systems? How does power and agency influence transformation?		85 %	15 %

Note: The percentage of global population exposed to local transgressions of the safe and just (NSH) ESBs using the 2020 global population. These are calculated for climate, functional integrity, surface water, groundwater, nitrogen, phosphorus and aerosol currently transgressed by location.
[a] climate change exposure is calculated using sub global exposure to climate impacts (measured by three local exposure boundaries – exposure to mean annual temperature (MAT), extreme wet bulb temperature, and sea level rise).

transformations, especially considering the injustices that may be conducted in the name of staying within environmental boundaries. Implementing 1 °C or 1.5 °C can lead to unjust distribution of emission rights and stranded assets and a massive diversion of financial and infrastructure resources if atmospheric drawdown is attempted to return to 1 °C. Implementing the biosphere intactness boundary efficiently could increase pressure on the poorest countries. Implementing the biosphere functional integrity boundary could lead to gentrification and displacement. Implementing the surface water boundary could violate existing international water sharing treaties. Without identifying alternative sources of water supply, implementing the ground water boundary could cause extreme difficulties to farmers and others depending on that water (see Table 1).

This is why the Earth System Justice framework focused not only on adopting safe and just boundaries and meeting minimum needs (see Rammelt et al., 2023, Gupta et al., 2023) as its Ends, but also on Means. Means imply addressing the driving causes of harm (e.g. structural causes such as power, the focus on profits and GDP and the use of certain technologies) and the driving causes of inequality and vulnerability (since we argue that vulnerability is not innate but created). Means include a focus on liability for causing harm, changing the methods of allocating scarce resources and equitably sharing responsibilities.

5. Conclusions

This paper documented the process of defining NSH within the Earth

Commission as well as asked how just boundaries can be defined, their implications and the number of people exposed to crossing the proposed boundaries. We started by exploring the concept of not causing harm to others as a way to define just boundaries and examined the roots of the concept (see Section 2). We concluded that different societies believe in not causing harm to others (and may even go so far as to argue that one should also help those undergoing harm) and that this is institutionalized in law, although ignored in the climate treaty and SDG agreements. Our work thus attempted to correct this blind spot.

We then spent years of research, debate and workshops to develop a definition of harm, how it relates to vulnerability and meeting minimum needs, and how all of this can be integrated into an Earth System Justice framework. We undertook a literature review and developed a series of methods to identify just boundaries and concluded that a deductive approach would not work and a domain-by-domain inductive approach was needed. Retrospectively, we implicitly and explicitly adopted nine justice criteria and discussed the limits of our approach (see Section 3).

We then showed how we came to the proposed just boundaries and the need to ensure further research and public debate on this. We conclude that from a justice perspective, just boundaries must complement safe boundaries, just boundaries are based on applying Earth System Justice concepts, just boundaries must be implemented justly, just boundaries may leave out certain justice issues, just boundaries must be contextualized and include locally appropriate standards, and just boundaries must be debated to enhance legitimacy.

We showed the numbers of people who are harmed as these proposed safe and just boundaries have been crossed. We find that people exposed to harm from exceeding safe and just boundaries today range from 14 to 85 % for each of the domains studied (climate, biosphere, water, nutrients, aerosols). The 14 % refers to climate change today, a problem that will increasingly harm people and species worldwide. This alone justifies the need to conduct an assessment of harm as that undertaken by the Earth Commission, given the reluctance of the climate change and biodiversity treaty regime to do so.

We argue that tacitly the absolute upper limit for significant harm is possibly harm to 1 % of the population, which although not stringent enough to leave no one behind, requires radical transformations, given that we have crossed this threshold and the high populations currently above the threshold. We suggest that the principle of not causing significant harm to others should underpin our use of natural resources and hope that the International Court of Justice will support our argumentation in its Advisory Opinion in the current Vanuatu case. We believe that there should be further research and discussions on just boundaries to enable a more robust set of numbers.

A critical follow-up question is whether a standard number, such as 1 % can be used to determine the upper limit to a safe and just boundary. Is harm to 1 % of the global population above background rates the way to go? While this is significantly higher than the ten dead people of the World Disaster Report, it is much lower than IPCC numbers (see Section 3.7.). Such value judgements need to be explicitly debated by the global community. Yet ultimately, the bigger question is: has the global community decided to avoid addressing the issue of harm because it challenges the dominant narrative about development, and causes uncomfortable doubts regarding human activities that are not forbidden by international law and embedded in economic practice? As Al Gore put it: An Inconvenient Truth.

CRediT authorship contribution statement

Joyeeta Gupta: Writing – review & editing, Writing – original draft, Project administration, Methodology, Visualization, Investigation, Funding acquisition, Conceptualization. **Jesse F. Abrams:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Conceptualization. **David Armstrong McKay:** Writing – review & editing, Writing – original draft, Conceptualization. **Xuemei Bai:** Writing – review & editing, Conceptualization. **Kristi L. Ebi:** Writing – review & editing, Conceptualization. **Paola Fezzigna:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Giuliana Gentile:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Lauren Gifford:** Writing – review & editing, Conceptualization. **Syezlin Hasan:** Writing – review & editing, Conceptualization. **Lisa Jacobson:** Writing – review & editing, Conceptualization. **Aljoscha Karg:** Writing – review & editing, Conceptualization. **Steven Lade:** Writing – review & editing, Writing – original draft, Conceptualization. **Tim Lenton:** Writing – review & editing, Conceptualization. **Diana Liverman:** Writing – review & editing, Conceptualization. **Awaz Mohamed:** Writing – review & editing, Writing – original draft, Conceptualization. **Nebojsa Nakicenovic:** Writing – review & editing, Conceptualization. **David Obura:** Writing – review & editing, Conceptualization. **Johan Rockström:** Writing – review & editing, Conceptualization. **Ben Stewart-Koster:** Writing – review & editing, Writing – original draft, Conceptualization. **Detlef van Vuuren:** Writing – review & editing, Conceptualization. **Peter Verburg:** Writing – review & editing, Conceptualization. **Raimon C. Ylla-Català:** Writing – review & editing, Conceptualization. **Caroline Zimm:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

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Data availability

Data will be made available on request.

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