

# Planetary boundaries at the intersection of Earth system law, science and governance: A state-of-the-art review

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## Abstract

First developed in Earth system science, the idea of planetary boundaries has gradually spilled over into social science research in the past decade. An interdisciplinary body of literature has emerged as a result at the intersection of Earth system science, law and governance. In this article, we provide a bird's eye view of the state of the art, and examine how social scientists frame the planetary boundaries framework and what they identify as key regulatory challenges and implications. To that end, we conducted a systematic review of 80 peer-reviewed articles identified through a keyword search. Our survey finds that social scientists have approached the planetary boundaries framework using four key problem framings, which revolve around the notion of planetary boundaries as embodying a set of interdependent and politically constructed environmental limits that are global in scale. We also identify four key clusters of governance solutions offered in the literature, which broadly relate to the ideas of institutionalizing, coordinating, downscaling and democratizing planetary boundaries. We then apply the foregoing insights to the legal domain and explore their implications for law. More specifically, we discuss how the recently proposed notion of Earth system law is related to these emerging problem framings and how it might contribute to these responses.

## 1 | INTRODUCTION

Acting as tangible limits of what we can and cannot do, boundaries allow us to operate as a society and to co-exist in an orderly way. While we have been effective in setting and enforcing boundaries related to a dizzying array of issues, we have been surprisingly reluctant to limit ourselves with respect to our harmful impact on the planetary environment. Yet, the idea of boundary setting (otherwise understood as creating limits to restrict and guide human behaviour) in relation to the Earth system has a relatively long history.<sup>1</sup> The

1972 United Nations Conference on the Human Environment marked the first significant global consensus that the current trajectory of human development is ultimately unsustainable. As evidenced by the spectacular subsequent growth of international environmental law (and the many legal 'boundaries' this body of law imposes), a period of intensive global rule-making followed,<sup>2</sup> interspersed and supported by the notions of limits to growth<sup>3</sup> and sustainable development, which in trite terms aims to limit social and

<sup>1</sup>K Brown, 'Global Environmental Change II: Planetary Boundaries – A Safe Operating Space for Human Geographers?' (2016) 41 *Progress in Human Geography* 118; AS Downing et al, 'Learning from Generations of Sustainability Concepts' (2020) 15 *Environmental Research Letters* 083002.

<sup>2</sup>RB Mitchell et al, 'What We Know (and Could Know) About International Environmental Agreements' (2020) 20 *Global Environmental Politics* 103.

<sup>3</sup>D Meadows et al, *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (Universe Books 1972).

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economic development to ensure environmental protection.<sup>4</sup> Related concepts that more explicitly captured the idea of regulating human behaviour and impacts through a boundaries approach continued to emerge, such as the human ecological footprint,<sup>5</sup> planetary guard rails and tolerable windows.<sup>6</sup>

But it was only in 2009 that a group of 29 environmental scientists led by Johan Rockström offered a detailed, concrete and popular vision that defines a 'safe operating space' for humanity.<sup>7</sup> They argued that we can identify a set of nine specific planetary boundaries for key Earth system processes such as climate change and stratospheric ozone depletion. If these boundaries are crossed, the chance of maintaining the current relatively stable and harmonious Holocene-like state for human development significantly diminishes as we approach 'dangerous levels', or where applicable, 'tipping points' in Earth system processes. In 2015, a partially overlapping group led by Will Steffen published an update of the initial research with some adjustments and elaborations.<sup>8</sup> The framework has so far attracted significant interest in academic, policy and social advocacy circles.<sup>9</sup>

In the academic domain specifically, a sizeable body of scientific literature has emerged since the planetary boundaries framework was first proposed. Because the framework originates from within the discipline of Earth system science, it only seems logical that most of this research will be situated within this natural science domain. Increasingly, however, social science studies, especially those in the field of Earth system governance,<sup>10</sup> have been exploring the multifaceted challenges presented by the planetary boundaries, including the myriad social processes, impacts and aspects related to these boundaries.<sup>11</sup> While there will obviously be several others, the broader issue of *governance* and the more specific, but related, issue of *law* are two prominent social regulatory institutions that social scientists focus on within the context of the planetary boundaries. Yet, despite the increased interest, it remains unclear how social scientists understand and approach the planetary boundaries framework, what they identify as key implications or necessary responses, what kind of regulatory paradigm we could imagine as contributing to keeping humanity within a safe operating space and what role law could potentially play in this endeavour.

In an effort to decipher the engagement of social scientists with the planetary boundaries framework and their contribution to the planetary boundaries debate, and to critically reflect on the issues they are typically interested in, our objective in this article is to offer a systematic synthesis of the interdisciplinary literature sitting at the interface of Earth system science, law and governance. In doing so, we offer a state-of-the-art survey of social science research over the past decade that grapples with the challenge of navigating the complexity of planetary boundaries by means of law and governance.

We conducted a systematic qualitative literature survey using Scopus and the Web of Science to find relevant peer-reviewed literature that focuses on the institutional dimension of planetary boundaries. We identified a set of publications published in English between 2009 and 2019 that include 'planetary boundar\*' AND (law\* OR institution\* OR govern\* OR polic\*) in their title, abstract or keywords. We consciously excluded the keyword 'Anthropocene' to pursue a more focused analysis of the role and place of law and governance in relation to the planetary boundaries. The two databases offered broadly similar but also different results, which we merged. We ended up with about 250 publications after removing duplicates and those that are written about the 'planetary boundary layer' in the atmosphere. Among those, we selected 80 relevant publications which we then analysed.<sup>12</sup> We also drew, albeit to a limited extent, on other related sources that cite or are cited by the selected publications, which we relied on to guide, elaborate and substantiate our discussion of the specific research findings. Importantly, our analysis is not a neutral summary representation of each and every extant view contained in all 80 publications. While our analysis does aim to offer a broad-brush overview of these views, it is also a critical reflection upon, and our own interpretation and critique of, these views.

This article is organized as follows. We first distil and discuss four key framings of the planetary boundaries framework that emerged from the literature. There will certainly be others that could be explored through future research, but we focus on those that, by our reading, currently dominate the debate. These include planetary boundaries as embodying environmental limits; as being interdependent and interacting phenomena; as being global in scale; and as being value-laden politically clouded constructs. This is followed by a discussion of four related clusters of regulatory interventions that the social sciences are currently proposing as a response to the characteristics above. These broadly relate to the ideas of institutionalizing, coordinating, downscaling and democratizing planetary boundaries. A main insight resulting from our analysis is that discussions about law and its role in planetary boundaries governance seem, on balance, to remain relatively restrained and limited. While there are several emerging options for law to play a more decisive role in planetary boundary governance, we conclude the article by briefly exploring one option by means of which we believe law could bolster its contribution to the planetary boundaries governance

<sup>4</sup>World Commission on Environment and Development, *Our Common Future* (Oxford University Press 1987).

<sup>5</sup>P Wackernagel and W Rees, *Our Ecological Footprint: Reducing Human Impact on the Earth* (New Society Publishers 1998).

<sup>6</sup>German Advisory Council on Global Change, *World in Transition: The Research Challenge* (Springer 1997).

<sup>7</sup>J Rockström et al, 'A Safe Operating Space for Humanity' (2009) 461 *Nature* 472.

<sup>8</sup>W Steffen et al, 'Planetary Boundaries: Guiding Human Development on a Changing Planet' (2015) 347 *Science* 1259855.

<sup>9</sup>M Milkoreit et al, 'Resilience Scientists as Change-Makers: Growing the Middle Ground between Science and Advocacy?' (2015) 53 *Environmental Science and Policy* 87.

<sup>10</sup>F Biermann, *Earth System Governance: World Politics in the Anthropocene* (MIT Press 2014).

<sup>11</sup>F Biermann and RE Kim, 'The Boundaries of the Planetary Boundary Framework: A Critical Appraisal of Approaches to Define a "Safe Operating Space" for Humanity' (2020) 45 *Annual Review of Environment and Resources* 497.

<sup>12</sup>See the supplementary materials for a list of the 80 publications analysed.

debate, namely, through the recently proposed framework of Earth system law.<sup>13</sup>

## 2 | CHARACTERIZATIONS AND FRAMINGS

How do social scientists understand the planetary boundaries framework in broad terms? While there may be others, we present below four key emerging themes around which social scientists seem to frame their planetary boundaries-related research. These four framings revolve around the notion of planetary boundaries as embodying a set of interdependent and politically constructed environmental limits that are global in scale.

### 2.1 | Planetary boundaries as limits

Social scientists consider a key function of the planetary boundaries framework as defining an upper limit to the total human impact on the Earth system in the long run. For example, atmospheric carbon dioxide concentrations of 350 parts per million is the boundary limit for climate change, and the maximum amount of consumptive freshwater use is proposed at 4,000 km<sup>3</sup> per year globally.<sup>14</sup> It is argued that humanity should not cross these quantified limits to have a reasonable chance at maintaining a stable Holocene-like state as the Earth transitions deeper into the Anthropocene. That is to say, if humanity fails to respect the climate change boundary, for example, we enter an unsafe operating space or zone of uncertainty where the Earth system may hit a tipping point and transform abruptly and irreversibly into a 'hothouse' as a result.<sup>15</sup>

While the planetary boundaries framework essentially sets environmental limits that we must not overshoot, the literature we surveyed underlines several shortcomings of such a framing from a social science perspective. Key questions raised include who sets the limits, on what basis and for whom? Some commentators problematize the fact that these environmental limits were decided and set through an expert review process involving 29 scientists from the global North with a predominantly natural science background.<sup>16</sup> The boundaries, after all, were not developed through an intergovernmental process like that of the Intergovernmental Panel on Climate Change, or with the involvement of civil society stakeholders.

Furthermore, some commentators stress that the planetary boundaries framework says little about the drivers of global

environmental change and how to govern them.<sup>17</sup> The framework is therefore seen to be conspicuously silent about the structurally embedded causes of Earth system transformation. The lack of explicit reference to drivers could possibly side-line important questions relating to who needs to do what and when, and which measures are considered legitimate, and ultimately useful and appropriate. Obviously, some of the drivers are hinted at through the selected control variables associated with the planetary boundaries, such as 'atmospheric carbon dioxide concentration' and 'change in radiative forcing' proposed for the climate change boundary. As is apparent from these examples, however, the variables can be controlled in a variety of ways. The remarks by Johan Rockström at a climate conference alluding to the need for geoengineering measures, for example, demonstrate the wide range of the potential interventions implied by planetary boundaries thinking.<sup>18</sup> Yet, some of these measures include highly controversial solar radiation management dubbed a 'rich man's solution',<sup>19</sup> which is very likely to exacerbate the already unequal distribution of vulnerabilities across countries and regions.

Some critical studies claim that the planetary boundaries as environmental limits are proposed from a particular perspective of certain prominent, privileged groups. For one, the boundaries framework is inherently anthropocentric in nature. After all, the architects selectively identified key Earth system processes and quantified boundary levels with a view to avoiding unacceptable global environmental change to humanity, not to ecosystems at large.<sup>20</sup> In other words, the 'safe operating space' is seen mostly to be accommodative of humans, and not also of the more-than-human world. What is considered to be acceptable and to which Earth system constituents, however, remains an open and critically important question. In the same vein, it is unclear from the current framework which segments of humanity should benefit from the treasured safe operating space. This, in turn, raises critical questions of inter- and intra-generational justice. Presumably, the implication is that all of humanity should benefit,<sup>21</sup> but the reality is that 'humanity' is used in a highly undifferentiated way in the standard framing of the planetary boundaries. Critics point out that the 'we' at the heart of the planetary boundaries' universalized 'humanity' is, in reality, a small

<sup>17</sup>BM Campbell et al., 'Agriculture Production as a Major Driver of the Earth System Exceeding Planetary Boundaries' (2017) 22 *Ecology and Society*.

<sup>18</sup>F Harvey, 'UN Climate Talks Are Failing to See Urgency, Says Scientist' (*The Guardian*, 8 December 2019). See also V Galaz, 'Geo-engineering, Governance, and Social-Ecological Systems: Critical Issues and Joint Research Needs' (2012) 17 *Ecology and Society*.

<sup>19</sup>F Biermann and I Möller, 'Rich Man's Solution? Climate Engineering Discourses and the Marginalization of the Global South' (2019) 19 *International Environmental Agreements: Politics, Law and Economics* 151.

<sup>20</sup>AJ Green et al., 'Creating a Safe Operating Space for Wetlands in a Changing Climate' (2017) 15 *Frontiers in Ecology and the Environment* 99.

<sup>21</sup>W de Vries et al., 'Assessing Planetary and Regional Nitrogen Boundaries Related to Food Security and Adverse Environmental Impacts' (2013) 5 *Current Opinion in Environmental Sustainability* 392; W Heesterman, 'The Right to Food and the Planetary Boundaries Framework' (2017) 100 *Science Progress* 5; DW O'Neill et al., 'A Good Life for All within Planetary Boundaries' (2018) 1 *Nature Sustainability* 88; J Hinkel, 'Is It Possible to Achieve a Good Life for All within Planetary Boundaries?' (2019) 40 *Third World Quarterly* 18.

<sup>13</sup>LJ Kotzé and RE Kim, 'Earth System Law: The Juridical Dimensions of Earth System Governance' (2019) 1 *Earth System Governance* 100003; LJ Kotzé, 'Earth System Law for the Anthropocene' (2019) 11 *Sustainability* 6796.

<sup>14</sup>JJ Bogardi, BM Fekete and CJ Vörösmarty, 'Planetary Boundaries Revisited: A View through the "Water Lens"' (2013) 5 *Current Opinion in Environmental Sustainability* 581.

<sup>15</sup>W Steffen et al., 'Trajectories of the Earth System in the Anthropocene' (2018) 115 *Proceedings of the National Academy of Sciences of the United States of America* 8252.

<sup>16</sup>Biermann and Kim (n 11).

and particularized privileged subset of the global human population.<sup>22</sup> The argument, consequently, is that 'humanity' cannot and should not be universalized in an unqualified way through the planetary boundaries framework.

## 2.2 | Planetary boundaries as dynamic and interdependent

Despite how the planetary boundaries are visualized as discrete slices of a pie, they are not isolated, lone-standing entities, but instead coupled in a hierarchical network of interacting Earth system processes.<sup>23</sup> The planetary boundaries framework, by serving as a concrete manifestation of a complex Earth system, allude to the possibility that crossing one boundary may negatively affect other boundaries, and that this impact may cascade and even become amplified.<sup>24</sup> In addition, the interaction between planetary boundaries will likely change the boundary values themselves, which implies that boundaries are not static but dynamic, and the size of the safe operating space is in constant flux.

Social scientists have been alert to such interdependency between dynamic planetary boundaries.<sup>25</sup> To them, the planetary boundaries framework serves as an important rationale for the need to grapple with the problem of misfit between the complexity of the Earth system on the one hand, and our currently fragmented regulatory systems on the other.<sup>26</sup> They argue, for example, that if we do not integrate or better coordinate international environmental institutions in line with how planetary boundaries are interacting, we run the risk of protecting one boundary at the cost of another.<sup>27</sup> Examples of such a phenomenon of environmental problem shifting include the case of increased ocean acidification using the ocean as carbon sinks and reservoirs, and the case of exacerbating climate change using certain substitutes with a high global warming potential for conventional ozone-depleting substances. Yet, other commentators point to the hierarchy among the boundaries highlighted

by Steffen and colleagues,<sup>28</sup> and argue that it is possible to create synergies by addressing the two core boundaries—climate change and biosphere integrity—that provide the planetary-level overarching systems within which the other boundary processes operate.<sup>29</sup>

Commentators point to another complicating factor that arises in the foregoing context, namely time lags or feedback delays in the interaction between planetary boundaries. Long feedback delays are common in Earth system processes. For example, many tipping elements in the climate system have a transition timescale of over 100 years,<sup>30</sup> and feedback delays could easily lock the Earth system into certain trajectories. Therefore, social scientists ask: how should our current temporally constrained law and governance arrangements deal with such time lags and feedback delays?<sup>31</sup> The principal concern is that because social institutions are often oriented towards the here and now, they are unable to tackle effectively and comprehensively critical existential global scale challenges such as climate change, the full impacts of which will only become apparent well into the future. The inevitable result of such temporal dysfunctionality is often inertia, as evidenced by the lack of progress in global climate governance. A related concern is that social institutions become so preoccupied with a critical global challenge that upsets the current status quo, that they tend to ignore other (often very much interrelated) global challenges.

## 2.3 | Planetary boundaries as global in scale

Social scientists have also turned their attention to the planetary categorization, or scale, of the boundaries, the totality of the human impact on the planet and the possible implications of such a vision for social institutions. The adoption of such a planetary lens is useful and necessary at the global level because it reveals the importance and relevance of the Earth system perspective for law and governance.<sup>32</sup> In stark contrast to localized approaches to environmental protection, the all-embracing Earth system perspective embedded in the planetary boundaries framework shifts our focus to the planetary scale. In doing so, it challenges law and governance at all levels, from the local to the global, to more fully accommodate and respond to complex and dynamic Earth system processes, irreversible impacts of interacting stresses, multiple scales of organization, and the

<sup>22</sup>F Biermann, 'Planetary Boundaries and Earth System Governance: Exploring the Links' (2012) 81 *Ecological Economics* 4.

<sup>23</sup>J Rockström et al, 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity' (2019) 14 *Ecology and Society*; GM Mace et al, 'Approaches to Defining a Planetary Boundary for Biodiversity' (2014) 28 *Global Environmental Change* 289; J Liu et al, 'Systems Integration for Global Sustainability' 347 *Science* 1258832; SJ Lade, 'Human Impacts on Planetary Boundaries Amplified by Earth System Interactions' (2020) 3 *Nature Sustainability* 119; Steffen et al (n 8).

<sup>24</sup>T Sterner et al, 'Policy Design for the Anthropocene' (2019) 2 *Nature Sustainability* 14.

<sup>25</sup>B Walker et al, 'Looming Global-Scale Failures and Missing Institutions' (2009) 325 *Science* 1345; V Galaz et al, 'Planetary Boundaries: Exploring the Challenges for Global Environmental Governance' (2012) 4 *Current Opinion in Environmental Sustainability* 80; KH Robèrt, GI Broman and G Basile, 'Analyzing the Concept of Planetary Boundaries from a Strategic Sustainability Perspective: How Does Humanity Avoid Tipping the Planet?' (2013) 18 *Ecology and Society*.

<sup>26</sup>J Castro Pereira and E Viola, 'Catastrophic Climate Change and Forest Tipping Points: Blind Spots in International Politics and Policy' (2018) 9 *Global Policy* 513.

<sup>27</sup>RE Kim and H van Asselt, 'Global Governance: Problem Shifting in the Anthropocene and the Limits of International Law' in E Morgera and K Kulovesi (eds), *Research Handbook on International Law and Natural Resources* (Edward Elgar 2016) 473.

<sup>28</sup>Steffen et al (n 8).

<sup>29</sup>Mace et al (n 23).

<sup>30</sup>TM Lenton et al, 'Tipping Elements in the Earth's Climate System' (2008) 105 *Proceedings of the National Academy of Sciences of the United States of America* 1786.

<sup>31</sup>V Galaz, *Global Environmental Governance, Technology and Politics: The Anthropocene Gap* (Edward Elgar 2014); B Richardson, *Time and Environmental Law: Telling Nature's Time* (Cambridge University Press 2017). See also F Hanusch and F Biermann, 'Deep-time Organizations: Learning Institutional Longevity from History' (2020) 7 *The Anthropocene Review* 19.

<sup>32</sup>LJ Kotzé, 'Earth System Law for the Anthropocene: Rethinking Environmental Law Alongside the Earth System Metaphor' (2020) 11 *Transnational Legal Theory* 75.

various actors and their agendas that influence Earth system change.<sup>33</sup>

While many social scientists agree about the added value that the planetary boundaries framework brings through its global imagery, they also point to an important challenge. That is, the boundaries framework could obscure the socially differentiated nature of global environmental change at sub-global levels.<sup>34</sup> In fact, the planetary boundaries architects themselves acknowledge that their framework is silent on the 'deeper issues of equity'.<sup>35</sup> Critics say this is a key limitation of the framework, to the extent that it is unable to suggest what the fair share of one's responsibility is in relation to protecting the boundaries.

To have significant practical application, the planetary boundaries need to be translated or operationalized to match the scale and levels at which most governance decisions are made. This includes not only national governments and other subnational state agencies but also non-State actors, such as multinational corporations that make decisions and engage in actions with consequences for planetary boundaries.<sup>36</sup> All these actors should understand and accept their share of responsibility with respect to governing planetary boundaries. This means that planetary boundaries, although planetary in scale, are not necessarily multi-scalar per se, and they need to become operationalized in the polycentric context of multi-level (top-down and bottom-up) and multi-actor governance, rather than being a global top-down, predominantly State-driven, approach.<sup>37</sup>

The type of operationalization that this inevitably implies is difficult to achieve through a purely scientific approach because, as the name itself suggests, planetary boundaries are not designed to be disaggregated to smaller levels. That is because of the interdependent nature of Earth system processes as well as nonlinear processes that display threshold behaviour. Although the 2015 update of the framework introduces a two-tier approach for several of the boundaries that accounts for regional heterogeneity,<sup>38</sup> the planetary scale of the boundaries continues to raise the difficult question for social scientists of how to determine a fair share of the safe operating space and concomitant responsibilities among various actors at multiple levels of governance to stay within this space and to avoid breaching the boundaries.

## 2.4 | Planetary boundaries as political constructs

Earth system scientists quantified planetary boundaries at a safe distance from dangerous levels or tipping points in Earth system processes. What exactly is considered to be 'safe' would, however, vary significantly depending, among others, on who makes the assessment, and who would be impacted to what extent by remaining within or falling outside of this safe space. Therefore, some social scientists have highlighted that although the concept of planetary boundaries was meant to be normatively neutral and simply to be based on a pure scientific determination, its operationalization and societal application, which necessarily depends on subjective risk perceptions, cannot be.<sup>39</sup> According to these commentators, the planetary boundaries are and should be considered as being embedded within a socio-political context (that is itself highly variable), even if that is not always explicitly stated or recognized.

It thus follows that the scientific determination of the planetary boundaries is necessarily also a non-neutral political process that reflects multiple interests, concerns and values.<sup>40</sup> Therefore 'these boundaries cannot be described exclusively by scientific knowledge-claims'; they 'have to be identified by science-society and transdisciplinary deliberations'.<sup>41</sup> Yet, the expert-driven approach to governing global sustainability risks is often criticized for its lack of legitimacy in relation to the chosen planetary boundaries and their boundary values.<sup>42</sup> The inevitable result could be significant: if scientific frameworks such as the planetary boundaries are not perceived by people to be legitimate, they will have little value, if any, beyond the pure scientific confines of the discourse that invented them in the first place.

In fact, the apparent limited political use of the planetary boundaries framework is, according to commentators, largely due to its 'politically contentious nature sustained by global inequalities and conflicting perspectives on sustainable development'.<sup>43</sup> This is one of the reasons why the framework is seen by some to have had less-than-expected impact at the Rio+20 global summit and on the 2030 Agenda for Sustainable Development.<sup>44</sup> Writing from the perspective of the developing world, D'Souza offers two key reasons why such an expert-driven process is not always all that appealing to the global South.<sup>45</sup>

<sup>33</sup>F Biermann et al, 'Earth System Governance: A Research Framework' (2010) 10 *International Environmental Agreements: Politics, Law and Economics* 277. See also WC Clark and AG Harley, 'Sustainability Science: Toward a Synthesis' (2020) 45 *Annual Review of Environment and Resources* 331.

<sup>34</sup>K Raworth, *Doughnut Economics: Seven Ways to Think like a 21st-Century Economist* (Cornerstone Digital 2017). See also J Randers et al, 'Achieving the 17 Sustainable Development Goals within 9 Planetary Boundaries' (2019) 2 *Global Sustainability*; Hickel (n 21).

<sup>35</sup>Steffen et al (n 8) 8.

<sup>36</sup>G Whiteman, B Walker and P Perego, 'Planetary Boundaries: Ecological Foundations for Corporate Sustainability' (2013) 50 *Journal of Management Studies* 307; MG Edwards, JM Alcaraz and SE Cornell, 'Management Education and Earth System Science: Transformation as If Planetary Boundaries Mattered' (2018) 50 *Business & Society* 1; C Folke et al, 'Transnational Corporations and the Challenge of Biosphere Stewardship' (2019) 3 *Nature Ecology & Evolution* 1396.

<sup>37</sup>V Galaz et al, 'Global Environmental Governance and Planetary Boundaries: An Introduction' (2012) 81 *Ecological Economics* 1; M Hajer et al, 'Beyond Cockpit-ism: Four Insights to Enhance the Transformative Potential of the Sustainable Development Goals' (2015) 7 *Sustainability* 1651.

<sup>38</sup>Steffen et al (n 8).

<sup>39</sup>Biermann (n 22).

<sup>40</sup>ibid; OR Young and F Schmidt, 'Protecting the Global Commons: The Politics of Planetary Boundaries' in B Hudson, J Rosenbloom and D Cole (eds), *Routledge Handbook of the Study of the Commons* (Routledge 2019) 412.

<sup>41</sup>F Schmidt, 'Governing Planetary Boundaries: Limiting or Enabling Conditions for Transitions towards Sustainability?' in L Meuleman (ed), *Transgovernance: Advancing Sustainability Governance* (Springer 2013) 215.

<sup>42</sup>FP Saunders, 'Planetary Boundaries: At the Threshold... Again: Sustainable Development Ideas and Politics' (2015) 17 *Environment, Development and Sustainability* 823.

<sup>43</sup>V Galaz, 'Planetary Boundaries Concept Is Valuable' (2012) 486 *Nature* 191, 191.

<sup>44</sup>Saunders (n 42).

<sup>45</sup>R D'Souza, 'Nations without Borders: Climate Security and the South in the Epoch of the Anthropocene' (2015) 39 *Strategic Analysis* 720, 726.

Firstly, a science that argues for planetary-scale interventions without being mindful of the long-term politics of injustice and histories of inequity between regions and countries will find it hard to sustain the claim that 'we' are all in this together. Secondly, shifting much of the burden of decision making onto global technocratic elites, in which the ownership of the science might remain predominantly with the North, can easily breed anxieties within governments in the South about being disempowered. Nations without borders can become a palpable fear, if the rule of the expert overrides national self-determination.

The challenge that social scientists highlight in this regard is how the international community could establish science-based Earth system limits, and at the same time ensure their democratic legitimacy, social relevance and utility, and buy-in and support for observing these limits.<sup>46</sup> Important questions remain about the formal State-driven global environmental governance institutional framework that is perceived as being biased towards promoting the interests of the global North at the expense of the global South. In light of ever-increasing global inequality, critics argue that conceptual frameworks such as the planetary boundaries may only serve to whitewash the politics of global environmental governance.<sup>47</sup> The boundaries framework then may not be all that helpful in addressing deeply divided and pervasive political concerns that continue to pitch a perceived rich, scientifically empowered and developed global North against a poor, ever-dependant, developing global South that is forever subjected to the continuing need of 'capacity building'.

### 3 | PROPOSED SOLUTIONS AND REMAINING CHALLENGES

The foregoing emerging thematic characteristics and their associated framings have numerous and varied implications for the legal and governance aspects of planetary boundaries. While we again acknowledge that there may be others that we do not cover here, we focus below on four related ways of governing planetary boundaries which we identified from the literature and their respective challenges.

#### 3.1 | Institutionalizing planetary boundaries

The point of setting environmental limits is to respect them with a view to staying within the safe operating space of the planetary

boundaries. Respecting the limits of the planetary boundaries requires strong institutions at all levels of governance, especially, as some argue, at the international level.<sup>48</sup> There are several suggestions with respect to institutionalizing the planetary boundaries that range between 'mainstream' international relations scholarship on global governance and the more normatively driven (legal) scholarship focusing on the type of law and governance arrangements necessary for planetary boundaries.

Numerous governance scholars have considered the nine planetary boundaries (often separately) and their corresponding potential institutional challenges.<sup>49</sup> The emerging consensus seems to be against establishing separate multilateral processes and institutions for each planetary boundary.<sup>50</sup> Some commentators believe such a sectoral governance approach would only increase fragmentation and 'spread political will thinly'.<sup>51</sup> Instead, there seems considerable support for rather building on, improving and better coordinating existing multilateral environmental treaty regimes.<sup>52</sup> In essence, scholars urge the need to bolster those 'legal boundaries' that correspond with the planetary boundaries, by strengthening and better coordinating existing legislation with the view to creating a 'safe policy space'.<sup>53</sup>

Yet, the numerous and varied regulatory challenges that planetary boundaries present, go far beyond simply strengthening existing institutions as a solution to these challenges. The challenges also question some of the most fundamental ideas in contemporary law and governance. First, critics question if the current corporate-driven growth paradigm is compatible with planetary boundaries,<sup>54</sup> and they make a case for institutionalizing 'biosphere economics' where 'growth in human well-being is the focus rather than growth in [gross

<sup>48</sup>C Folke et al, 'Reconnecting to the Biosphere' (2011) 40 *Ambio* 719.

<sup>49</sup>ML Diamond et al, 'Exploring the Planetary Boundary for Chemical Pollution' (2015) 78 *Environment International* 8; V Heck et al, 'Land Use Options for Staying within the Planetary Boundaries: Synergies and Trade-offs between Global and Local Sustainability Goals' (2018) 49 *Global Environmental Change* 73.

<sup>50</sup>Galaz (n 43).

<sup>51</sup>SL Lewis, 'We Must Set Planetary Boundaries Wisely' (2012) 485 *Nature* 417.

<sup>52</sup>RE Kim, 'Is a New Multilateral Environmental Agreement on Ocean Acidification Necessary?' (2012) 21 *Review of European Community and International Environmental Law* 243; J Ebbesson, 'Planetary Boundaries and the Matching of International Treaty Regimes' (2014) 59 *Scandinavian Studies in Law* 259. See also P Morseletto, 'Confronting the Nitrogen Challenge: Options for Governance and Target Setting' (2019) 54 *Global Environmental Change* 40; M Franchini, E Viola and AF Barros-Platiau, 'The Challenges of the Anthropocene: From International Environmental Politics to Global Governance' (2017) 20 *Ambiente Sociedade* 177.

<sup>53</sup>G Chapron et al, 'Bolster Legal Boundaries to Stay within Planetary Boundaries' (2017) 1 *Nature Ecology & Evolution* 1; L Mouysset et al, 'Operationalizing Sustainability as a Safe Policy Space' (2018) 10 *Sustainability* 3682.

<sup>54</sup>JCM van den Bergh and G Kallis, 'Growth, A-growth or Degrowth to Stay within Planetary Boundaries?' (2014) 46 *Journal of Economic Issues* 909; C Hepburn et al, 'Resilient and Inclusive Prosperity within Planetary Boundaries' (2014) 22 *China & World Economy* 76; E Barbier and J Burgess, 'Natural Resource Economics, Planetary Boundaries and Strong Sustainability' (2017) 9 *Sustainability* 1; JH Spangenberg, 'Institutional Change for Strong Sustainable Consumption: Sustainable Consumption and the Degrowth Economy' (2017) 10 *Sustainability: Science, Practice and Policy* 62; P Bond, 'Environmental Critique' in M Juergensmeyer et al (eds), *The Oxford Handbook of Global Studies* (Oxford University Press 2018) 663; B Sjöfjell, 'Redefining the Corporation for a Sustainable New Economy' (2018) 45 *Journal of Law and Society* 29; PE Stoknes and J Rockström, 'Redefining Green Growth within Planetary Boundaries' (2018) 44 *Energy Research and Social Science* 41.

<sup>46</sup>J Pickering and Å Persson, 'Democratising Planetary Boundaries: Experts, Social Values and Deliberative Risk Evaluation in Earth System Governance' (2020) 22 *Journal of Environmental Policy and Planning* 59.

<sup>47</sup>Biermann (n 22).

domestic product]'.<sup>55</sup> Second, critics argue that State sovereignty is not necessarily a socio-ecologically protective idea that is appropriate for keeping humanity within a safe operating space.<sup>56</sup> This has led some scholars to propose the idea of 'common home of humanity', which sees Earth not as an amalgamation of independent separate States that must protect their sovereign integrity at all costs, but rather as an all-inclusive and accommodative home for all where it is possible to pursue 'a stable and accommodating state of the Earth System itself ... as the intangible, natural heritage of all humanity'.<sup>57</sup> Such radical counter-narratives align with the suggestion that 'maintaining the type and level of activities within and beyond our jurisdictional boundaries ... may become conditional upon respecting certain overall, planetary-scale boundaries'.<sup>58</sup>

In a similar vein, scholars have begun calling for the creation of a fundamental (possibly even universally applicable) norm, specifically dedicated to respecting planetary boundaries as limits to harmful activities,<sup>59</sup> as well as an accompanying system of institutions that supports the administration of such a norm.<sup>60</sup> Situated as it is within the emerging narrative of global environmental constitutionalism, one specific proposal is to constitutionalize international environmental law.<sup>61</sup> Several scholars agree that some degree of constitutionalization is necessary to provide a rule of law framework,<sup>62</sup> but the exact form of a global environmental constitution is still being debated. The World Charter for Nature, the Earth Charter and the IUCN Draft International Covenant on Environment and Development are some potential candidates.<sup>63</sup> Some also see potential in the Global Pact for the Environment currently under consideration as an overarching framework for bringing the fragmented sectoral and spatial multilateral environmental agreements together

under a single higher-order (or constitutional-like) global law;<sup>64</sup> yet others remain more sceptical about its potential.<sup>65</sup> More radical proposals make a case for a new 'framework convention on planetary boundaries'<sup>66</sup> or a 'safe operating space treaty'<sup>67</sup> as possible means to integrate the planetary boundaries approach into higher-order international law.

With specific reference to the need for radical global governance reforms, Steffen and colleagues propose 'an institution (or institutions) operating, with authority, above the level of individual countries to ensure that the planetary boundaries are respected'.<sup>68</sup> Such an institution could obviously be supported by and work in tandem with a higher-order planetary boundaries framework law. What this institution might precisely entail is not explained in detail, but the discussion clearly points to the need to create some sort of a supranational organization that could respond to the global governance challenges envisioned by the planetary boundaries. Linked to such discussions is the long-standing, but recently revitalized, debate around the need to upgrade the United Nations Environment Programme to a specialized agency such as a world environment organization.<sup>69</sup> Proponents contend that such a full-fledged institution for global environmental governance would increase the likelihood of 'identifying and addressing social behavior that threatens to violate planetary boundaries'.<sup>70</sup>

### 3.2 | Coordinating planetary boundaries

As a framework of interacting planetary boundaries and associated Earth system processes, the planetary boundaries framework highlights the importance of creating coherence between different and often sectoral institutions at all levels of governance.<sup>71</sup> Several lines of Earth system governance research centred on the notions

<sup>55</sup>A Crépin and C Folke, 'The Economy, the Biosphere and Planetary Boundaries: Towards Biosphere Economics' (2014) 8 *International Review of Environmental and Resource Economics* 57, 58.

<sup>56</sup>Biermann (n 22).

<sup>57</sup>W Steffen et al, 'The Emergence and Evolution of Earth System Science' (2020) 1 *Nature Reviews Earth & Environment* 54, 62.

<sup>58</sup>D Vidas, 'The Anthropocene and the International Law of the Sea' (2011) 369 *Philosophical Transactions of the Royal Society A* 909, 923–924.

<sup>59</sup>P Bridgewater, RE Kim and K Bosselmann, 'Ecological Integrity: A Relevant Concept for International Environmental Law in the Anthropocene?' (2014) 25 *Yearbook of International Environmental Law* 61; A Muller and M Huppenbauer, 'Sufficiency, Liberal Societies and Environmental Policy in the Face of Planetary Boundaries' (2016) 25 *GAIA* 105.

<sup>60</sup>Ebbesson (n 52).

<sup>61</sup>LJ Kotzé and W Muzangaza, 'Constitutional International Environmental Law for the Anthropocene?' (2018) 27 *Review of European, Comparative and International Environmental Law* 278. See also N Kanje et al, 'A Charter Moment: Restructuring Governance for Sustainability' (2012) 32 *Public Administration and Development* 292; F Biermann et al, 'Transforming Governance and Institutions for Global Sustainability: Key Insights from the Earth System Governance Project' (2012) 4 *Current Opinion in Environmental Sustainability* 51.

<sup>62</sup>J Gupta and N Sanchez, 'Global Green Governance: Embedding the Green Economy in a Global Green and Equitable Rule of Law Polity' (2012) 21 *Review of European Community and International Environmental Law* 12.

<sup>63</sup>RE Kim and K Bosselmann, 'International Environmental Law in the Anthropocene: Towards a Purposive System of Multilateral Environmental Agreements' (2013) 2 *Transnational Environmental Law* 285; LJ Kotzé, 'A Global Environmental Constitution for the Anthropocene?' (2018) 8 *Transnational Environmental Law* 11.

<sup>64</sup>C Voigt, 'How a "Global Pact for the Environment" Could Add Value to International Environmental Law' (2019) 28 *Review of European, Comparative and International Environmental Law* 13.

<sup>65</sup>LJ Kotzé and D French, 'A Critique of the Global Pact for the Environment: A Stillborn Initiative or the Foundation for *Lex Anthropocena*?' (2018) 18 *International Environmental Agreements: Politics, Law and Economics* 811; LJ Kotzé, 'International Environmental Law's Lack of Normative Ambition: An Opportunity for the Global Pact for the Environment?' (2019) 16 *Journal for European Environmental and Planning Law* 213.

<sup>66</sup>EF Fernández and C Malwé, 'The Emergence of the "Planetary Boundaries" Concept in International Environmental Law: A Proposal for a Framework Convention' (2018) 28 *Review of European, Comparative and International Environmental Law* 48.

<sup>67</sup>P Magalhães (eds), *The Safe Operating Space Treaty: A New Approach to Managing Our Use of the Earth System* (Cambridge Scholars Publishing 2016).

<sup>68</sup>W Steffen, J Rockström and R Costanza, 'How Defining Planetary Boundaries Can Transform Our Approach to Growth' (2011) 2 *Solutions* 59, 64–65.

<sup>69</sup>F Biermann and S Bauer (eds), *A World Environment Organization: Solution or Threat for Effective International Environmental Governance?* (Ashgate 2005).

<sup>70</sup>Biermann (n 22) 5.

<sup>71</sup>Galaz et al (n 25); V Galaz et al, 'Polycentric Systems and Interacting Planetary Boundaries: Emerging Governance of Climate Change–Ocean Acidification–Marine Biodiversity' (2012) 81 *Ecological Economics*, 21.

of complexity and fragmentation aim to address these challenges.<sup>72</sup>

For example, drawing on the notion of polycentricity,<sup>73</sup> some scholars argue that polycentric coordination is an effective approach to governing interacting planetary boundaries. Galaz and colleagues, for example, believe that a polycentric order provides certain useful functions such as information sharing to better coordinate governance actions and to facilitate conflict resolution.<sup>74</sup> Claims such as these have been tested through multiple empirical case studies on, for example, the Collaborative Partnership on Forests,<sup>75</sup> the Global Partnership on Climate, Fisheries and Aquaculture<sup>76</sup> and the Global Partnership on Nutrient Management,<sup>77</sup> which all seek to address interaction between multiple planetary boundaries. But it has also been noted that polycentric coordination is 'vulnerable to internal tensions, unreliable external flows of funding, and negative institutional interactions', as well as to 'changes in the overarching institutional landscape'.<sup>78</sup> Therefore, in the quest for increased polycentric governance, continued support emanating from formal top-down State-driven global institutions that predominantly rely on and enforce international law remains critically important.<sup>79</sup>

In particular, studies have emphasized the potentially significant role of a set of central principles or norms to facilitate coordination that could emanate from a centralized institution and that could serve as 'the ultimate arbiter of the myriad trade-offs that need to be managed'.<sup>80</sup> To this end, Biermann argues that overarching principles are useful for, among others, governing the interaction as well as regulating norm-conflicts between different institutions.<sup>81</sup> In a similar vein (and harking back to the global envi-

ronmental constitutionalism issue raised above), scholars make a case for a single, legally binding, superior planetary integrity norm (or *Grundnorm*) that provides all international regimes and organizations a shared purpose to which their specific objectives must collectively contribute.<sup>82</sup> They contend that such an overarching goal would provide a point of reference for legal reasoning and interpretation, thereby enhancing institutional coherence across the Earth's sub-systems.

Such hierarchical steering through a strong institutional core, or spine, will likely counterbalance the 'self-organizing evasive possibilities' inherent in complex polycentric systems settings.<sup>83</sup> For example, a strong overarching norm could help address normative conflicts between planetary boundaries of equal priority or urgency, such as climate change and biosphere integrity.<sup>84</sup> Yet, as some commentators point out, one critical aspect that needs to be clarified in terms of such a central norm is to what extent, and which type of, trade-offs should be allowed between planetary boundaries to optimize the effectiveness of securing the overall integrity of Earth's life-support systems.<sup>85</sup>

### 3.3 | Downscaling planetary boundaries

Downscaling is a form of operationalizing the planetary boundaries, which is critical for applying the framework in practice. Closely related to polycentric governance discussed above, downscaling is mostly concerned with allocating the contribution of States and major subnational actors to global environmental change, and to situating governance priorities at the best possible and most suitable scale for their effective implementation.<sup>86</sup> Examples of downscaling

<sup>72</sup>F Biermann and RE Kim (eds), *Architectures of Earth System Governance: Institutional Complexity and Structural Transformation* (Cambridge University Press 2020); RE Kim, 'Is Global Governance Fragmented, Polycentric, or Complex? The State of the Art of the Network Approach' (2019) *International Studies Review*. See also F Zelli and H van Asselt 'The Institutional Fragmentation of Global Environmental Governance: Causes, Consequences, and Responses' (2013) 13 *Global Environmental Politics* 1; S Oberthür and OS Stokke (eds), *Managing Institutional Complexity: Regime Interplay and Global Environmental Change* (MIT Press 2011).

<sup>73</sup>E Ostrom, 'Polycentric Systems for Coping with Collective Action and Global Environmental Change' (2010) 20 *Global Environmental Change* 550. See also A Jordan et al (eds), *Governing Climate Change: Polycentricity in Action?* (Cambridge University Press 2018).

<sup>74</sup>Galaz et al (n 37); Galaz et al (n 71); V Galaz, 'Global Networks and Global Change-induced Tipping Points' (2016) 16 *International Environmental Agreements: Politics, Law and Economics* 189.

<sup>75</sup>G Reischl, 'Designing Institutions for Governing Planetary Boundaries: Lessons from Global Forest Governance' (2012) 81 *Ecological Economics* 33.

<sup>76</sup>Galaz et al (n 71).

<sup>77</sup>H Ahlström and SE Cornell, 'Governance, Polycentricity and the Global Nitrogen and Phosphorus Cycles' (2018) 79 *Environmental Science and Policy* 54.

<sup>78</sup>Galaz et al (n 37) 1.

<sup>79</sup>Folke et al (n 48); RE Kim et al, 'Hierarchization' in Biermann and Kim (n 72) 275.

<sup>80</sup>Steffen et al (n 68) 59.

<sup>81</sup>Biermann (n 22).

<sup>82</sup>RE Kim and Bosselmann, 'Operationalizing Sustainable Development: Ecological Integrity as a Grundnorm of International Law' (2015) 24 *Review of European, Comparative and International Environmental Law* 194; OR Young et al, 'Goal Setting in the Anthropocene: The Ultimate Challenge of Planetary Stewardship' in N Kanie and F Biermann (eds), *Governing through Goals: Sustainable Development Goals as Governance Innovation* (MIT Press 2017) 53; A Underdal and RE Kim, 'The Sustainable Development Goals and Multilateral Agreements' in Kanie and Biermann, *ibid.*, 241. See also C Brandt, 'Safeguarding the Earth System as a Priority for Sustainable Development and Global Ethics: The Need for an Earth System SDG' (2015) 11 *Journal of Global Ethics* 32; JJ Schmidt, 'The Moral Geography of the Earth System' (2019) 44 *Transactions of the Institute of British Geographers* 721.

<sup>83</sup>DH Meadows, *Thinking in Systems: A Primer* (Chelsea Green 2008) 137. See also Kim et al (n 79).

<sup>84</sup>Steffen et al (n 8).

<sup>85</sup>RE Kim, 'The Nexus between International Law and the Sustainable Development Goals' (2016) 25 *Review of European, Comparative and International Environmental Law* 15.

<sup>86</sup>JF McLaughlin, 'Safe Operating Space for Humanity at a Regional Scale' (2018) 23 *Ecology and Society*; MS Hossain and CI Speranza, 'Challenges and Opportunities for Operationalizing the Safe and Just Operating Space Concept at Regional Scale' (2020) 27 *International Journal of Sustainable Development and World Ecology* 40.



are found at regional,<sup>87</sup> national<sup>88</sup> and local levels.<sup>89</sup> The rise and increased popularity of urban governance for planetary boundaries is a specific case in point.<sup>90</sup> Downscaling is also now reaching into the non-State domain to corporations where the need to strengthen corporate social responsibility has become crucial in the face of the severe impacts of multinational corporations and global supply chains on Earth system processes.<sup>91</sup>

Downscaling is a political as well as a scientific exercise. These two dimensions of downscaling are intertwined and pose a range of complex challenges. From a strictly technical scientific standpoint, downscaling seems to be relatively straightforward for some planetary boundaries such as biosphere integrity that are based on aggregates of many sub-global actions.<sup>92</sup> However, the challenge of downscaling lies in particular with planetary boundaries for more spatially heterogeneous, systemically connected processes, such as climate change, ozone depletion and ocean acidification. Bridging planetary boundaries with life-cycle assessment of certain consumer products may help to downscale these planetary boundaries to sub-global levels,<sup>93</sup> including to specific industries.<sup>94</sup> Yet, some argue that the applicability of life-cycle assessment to downscaling remains inherently limited because resilience thinking underlying the

planetary boundaries framework is absent from life-cycle assessment.<sup>95</sup>

From a political perspective, there is a need for the planetary boundaries framework to address not only the biophysical and socio-economic but also the ethical dimensions of bridging across scales.<sup>96</sup> This is so because downscaling necessarily involves allocating shares of environmental responsibilities to different State and non-State actors. Nilsson and Persson, for example, ask, what is a fair share of the planetary boundaries for the European Union?<sup>97</sup> Any answer to this question depends on the ethical principles (if any) applied in addressing the question.<sup>98</sup> Here, some guidance could be obtained from the fairness and equity debates (or principles of allocation) that are to some extent already articulated for climate change and biodiversity loss;<sup>99</sup> and these could be extended to other issues. A more explicit inclusion of such ethical dimensions in the planetary boundaries framework could offer useful opportunities to re-orientate the perceived anthropocentric, Northern ontology of the planetary boundaries and cater for global differentiation.

Our analysis also shows that studies employ different approaches to downscaling, which in turn suggests that a common conceptual framework related to downscaling is still lacking.<sup>100</sup> Going forward, it might be useful to develop a common conceptual framework. This will require a major interdisciplinary collaboration as we are unlikely to fully refine the science of the Earth system to be able to downscale planetary boundaries through pure technical means. Incorporating the politics of downscaling into such a common conceptual framework, including many ethical considerations, should also be a priority.

### 3.4 | Democratizing planetary boundaries

The analysis above suggests that some commentators see the process of planetary boundary setting as lacking democratic legitimacy. In response to such concerns, Pickering and Persson argue that

<sup>87</sup>JA Dearing, 'Safe and Just Operating Spaces for Regional Social-Ecological Systems' (2014) 28 *Global Environmental Change* 227; GS Cooper and JA Dearing, 'Modelling Future Safe and Just Operating Spaces in Regional Social-Ecological Systems' (2019) 651 *Science of the Total Environment* 2105.

<sup>88</sup>MJ Cole, RM Bailey and MG New, 'Tracking Sustainable Development with a National Barometer for South Africa Using a Downscaled "Safe and Just Space" Framework' (2014) 111 *Proceedings of the National Academy of Sciences of the United States of America* 4399; H Dao, P Peduzzi and D Friot, 'National Environmental Limits and Footprints Based on the Planetary Boundaries Framework: The Case of Switzerland' (2018) 52 *Global Environmental Change* 49; H Kahiluoto et al, 'Local and Social Facets of Planetary Boundaries: Right to Nutrients' (2015) 10 *Environmental Research Letters* 104013; PL Lucas et al, 'Allocating Planetary Boundaries to Large Economies: Distributional Consequences of Alternative Perspectives on Distributive Fairness' (2019) 60 *Global Environmental Change* 102017.

<sup>89</sup>HY Teah et al, 'Assessment of Downscaling Planetary Boundaries to Semi-arid Ecosystems with a Local Perception: A Case Study in the Middle Reaches of Heihe River' (2016) 8 *Sustainability* 1233; S Stoll-Kleeman and T O'Riordan, 'The Challenges of the Anthropocene for Biosphere Reserves' (2017) 23 *Parks* 89; L Vargas, L Willemsen and L Hein, 'Linking Planetary Boundaries and Ecosystem Accounting, with an Illustration for the Colombian Orinoco River Basin' (2018) 18 *Regional Environmental Change* 1521; V Uusitalo et al, 'Environmental Sustainability Assessment from Planetary Boundaries Perspective: A Case Study of an Organic Sheep Farm in Finland' (2019) 687 *Science of the Total Environment* 168.

<sup>90</sup>H Hoornweg, 'An Urban Approach to Planetary Boundaries' (2016) 45 *Ambio* 567; B Norman, *Sustainable Pathways for our Cities and Regions: Planning within Planetary Boundaries* (Routledge 2019).

<sup>91</sup>G Whiteman, B Walker and P Perego, 'Planetary Boundaries: Ecological Foundations for Corporate Sustainability' (2013) 50 *Journal of Management Studies* 307; C Butz et al, 'Towards Defining an Environmental Investment Universe within Planetary Boundaries' (2018) 13 *Sustainability Science* 1031.

<sup>92</sup>S Cornell, 'On the System Properties of the Planetary Boundaries' (2012) 17 *Ecology and Society*.

<sup>93</sup>MW Ryberg, 'Development of a Life-Cycle Impact Assessment Methodology Linked to the Planetary Boundaries Framework' (2018) 88 *Ecological Indicators* 250.

<sup>94</sup>MW Ryberg et al, 'How to Bring Absolute Sustainability into Decision-making: An Industry Case Study Using a Planetary Boundary-based Methodology' (2018) 634 *Science of the Total Environment* 1406; N Bowles, S Alexander and M Hadjikakou, 'The Livestock Sector and Planetary Boundaries: A "Limits to Growth" Perspective with Dietary Implications' (2019) 160 *Ecological Economics* 128.

<sup>95</sup>AS Downing et al, 'Matching Scope, Purpose and Uses of Planetary Boundaries Science' (2019) 14 *Environmental Research Letters* 073005. See, e.g., K Fang, R Heijungs and GR de Snoo, 'Understanding the Complementary Linkages between Environmental Footprints and Planetary Boundaries in a Footprint-Boundary Environmental Sustainability Assessment Framework' (2015) 114 *Ecological Economics* 218.

<sup>96</sup>W Steffen and M Stafford Smith, 'Planetary Boundaries, Equity and Global Sustainability: Why Wealthy Countries Could Benefit from More Equity' (2013) 5 *Current Opinion in Environmental Sustainability* 403; T Häyhä et al, 'From Planetary Boundaries to National Fair Shares of the Global Safe Operating Space: How Can the Scales Be Bridged?' (2016) 40 *Global Environmental Change* 60; S Klinsky et al, 'Why Equity Is Fundamental in Climate Change Policy Research' (2017) 44 *Global Environmental Change* 170.

<sup>97</sup>M Nilsson and Å Persson, 'Can Earth System Interactions Be Governed? Governance Functions for Linking Climate Change Mitigation with Land Use, Freshwater and Biodiversity Protection' (2012) 75 *Ecological Economics* 61. See also M O'Brien et al, 'Living within the Safe Operating Space: A Vision for a Resource Efficient Europe' (2014) 2 *European Journal of Futures Research* 48.

<sup>98</sup>R Clift et al, 'The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-making in Companies with Global Supply Chains' (2017) 9 *Sustainability* 279.

<sup>99</sup>EA Page, 'Distributing the Burdens of Climate Change' (2008) 17 *Environmental Politics* 556.

<sup>100</sup>Teah et al (n 89).

planetary boundaries can be interpreted in ways that largely remain consistent with democratic decision-making.<sup>101</sup> Drawing on deliberative democracy research and the role of science in democratic societies more generally, they argue that we need 'an iterative, dialogical process to formulate planetary boundaries and negotiate planetary targets'.<sup>102</sup> In their view, the process of democratizing planetary boundaries could form the basis for a 'democratically legitimate division of labour among experts, citizens and policymakers in evaluating and responding to Earth-system risks'.<sup>103</sup> What would be crucial to such a division of labour is the need to open up space for 'deliberative contestation about the value judgments inherent in collective responses to Earth-system risks'.<sup>104</sup> If this could materialize, then the fact that experts are issuing warnings about what they consider to be unacceptable risks will not be a problem in and of itself. It would consequently be possible to allow the expert-driven assessments to continue alongside, and supported by, associated iterative and deliberative processes.

The democratic potential of planetary boundary setting is once again put to test through the ongoing work of the Earth Commission, which is 'a group of leading scientists convened by Future Earth' (a global network of sustainability scientists) to develop 'science-based targets for the Earth system'.<sup>105</sup> The Commission will build on 'analysis conducted by a series of international working groups of experts' and the process promises to involve multiple stakeholders including major corporations.<sup>106</sup> This sounds similar, at least in form and function, to a possible international panel of experts operating at the interface between science and policy on planetary boundaries that some scholars are calling for.<sup>107</sup> Will the Commission, as a group of some 20 scientists, manage to provide the democratic legitimacy to Earth system targets that planetary boundaries seemingly have failed to secure? While only time will tell, some commentators express concerns over the Earth Commission's perceived uncritical acceptance of, and reliance on, value-free global change science, and the possible marginalization of the global South in the debate.<sup>108</sup>

#### 4 | EARTH SYSTEM LAW AS A LEGAL RESPONSE?

Even though law is a central element of global environmental governance, when compared to Earth system science and governance,

it seems to feature less prominently in the planetary boundaries-focused social science debates we have explored above.<sup>109</sup> Our analysis further suggests that generally speaking, the implicitly related, twin-tracked law and governance debates remain somewhat distinct, with co-learning yet to be fully embedded. This is surprising because law, by its very nature as a regulatory tool specifically designed for social organization, offers an ideal opportunity to determine and set enforceable limits on human behaviour within the broader environmental governance effort.<sup>110</sup> This is especially true in the context of the Anthropocene, where humans have become dominant geological agents that must be restrained by setting limits that would keep us within a safe operating space.<sup>111</sup>

While we refrain here from speculating why law is underrepresented in the social science-related planetary boundaries discourse, and why law and governance debates mostly remain on their individual separate tracks,<sup>112</sup> we believe law will remain a key aspect of planetary boundaries governance. In fact, law should assume a more active role in this respect. To this end, we agree with Chapron and colleagues in their call for bolstering 'legal boundaries [that] translate the physical reality of a finite world into law and thereby delimit acceptable levels of human activity'.<sup>113</sup>

For this to materialize in a democratic manner, law and lawyers would need to start grappling more deliberately with the social science aspects of the Earth system, including the associated aspects of the planetary boundaries that we have outlined earlier in this article. Earth system governance offers a comprehensive framework for social scientists to contemplate the governance implications of the Earth system metaphor, and some legal scholars can and often do conduct research within the parameters of this framework.<sup>114</sup> However, there is still no unified, comprehensive and representative *juridical* framework that fully embraces Earth system governmentality in any meaningful way.<sup>115</sup> A deeper understanding of law's ability and potential contribution to respond to the regulatory challenges and implications flowing from Earth system thinking remains therefore absent; a concern that at once also renders it less likely to be

<sup>101</sup>Pickering and Persson (n 46).

<sup>102</sup>*ibid* 59.

<sup>103</sup>*ibid*.

<sup>104</sup>*ibid*.

<sup>105</sup>'The Earth Commission, Terms of Reference' (April 2019) <<https://futureearth.org/wp-content/uploads/2019/04/Earth-Commission-Terms-of-Reference-April-2019.pdf>>.

<sup>106</sup><<https://earthcommission.org>>.

<sup>107</sup>Fernández and Malwé (n 66).

<sup>108</sup>Biermann and Kim (n 11).

<sup>109</sup>For present purposes, we attribute a wide meaning to 'law' as including all those legal and law-like norms that have a bearing on regulating human behaviour *vis-à-vis* Earth system components and processes, including, but not limited to, hard and soft law norms, and State and non-State legal norms that operate at international, regional, national and local levels, including through transnational legal processes.

<sup>110</sup>HLA Hart, *The Concept of Law* (Oxford University Press 2012).

<sup>111</sup>Y Malhi, 'The Concept of the Anthropocene' (2017) 42 *Annual Review of Environment and Resources* 77.

<sup>112</sup>O Pedersen (ed), *Perspectives on Environmental Law Scholarship: Essays on Purpose, Shape and Direction* (Cambridge University Press 2018).

<sup>113</sup>Chapron et al (n 53) 1.

<sup>114</sup>See, e.g., Ebbesson (n 52).

<sup>115</sup>E Löwbrand, J Stripple and B Wiman, 'Earth System Governmentality: Reflections on Science in the Anthropocene' (2009) 19 *Global Environmental Change* 7.

able to tackle the regulatory implications of the planetary boundaries.<sup>116</sup>

#### 4.1 | The definition of Earth system law

It is the lack of such an innovative juridical imaginary that recently prompted us to propose the notion of Earth system law,<sup>117</sup> which we consider a new legal paradigm that can better respond to the Earth system's complex governance challenges and that is better fit for purpose in the Anthropocene. This new legal paradigm need not necessarily become a distinct new field of law, although it could over time. For now, Earth system law could usefully represent a framework for reimagining law in the context of the Anthropocene. Or, as Affolder argues with reference to emerging 'transnational climate law', Earth system law could become a visual field enabling lawyers to identify, understand and explore, with some measure of 'determined attentiveness', the implications of the Earth system metaphor for law.<sup>118</sup>

By way of summary, we consider Earth system law to be an essential part of Earth system governance, or 'organised human responses to earth system transformation, in particular the institutions and agents that cause global environmental change and the institutions, at all levels, that are created to steer human development in a way that secures a "safe" co-evolution with natural processes'.<sup>119</sup> Instead of taking Holocene stability for granted, Earth system law departs from long-term planetary dynamism and fully embraces, and seeks to respond to, the Earth system's key characteristics such as complexity, instability and unpredictability. Revolving on a systems perspective as it does, Earth system law is therefore fully anchored in the Anthropocene's planetary context.

In a prescriptive or normative sense, Earth system law must better respond to the type of planetary governance challenges that the dynamic and complex Earth system presents, and offer solutions aimed at increasing Earth system resilience and reducing vulnerabilities. In other words, Earth system law should provide a framework within which it would be possible to design better laws to better govern a complex Earth system.

Relatedly, in a transformative sense, Earth system law must, alongside all other governance interventions, contribute to enabling desirable futures for all Earth system components and processes, including human and more-than-human entities. It should therefore offer a paradigm for law to facilitate the type of transformation that is in step with a continuously transforming Earth system and that would be needed to service the socio-ecological crisis of the Anthropocene.

In a descriptive or analytical sense, Earth system law offers a framework to critique the current deficiencies of law in the Anthropocene and to reimagine law for the Anthropocene; to open up the hitherto 'closed' epistemologies of Earth system science for lawyers while at once illuminating the juridical aspects of Earth system governance for Earth system scientists; to reveal the regulatory implications of the Earth system metaphor for law; and to serve as a new crosscutting theme of scientific enquiry for scholars working in the area of sustainability.

Based on the foregoing, we define Earth system law as an innovative legal imaginary that is rooted in the Anthropocene's planetary context and its perceived socio-ecological crisis. Earth system law is aligned with, and responsive to, the Earth system's functional, spatial and temporal complexities; and the multiple Earth system science and social science-based governance challenges arising from a no-analogue state in which the Earth system currently operates. Earth system law therefore seeks to respond to the Earth system's instability and unpredictability through a continuous norm development process that drives meaningful transformations as well as interdisciplinary learning and deliberation. Fully embracing the need to guide the making of desirable planetary futures, Earth system law offers (i) an interdisciplinary analytical framework to better understand and respond to the juridical dimensions of Earth system governance; (ii) the normative foundation to govern the full spectrum of Earth system relationships in a way that promotes planetary integrity and justice in their fullest sense and; (iii) the legal means to facilitate transformative Earth system governance for socio-ecological sustainability.

#### 4.2 | Earth system law for planetary boundaries

With specific reference to the planetary boundaries (which itself also is an innovative imaginary to understand Earth system limits), Earth system law should accomplish at least four objectives which we outline below. They correspond with one or more of the social science characteristics and responses we have analysed above.

First, Earth system law must pursue ways to become more effective at keeping humanity from crossing planetary boundaries while better achieving the type of deep structural changes in and of society and its normative systems and related institutions that are necessary to navigate the Anthropocene. To this end, Earth system law should do what law does best, by institutionalizing the planetary boundaries through the creation and enforcement of non-negotiable, and above all ambitious, legally binding environmental limits.

Second, Earth system law must broaden its sources of authority, and the scope of its legitimacy and effectiveness to beyond the strict confines of the State; its existential justification cannot exclusively lie in the State in the same way that international environmental law, for example, does.<sup>120</sup> Such considerations reveal that Earth system law is

<sup>116</sup>Kotzé (n 32); A Cardesa-Salzmann and E Cocciolo, 'Global Governance, Sustainability and the Earth System: Critical Reflections on the Role of Global Law' (2019) 8 *Transnational Environmental Law* 437.

<sup>117</sup>Kotzé and Kim (n 13); Kotzé (n 13).

<sup>118</sup>N Affolder, 'Transnational Climate Law' in P Zumbansen (ed), *Oxford Handbook of Transnational Law* (Oxford University Press 2020) fc.

<sup>119</sup>F Biermann, "'Earth System Governance' as a Crosscutting Theme of Global Change Research' (2007) 17 *Global Environmental Change* 326, 328.

<sup>120</sup>LJ Kotzé, 'International Environmental Law and the Anthropocene's Energy Dilemma' (2019) 36 *Environmental and Planning Law Journal* 437.

also political, because it is fundamentally shaped by politics and used to realize those political goals that should (ideally) have been democratically set by majority consent through a fully representative and all-inclusive law-making process. Earth system law must be fully representative and inclusive of all State and non-State interests (and their justice-related concerns), including of those in the global North and the global South, of present and future generations, and of humans and more-than-humans.<sup>121</sup> To this end, Earth system law could meaningfully address the perceived democracy deficit in global environmental governance,<sup>122</sup> which is a concern that is highlighted by social scientists in the context of the planetary boundaries.<sup>123</sup>

Third, Earth system law must pursue an ecological form of justice and democracy.<sup>124</sup> A fully representative form of democratic Earth system law should pursue equal justice for all present and future humans in the global South and global North, and explore ways in which to accommodate non-anthropocentric ontologies and ethical care by prioritizing protection of the more-than-human world in addition to human interests. If Earth system law succeeds in doing so, it could significantly contribute to addressing the challenges of downscaling planetary boundaries and hence the broader planetary justice issue of access and allocation.<sup>125</sup>

Fourth, Earth system law must discard any trite assumptions of Holocene stability, and instead embrace complexity, instability and unpredictability, while allowing for forward-looking measures that also foresee harm instead of only addressing it in an *ex post facto* way. Earth system law should itself be a fully functioning complex adaptive system that adaptively manages other complexly adaptive natural and social systems.<sup>126</sup> It must respect planetary scale tipping points and pay due consideration to the dynamic interconnections of Earth system components while embracing the complexity of interacting planetary boundaries and safeguarding the integrity of Earth's life-support systems. This objective speaks to the social science themes characterizing the planetary boundaries as being interdependent and interacting phenomena, and as being planetary in scale,

which would require, in turn, better measures for the coordination of the planetary boundaries.

## 5 | CONCLUSION

The planetary boundaries framework has been captivating the minds of those interested in the Earth system science-law-governance nexus. The framework manages to capture 'multiple global environmental stresses within one integrated framework'; which, in turn, foregrounds the 'urgency of political action through its emphasis on the risks associated with transgressing critical Earth system [limits]'.<sup>127</sup> For the purpose of Earth system governance, it offers a crucial specification of environmental target indicators to support decision-making,<sup>128</sup> while pointing to the critical importance of a systems approach to global sustainability.<sup>129</sup> In light of its continued impact, we offered here a systematic qualitative review of the social science-oriented literature sitting at the intersection of Earth system science, law and governance in relation to the planetary boundaries framework. The aim was to broadly identify and discuss thematic characteristics and their associated framings of planetary boundaries, and explore possible corresponding responses that flow from these key framings.

Our literature survey revealed that the planetary boundaries framework has now infiltrated the social science domain, and it has become an important object of scientific enquiry to guide critical assessments of the role of law and governance in preventing the boundaries being crossed. At the crux of this endeavour lies the challenging imperative for social scientists to navigate through the complexity of planetary boundaries. To build a system of effective planetary boundaries governance, and to craft a viable role for law and governance in that endeavour, more research is needed on the institutionalization, coordination, operationalization and democratization of planetary boundaries. We also need to continue experimenting with various innovative solutions for transforming our societies and economies, and expand and further improve those solutions that seem to work.<sup>130</sup> We suggest that for law at least, this could be done in terms of the nascent Earth system law framework.

Reflecting back on our analysis, we observe that there is some agreement that the planetary boundaries framework has proven useful and influential in driving academic debate and, at the very least, in initiating policy change discussions that could benefit Earth system governance for planetary integrity and justice. Looking ahead, however, the framework needs to be constantly updated and utilized to remain relevant. As its architects

<sup>121</sup>F Biermann and A Kalfagianni, 'Planetary Justice: A Research Framework' (2020) *Earth System Governance*; P Kashwan et al, 'Planetary Justice: Prioritizing the Poor in Earth System Governance' (2020) *Earth System Governance*.

<sup>122</sup>K Bäckstrand, 'Democratizing Global Environmental Governance? Stakeholder Democracy after the World Summit on Sustainable Development' (2006) 12 *European Journal of International Relations* 467; CA Sénit, F Biermann and A Kalfagianni, 'The Representativeness of Global Deliberation: A Critical Assessment of Civil Society Consultations for Sustainable Development' (2017) 8 *Global Policy* 62.

<sup>123</sup>Biermann and Kim (n 11).

<sup>124</sup>K Bosselmann, 'Ecological Justice and Law' in BJ Richardson and S Wood (eds), *Environmental Law for Sustainability: A Reader* (Hart 2006) 129; R Eckersley, 'Ecological Democracy and the Rise and Decline of Liberal Democracy: Looking Back, Looking Forward' (2020) 29 *Environmental Politics* 214. See also G Garver, 'The Rule of Ecological Law: The Legal Complement to Degrowth Economics' (2013) 5 *Sustainability* 316; G Garver, 'Moving from Environmental Law to Ecological Law: Frameworks, Priorities and Strategies' in L Westra et al (eds), *Ecological Integrity, Law and Governance* (Routledge 2018) 141.

<sup>125</sup>J Gupta and Louis Lebel, 'Access and Allocation in Earth System Governance: Lessons Learnt in the Context of the Sustainable Development Goals' (2020) 20 *International Environmental Agreements: Politics, Law and Economics* 393.

<sup>126</sup>JB Ruhl, 'Panarchy and the Law' (2012) 17 *Ecology and Society*; RE Kim and B Mackey, 'International Environmental Law as a Complex Adaptive System' (2014) 14 *International Environmental Agreements: Politics, Law and Economics* 5.

<sup>127</sup>Galaz et al (n 37) 1.

<sup>128</sup>Biermann (n 22) 5.

<sup>129</sup>Kim and Bosselmann (n 63).

<sup>130</sup>M Leach et al, 'Transforming Innovation for Sustainability' (2012) 17 *Ecology and Society*; K Jacob et al, 'Governance for the Sustainable Economy: Institutional Innovation from the Bottom Up?' (2019) 28 *GAIA* 204.

envisioned, it should be considered as a living framework to which scientists and policymakers add new boundaries or adjust existing boundaries.<sup>131</sup> While Earth system scientists have been leading the discussion,<sup>132</sup> social scientists should continue and increase their engagement with the debate to reveal the regulatory implications of the planetary boundaries framework more clearly for law and governance, and to make the framework more effective and legitimate. After all, the Earth system science-derived planetary boundaries framework describes the problem, but it offers little as far as solutions are concerned. These solutions lie at the heart of the 'social world' of law and governance that interdisciplinary efforts can helpfully identify, interrogate and apply. Again, we see considerable potential for Earth system law to facilitate such an engagement.

At the same time, however, it is important to be mindful of the fundamental assumption underlying the planetary boundaries approach to Earth system governance, that the Earth system has not (yet) passed critical tipping points. By symbolically acting as a safety net that is erected on the edge of a cliff, the planetary boundaries might lose much of their relevance and usefulness once we fall off the cliff, as it were. Considering the increasing probability of future tipping events occurring sooner than later,<sup>133</sup> more scholarly attention could be directed towards exploring novel law and governance solutions, represented in this instance by Earth system law, for navigating, and ultimately surviving, the unknown and 'unsafe' space that lies far outside the planetary boundaries' upper limits. Whether social science theorizing should seek to prevent us arriving there, or should begin to sketch out what it might look like when we do, is a meta-conversation and question that unfortunately we have little time to ask.

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The authors thank Duncan French, Frank Biermann and the anonymous reviewers for their helpful comments on an earlier version of this article.

## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

**How to cite this article:** Kim RE, Kotzé LJ. Planetary boundaries at the intersection of Earth system law, science and governance: A state-of-the-art review. *RECIEL*. 2021;30:3–15. <https://doi.org/10.1111/reel.12383>

<sup>131</sup>P Villarrubia-Gómez, SE Cornell and J Fabres, 'Marine Plastic Pollution as a Planetary Boundary Threat: The Drifting Piece in the Sustainability Puzzle' (2018) 96 *Marine Policy* 213.

<sup>132</sup>KL Nash et al, 'Planetary Boundaries for a Blue Planet' (2017) 1 *Nature Ecology & Evolution* 1625.

<sup>133</sup>T O'Riordan and TM Lenton, 'Into a Precarious Future' in T O'Riordan and TM Lenton (eds), *Addressing Tipping Points for a Precarious Future* (Oxford University Press 2013) 301; Y Cai, TM Lenton and TS Lontzek, 'Risk of Multiple Interacting Tipping Points Should Encourage Rapid CO<sub>2</sub> Emission Reduction' (2016) 6 *Nature Climate Change* 520.