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Earth system justice needed to identify and live within Earth system boundaries

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Living within planetary limits requires attention to justice as biophysical boundaries are not inherently just. Through collaboration between natural and social scientists, the Earth Commission defines and operationalizes Earth system justice to ensure that boundaries reduce harm, increase well-being, and reflect substantive and procedural justice. Such stringent boundaries may also affect 'just access' to food, water, energy and infrastructure. We show how boundaries may need to be adjusted to reduce harm and increase access, and challenge inequality to ensure a safe and just future for people, other species and the planet. Earth system justice may enable living justly within boundaries.

Rapid Earth system changes in the Anthropocene are harming nature and humans. The Anthropocene is also marked by increasing inequalities[1] and vulnerabilities[2]. Scientists have proposed planetary boundaries, such as climate targets, to reduce global environmental risks. Within the Earth Commission, we aim to propose 'safe and just Earth system boundaries' (ESBs) that go beyond planetary boundaries as they also include a justice perspective and suggest transformations to achieve them[3]. Safe and just ESBs aim to stabilize the Earth system, protect species and ecosystems and avoid tipping points, as well as minimize 'significant harm' to people while ensuring access to resources for a dignified life and escape from poverty. If justice is not considered, the biophysical limits may not be adequate to protect current generations from significant harm. However, strict biophysical limits, such as reducing emissions or setting aside land for nature, can, for example, reduce access to food and land for vulnerable people, and should be complemented by fair sharing and management of the remaining ecological space on Earth[4]. Behavioural experiments show that people contribute to common pool resource stewardship if they see the process and outcomes as just[5]. This perspective offers an approach to Earth system justice (ESJ) that can guide and operationalize the identification of 'just ends' in terms of Earth system boundaries (ESBs) and access indicators, and 'just means' in terms of sustainability transformations. It provides a discursive shift to reframe environmental science and policy to pay attention to distributive justice[6].

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Environmental justice scholarship has many different ontological, epistemological, disciplinary and normative starting points[7]. While social scientists may focus on distributional issues and power, including equity and fairness in emission reductions, climate vulnerability, adaptation, conservation and pollution responses[8,9], economists tend to examine the distribution of income, costs and benefits, while legal scholars focus on just principles and processes, and reimagining legal paradigms in the context of the Anthropocene[10]. Some scholars argue that in the Global North, the view tends to be 'no humanity without nature', while in the Global South, the focus is on 'no nature without social justice'[11]. Researchers also examine who is included and excluded from science, policy, development and institutions, or consider ethical approaches to the environment[12].

Global justice scholarship emerged from critiques and extensions of Rawls' conception of justice, proposes global normative standards, highlights the duties of states and people to address global social issues, and increasingly includes environmental issues[13]. Under the umbrella of global justice and environmental and Earth system governance, there is a growing literature on access and allocation[14], uneven impacts and planetary justice. Planetary justice scholarship goes further than global justice to call for radical or profound changes to justice understandings in the Anthropocene, critiques anthropocentricism and calls for greater engagement with the non-human world[15].

Environmental justice scholars have written on injustices arising from the unequal impacts of pollution[16], as well as the injustices that can occur when land is set aside for wilderness. Related justice scholarship includes that on climate, water, energy and biodiversity, and is both conceptual and empirical and considers the unequal responsibilities for environmental degradation, the differential impacts of climate change, unequal access to energy[17], transport, food and water[18], and justice for women, Indigenous peoples and non-humans. The Environmental Justice Atlas reveals cases of injustice in different parts of the world[19] and the Sabin Climate Litigation Database documents how justice is being addressed in the courts[20]. A growing literature addresses justice in solutions to environmental change including, for example, in climate mitigation and adaptation projects, the need for compensation for loss and damage, and just conservation, energy and food transitions[21]. There are also important contributions to principles of interspecies justice and our obligations to other living things[22]. Scholars and activists examine inequalities in terms of who is causing the problem and who is affected, as well as historical injustices[12]; elaborate on unequal distributions of responsibilities, impacts and knowledges; advocate for the inclusion of multiple knowledge[23]; and explore how equity is intertwined with sustainability[24]. Both the Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services conclude that transformative changes are needed to achieve climate-resilient development and protect nature[25], but provide limited guidance for assessing just and desirable boundaries, boundary conditions and transformations. The Assessment of Assessments[26] calls for a just approach but does not define justice.

Raworth and colleagues have pushed for social issues and equity to underpin the planetary boundaries by highlighting the social foundations in 'doughnut economics'[27]. We build on these ideas (Fig. 1) to propose the concept of Earth system justice — an integrated framework that reduces the risks of global environmental change (safe) while ensuring well-being (just) with an equitable sharing of nature's benefits, risks and related responsibilities among all people in the world, within safe and just Earth system boundaries to provide universal life support — and illustrate how we implement this by looking at means to reduce harm, provide access to the poor and achieve just transformations.

Below we propose our conceptual justice approach and summarize the collaboration between natural and social scientists that uses joint knowledge to identify safe and just ESBs for blue water, climate

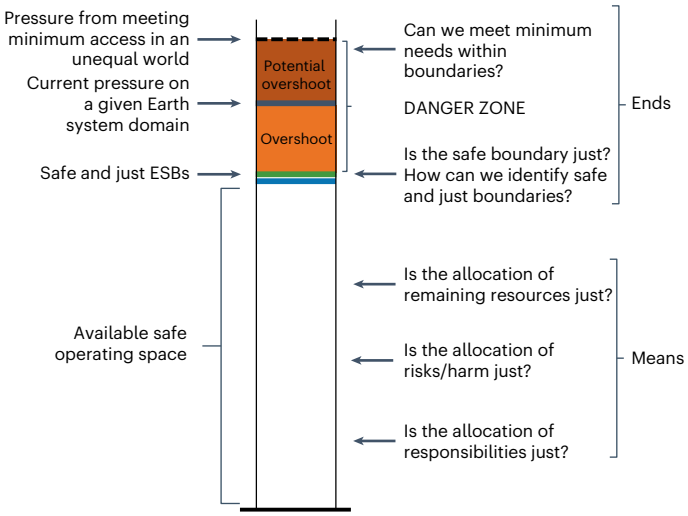

Fig. 1 | Adding a justice perspective on boundaries. The justice questions in relation to one Earth system domain: ESJ focuses on the justice issues with respect to ends (boundaries, access to minimum resources) and means (the allocation of remaining resources, risks and responsibilities).

change, biodiversity, nutrients (nitrogen and phosporus (N & P)) and air pollution. Our work seeks 'just ends' through boundaries that reduce significant harm from global environmental change and ensure access to resources, as well as 'just means' in processes of transformation (Fig. 1). We discuss how biophysical boundaries may need to be adjusted according to principles of justice to reduce harm to the most vulnerable. We operationalize justice in terms of access to minimum needs for the poorest. Guided by the Sustainable Development Goals (SDGs) and international human rights principles, our operationalization of justice posits that everyone should have at least minimum access to the food, energy, water and infrastructure (housing and transport) needed for a dignified life or to escape from poverty. However, ensuring such minimum access adds significant pressure on the environment[28] unless we address issues of sharing the remaining resources, risks/harm and responsibilities and implement sustainability practices combined with structural and systemic transformations in inequality, accumulation, consumption, technology, values and other social underlying drivers of environmental change and vulnerability. Just transformations may require redistributive strategies that reallocate consumption, risks and responsibilities, and address vested interests. We also consider how target setting and transformation may create further injustices. For example, a 1.5 °C global limit on warming is not strict enough to prevent harm to many vulnerable people, countries and species that are already impacted by the current average warming of 1.1 °C (ref. [29]). Our perspective on Earth system justice underpins the work of the Earth Commission, hosted by Future Earth and the scientific component of the Global Commons Alliance. It emerges from several years of discussions and workshops between social scientists, legal scholars and natural scientists from the Global North and South to devise safe and just boundaries for the Earth system and the transformations needed to achieve them.

Conceptions of justice

Scholars promote 'recognition'[24,30] and 'epistemic'[31] justice to highlight the injustices that arise from the lack of opportunities for misrecognized and marginalized groups to influence the framing of environmental problems, choice and implementation of possible solutions. 'Recognition injustice' occurs when powerful interests (for example, countries, corporations) dominate national to global-level decision-making on environmental issues and decide who is involved. Recognition justice includes the excluded and marginalized — women,

Indigenous people, local communities and developing countries, accounting for their views and ways of knowing. 'Epistemic injustice' occurs when different sources and types of knowledge are ignored[32], their credibility is questioned, or access to different types of knowledge, including traditional and Indigenous, is blocked.

'Procedural justice' focuses on inclusiveness through fair and transparent processes and comprises providing access to information, decision-making, civic space and courts for all[31]. This enables people to develop informed opinions, participate in and influence the processes of decision-making, and object to decisions if these are perceived as unfair — on the street in protests but also in courts to demand climate action or compensation.

'Substantive justice' concerns fairness of access and final allocation of benefits and burdens including rights, resources, capital, responsibilities, risks (including risk of harm) and blame. For example, for transboundary rivers, do upstream countries harm downstream countries through pollution or water diversion? Or, how should water be shared between and/or jointly managed by the countries along the river? Substantive justice can range from conservative norms that demand the preservation of existing practices and expectations to more ideal conceptions that call for radical change and redistribution[33].

'Conservative justice' maintains the status quo and expectations with demands for transitional justice (for example, compensation) if existing property rights to, for example, water, land or minerals are taken away[34]. This includes the 'quasi' property rights written into a contract between a state and a foreign investor[35] and the granting of 'grandfathered' rights that implicitly emerge from current use practices. By contrast, 'ideal justice' aims at reforming, radically changing or abolishing existing laws, policies and institutions for more equitable distribution. This is connected to distributive justice[36], which proposes how to share rights, resources, risks and responsibilities between people on the basis of principles that range from (1) equal distribution (egalitarian); (2) meeting minimum needs for all (sufficientarian); (3) prioritizing the worst off (prioritarian); (4) applying principles of merit; and (5) limiting excess resource use (limitarian)[37]. In sharing rights, resources, risks and responsibilities, one can adopt a non-comparative (for example, where each one gets what they need to survive) or comparative justice approach (where shares are allocated on the basis of competing claims).

When harm is done, access denied or the procedure is not inclusive, justice principles can apply to how wrongs are addressed. Justice options can be (1) retributive (the wrongdoer is punished; for example, the person/company that pollutes water pays a substantial fine); (2) corrective (the wrongdoer must reduce the harm caused and if possible compensate for it; for example, the person/company/country that emits greenhouse gases reduces emissions and compensates others for the negative impacts); or (3) restorative (the wrongdoer must help to solve the problem through a reconciliation process; for example, there is no real compensation provided but there is a mutual reconciliation process started). Such principles have been debated within climate and biodiversity scholarship, negotiations and court cases[38]. For example, climate justice in terms of allocating responsibility for emissions can be based on equal per capita, responsibility for cumulative or current harm, or reparations and compensation for historical responsibility[39].

Most scholars focus on justice for humans. 'Relational' justice is based on obligations that arise when people stand in relationship to one another, such as being citizens of the same state or when some cause suffering or harm to another[40]. 'Non-relational justice' is based on obligations that arise from equal moral worth independent of interactions, such as those based on human rights[41]. There are hundreds of international negotiations on sharing water, addressing air pollution, climate change and biodiversity loss where justice issues are relevant but often minimized or ignored. For example, there are many concerns about the rights of Indigenous people within countries and the importance of their norms, knowledge and practices in protecting nature[42].

Justice between humans includes relationships between present humans (intragenerational)[42,43] and justice between states (international)[44], among people of different states (global)[45] and between community members or citizens (communitarian or nationalist)[46]. 'Intersectional' justice considers multiple and overlapping social identities and categories (for example, gender, race, age, class, health) that underpin inequality, vulnerability and the capacity to respond[47]. Scholars have shown intersectional injustice when pollution is higher in poor and black neighbourhoods[16], and Indigenous peoples, the minoritized and the poor are more exposed to environmental pollution than others[48]. For example, climate impacts, water scarcity and loss of nature's services are often disproportionally experienced by women, especially those who are poor, Indigenous or elderly.

'Intergenerational' justice also examines relationships between generations, such as the legacy of greenhouse gas emissions or ecosystem destruction for youth and future people. Such intergenerational justice assumes that natural resources and environmental quality are shared across generations and should not be degraded[49]. Intergenerational impacts occur because of the long life of carbon dioxide and plastics, or when biodiversity loss results in irreversible extinction. Intergenerational justice challenges the dominant political and economic focus in the short term and calls for recognizing the long term[50]. Traditional peoples such as the Maori and many Native Americans see past, present and future peoples as part of the same spiral of time, with obligations across at least seven generations; can include relations to other species and nature; and see the role of humans as guardians and stewards of nature[51,52].

Justice is also important in the relation between humans and nature (interspecies justice)[22], with some justice scholars rejecting human exceptionalism[53]. Some scholars focus on animal welfare on the basis of utilitarian principles[54], treating other species as sentient/feeling beings[55] (sentientism)[55,56], or on species rather than individual living things, including biotic communities and ecosystems, and multi-scale and multi-actor/species justice[57]. The more-than-human world should be included in decision-making[52], possibly through engaging with different ways of knowing[58]. Visual, embodied, ethical and political encounters with the more-than-human world can enable responsible behavior[59]. For example, the right of rivers to run free and clean is recognized by law or courts in New Zealand, India and Ecuador[60].

Earth system justice

On the basis of the definitions above, the Earth Commission defines ESJ as an equitable sharing of nature's benefits, risks and related responsibilities among all people in the world, within safe and just Earth system boundaries to provide universal life support. We conceptualize ESJ as illustrated in Fig. 2. We implement recognition justice by prioritizing the most marginalized and the poorest people. More than half the world's population lives on less than US$5.50 per day, limiting their access to resources and exposing them disproportionately to environmental degradation. Vulnerability and marginalization are not innate but created by human systems[61], hence the response to Earth system risks must address the drivers of such vulnerability. We choose ideal rather than conservative justice because it will be impossible to meet the basic needs of the poorest within ESBs without redistribution and radical transformation of the global system[28]. Epistemic justice leads us to consider scholarship on other knowledge systems, especially local and Indigenous[62], and respect attempts by unrecognized or misrecognized groups to frame and decide transformations and establish epistemic equity between different forms of knowing[63].

We adopt the '3 Is of justice': interspecies justice and Earth system stability; intergenerational justice (between past and present, and present and future); and intragenerational justice (between countries, communities and individuals). These principles derive from the seminal work of Weiss on intergenerational and intragenerational equity[64], with additional focus on interspecies justice. In interspecies justice,

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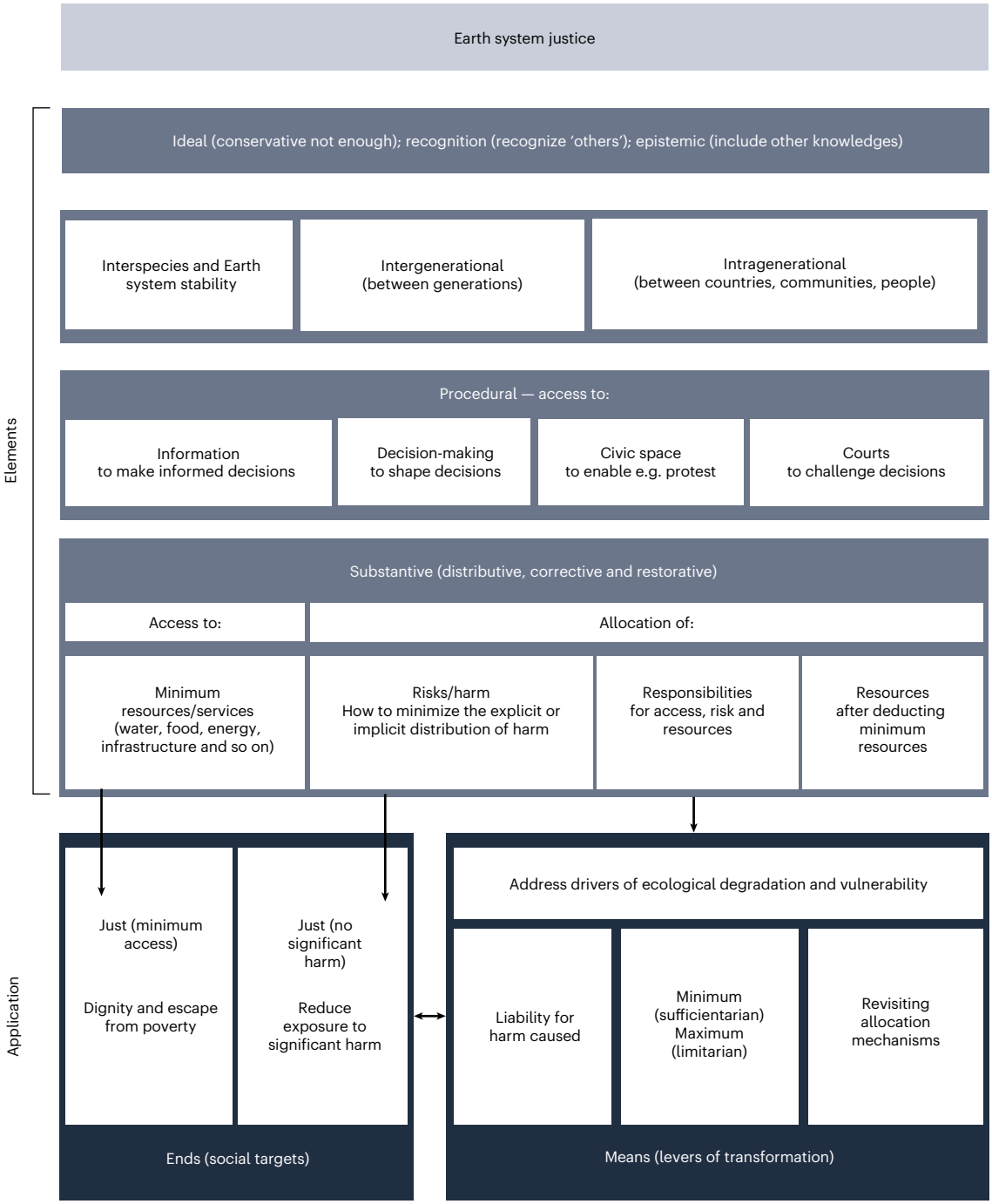

Fig. 2 | Conceptualization of ESJ through just ends and just means. The elements of ESJ include concepts (ideal, recognition and epistemic), the subjects of justice (interspecies and Earth system stability, intergenerational and intragenerational justice), procedural justice (access to information, decision-making, civic space and courts) and substantive justice operationalized as ends that include targets that reduce exposure to significant harm and provide access to resources/services and equitable allocation of resources, risks/harm and responsibilities. Equitable access and allocation within safe and just ESBs are difficult without just means (levers of transformation), which includes addressing the drivers of ecological degradation and vulnerability, liability for harm caused, setting minimum needs and maximum consumption levels, and revisiting allocation mechanisms.

we include justice that promotes Earth system stability to prevent the collapse of conditions of life for all species. We fold intercommunity, interstate and interindividual justice into a broad category of intragenerational justice, which includes concern for intersectional justice. These elements of justice are applied to define and quantify our ESBs.

Our conceptualization of ESJ includes procedural justice — the processes through which decisions are made, including the setting of goals and how the allocation of benefits and burdens is determined. The Rio Principles on Environment and Development[65] provide our basis that includes 'access to information, decision-making and legal remedies', to which we add 'access to civic space'. Such processes aim to be inclusive and enable all to participate in decision-making. For the underprivileged, equality of opportunity to participate is not enough; they need greater support and capabilities to enable effective involvement and to challenge powerful interests[66]. However, we note that our proposals are based on literature reviews and expert workshops but have not yet themselves been subject to procedural review. We also recognize that we have not adequately addressed recognition justice

by including a broader representation of scholars or interested people in our selection of boundaries and research, although the Earth Commission includes people from a range of countries and has hosted workshops and open fora.

We have initially operationalized substantive justice in terms of 'access' and 'allocation'. Our approach to just access goes beyond mere survival and assumes access to resources to lead a dignified life or escape from poverty, and is associated with calls to achieve human rights and the SDGs for all[14,67]. For example, the SDGs provide a mandate to address issues of access to water, food and other basic needs and for reducing inequality, but the large number of targets and lack of detail on justice and social drivers hamper their implementation. On ecological issues, the SDGs call for protecting our environment. Allocation looks at justice in how resources are shared, how risks/harm are distributed and how responsibilities are assigned — Earth system boundaries need to reduce harm while not adding any additional inequities.

Operationalizing Earth system justice

Stabilizing the Earth system to reduce harm

The Earth Commission approach operationalizes interspecies justice and Earth system stability (I1) by looking at each biophysical domain to determine how to enable stability, uphold resilience and ensure that ecological functions, and thereby the Earth system state remains conducive for all life. The goal is to set boundaries to avoid biophysical system collapse; in the case of climate, to reduce emissions to avoid dangerous anthropogenic climate change, especially tipping points. Such boundaries by definition partly meet intergenerational justice (I2) but have sometimes been strengthened or complemented to also ensure intragenerational justice (I3). For biodiversity, we aim to identify a natural ecosystem area measure (maintaining and restoring natural ecosystems on land) that builds on the latest ecological and Earth system science, promotes interspecies justice by making 'space' for other species to survive and thrive, and halts extinction of species and loss of intact biomes. Preserving ecosystem area is sometimes critiqued as 'fortress conservation' by environmental justice scholars, limiting access for poor or Indigenous people[68]. An ecosystem area boundary therefore requires careful consideration and involvement of the local communities, for example by not demanding that intact areas preclude human inhabitation and sustainable use and/or recognizing the role of Indigenous peoples and local communities in already protecting these areas. Ensuring a minimum level of nature's contributions to people also requires integrity of ecosystem functions on human dominated lands (for example, agricultural), freshwater and marine systems. The Earth Commission will define a spatial target of the minimum percentage of each surface unit of managed nature that is needed to preserve ecological functions. Our surface water boundary seeks to maintain the natural flow regime across all months of the year because that is the regime to which the ecosystem is adapted. For example, some fish species spawn during low-flow periods to minimize impacts of high flows on hatching larvae and ensure that prey are concentrated at higher densities in smaller areas of aquatic habitat[69]. Other organisms use high flows for spawning or moving to new foraging habitats that are otherwise inaccessible (for example, floodplain wetlands and other habitats that become connected by wet-season flows)[70]. Thus, the natural flow regime provides a range of hydrological conditions to which species are adapted and maintaining it serves to protect aquatic species. We also developed the ESB for groundwater considering the terrestrial and aquatic ecosystems that depend on subsurface water flows. The Commission's nitrogen and phosphorus boundaries will try to minimize air and water pollution and eutrophication to enable more biodiverse ecosystems to flourish (Box 1).

These boundaries have been developed as a balance between the 3 Is — a balance between the needs of present generations and ecosystems and future generations and ecosystems. They can stabilize the Earth system and protect future generations (I2), but they do not reduce all harm to people and ecosystems today. The unequal impacts of Earth system change can be addressed by ESBs that adjust for justice by minimizing significant harm to humans and the biosphere. What counts as significant is subjective and differs with changing biophysical domains, contexts, changing ideas around what constitutes harm and who defines 'significant to whom'. We propose that significant harm can be broadly defined as widespread severe existential or irreversible negative impacts on countries, communities, people and the more-than-human world from Earth system change. For humans, this includes loss of lives and livelihoods, displacement, loss of access to basic resources, and chronic disease and injury within present populations and across generations. Current generations may be inadequately protected by purely biophysical ESBs — we know that 6–7 million people die annually from air pollution, and 3.2 billion people live in degraded lands[71]. The impacts of climate variability and change at a 1 °C warming affect tens of millions of people. We propose that from a justice perspective, ESBs may need to be more stringent or complemented by local standards. Even so, not every human and country will be protected from damage, as we have drastically degraded our environmental systems. Leaving no one behind

BOX 1

The 3 Is in relation to identifying Earth system boundaries

Defining the 3 I approach

I1 (interspecies and Earth system stability): reject human exceptionalism; focus on the more-than-human world; humans as guardians of the natural world. I2 (intergenerational): between past and present (I2a); between present and future (I2b). I3 (intragenerational): between countries, communities including Indigenous peoples, and individuals.

Balancing the 3 Is for some Earth system domains and complementing with universally applicable local standards

Climate change: boundaries are set to prevent tipping points, remain within past temperatures ranges 'and' minimize significant harm to humans and nature.

Natural ecosystem area: halt loss of intact nature, and invest in restoration and regeneration of degraded ecosystems, taking human considerations and global biosphere functions such as carbon storage, water cycling and species extinction risk into account.

Biodiversity integrity: secure a minimum level of ecological diversity and functions in all managed land (% km^{-2}), taking human dependence into account.

Surface water: protect natural freshwater flows to enable species to recover and water-based ecosystems to flourish and protect current and future generations.

Groundwater: protect species dependent on groundwater, and current and future generations.

N & P: boundaries are set to prevent water and land eutrophication to enable low-nutrient adapted species and ecosystems to survive, and minimize present and future human exposure to significant harm.

Universally applicable but contextually tailored emission, ambient and other standards can simultaneously help to reduce local injustices.

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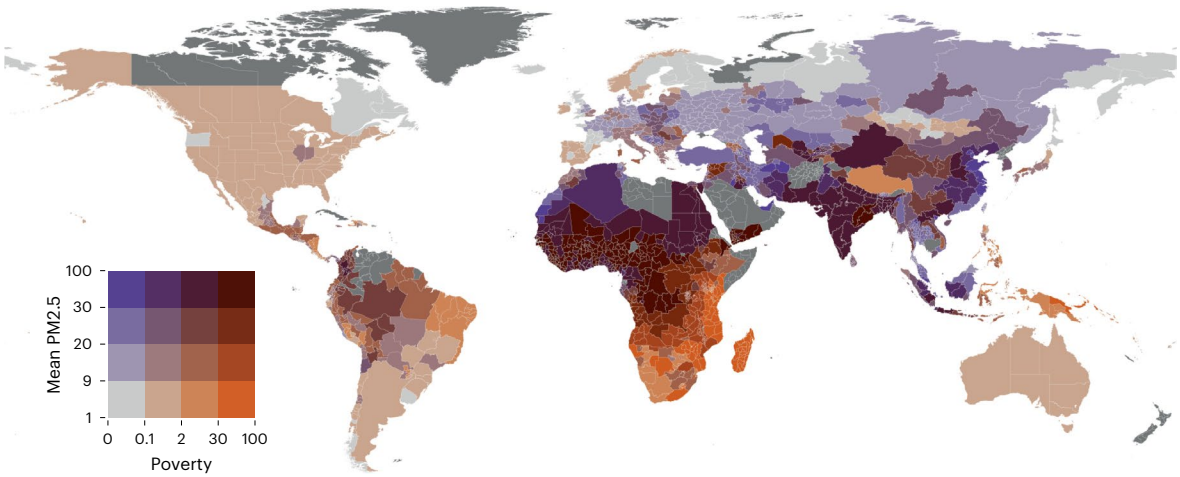

Fig. 3 | Mapping exposure to harm from air pollution. Exposure to air pollution (PM2.5) combined with poverty shows how local boundaries are crossed and how local people may be affected.

is thus very difficult to achieve without substantial transformation of our economies.

Understanding 'risk allocation' is also critical to assess who is at risk of harm and who is responsible for it. Figure 3 shows our attempts at spatially demonstrating the distribution of risk of harm worldwide, using the example of air pollution, by combining the exposure to fine particulate matter (PM2.5) with poverty levels. Many regions of the world with the most polluted air also have some of the highest levels of poverty (for example, parts of South and Central Asia).

There are just principles of not causing significant harm[72], especially to the most vulnerable. Solutions require reducing the risk of such harm through, for example, the precautionary principle, reducing vulnerabilities, adopting stringent global or universally applicable targets and/or the polluter pays principle. The principle of liability requires compensating for the harm that has already been caused and we propose that 'corrective and restorative justice' may be more effective and acceptable in addressing social–environmental challenges than 'retributive justice', which focuses more on punishment.

Access for all

The SDGs include goals of access for all to food, water, energy and other resources in line with substantive justice. Stringent ESBs to stabilize the Earth system reduce the volume of resources we can use and the pollution we can cause. This may directly impact the ability of the poor to access resources. Hence, another critical end that needs to be prioritized is meeting the minimum needs of people for a dignified life or even to escape from poverty, building on the political consensus in the SDGs.

We have operationalized access in terms of (1) quantifying four key material needs: water, food, energy and infrastructure (housing and transport) at (2) two levels: dignity (going beyond survival to some degree of dignity) and escape from poverty (where basic material needs are satisfied and may enable livelihoods) to assess the impacts on environmental pressure in a separate paper[28]. We then assess what the additional impact on biophysical domains would have been for 2018 (ref. [28]) and for 2050 (Fig. 4).

In the hypothetical case of meeting these basic needs in 2018, given the existing pressure on climate change, meeting those needs leads to greatly crossing the 1.5 °C mark. Figure 5 shows in green the annual emissions that can be considered as a safe level of pressure on climate change, which would lead to a 50% chance of staying below 2 °C of warming; current pressure is shown in orange and what meeting minimum needs would imply is shown in red. The black line in Fig. 5 shows that redistribution is not enough; if everyone's emissions are equalized at escape from poverty levels, then we would still overshoot the climate boundaries, hence we need redistribution as well as new technologies to achieve just ends. We find that meeting such access needs for the billions in poverty may lead to crossing ESBs unless resources are reallocated from the rich to the poor[28], in line with limitarian and sufficientarian justice[37,73].

Since minimum access levels for the poor cannot be met within the ESBs without substantial reallocation of resources, we propose minimum access levels for all people. These levels provide the floor or foundation of a corridor, while the ESBs constitute the ceiling (Fig. 6). If resources, responsibilities and risks are allocated in a just manner (Fig. 1), we consider this a 'safe and just corridor'.

The means of justice

The above proposals for just ends need to be subject to wide discussion to further refine our proposals and better meet principles of procedural justice and to analyse the transformations that will achieve this. Just means include ensuring that different knowledge systems are represented in assessments and collective action that challenges dominant sociocultural norms and assumptions about misrecognized groups.

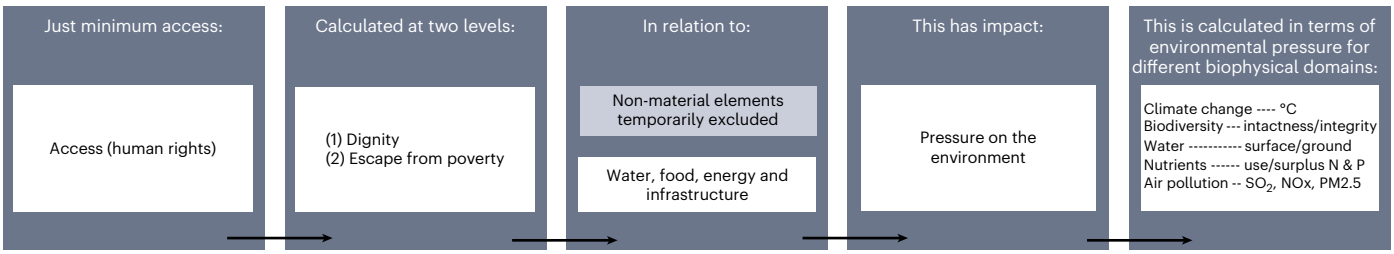

Fig. 4 | The process of calculating the impacts of meeting minimum needs on biophysical domains.

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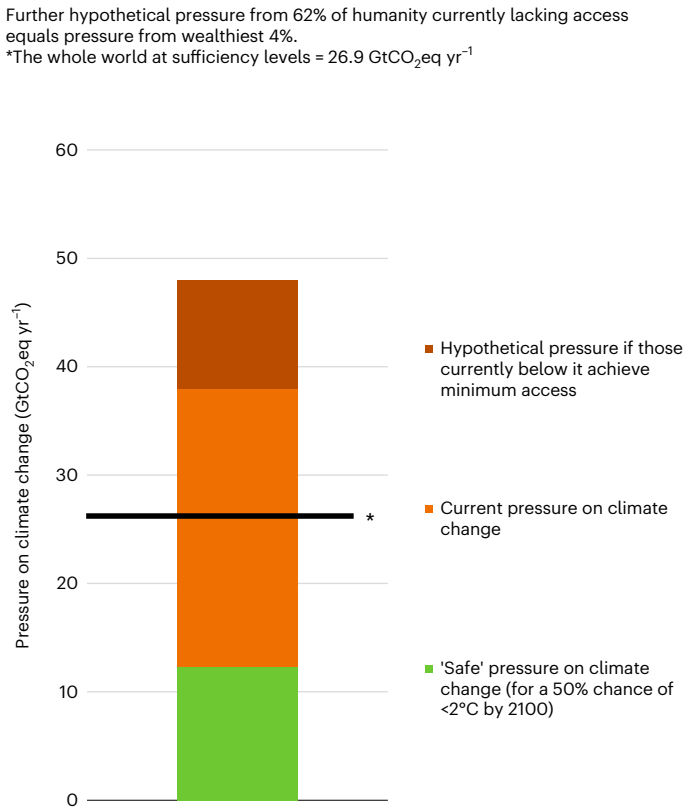

Fig. 5 | The extra pressure on climate change from meeting access in relation to 'safe' boundaries.

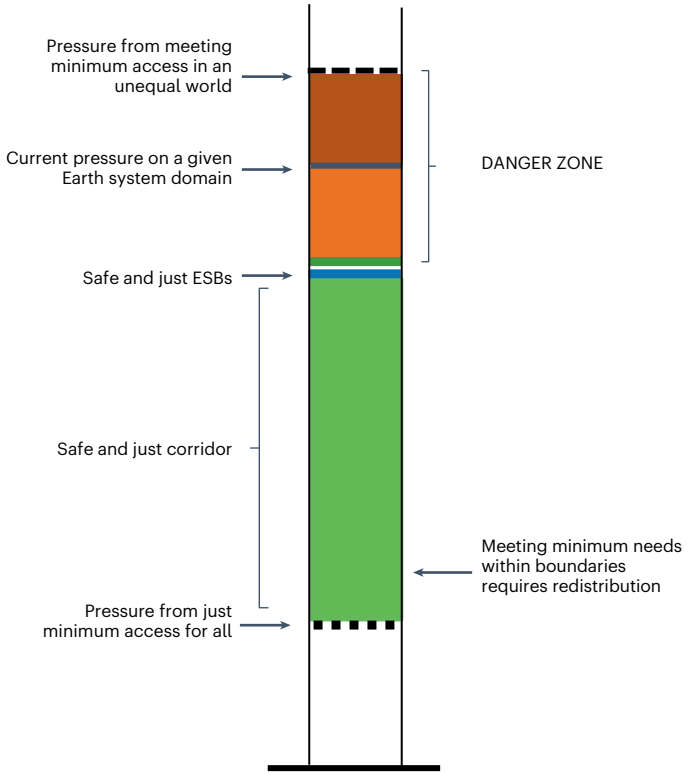

Fig. 6 | Creating a corridor. In an unequal world, providing the poor access to minimum needs leads to further crossing the boundaries (Fig. 1). Hence, we propose to reserve a certain minimum access level for all people. This provides the foundation for a corridor. The ceiling of the corridor is the safe and just boundary.

Transformations are also key to reducing harm and ensuring access including addressing the drivers of ecological degradation and vulnerability. Such drivers include values, governance, inequality, population and demography, technology, consumption, accumulation and biophysical processes. An example of how transformations in equality and governance could reduce harm would be to enforce liability for harm caused. Growing calls from social, environmental and climate justice movements focus on local to global environmental harm caused by powerful actors and relatively richer producers and consumers, and propose reparation or compensation for local pollution (for example, by extractive industry) or for loss and damage under climate change. Another just transformation might include maximum levels of consumption through, for example, consumption corridors[37], progressive consumption taxes or limits on the environmental footprints of countries.

Just transformations challenge power politics, which are often based on vested interests, cost-effectiveness and cost-recovery principles. Addressing deforestation through forest policy may not be adequate to counter agricultural policies that promote land use change to ensure more production and higher gross domestic product (GDP). Carbon markets may be captured by entrepreneurs seeking profit and may not be equitable or effective and can allow pollution to continue. In 'allocating policy responsibilities', it is important to not only understand and challenge dominant discourses on increasing GDP at all costs, but also ensure that solutions do not reproduce, redistribute or increase injustices. Policy choices can reproduce inequality especially if they do not address the underlying drivers that are the persistent cause of ecological degradation and poverty. For example, low-carbon infrastructure and devices rely on the extraction of metals and minerals, which can worsen environmental degradation and social marginalization[74]. Our concept of ESJ assumes fair sharing of responsibilities among different actors, ensuring that those who are most responsible and capable do the most. For example, the Earth Commission has developed principles for sharing responsibilities for cities and companies[37]. We can also build upon other internationally agreed approaches to allocation which include the equitable and optimal utilization of water included in the 1997 UN Watercourses Convention, fair access and benefit sharing in the biodiversity domain, and the principle of common but differentiated responsibilities and respective capabilities in responding to climate change. Access needs cannot be met without revisiting current market allocation mechanisms: the price of scarce resources keeps going up due to increasing demand from the rich, making them unaffordable to the poor[67].

Going forward

We have synthesized and operationalized an ESJ narrative drawing from a broad literature. If we are to achieve just and sustainable futures, we need to grapple with what ESJ means and how it can be put into practice to ensure that historical and present injustices are addressed and not continuously postponed or reproduced. This requires some difficult conversations on what structural reconfigurations need to take place to ensure a more just level of resource consumption so that the needs of all people can be met while also ensuring justice between species and a stable Earth system. We acknowledge that we have not been able to address all justice issues and especially the conflicts between different justice issues addressing different actors, levels, species and over time. Our narrative will clearly need to be discussed, debated, clarified and further refined. We hope that we have at least been able to argue that planetary and Earth system boundaries need to be discussed alongside considerations of justice.

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The authors declare no competing interests.

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