New directions in earth system governance research

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ABSTRACT

The Earth System Governance project is a global research alliance that explores novel, effective governance mechanisms to cope with the current transitions in the biogeochemical systems of the planet. A decade after its inception, this article offers an overview of the project's new research framework (which is built upon a review of existing earth system governance research), the goal of which is to continue to

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stimulate a pluralistic, vibrant and relevant research community. This framework is composed of contextual conditions (transformations, inequality, Anthropocene and diversity), which capture what is being observed empirically, and five sets of research lenses (architecture and agency, democracy and power, justice and allocation, anticipation and imagination, and adaptiveness and reflexivity). Ultimately the goal is to guide and inspire the systematic study of how societies prepare for accelerated climate change and wider earth system change, as well as policy responses.

1. Introduction

The Earth System Governance Project was launched in 2009 and has become the largest social science network in the area of governance and global environmental change. As presented in its ten-year Science and Implementation Plan (Biermann et al., 2009a), this global research alliance explores political solutions and novel, more effective governance mechanisms to cope with the current transitions in the biogeochemical systems of the planet. The Science and Implementation Plan proposed to coordinate research using a framework of five analytical problems: Accountability, Adaptiveness, Agency, Allocation and access, and Architecture ('the five As'), with crosscutting themes of knowledge, norms, power and scale.

A decade after its inception, a new Science and Implementation plan was prepared and released to the community in November 2018. This plan explores the innovations, opportunities and complexities emerging in earth system governance with the goal of stimulating a diverse, vibrant and relevant research community in this field. While the plan offers an extensive exploration of the methodological pluralism that has come to characterize this community, and specific guidance on implementation of the network, this article focuses squarely on the plan's research framework. We build on past work, but a particular need has also been identified to more prominently incorporate concepts like democracy, power, anticipation and imagination in the analytical framework. Ultimately, we hope to spark the development of new research questions that will guide scholarship in the decade to come, rather than prescribing them.

The aim of this plan is to learn from past achievements and simultaneously take the next step in our efforts to understand emerging and existing problems and solutions related to global environmental change. This plan also aims to expand the global mobilization of researchers, stimulate and facilitate research collaboration, and effectively communicate and engage with society.

This article first presents the evolving context of governance challenges, followed by three sections that develop a research framework out of which exciting new questions and methodologies can emerge. It concludes by considering this framework in the context of the pluralistic forms of knowledge that can come to bear on earth system governance research, and the evolving role of researchers in relation to society. Ultimately the aim of this paper is to foster creative collaboration, innovative thinking, and solutions-oriented research to tackle the complex landscape of global socio-environmental challenges.

2. An evolving constellation of governance challenges

The world has changed tremendously over the last decade. While successes have been secured in promoting human development and reversing some environmentally unsustainable trends (Pinker, 2018), new problems have emerged, longstanding problems remain inadequately addressed and many diverse problems are becoming ever more tightly intertwined. Since the first science and implementation plan for earth system governance research was launched a decade ago (Biermann et al., 2009a), global shifts in interconnected social, political, economic, technological and environmental systems have reshaped the empirical context for earth system governance research in profound ways. For this reason, this plan presents a research framework fit for the coming decade.

The scale and rate of change in both natural and human systems is also accelerating. Some global indicators have improved in recent years — for example, the growth of the growth of carbon dioxide emissions from the combustion of fossil fuels seems to have slowed down seems to have slowed down (Global Carbon Project, 2017), the number of oil spills has dropped (ITOPF, 2018) and the spatial extent of marine and terrestrial protected areas has increased globally (United Nations Environment Programme, 2016a). Even so, many others demonstrate rapid change and cause for concern, like atmospheric carbon dioxide concentration (NOAA, 2017), biodiversity loss (IUCN, 2017) and global fish stock depletion (FAO, 2016), and global plastic waste (Geyer et al., 2017). Compared with 1990, natural disasters are more frequent and have higher costs (Guha-Sapir, 2017), as well as non-economic losses. While there has been relative decoupling of carbon dioxide emissions from economic growth at the global level (World Bank, 2018), the fact that the global economy has grown faster means that there has not yet been an absolute decoupling.

Global trends, however, mask local problems and uneven distribution of environmental pressures and impacts, including food insecurity, water stress and vulnerability to natural hazards. Air pollution is having dire human health and environmental effects, not least in growing urban areas in the developing world (Watts et al., 2015).

Over the past decade, the governance response to growing problem awareness at the global level has frequently been to increase the level of ambition of targets, as seen for example with the 2010 Aichi targets on biodiversity, the 2015 Paris climate target to limit global warming to 2 °C (and preferably 1.5 °C) degrees and the 2015 UN Sustainable Development Goals. Concrete mechanisms to achieve these kinds of targets, however, have generally become less specified and more uncertain, leading to studies of 'governance through goals' (Kanie and Biermann, 2017). There appears to have been a general shift away from 'hard law' frameworks towards voluntary, 'pledge-and-review' approaches. While this shift could be seen as a symptom of a general decline in multilateralism, the new approaches can also be seen as 'all-hands-on-deck' and crowd-sourced models where both state and non-state actors contribute and can be held to account by their respective constituencies (Chan et al., 2015).

In either case, in the coming decade the onus is on states and sub-national actors, as national plans and domestic action to achieve the targets need to be implemented. It remains to be seen to what extent such a large-scale and society-wide implementation effort will lead to the development of new governance approaches, and to what extent it will rely on traditional policy tools policy tools such a mix of taxation, regulation, and public and private investment. It also remains to be seen how domestic implementation will be characterized by multi-level governance, and how power and

authority will be configured among national, sub-national and non-state actors.

This is particularly important in view of changing social and political dynamics. Income inequality is falling globally but increasing in many parts of the world, both developed and developing (ISSC, 2016; Picketty, 2014). The level of human development is higher globally than ever before, largely due to poverty reduction strategies in China, India and elsewhere (UNDP, 2016). Many of the world's cities and regions now stand on the brink of making major infrastructure investments (NCE, 2016) and, taking up this challenge, some of them increasingly assert themselves as key agents of change for low-carbon transitions. The next couple of decades is likely to see a tremendous wave of global infrastructure investment, both within and beyond cities, which will have profound impacts on the biosphere (Elmqvist et al., 2013), with critical implications for addressing climate change and the UN Sustainable Development Goals. Migration and mobility, shifting geopolitics and trade patterns, rapid and sometimes disruptive technological change, and 'globally networked risks' (Galaz et al., 2017) also signify the changing circumstances within which earth system governance is embedded.

The empirical context for earth system governance is thus rapidly changing and becoming more complex and dynamic than a decade ago. Considering interconnections and global variation in impacts and progress, there is no simple list of empirical areas and problems that should guide the next generation of earth system governance research. Future research should focus on emerging problems, as well as longstanding, intractable ones. Multiple levels of earth system governance and interactions between environmental and societal problems will require examination and critical engagement. To respond to this shifting landscape, the community of earth system governance scholars has convened to generate an innovative and flexible analytical framework that aims to acts as a source of mobilization, coordination and stability in the joint research effort.

3. A new earth system governance research framework

This plan sets out a revised and updated research framework, which recognizes that multiple world views coexist and that drivers and directions of change are often messy and dynamic. To account for this complexity, this framework is composed of contextual conditions, which capture what is being observed empirically, and research lenses, which offer analytical power by engaging with these conditions that fundamentally shape earth system governance scholarship (see Fig. 1).

The four contextual conditions that comprise the first part of the framework are: transformations, inequality, Anthropocene and diversity. Against the backdrop of complex and dynamic trends across the world, these represent meta-level conditions that define the research context we observe at the outset of the second decade of earth system governance research. These four conditions encompass and distil broader patterns of change. A common denominator is that all four are subject to extensive empirical research and to scientific and societal debate. Note that not all future earth system governance research is expected to actively and explicitly relate to one or several of these four conditions, and they are not intended to be exclusive entry points. Instead, they are intended to help provide a common language for the research context in which the Earth System Governance Project operates and to stimulate interesting and relevant research questions, when brought together with the second part of the framework.

The second core part of the framework is the five sets of research lenses: architecture and agency, democracy and power, justice and

allocation, anticipation and imagination, and adaptiveness and reflexivity. These lenses together provide a multifaceted view of earth system governance. Individually, they relate to established or emerging research fields, with roots in various social scientific disciplines. The lenses were intentionally coupled to enrich analysis of earth system governance, by highlighting not only similarities but also productive tensions between the two paired concepts. Individual lenses can be paired in myriad ways and new pairings can lead to new research questions. These pairs of research lenses have been identified as the most pertinent and productive when starting this new phase of earth system governance research, as well as representing distinct clusters of earth system governance research activity. However, researchers are encouraged to use the framework to consider alternative pairings, in an effort to generate novel and relevant research questions.

4. Contextual conditions

This section discusses one part of the framework: the context within which earth system governance research takes place. We expect that our analytical concerns, our normative commitments, our critical interrogations of our specific research topics will necessarily engage with this context. We identify four key conditions that characterize this context: (a) the numerous political, technological and socio-economic *transformations* that are shaping and being shaped by governance processes; (b) the increasing and multifaceted *inequalities* across and within countries and socio-economic groups; (c) the tremendous and contested impact of human beings on the entire planet and the changing human-nature relationship captured by the notion of the *Anthropocene*; and (d) the opportunities and challenges offered by the *diversity* and pluralism of human societies in knowledge, culture and identities that have a bearing on how sustainability challenges are addressed in the contemporary world. These do not represent the universe of relevant contextual conditions but rather emerging and powerful trends that are particularly relevant in this field. Below we conceptualize these four conditions and draw the links between each of them and earth system governance research.

4.1. Transformations

Social science enquiry has long been concerned with understanding many different forms of change in human society. Yet, the deepening urgency of major global sustainability and human development challenges is now catapulting a focus on transformative change to the forefront of earth system governance scholarship. Transformations are both processes as well as conditions for earth system governance research: here we consider their role as conditions in order to highlight the deeply dynamic and uncertain contemporary contexts that governance research must grapple with, descriptively, analytically and normatively.

We define transformations as shifts that involve fundamental changes in structural, functional, relational and cognitive dimensions of linked socio-technical-ecological systems (de Haan and Rotmans, 2011; Feola, 2014; Hackmann and Clair, 2012; O'Brien, 2012). This includes both pervasive global changes in human societies (e.g. urbanization, climate change, economic globalization, digitization), but also efforts to (re)imagine and intentionally pursue desirable (sustainable) futures in a wide range of ways. The study of transformations can be approached in several ways: analytically (e.g. what actually happens, and how and why), normatively (e.g. as a good/desirable thing to do) or critically (e.g. who is deciding, shaping, and benefiting from certain transformations and why). Crucially, transformations imply changes in
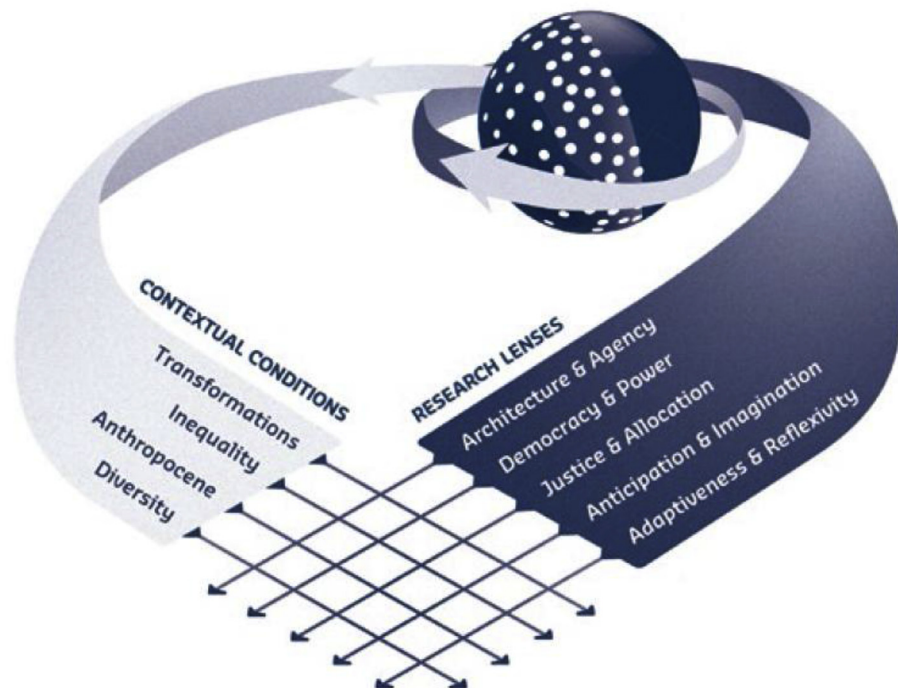
Fig. 1. Earth System Governance research framework, including intersecting contextual conditions and research lenses.

power relations (e.g. challenging, disrupting or entrenching), and thus are deeply contested, political phenomena.

Overall the role of governance in sustainability transformations remains underdeveloped and often ambiguous. Different angles may include:

- Governance for transformations (i.e. governance that creates the conditions for transformation in socio-technical-ecological systems to emerge),
- Governance of transformations (i.e. governance to actively trigger and steer a transformation process), or
- Transformations in governance (i.e. transformative change in governance regimes).

All three angles are important, but have different implications for understanding governance in relation to sustainability transformations.

The last decade of earth system governance research exploring forms, effects and complexity of governance lays an outstanding foundation for novel efforts to understand transformations in governance systems and human societies looking forward over the next decade. Moreover, earth system governance scholars take as a departure point that sustainability problems are deeply political, and sustainability transformations must also be seen this way (Meadowcroft, 2011; Scoones et al., 2015; Smith and Stirling, 2010). Transformations will be increasingly salient in many areas of earth system governance, including global governance systems (e.g. Biermann et al., 2012), responding to the Anthropocene (Dryzek, 2016; Galaz, 2014), and shaping the unfolding wave of global urbanization in sustainable directions. Furthermore, earth system governance scholars are ideally placed to draw on insights from other bodies of social science theory such as analyses policy, institutional, economic and societal change to effectively leverage and build on existing knowledge about transformations in the social sciences.

Interestingly, a dichotomy is increasingly drawn in the literature between 'incremental' and 'transformative' change (e.g. Kates et al., 2012), which can be useful as a simple heuristic, but is likely to belie a more complex reality. For example, Duit et al. (2010: p. 367) argue that "at the end of the day, governance solutions for many of those problems rooted in complex systems dynamics will, as always, consist in incrementally implemented, heterogenic, and piecemeal mixes of policy instruments, institutions, networks and organizations." Earth system governance scholars need to understand how both incremental and more radical change interrelate.

The deeply political nature of transformations, furthermore, poses challenges for governance such as dealing with redistributional impacts, powerful vested interests, the short-termism of policy and political cycles that discourages longer-term agendas, institutional fragmentation and deficits in representation. It also links closely to the other key contextual conditions of inequality, the Anthropocene and diversity. It raises questions about sources of agency, the role of the state, emergence and embedding of new norms, and tensions between singular or plural transformation goals. Yet, earth system governance also needs to consider contexts that are under-studied to date, such as authoritarian regimes and politically unstable settings (including those experiencing civil conflict). current theories may be vastly underprepared to explain such settings.

Lastly, tensions are evident in the ways scholars talk about the potential for shaping transformations, versus the open-ended, emergent, and to a large degree unpredictable nature of actual transformations in practice. This is reflected through the UN Sustainable Development Goals, which may be useful as a high-level driver, but at the same time should not create a 'cockpit' view where it is assumed that "top-down steering by governments and intergovernmental organizations alone can address global problems" (Hajer et al., 2015: p. 1652). Ultimately, it is vital to understand the interplay between top-down and bottom-up efforts for sustainability transformations (e.g. Westley et al., 2011).

4.2. Inequality

Inequality is becoming a central academic and political discourse after decades of neglect (Klinsky et al., 2017; Milanovic, 2011; Oxfam, 2016; Picketty, 2014; United Nations Development Programme (UNDP), 2013; WSSR, 2016). Inequality pervades almost all spheres of social life, from income distribution to gender, education, to the burdens of environmental harm or unequal access to opportunity or resources across different countries and socio-economic groups (Ragin and Fiss, 2017). Thus, inequality is multi-faceted as well as intersectional, i.e. one form of inequality may influence and reinforce another (Ragin and Fiss, 2017). Against this context, scholars face the challenge to develop research that sharpens our understanding of inequality as a theoretical concept and its concrete implications for earth system governance, while also acknowledging that the research community itself may be hampered by inequality.

Inequality in earth system governance is often the outcome of unjust procedural and distributive justice systems (Deutz, 2014; Ikeme, 2003). International, global and national justice systems have increased inequalities (Klinke, 2014; Spagnuolo, 2011) and disempowerment (Gupta et al., 2015). Inequality is the seed, driver and consequence of unjust social and ecological systems (Wilkinson and Pickett, 2009, 2011). Poor governance in resource allocation and distribution systems leads to unfair distribution of environmental rights, duties, risks, hazards and harms. Earth system governance research is challenged to discover how inequality is embedded in the complex interactions of governance (actors, sectors, interests, forums, scales, technologies, etc.); within unpredictable natural systems; and in the context of competing economic (Ehresman and Okereke, 2015) and political pressures to allocate limited resources. Environmental inequality is also embedded in the diffuse and often contradictory processes, forces, outcomes of global and national politics (Hyle, 2016), finance, taxation and subsidies, and broader development trajectories (Gupta and Vegelin, 2016).

Earth system governance architectures (Biermann et al., 2009b) − a research lens that we explore in more detail below - have the potential to challenge inequalities if adequately inclusive in their construction (Andersson and Agrawal, 2011). If not, these architectures risk locking in existing inequalities. Democratic governance systems that seek to distribute power among different actor groups in ways that curtail the power of any single individual or interest group can potentially reduce inequalities among individuals and groups. But democratic institutions may also be permeated with and entrench power inequalities among the various interest groups.

Although the body of research on inequality and sustainability governance is growing, more studies are necessary to understand how structural inequalities, power imbalances and intersecting axes of privilege and marginalization shape vulnerabilities to global environmental change, and in turn are shaped by them. Likewise, attention to the relationship between the intersecting forms of discrimination on the basis of age, class, race, caste, ethnicity, indigeneity, religion, (dis)ability and earth system governance needs to be strengthened (Olsson et al., 2014).

4.3. Anthropocene

The Anthropocene refers to the idea that the earth has entered a new geological epoch characterized by humanity's collective transformation of the earth system (Steffen et al., 2007). Proponents of the Anthropocene concept point to rapid changes in the world's population, patterns of material production and consumption, and consequential environmental degradation, particularly since the 'Great Acceleration' that began around 1945 with the end of World War II (Steffen et al., 2015a). These changes, proponents argue, have moved the earth system beyond the parameters of the Holocene epoch, which began around 11,700 years ago when the last ice age ended. Whether or not it achieves official geological recognition, the Anthropocene has already come to serve as a fruitful but contested contextual condition for understanding ongoing changes in the earth system.

The distinctive character of the Anthropocene gives rise to the possibility that previous modes of governing environmental change may no longer be fit for purpose (Galaz, 2014). Importantly, the Anthropocene idea reinforces the need to think not only about environmental governance in general, but specifically about earth system governance (Biermann, 2014). Pattberg and Zelli (2016) argue that the Anthropocene involves three major challenges for earth system governance: urgency, responsibility and complexity. These three challenges are not new to environmental governance but become particularly pressing when combined under the conditions of the Anthropocene.

The transformations embodied by the Anthropocene raise important dilemmas about how to safeguard other values such as justice and democracy when urgent action is required, and how to build and maintain political support for radical technological and economic change. A related dilemma is to ascertain whether it is possible to overhaul institutions completely within the time available. One critique is that "[t]he fundamental challenges to societal organization posed by the Anthropocene are, paradoxically, to be countered by many of the same institutions that have allowed the recent human conquest of the natural world" (Lövbrand et al., 2015, p. 214), such as unregulated capitalist markets or governments that prioritize economic growth over environmental imperatives (see also Dryzek, 2016). The urgency of responding to the planetary instability associated with the Anthropocene also raises questions about what kinds of governance responses should be prioritized: should societies aim to restore the earth system to the more stable conditions that prevailed in the Holocene epoch (see Rockström et al., 2009)? Or, given that many changes are now irreversible, is the task for governance to find new benchmarks and focus on how societies can adapt to the inevitability of an altered earth system (Dryzek and Pickering, 2017)

Assigning *responsibility* for reducing risks to the earth system, and for remedying environmental loss and damage, becomes ever more difficult because unsustainable patterns of consumption are driven by a wide range of actors across many countries, including producers, consumers, investors and governments. Thus it is necessary to rethink, possibly through constructing new theories of justice, how subjects and objects of ethical responsibilities are redefined in the Anthropocene (Meisch, 2016; Schmidt et al., 2016) and to develop new forms of legal and policy instruments for attributing responsibilities for action (Kim and Bosselmann, 2015; Young et al., 2017; Stephens, 2017).

Complexity reaches beyond questions of responsibility to include the multifarious interactions between society and non-human nature, and the possibility of non-linear changes (or state shifts) in the earth system (Underdal, 2010; Young, 2017). Wissenburg (2016) stresses that the Anthropocene brings together several different types of complexity, including the natural complexity of the planet's ecology, the psycho-social complexity of humans and their institutions, and the political or moral complexity of bringing both together in a meaningful way. This multi-faceted view of the earth system as a complex, interconnected system places considerable importance on understanding and governing key processes that regulate the system, including the climate, biodiversity, land use and global chemical flows.

Finally, complexity highlights the importance of science-policy interactions in governing the Anthropocene. Scientific expertise is crucial for understanding earth system processes and anticipating potential state shifts. The idea of planetary boundaries (Rockström et al., 2009) has been widely discussed both as a way of understanding how these processes interact to characterize the Anthropocene, as well as a guide for policymakers on what is needed to avoid dangerous thresholds in the earth system. However, some critics raise the concern that the Anthropocene could imply delegating too much power to experts and other elites at the expense of democratic processes (Leach et al., 2013; Baskin, 2015). Thus Lövbrand et al. (2015, p. 214), building on the work of Swyngedouw (2013), warn of the dangers of a post-political ontology − a "socio-political arrangement that replaces ideological contestation and struggles by techno-managerial planning" − which may obscure the possibility of political transformation of societies.

4.4. Diversity

As a contextual condition, diversity influences governance research and practice. We consider governance to refer to modern forms of steering (as per Biermann et al., 2009a), thus it is important to consider that the different directions in which societies can be steered result not only from power struggles but also from diversity in worldviews, knowledge systems, values and norms, and ecosystems. Moreover, as earth system governance researchers live and work in different contexts and come from different disciplinary backgrounds, such facts influence how we produce, validate and diffuse knowledge, as well as the way we teach and educate youths and are involved in governance capacity building.

Below, we explore diversity as an ontological standpoint and empirical condition for governance of earth systems, emphasizing that diversity is a norm that calls for participation of different actors in governance processes, but also and most importantly that diversity in norms, worldviews and knowledge systems affects governance.

Earth system governance research should give prominence to the drivers and nature of diverse and (often) conflicting norms. Norms are accepted standards, principles of behaviour or claims as to how things ought to be. Norms may be constitutive (creating standards or principles), regulatory (establishing laws and regulating behaviour), prescriptive (directing acceptable types of action) or visionary (prescribing a desired state of affairs). Norms are dynamic and have life cycles − from emergence to demise or rebirth (Finnemore and Sikkink, 2005). Norm life cycles are influenced by other norms, actor interests, and contexts. The underlying sources, dynamics, tensions and consequences of normative diversity and the contestation of norms contribute to the formation, longevity and demise of governance architectures and environmental policies.

Normative diversity relates to desired or contested governance outcomes. Diversity also connects to desired methodologies of governance that influence outcomes: the inclusion of actors, voices and knowledge systems that are traditionally excluded, consensus, deliberation (Dryzek and Pickering, 2017), coproduction, top down and bottom up, scenario building, imagining futures, decentralization (Dennis et al., 2016), inclusive conservation (Matulis and Moyer, 2017), community management (Van Putten et al., 2016), and science in governance (Nilsson, 2017; Montana, 2017; Matulis and Moyer, 2017). As such, we need to identify, understand and theorize normative diversity and how it interacts with governance practice and research in different ecological contexts. It is important to consider how societies and ecosystems are intertwined, and that diverse socio-ecological systems require specific responses.

Ultimately, diversity means that multiple knowledge systems exist. The earth system governance community provides a forum for exchange among different forms of knowledge from different (and not mutually exclusive nor homogenous) groups or sectors that can contribute to earth system research. These include, but are not limited to, the scientific community, policymakers, civil society, think tanks, businesses, indigenous peoples and the global poor. Tengö et al. (2014, p. 589) argue that it is necessary to promote dialogue among different knowledge systems for improved policy and to support mechanisms for learning and decision-making. The challenge here is to balance the breadth and depth of the various forms of knowledge held by various groups or sectors with a desire to present timely answers to pressing environmental problems. While including all viewpoints, all voices and all interests may provide for high levels of equality, it is unlikely to result in an efficient process of decision-making or knowledge creation. Yet, excluding viewpoints, voices and interests from dialogues will result in power imbalances. Earth system governance research is challenged to seek forms of knowledge creation and governance solutions that are as inclusive as possible within the functional boundaries of their research projects.

While diversity in norms and knowledge systems can be an asset, it can also hamper just and ecologically sound governance. Rather than relying on the dominant or most abundant knowledge, policymakers, civil society and the business sector may select different understandings of phenomena to support their views and interests. Diversity in knowledge allows policymakers and the business sector to use the knowledge that best suits their interests in making decisions. Different understandings in the science community of, for instance, the risks of climate change have long fuelled climate skepticism as well as hampered policy action (Hoffmann, 2015). But even a similar piece of knowledge may transfer or be used differently merely because of diversity in the subject and medium of communication. A scholar's gender, nationality, institutional affiliation and so on, may give them more or less credibility in the eyes of receivers. Likewise, diversity in communication channels − a peer-reviewed journal article, a blog post, a video clip, a one-on-one discussion, etc. − may affect how knowledge is received and used (Lauring, 2009).

Diversity in knowledge systems means that governance as a set of rules and practices, or institutions, is a result of a process or processes that reflect diverse values and worldviews. The challenge is how to create and maintain decision-making processes that are at the same time inclusive and efficient. We need to better analyse, theorize and criticize how diversity affects earth system governance practice.

5. Research lenses

In this section, we elaborate upon the five sets of interconnected research lenses that constitute the central element of the Earth System Governance Project's research framework. This section builds on the elaboration in the previous section of the contextual conditions that constitute part of the research framework. This section discusses each coupled research lens by first introducing each one, then elaborates upon the current understanding and knowledge. We then explore longstanding and emerging interlinkages and productive tensions between each set of coupled concepts, highlighting how each coupled research lens engages with and can be considered in light of our four contextual conditions. We conclude by identifying some timely research questions in each case.

5.1. Architecture and agency

This research lens focuses on understanding the institutional frameworks and actors implicated in earth system governance and how these institutions and actors resist or respond to change and evolve over time. It combines two previously separate elements of the original Earth System Governance Project research framework: Architecture and Agency. Over the last decade, researchers studying governance have increasingly highlighted the interaction between architecture and agency within governance systems. Combining these topics as a coupled research lens offers new opportunities for understanding dynamics and change in governance systems and the actors herein, as a key ambition of the new Earth System Governance Science and Implementation Plan.

5.1.1. Architecture

We define governance architecture as "the interlocking web of widely shared principles, institutions and practices that shape decisions at all levels in a given area of earth system governance" (Biermann et al., 2009a, p. 31). This has been an important focus of earth system governance research over the last decade. Three themes that have been particularly prominent are: fragmentation, complexity and polycentricity.

Fragmentation research has studied patterns of integration and decentralization in global environmental governance (Biermann et al., 2009b; Biermann, 2014; Keohane and Victor, 2011; Zelli and van Asselt, 2013; Zürn and Faude, 2013). It has considered the growing prominence of 'private' governance (e.g. CST, self-regulation, certification) (Auld et al., 2015; van der Ven, 2015), the role of partnerships between state and non-state actors (Kramarz, 2016; Pattberg, 2010; Pattberg and Widerberg, 2016; Szulecki et al., 2011), and implications for the legitimacy of global governance systems (Bäckstrand and Kylsäter, 2014; Karlsson-Vinkhuyzen and McGee, 2013). More recently, scholars have turned to considering how to respond to fragmentation, including ways of managing fragmented governance systems (van Asselt and Zelli, 2014), particularly through attention to interactions between different regimes within and beyond the environmental domain (Jinnah, 2014; Jinnah and Lindsay, 2016; van Asselt, 2014).

Complexity is also an important lens for analysing governance systems, from local to global scales (Duit et al., 2010; Duit and Galaz, 2008; Oberthür and Stokke, 2011; Underdal, 2010; Zelli and Pattberg, 2016). Complexity has long been a defining feature of environmental governance, and it is now becoming an explicit topic of analytical study in earth system governance research, especially in light of increasing interest in regime complexes (Abbott, 2012; Keohane and Victor, 2011; Orsini et al., 2013) and network analysis (Kim, 2013). Complexity in governance architectures is likely to continue to be a key theoretical topic in earth system governance research, particularly with continued attention to institutional interplay between environmental and non-environmental domains (e.g. global trade, security, technology; Jinnah, 2014; van Asselt, 2014) and increasing attention to systemic global risks resulting from these cross-sectoral, cross-scale interdependencies (Galaz, 2014; Galaz et al., 2017, 2016, 2014; van Asselt, 2014; van Asselt and Zelli, 2014).

Polycentricity is a topic that is rapidly gaining prominence in scholarly debates about environmental governance. Originally proposed in the 1960s and 1970s (Aligica and Tarko, 2012), research on polycentricity has recently been experiencing resurgent interest in several domains of earth system governance, including climate change (Dorsch and Flachsland, 2017; Jordan et al., 2015; Ostrom, 2009, 2010a), water (Huitema et al., 2009; Pahl-Wostl and Knieper, 2014), biodiversity (Morrison, 2017; Nagendra and Ostrom, 2012) and regarding the interplay of multiple domains (Galaz et al., 2012). Polycentricity refers to governance systems involving multiple coordinated but independent centres of decision-making across sectors and scales (Aligica and Tarko, 2012; Ostrom, 2010). Polycentricity is salient to earth system governance research for analysing whether and how fragmented and complex governance systems may come to successfully govern environmental issues (van Leeuwen, 2016). It also resonates with the concepts of regime complexes (Abbott, 2012; Keohane and Victor, 2011) and orchestration (Abbott and Snidal, 2010), although identifying exactly how these ideas relate and interact requires further research.

5.1.2. Agency

A key starting point for questions of agency is: who are agents in earth system governance and what roles do they play? Who acts, and in whose name, and to further what aims? And importantly, how are agents constituted (through what means, methods and political processes)? Traditionally, questions of agency have centred on actors such as states (local, state/provincial, national) (WBGU, 2011), international bodies (e.g. UN, World Bank, development banks), the private sector (e.g. industries, transnational corporations), environmental NGOs (both domestic and international), scientists, indigenous peoples and citizens. Over the last decade of earth system governance research, there has also been growing attention to intergovernmental institutions (e.g. European Union, trade regulators, standard-setting bodies; Mitchell, 2013), international bureaucracies (Jinnah, 2014; Bauer et al., 2012; Biermann and Siebenhüner, 2009), global financial investors and different types of 'non-state' actors (Bäckstrand et al., 2017; Kuyper and Bäckstrand, 2016; Scobie, 2017a) including transnational networks (Bulkeley et al., 2014a; Chan et al., 2015; Widerberg and Pattberg, 2017) and the agency of global norms and their power to shape domestic policy especially in weaker societies and small-island developing states (Scobie, 2017a; 2017b). There is growing attention to 'new agents' that have been traditionally under-studied, such as small- and medium-sized enterprises (SMEs) (Burch et al., 2016), cities (Kraas et al., 2016; NCE, 2016), voluntary governance initiatives (van der Ven, 2015), and to groups at risk of being disproportionately affected by escalating environmental impacts and societal transformations (e.g. disadvantaged socioeconomic groups, women, ethnic minorities, displaced people, indigenous groups, and vulnerable sectors in developing countries) (Scobie, 2013). Finally, it is also necessary to better understand the role of traditional media and social media, especially given allegations of 'post-truth' societies, as well as celebrity culture seeking to influence debates about environmental issues such as climate change. More more broadly, a focus on non-traditional and otherwise 'hidden' forms of agency and actorness is as crucial as those more readily seen.

Agency interactions include norm creation and diffusion, orchestration, regime creation, modification and demise. These interactions lead to questions relating to the relative power of the actors involved and the nature and implications of their actions in governance, including: the ethical (legal and fiduciary), normative (transparency, equity, accountability, inclusiveness), technical (effectiveness, sustainability), temporal (present and future consequences), spatial and scalar (state/non-state, global/international, geographical, economic, political, uni-/multi-/interdisciplinary). Orchestration, frequently used by international organizations when they engage intermediary actors to influence a target actor (Abbott et al., 2012; Schleifer, 2013), raises new legitimacy questions (Bäckstrand and Kuyper, 2017) and has been a particular area of legitimacy studies in the earth system governance community (Abbott et al., 2015; Abbott and Bernstein, 2015; Abbott and Snidal, 2010).

5.1.3. Interplay between architecture and agency

The interplay between architecture and agency opens up novel opportunities for studying institutional dynamics, relationships and change in governance systems. Earth system governance scholars increasingly point to the dynamic nature of institutional structures (Young, 2010), and the importance of understanding relationships between actors and structures within evolving governance systems (Beunen et al., 2017; Beunen and Patterson, 2016; Scobie, 2016). Institutional structures condition the behaviour of actors, but actors can also question, disrupt or modify institutional structures and thus cause them to change (Bloomfield, 2017; Lawrence et al., 2009). It is also crucial to consider the interplay between structures, practices and agents that keep up unsustainable practices. Agency is important for learning about processes of creating governance architectures, their persistence or failure, and how they can be adapted to meet changing needs and expectations.

In light of the urgency of climate change and many other sustainability and development challenges, there is increasing attention to innovation in governance (Auld et al., 2014; Jordan and Huitema, 2014a, 2014b), and overcoming path dependency and lock-in (e.g. Seto et al., 2016) in governance systems that are no longer fit for purpose to solve the problems at hand, at global to local scales (Biermann et al., 2016, 2012). Tackling this theoretical problem places earth system governance research at the forefront of institutional scholarship generally, because, as Hall (2010) surmises, the institutions literature has traditionally focused on exploring how institutions shape behaviour (a 'first-order problem') and is only now starting to shift towards exploring how institutions themselves change (a 'second-order problem').

Key research questions that emerge out of this interplay include: What are the implications for earth system governance of polycentricity and long-standing and growing diversities and power disparities among agents? What are the analytical and normative implications of this? How, why and with what implications are shifts in authority and power in earth system governance occurring (e.g. new actors emerging, state-business-society interactions, hidden actors)?

5.2. Democracy and power

Democracy worldwide is under pressure from new configurations of power within states, notably the resurgence of populism and authoritarianism, often with a strident anti-environmental tenor (Bomberg, 2017). Political currents at the national level may in turn have far-reaching implications for the international community's capacity to solve collective problems. In these conditions it is imperative for future research in earth system governance to examine whether new conceptions of democracy and power can help make sense of, and craft responses to, these trends. Earth system governance research must also contend with the fact that the exercise of power extending well beyond conventional political institutions may influence global environmental change, not least through the ways in which business interests and dominant discourses shape patterns of production and consumption. Any interrogation of democracy must also challenge the assumption that, prior to the emergence of new threats and pressures, meaningful democracy was already being widely practiced, even though many societies classed as 'democracies' fall well short of democratic ideals.

5.2.1. Democracy

Democracy bears on earth system governance at all levels: global, regional, national, sub-national and local. Earth system governance has a special concern with global governance, and so with global democracy. Despite a burgeoning literature on global democracy (Held, 1995; Archibugi et al., 2011), relatively little research has addressed global democracy explicitly from an earth system governance perspective (for exceptions see Dryzek and Stevenson, 2011; Stevenson and Dryzek, 2014). This literature underscores, however, that claims for global democracy may be advanced even in the absence of some features that are often taken to be defining aspects of democracy at other levels (such as elections or a well-defined demos). At the same time, the Earth System Governance Project also welcomes contributions that are skeptical about the possibility or desirability of global democracy (e.g. Keohane, 2015). Furthermore, whatever the prospects for global democracy, strengthening democratic institutions at national and sub-national levels is crucial for securing what could be called earth system democracy worldwide. The intersections between global, national and local democracy are particularly important to study, not least because the legitimacy of national representatives in multilateral for a depends on the legitimacy of domestic processes for forming collective preferences. Similarly, democracy can be understood not only as a quality of state institutions, but also as extended to non-state actors and hybrid forms of governance.

The relationship between democracy and sustainability has been a longstanding theme of environmental political theory. From the 1980s and onwards, theories of ecological (or green) democracy emerged to explore - and seek ways of resolving - potential tensions between democratic processes and environmental outcomes (see for example Dryzek, 1987; Eckersley, 1992; Goodin, 1992). Public involvement in environmental decision-making is widely seen to improve the quality of those decisions, particularly by harnessing the knowledge of communities affected by environmental concerns or those with experience in managing environmental problems (Arias-Maldonado, 2007). But, given that citizens often accord relatively low priority to environmental matters compared to other policy issues, it remains contested whether democratic institutions produce pro-environmental outcomes more reliably than autocratic or technocratic forms of decision-making. This makes the analysis of environmental governance in non-democratic settings essential (e.g. Böhmelt, 2014). The tension between democracy and sustainability has become particularly acute with the rise of populist leaders espousing climate science denial and broader anti-environmental views. This raises the further concern whether earth system governance can simultaneously attain input legitimacy (in relation to decision-making procedures) and output legitimacy (in relation to institutional outcomes) (see generally Bäckstrand, 2006). A particular focus of continuing research in this context is how to secure more accountable state, non-state and hybrid governance arrangements, and what the transformative potential of transparency is, with regard to both empowerment and improved sustainability outcomes (see generally, Gupta and Mason, 2014; Kramarz and Park, 2016)

Such research can also occur in the context of recent renewal of interest in the 'dilemma' of green democracy (Wong, 2016). However, the challenges are conceptual as well as practical. It is important to consider, for example, whether the conditions of the Anthropocene make it harder to secure democracy and sustainability simultaneously, or whether the very concept of democracy (and its relationship to sustainability) now needs to be rethought in the light of the Anthropocene (Eckersley, 2017). Similarly, researchers should consider whether and how the tensions between democracy and sustainability in earth system governance are more or less acute across different policy areas and governance levels, whether different varieties of democracy (e.g. corporatist or adversarial systems) are more adept at managing those tensions, or how articulations of ecology and democracy in different cultures

yield new insights (Kothari, 2014). Thus, whether or not democracy is valued instrumentally (as a means to achieve better governance outcomes) or in its own right, much remains to be known about what is needed to secure democracy in earth system governance.

The inclusion of non-state actors and discourses has been a major theme of research in earth system governance that draws on theories of deliberative and stakeholder democracy (Dryzek and Stevenson, 2011; Baber and Bartlett, 2015; Bäckstrand et al., 2010). Although the involvement of non-state actors is often seen as essential for democratizing global environmental governance, questions remain about the extent to which the internal practices of non-state actors reflect norms of democratic legitimacy, including inclusive and high-quality deliberation (Bäckstrand and Kuyper, 2017). A major challenge for democratization is how to ensure the inclusion of marginalized or under-represented groups, including indigenous peoples, women, future generations and non-human entities such as animals and ecosystems. A further major area for earth system governance research is whether and how multilateral environmental knowledge assessments should be democratized by opening up their practices to more diverse forms of knowledge (Cornell et al., 2013; Santos, 2014, 2016).

5.2.2. Power

Based on Barnett and Duvall (2005, p. 42), we define power as the "production, in and through social relations, of effects that shape the capacities of actors to determine their circumstances and fate." In this light, dealing with power is inescapable in any kind of governance. An earth system governance perspective can add specific insights to more general debates about the role of power in governance, such as how the way in which environmental questions are constructed can serve some interests and repress others.

Countries wielding greater economic or political power are often seen as having greater responsibility to act on global environmental concerns (Bukovansky et al., 2012). Unequal power relations between the developing and industrialized countries have long been a key dynamic of global environmental governance (Martinez-Alier and Joan, 2002; Ciplet et al., 2015). Global power relations also intersect with other kinds of power asymmetries, including gender and racial discrimination (Schlosberg and Collins, 2014) and the privileged position of some interest groups (e.g. business) over others (e.g. environmental groups) in domestic politics (Falkner, 2008; Bloomfield, 2017). New distributions of power may emerge where non-state actors become more closely involved in governance (Betsill and Corell, 2008; Green, 2013), or where international organizations enter into relationships with other actors through delegation or orchestration (Schleifer, 2013; Abbott et al., 2016; Bäckstrand and Kuyper, 2017).

Discursive power may be exercised, among other ways, through overarching discourses such as sustainability and the green economy, as well as through more specific concepts such as ecosystem services and natural capital (Dryzek, 2013). Civil society actors lacking formal decision making power may nevertheless exercise 'framing power' by drawing attention to the concerns of vulnerable groups, as with civil society organizations' efforts to frame loss and damage resulting from climate change as a matter of justice rather than as a technical issue (Allan and Hadden, 2017).

The idea of the Anthropocene underscores the unprecedented power that humans exert over non-human nature, while at the same time cautioning that human interference with earth system processes has the potential to trigger major (and possibly catastrophic) state shifts in the entire system that elude human control. A key strand of optimistic narratives of the Anthropocene is that humanity has the power to shape the earth system for the better (Breakthrough Institute, 2015), notably through climate-related geoengineering. Some scholars have criticized the notion of the Anthropocene for its inattention to issues of power. Thus Baskin (2015, p. 16) argues that "the term 'Anthropocene' reveals the power of humans, but it conceals who and what is powerful, and how that power is enacted." Others argue that it is possible to form a nuanced understanding of the Anthropocene that takes issues such as power and diversity into account (Biermann et al., 2016).

So, for example, power analysis may help to uncover the relative power of actors in complex global supply chains over the environmental impacts of world trade (Fuchs et al., 2016). Power analysis can also serve to challenge prevailing orthodoxies about desirable architectures for earth system governance. Morrison (2017), for example, argue that while polycentric governance is often seen as an antidote to excessive centralization of power, existing literature often overlooks that polycentric systems may embed other forms of power asymmetry. This kind of analysis may in turn shed light on how power inequalities could be alleviated and abuses of power curtailed. Research to identify power inequalities and abuses must be sensitive to the fact that these phenomena may manifest themselves differently depending on the type of power in question (e.g. governmental or corporate power); the governance responses required may vary accordingly.

5.2.3. Interplay between democracy and power

Democracy and power are distinct but closely interlinked. Democracy promises a means of distributing political power among citizens and transferring power to their representatives without resorting to violence or coercion, as well as a means of curtailing the arbitrary exercise of power. Yet inequalities of power infuse democratic institutions, as demonstrated by the success of fossil fuel interests in shaping climate policy. Concern about preventing and remedying abuses of power may stem from a belief in the value of global democracy, but it need not: such a concern could be grounded in a more basic interest in ensuring the legitimate exercise of authority in global governance (Grant and Keohane, 2005).

Many of the practices that could serve to democratize earth system governance may help simultaneously to alleviate power inequalities, particularly by empowering citizens and marginalized groups. However, a dedicated focus on power is required to illuminate how different forms of unequal power are generated and sustained in institutions for global environmental governance. This gives rise to abundant new research questions, including: How can interlinkages between accountability, legitimacy, and transparency as key qualities of governance arrangements be conceptualized and realized? Under what conditions does transparency contribute to more accountable and legitimate earth system governance?

5.3. Justice and allocation

Currently, governments and intergovernmental organizations formulate goals and set priorities for action that aim to address issues of justice and allocation on a global scale. For example, two of the goals of the recently adopted Sustainable Development Goals address reducing inequalities within and across countries (Goal 10) and promoting peace and justice (Goal 16). In addition, private actors, such as businesses and civil society organizations, create institutions that use the market to generate 'fair' distribution of environmental and/or social goods, such as the Ethical Trading Initiative and the Fairtrade Labelling Organization. Likewise, activist and grassroots networks such as Global Justice Now are also engaged with justice concerns. As justice, and its core demand of allocation, become fundamental political and social concerns, there is an urgent need to develop a systematic analytical, philosophical and empirical investigation.

5.3.1. Justice

"We do not live in a just world" (Nagel, 2005). The fact that this proposition is uncontroversial does not mean that the concept of justice is not contested or elusive. For the purpose of earth system governance, we find it useful to conceptualize justice in three dimensions (Jerneck et al., 2011): intergenerational (between generations), international (between states and regions) and intersectional (between groups/categories in society).

Intergenerational justice is core to environmental concerns for both natural and social reasons. The inertia of many natural systems and phenomena is one obvious reason why inter-generational considerations are essential. For example, greenhouse gases are persistent over more than one generation, while the atmosphere responding to these gases interacts with oceans and icecaps operating at timescales of decades and millennia. Extraction of finite resources, be they oil, coal or minerals, is fundamentally a matter of intergenerational justice. So is the generation of long-lived hazardous materials, such as nuclear waste where one generation reaps the benefits of nuclear power while hundreds of generations will live with the waste. Irreversible processes, such as extinction of species or permanent depletion of resources are also of intergenerational importance. In practice, however, it remains contested and difficult to accept that future generations may have moral rights with respect to us, and that we may have obligations with respect to them.

International justice has a long tradition of research and scholarship in earth system governance, often from the point of view of international relations. Many of our most pressing environmental challenges (e.g. climate change, biodiversity loss, overfishing, depletion of water resources) have explicit and implicit international implications and drivers. Historically, those contributing most to climate change have been industrialized countries, though a changing climate will have much more severe negative impacts on developing countries. Similarly, many of the policies and mechanisms for addressing climate change are initiated by the industrialized countries but with significant implications for people in the developing countries.

Intersectional justice relates to the concept of intersectionality, expressing the multiple dimensions and modalities of social relations and subject formations we belong to (McCall, 2005). In earth system governance, intersectional justice can be understood in relation to multiple deprivations at context-specific intersections of age, class, caste, (dis)ability, gender, indigeneity and race. Examples of intersectional (in)justice are rife in regard to climate change impacts as well as impacts of climate change policies (Olsson et al., 2014).

5.3.2. Allocation

Justice as allocation or distributive justice evaluates how and to what end a just society allocates the costs and benefits of social cooperation (Rawls, 1971). This perspective emphasizes that justice fundamentally concerns the basic structure of society and how this defines and regulates social, economic and environmental equality and inequality. For earth system governance, distributive justice addresses the institutions that are responsible for distributing such costs and benefits across different generations, among nation states and among different groups in global societies. There is no widespread consensus on what is considered just distribution, however, and different principles apply (Luterbacher and Sprinz, 2001). To illustrate, utilitarians accept as just the distribution that on average produces more benefits than costs. Scholars in the liberal egalitarian tradition, in contrast, adopt a (global) 'difference principle' whereby inequality in the distribution of costs and benefits is acceptable as long as this benefits the least advantaged members of society (Beitz, 1979; Caney, 2001, 2005; Moellendorf, 2002). Still

others advocate a needs-based minimum floor principle whereby basic needs should be satisfied first before any distribution is considered (Brock, 2009). The plurality of distributive justice principles invites earth system governance research to clarify and unravel the principles that underline the multiple governance processes in which decisions regarding 'who gets what and why' are being negotiated and disputed.

For justice as allocation to materialize, however, scholars contend that two other elements are important, namely recognition and representation (Fraser, 2001). If a group or individual lacks recognition in the social or political structures within a society, it will contribute to maldistribution (Fraser, 1997, 2001; Young, 1990). Representation describes the democratic, fair and equitable processes in decision-making (Schlosberg, 2007). It demands that all groups, especially those most affected, are fully provided the opportunity to participate in the decision-making process, and the decision-making should be shared. It also requires that all (affected) actors participate in an impartial way and ensure full disclosure so as to facilitate effective participation − this includes the content of the information, how it is provided, if it is provided in a timely manner and to whom it is given. In other words, representation emphasizes the importance of the political process through which existing injustices in distribution and recognition can be addressed (Young, 1990). For earth system governance research, representation requires evaluating, for instance, the democratic character of the processes through which decisions affecting the distribution of environmental costs and benefits, as well as the economic costs and benefits of proposed solutions. It further entails questioning who are considered and recognized as legitimate participants and beneficiaries of cooperation and who are not (including nation states, social groups and different generations).

5.3.3. Interplay between justice and allocation

In international fora, human rights are seen as one path to advance equity claims of disadvantaged and underserved peoples. Human rights to water, for example, are considered to have enormous mobilizing potential and may help redress the imbalance between the haves and the have-nots in water allocation and use (Sultana and Loftus, 2012). In those countries that have institutionalized the human right to water as a constitutional protection or through national legislation, it may serve as a moral articulation and as a basis for legal challenges, even if there are limitations in terms of implementation (Gerlak and Wilder, 2012). Among other things, access to systems of implementation and justice at national and international levels are needed to ensure implementation of those rights for the poorest and most vulnerable (Gupta and Lebel, 2010), and proper recognition.

Likewise, just and non-discriminatory legal and regulatory systems and institutional frameworks directly reduce human suffering and the causes of violence, while legitimate and transparent democratic processes permit societies and communities to choose equitable policies to address environmental problems (Biermann et al., 2012). New alternative discourses and social movements are often necessary to promote a re-allocation of resources and shift to more just and equitable patterns of use (Gupta and Lebel, 2010). Economic tools typically focus on distributive justice. For example, some advocate for stronger financial support for poorer countries, through direct support payments for climate change mitigation and adaptation programmes based on international agreements or through international market mechanisms, like global emissions markets (Biermann et al., 2010). Finally, personal religious and ethical world views (Dash, 2014; Esquivel and Mallimaci, 2017) are often the drivers for solidarity and subsidiarity at global to local levels and in earth system governance form the

overarching delivery framework and contexts for partnerships for ending poverty and inequality (Feygina, 2013).

The paired justice and allocation research lenses might lead earth system governance researchers to ask: What types of steering have been effective and not effective to channel personal, regional, national and global world views towards more sustainable approaches to environmental rights and duties? What kind of tradeoffs may be identified between the different dimensions of justice and allocation?

5.4. Anticipation and imagination

Increasingly, earth system governance includes proliferating processes of anticipating and imagining diverse futures, including, among others, through modelling, integrated assessments, foresight and scenario building. There is an urgent need to examine how to govern such diverse anticipation processes, but also to scrutinize how anticipation itself becomes a site of politics and governance. Analysing these twin processes is a crucial and timely task for the social and interdisciplinary sciences, including for the earth system governance community. This subsection identifies a research agenda relating to the increasingly central role of processes and tools of anticipation and imagination in earth system governance, keeping in mind the contextual conditions of transformation, inequality, the Anthropocene and diversity discussed in the previous section.

5.4.1. Anticipation

Seeking to steer (or govern) an unknown and largely unknowable future is fraught with normative and scientific uncertainties and conflicts (Hulme, 2010; Nordmann, 2014). We define anticipatory governance as the evolution of steering mechanisms in the present to govern future earth system transformations, in the face of extreme normative and scientific uncertainty and conflict over the very existence, nature and distributive implications of such transformations (Gupta, 2001, 2011; Guston, 2010). As such, it is a politically charged and challenging endeavour. Governance is always anticipatory to a greater or lesser extent, particularly in policy domains such as military planning or budgeting. Increasingly, however, anticipatory governance is becoming central to the environmental and sustainability realm, with its long-standing tendency towards reactive or retrospective governance, given accelerating earth system transformations and their potentially disruptive societal and distributional consequences. This holds also for governance challenges associated with potentially transformative and powerful emerging technologies, characterized by strong claims of global benefit but also extreme uncertainties and contested risk, such as biotechnology, nanotechnology, geoengineering or synthetic biology. Anticipatory governance of novel technological trajectories or earth system transformations requires attention to contested aspects such as securing accountability, ascribing responsibility, determining liability or ensuring compensation for environmental risk or harm. Yet these contentious issues, long plaguing earth system governance, become vastly more complicated in the context of ex-ante, rather than ex-post governance, given uncertain and unknowable (future) risk and associated uncertain distributions of risk and harm.

Perspectives on anticipation and anticipatory governance vary in their conceptions of the future, including the extent to which the future is knowable (cf. Edwards and Bulkeley, 2017) and subject to steering. As Jasanoff suggests, it is important to consider the political implications in the present of "fabrications of the future" (2015, p. 337). For some, anticipatory governance is less about guessing the future and more about developing "a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible" (Guston, 2014, p. 219). For Guston, anticipatory governance is about capacities rather than knowing or predicting futures, with anticipation seen as "practicing, rehearsing, or exercising a capacity … [rather than] divining a future" (Guston, 2014, p. 226).

Anticipation processes thus increasingly entail imagining and 'pre-experiencing' pluralistic, challenging futures, in order to question limiting assumptions about what futures may be possible, and experiment with strategies aimed at transformational change (Vervoort et al., 2015). Key tools here include foresight and scenario-building exercises, which are now proliferating in sustainability-related research and planning contexts (Wilkinson et al., 2011; Vervoort et al., 2014a). There has nonetheless been very little critical social science scrutiny of the multiple global, regional and national anticipation processes (centred around foresight, modelling and scenario building) now underway. There is thus an urgent need for meta-analyses of anticipation processes, including through a critical governance lens, by asking first-order questions of who governs, for whom and why, and examining how the content of anticipation processes is created in ways that shape and limit what futures can be imagined.

However, there are important disconnects between, on the one hand, foresight research that is rooted mainly in environmental sciences, macroeconomics and business planning, and, on the other hand, research on climate policy and governance, rooted in the interpretive social sciences. There is a) a lack of understanding of foresight as a political intervention and hence the need to govern foresight processes and b) a lack of understanding of whether and to what extent foresight is integrated with earth system governance and policy processes. It is also important to take into account that foresight initiatives led by civil society or private sector actors may have very different characteristics to government-led initiatives in terms of how processes are organized and in terms of who is empowered to deliver on the process. The levels of governance at which foresight is aimed are also significant (Zurek and Henrichs, 2007).

5.4.2. Imagination

To support the goal of anticipating and effectively preparing communities for the transformative social and ecological shifts that are already under way, and to move beyond the status quo, it is becoming clear that creative and therefore imaginative approaches to governance are required. Imagination is a particularly important ingredient of governance that addresses 'wicked problems', i.e. those challenges that appear to have no easy or 'right' solution, that seem to defy our attempts to define them, and that do not appear to be solvable using traditional modes of decision-making (Rittel and Webber, 1973). Imagination allows a transcending of such assumptions and long-established myths about problem-solving, including the assumption that wicked problems remain unsolved due to complexity, rather than because of the habitual, unimaginative or politically prescient filtering out of simple but unconventional solutions.

Social imaginaries, as the creative and symbolic dimensions of social worlds that frame imaginations (Thompson, 1984), play an important role in directing and limiting what new approaches to governance can be considered. Existing (and hegemonic) social imaginaries contribute, for example, to failures to imagine approaches to governance that are fit to deal with unprecedented challenges, or to maintaining institutionalized inequity and exclusion. While decision makers have long been tasked with producing effective strategies that address issues pertaining to the public good, it has been argued that "patterns of thought of a previous era can create serious problems for the next" while entanglement of

scientific claims in the media with ideological standpoints creates challenges for informed public conversations about issues like climate change, but also offers opportunities for a more engaged (and engaging) discourse (Carvalho, 2007, 2010).

Governance that explicitly recognizes the need for imagination may thus have certain characteristics, yet this is clearly challenging on multiple levels. These characteristics include, among others, being reflexive about the constructed nature of existing social imaginaries and their limits, to recognize how these limits can be overcome; being inherently participatory, recognizing that different types and forms of knowledge enrich decision-making on complex issues; being iterative and flexible, i.e. allowing for social learning, changing course in the event of new information; and being systems-oriented, i.e. seeking connections between environmental and social issues, considering ripple effects, unintended consequences and emergent properties. The governance challenge is to direct this imagination towards collective aims, asking critical questions about who suffers and benefits from decisions over time.

Governing by imagination can be supported by emerging tools and methodologies (including artistic approaches, memes, visualizations, games, and other media) that offer unique opportunities for the co-production of knowledge, thereby weaving together complex and interwoven issues that offer potential for both synergies andtrade-offs. While abundant case studies exist that delve into the promises and pitfalls of these new tools, earth system governance research may benefit from more coherent, theoretically grounded and comparative work that captures important emerging trends and lessons (Vervoort and Mangnus, 2018).

5.4.3. Interplay between anticipation and imagination

The twin imperatives of anticipation and imagination are linked, insofar as anticipating uncertain futures is fundamentally also an act of the imagination. As such, in bringing these notions together, the research agenda becomes one of exploring the historical antecedents and understandings of anticipation, anticipatory governance and imagination within the social science and global change research communities, in order to ascertain whether and how these notions are being deployed, and with what political implications or uptake in environmental governance. A combined research focus on the roles of anticipation and imagination in processes of governance is underdeveloped, but urgently needed. Research focusing on anticipation alone risks overlooking how human imagination fundamentally frames what futures are considered, both in terms of adapting to future challenges and in terms of what futures are desired and how they may be achieved. Such imagined futures have fundamentally political origins as well as political consequences and should be researched as such.

Therefore, an integrated research agenda requires bringing critical and interdisciplinary social science perspectives to bear on processes of anticipation and imagination, the futures they generate, and the ways in which they are integrated into earth system governance processes. This includes assessing the current state of play with regard to institutional arrangements and normative presumptions relating to anticipation and imagination in diverse areas of sustainability governance. A key research gap is to analyse how processes of anticipation (i.e. planning and research processes aimed at exploring alternative futures) relating to environmental transformations are themselves being governed, i.e. who is steering them, to what end, and through what deliberative or representative processes. For instance, what institutions and practices underpinning processes of anticipation and imagination in earth system governance are most effective in generating desired sustainability outcomes? Through executing elements of the above research agenda, the aim is to shed light on the theoretical and empirical utility of an analytical lens on anticipation and

imagination within earth system governance and the role of these processes in addressing (and redressing) the transformative sustainability challenges of our times.

5.5. Adaptiveness and reflexivity

This research lens focuses on understanding how societies can navigate change towards global sustainability. We consider adaptiveness to be "an umbrella term for a set of related concepts — vulnerability, resilience, adaptation, robustness, adaptive capacity, social learning and so on — to describe changes made by social groups in response to, or in anticipation of, challenges created through environmental change" (Biermann et al., 2009a:45). In the context of earth system governance, reflexivity refers to the ability of actors and institutions to critically reflect on their own performance (especially their environmental impacts), and to reshape their goals, practices and values accordingly in order to wisely navigate complex, contested and changing human-environmental systems (Dryzek, 2016; Voß and Kemp, 2006). While these two concepts overlap, adaptiveness emphasizes responses to changing social and ecological conditions (which may be coordinated, self-organized or emergent), while reflexivity emphasizes the centrality of critical scrutiny of prevailing values and practices in governing processes of change.

5.5.1. Adaptiveness

Adaptiveness (particularly adaptive governance) has been extensively studied over the last decade, and continues to be at the forefront of environmental governance theory and practice (e.g. Conway et al., 2014). Adaptiveness has been studied from multiple angles, including collaborative governance (Emerson and Gerlak, 2014), learning (Gerlak et al., 2017; Pahl-Wostl, 2009), complexity (Booher and Innes, 2010) and agency (Huitema and Meijerink, 2009, 2010). Adaptiveness has become particularly important in the context of climate change, which has served as the arena for much conceptual development over the last decade. This includes a focus on: climate adaptation governance (Bauer and Steurer, 2014; Huitema et al., 2016; Jordan et al., 2010; Massey et al., 2014; Massey and Huitema, 2016), policy integration (Biesbroek et al., 2014, 2015; Dupuis and Biesbroek, 2013) and mainstreaming adaptiveness into existing activities within and beyond the state (Dovers, 2009; Uittenbroek, 2016). Maladaptation remains an important but under-explored topic, regarding the opening up and closing down of future opportunity space across diverse societies (Barnett and O'Neill, 2010). Cities have become a prominent empirical domain for studying adaptiveness, stimulated by foundational work on urban systems (Bai et al., 2016a; Bai et al., 2010; Bulkeley and Betsill, 2013, 2005; Bulkeley and Castán Broto, 2013) and policy advocacy on the importance of adaptation in cities (World Bank, 2011, 2010). Recently, climate change adaptation research has taken a transnational turn (Biermann and Boas, 2010; Bulkeley et al., 2014a; Dzebo and Stripple, 2015; Hall and Persson, 2017) in the shadow of intensifying climate policy debates about the role of adaptation within global agreements on climate change.

Questions about winners and losers (e.g. involving distributions of resources, risks and power), processes by which decisions are made and with what consequences, the role of power relations, and who decides — remain central in analysing adaptiveness and adaptive governance arrangements. These questions have received greater attention in recent years (Eriksen et al., 2015; Javeline, 2014; Sovacool et al., 2015). Yet on the whole, they remain vastly under-studied and must be a key priority in earth system governance research over the next decade, especially as the intensity of debates around climate change adaptation grow with more frequent climate impacts manifesting over time. Social justice has

also become a prominent theme in adaptiveness literature (Adger et al., 2017; Adger et al., 2012; Bulkeley et al., 2014b, 2013; Klinsky et al., 2017; Paavola and Adger, 2006; Schlosberg et al., 2017). Concerns about injustice and political disempowerment in the face of adaptation imperatives have seeded influential arguments about the need to pivot from adaptiveness (as responding to the impacts of climate change on various vulnerable groups) to transformation (of structural conditions that create vulnerability in the first place) (Moser and Ekstrom, 2010; O'Brien, 2012; Park et al., 2012; Pelling, 2011). A particular challenge for earth system governance research over the next decade will be to understand the politics of anticipatory adaptive action in all spheres, in climate change and beyond. For example, how to navigate the complex politics of adapting to climate and earth system changes in ways that pay attention to both effectiveness and social justice, particularly in contexts of failing global governance systems and weak political responses to growing problems.

5.5.2. Reflexivity

Concerns about the limits of adaptation have prompted interest among researchers not only in the potential for transformative governance but also in new forms of reflexive governance (Pickering, 2018). Dryzek (2016, p. 942) argues for ecological reflexivity as a critical competence for reshaping institutions in the Anthropocene, where "reflexivity entails a capacity to be something different rather than just do something different, which distinguishes it from adaptive management and governance". Dryzek's recasting of reflexivity in ecological terms marks a new turn in several decades of research on reflexive governance. Earlier interest in reflexivity is often traced back to sociologists such as Giddens (1990) and Beck (1992), who invoked the term to help understand the implications of modernity. Scholars frequently distinguish between 'first-order' reflexivity (whereby institutions generate effects that feed back on themselves) and 'second-order' reflexivity (whereby institutions build a capacity to critically scrutinize their own practices) (Voß and Kemp, 2006:6–7). For Dryzek, this kind of second-order reflexivity needs to take on a distinctively ecological character. Ecological reflexivity involves "listening more effectively to an active Earth system, capacity to reconsider core values such as justice in this light, and ability to seek, receive and respond to early warnings about potential ecological state shifts" (Dryzek, 2016:953).

Scholars have applied ideas of reflexive governance to a range of aspects of earth system governance, including reflexive governance of sustainable development (Voß et al., 2006), energy transitions (Hendriks and Grin, 2007), global environmental governance (Christoff and Eckersley, 2013; Dryzek and Pickering, 2017) and global climate governance (Stevenson, 2016). Most of these studies find that signs of reflexivity in existing institutions are at best limited and yield varying findings on whether reflexivity can be cultivated from within existing institutions, or whether reflexive change requires some kind of external catalyst (such as ecological or economic crisis, or the emergence of new social movements). Key research challenges include developing more robust empirical measures of reflexivity (a task that has advanced considerably further in the field of adaptive governance), understanding why some institutions are more reflexive than others, and identifying strategies for enhancing reflexivity. Possible strategies include opening up formal and informal spaces for knowledge creation, learning, experimentation and debate (Dryzek and Pickering, 2017), or countering forces that seek to suppress reflexivity (e.g. actors who spread misinformation about environmental risks or threaten litigation against social movements that challenge the status quo; McCright and Dunlap, 2010).

5.5.3. Interplay between adaptiveness and reflexivity

The preceding sections have discussed the notions of adaptiveness and reflexivity and some areas where they intersect, while illustrating their value as distinct concepts. Crucially, processes of reflexive scrutiny could create momentum for adaptive change. At the same time, some kinds of adaptive change could occur in non-reflexive ways, as where societies mount rapid responses to ecological disasters in timeframes that do not allow for extended processes of reflection. In addition, reflexive rethinking may result in the judgment that merely adapting existing systems will not suffice, instead, more thoroughgoing transformation may be necessary.

Drawing on these observations, three topics at the nexus of adaptiveness and reflexivity stand out as major new directions for earth system governance researchers over the next decade. First, an enduring challenge in understanding adaptiveness and reflexivity in governance is to navigate tensions between stability and flexibility (Biermann, 2007:331). This is because while "flexibility is important for governance systems to deal with uncertain, unpredictable, and non-linear forms of social and environmental change … governance systems [also] require stability to ensure that new policies persist over sufficient timeframes to bring about desired effects, and to stabilise expectations and enhance coordination over time" (Beunen et al., 2017). This core dilemma, surprisingly, still has not been robustly theorized. As such, we could ask: what kinds of governance attributes (e.g. polycentricity or centralization, flexibility or stability) are best suited to cultivating adaptiveness and reflexivity, and how can potential tensions between these attributes be managed?

A second key issue at the intersection of adaptiveness and reflexivity is dealing with globally networked risks. A critical empirical insight in recent years concerns the interconnected nature (in often hidden ways) of a plethora of causal forces and risk transmission pathways affecting environmental governance. Scholars pay increasing attention to the key causal role of factors that may be spatially, institutionally or temporally distant from a specific environmental issue of concern. For example, global trade agreements, financial investment decisions and technological change are increasingly recognized as playing a potentially decisive role in earth system governance (Galaz, 2014; Galaz et al., 2014; van Asselt, 2014; Young, 2008). These issues are broadly being framed as "globally networked risks" (Galaz et al., 2017), building on earlier work on cascading risks across scales (Galaz et al., 2011).

Lastly, an issue which has potential to fundamentally reshape earth system governance research over the next decade is the need to reshape governance systems at all scales within the Anthropocene. Boundary conditions upon which existing environmental governance systems were developed are changing in profound ways. This includes climatic change, impacts of transgressions in planetary boundaries and multiple simultaneous socio-economic-political transformations unfolding globally (e.g. urbanization, infrastructure, digital, geopolitical). Altogether this deeply challenges existing global environmental governance systems, possibly rendering them obsolete and wholly unprepared for the new challenges arising.

6. Conclusions

Novel approaches and innovative concepts are needed to study new and emerging — as well as existing — unsolved social and environmental problems. The analytical framework presented above represents an effort to guide and inspire the systematic study of how societies prepare for accelerated climate change and wider earth system change, as well as policy responses. To engage with the changing empirical context of earth system governance

research in the coming decade, the new plan sets out democracy, power, justice, anticipation, imagination and reflexivity as critically important research lenses. For example, who will imagine and decide over sustainability transformations (or lack thereof) and are their outcomes just? Architecture, agency, allocation and adaptiveness remain equally important lenses for understanding conditions for governance and are therefore incorporated in the new framework.

While the timeframe of this plan is the next ten years, we expect that there will be active engagement and discussion when taking it forward, to ensure strong relevance to governance challenges and new scientific findings. Implementation of science plan by the network of scholars engaged by the Earth System Governance Project is a varied and evolving task, involving mechanisms such as the appointment of distinguished Lead Faculty, communication among a growing cadre of Research Fellows, annual conferences, and the facilitation of smaller-scale research projects. We expect that this range of activities will grow and shift to enable better participation of scholars from the Global South and low-carbon collaboration.

The approach to earth system governance research described here acknowledges diverse knowledge systems and practices and encourages dialogue among disciplines, sciences and other ways of knowing that often are not recognized as valid knowledge. It therefore challenges scholars in this community to reflect on the traditions and ideologies they follow, and those of others. Finally, the plan does not impose or privilege certain methods, but recognizes the wide variety of methods presently used in the community and encourage more learning. Likewise, the plan welcomes a combination of in-depth disciplinary research, interdisciplinary research that weaves together the social sciences with natural sciences and a growing transdisciplinary research effort in which broader society is engaged to address real-world problems.

At a time of unprecedented urgency for global sustainability transition earth system governance scholars are tasked with reflecting upon their role in supporting, examining and even influencing decisionmaking. It is clear that earth system governance research is being challenged by an increasingly complex, contested and interlinked global context, and that many of the issues that earth system governance researchers will grapple with over the next decade will need to be tackled from outside of the narrow environmental governance domain. Earth system governance scholarship addresses rapidly changing issues that affect all sectors of society, and should be − and is − engaged with and relevant to society. Deepening and refining this relevance, however, is the ongoing task of the earth system governance community.

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