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How to Assess Knowledge Cumulation in Environmental Governance Research? Conceptual and Empirical Explorations

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ABSTRACT

Environmental governance research (EGR) has been criticized for not being cumulative, despite the importance of cumulative knowledge for evidence-informed decision-making in addressing global sustainability problems. However, defining, measuring, and assessing knowledge cumulation in EGR remain challenging. This study presents a systematic effort to address this challenge. Next to conceptualizing knowledge cumulation, we developed metrics to gauge the potential of EGR for knowledge cumulation on the levels of individual articles and scientific community. We applied those metrics to the "Earth System Governance" (ESG) research community within the field of EGR and analyzed its body of research through publications emerging from the first seven ESG conferences, resulting in 362 journal articles. Employing a comprehensive coding scheme, we further analyzed a random sample of 100 of those articles. Our findings suggest limited potentials for knowledge cumulation within ESG research. At the community level, we found a diverse journal landscape, a core-periphery structure in citation networks and co-authorship patterns, heterogeneous research questions, and only a few shared reference works, concepts, frameworks, and variables. At the article level, we observed few literature reviews, little data sharing, infrequent application of theories and frameworks, a shortage of clear definitions, and insufficient reflection on limitations. Moreover, we found that midsized author teams advance the knowledge cumulation potential. The ESG community aligns with Whitley's notion of a "fragmented adhocracy" characterized by diverse but disjointed research efforts, which still may foster interdisciplinary exchange. Our suggested conceptualizations, metrics, and results lay the foundation for future comparative and in-depth research on cumulating knowledge.

1 | Introduction

In an era of escalating environmental crises, the need for effective governance mechanisms has never been more urgent (Chaffin et al. 2016; Patterson et al. 2017). Environmental governance offers a diverse and expanding toolbox, encompassing approaches such as polycentric, multi-level, adaptive, participatory, and collaborative governance. To effectively apply this increasingly complex repertoire of governance approaches, decision-makers need to be informed by reliable knowledge on what works and in what contexts (Head 2010; Schoenefeld 2023). Without this foundation, governance initiatives risk being driven by transient fads of untested beliefs, ultimately failing to address pressing environmental challenges effectively.

Environmental governance research (EGR) plays a pivotal role in evaluating and improving environmental governance. By unravelling the structures, processes and mechanisms through which

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societies make and implement decisions about the environment, EGR sheds light on the roles, interests, power dynamics and capacities of diverse actors. EGR is instrumental in evaluating the desired and undesired effects of governance and policy interventions (Schoenefeld 2023) and thus serving to foster societal transformation to sustainability (Rosenbloom 2025). In doing so, EGR should "provide evidence for robust decision-making" (Earth System Governance Project 2018, 88).

The point has been made that such policy-relevant knowledge needs to be of a cumulative nature. Cumulative knowledge builds on previous achievements in a way that the understanding of governance arrangements and their effects is growing and deepening by adding to, challenging, or confirming existing research, whereas non-cumulative knowledge often represents isolated findings. Cumulative knowledge supports generalization while paying attention to specific contexts and integrates and synthesizes knowledge from diverse sources and research approaches (Jensen and Rodgers 2001; Ostrom 2009; Ide and Scheffran 2014; Newig and Rose 2020). Recent works in the philosophy of science (Bird 2023), sociology (Campbell 2019) and the social sciences more generally (Pfeffer 1993; Mahoney 2003; Elman et al. 2020) have highlighted the crucial role of knowledge cumulation for achieving scientific progress.

For a variety of reasons to be discussed below, scholars have voiced doubts whether research on environmental governance (and human–environment systems more broadly) is delivering cumulative knowledge, calling for a stronger anchoring of cumulative knowledge production in the fields of sustainability (Alexander et al. 2020; Pauliuk 2020), social science (Elman et al. 2020) and—at the intersection of both—environmental governance (Newig and Rose 2020; Hofmann 2022). Such observations raise questions about the actual (non-)cumulative nature of EGR, and, with it, the challenge of defining, measuring, and assessing knowledge cumulation.

To date, no research has attempted to systematically operationalize and "measure" knowledge cumulation—not for the field of EGR and not for any other social science research area. As a result, beyond claims based largely on experience (Pauliuk 2020; Newig and Rose 2020) and a few empirical studies on knowledge (non-)cumulation in specific areas within the social sciences (e.g., Goyal and Howlett (2018) or Zaki et al. (2022) for policy learning), we are left with educated guesses about the (non-)cumulative nature of the field, and hence, very general recommendations on how to reform future research.

This paper attempts first steps toward measuring knowledge cumulation in a research community within the broader field of EGR, exploring how and to what extent the published record in one research community lends itself to producing cumulative knowledge. Our research aims are threefold, namely conceptual, methodological, and empirical: (1) conceptually, we trace the debate on knowledge cumulation in the social sciences to develop an operable definition of knowledge cumulation. (2) We advance methods and metrics to assess the "cumulability" of knowledge on the levels of both individual published articles and the research community. (3) By way of an empirical illustration, we explore knowledge cumulability in the Earth System Governance (ESG) community within the broader field of EGR, analyzing 362 published articles, of which we studied a random sample of 100 in more depth. By doing so, we provide the first semi-quantitative analysis of knowledge cumulability in a research community.

The remainder of this paper proceeds as follows. As EGR is mostly a social science endeavor, Section 2 starts by engaging with the debate on knowledge cumulation in the social sciences more broadly, before addressing the specificities of the interdisciplinary research field of EGR. In Section 3, we conclude our conceptual considerations with a proposal to define knowledge cumulation and appropriate metrics to gauge the potential for knowledge cumulation in scientific articles and communities. Section 4 describes our methodology for defining the body of Earth System Governance literature based on identifying the publications emerging from ESG conferences, as well as coding Scopus-listed publications according to the metrics developed in Section 3. Section 5 presents and discusses the results of our exploratory analysis before we close in Section 6 with overall conclusions and an outlook for further inquiries into knowledge cumulation in EGR.

2 | Setting the Scene: Conceptual Considerations on Knowledge Cumulation

There appears broad consensus that knowledge cumulation is a key feature—if not the key feature—of scientific progress (Bird 2023). Progress implies that a scientific field develops a deeper, broader, more nuanced, more robust understanding of existing phenomena and causal processes in the world, or an initial understanding of emerging phenomena (Mahoney 2003; Campbell 2019; Elman et al. 2020). Notably in the social sciences, the production of cumulative knowledge has been "considered the ultimate criterion for evaluating scholarly progress" (Mahoney 2003, 163).

2.1 | Scientific Progress and Knowledge (Non-)Cumulation in the Social Sciences

EGR, while being an interdisciplinary undertaking informed by and contributing to a range of disciplines (Tacconi 2011), is at its core a field of social science. Even though it may consider natural science data when assessing environmental change as a governance outcome, its topics are social processes and phenomena, and accordingly, it uses social science methodology. Hence, the study of knowledge cumulation in EGR will benefit from considering the discussion of knowledge (non)cumulation in the social sciences more generally.

Overall, we understand little about knowledge cumulation in the social sciences because it has hardly ever been systematically investigated. Nevertheless, the issue has been occupying the social sciences for decades (see, e.g., Taveggia (1974) or Pfeffer (1993)). Remarkably, much of the literature on knowledge cumulation in the social sciences actually diagnoses deficits in the production of cumulative knowledge. For sociology, Gans (1992) found that scholars acknowledge the desirability of cumulative research, assuming that sociology generally is cumulative. He diagnosed that despite paying lip service to this goal, the field's incentive

structures discourage cumulation, such that overall, little cumulative knowledge is actually produced. These observations have been paralleled by scholars from different social sciences (Pfeffer 1993; Mahoney 2003; Abbott 2006; Campbell 2019; Watts 2017; Elman et al. 2020; Fecher et al. 2021).

As to incentive structures, the point has been raised for decades that in many social sciences, the academic system rewards novelty and "originality" at the expense of methodological rigor, replication and efforts to produce cumulative knowledge (Gans 1992; Campbell 2019; Gerring et al. 2020). Career incentives hinge on innovation and productivity, which are not necessarily compatible with practices most conducive to cumulation (Gerring et al. 2020). As Watts (2017) puts it: "[Social scientists] are rewarded for publishing (...) in peer-reviewed journals and conference proceedings, most of which value novel, counterintuitive or otherwise interesting results over steady cumulative advances in knowledge. ... As a result, facts and theories pile up in an incoherent heap" (p. 2). Specifically, Heijden et al. (2021) find that middle-range theories capable of explaining governance processes and contributing to knowledge cumulation are used too rarely, too inconsistently, and too superficially. Following fashions and attention cycles, "novel" theories and concepts may replace old ones, which often have not yet systematically been applied or tested (Gans 1992; Flyvbjerg 2001; Gerring et al. 2020).

Post-modernist tendencies have also been identified as detrimental to cumulation: For sociology, (Turner 1991, 249–50) found that cumulation through theory formation has been challenged by "relativism, solipsism, and nihilism (...) to the point where nothing is universal, where all is contextual, and little can be systematized," structurally supported "by the proliferation of subfields that allow sociologists to 'do their own thing' without paying attention to common disciplinary canons." As a result, individual publications may each investigate "a unique problem with a unique set of variables," which is the principal reason why "we do not build anything cumulative" (Davis 1994, 179–80).

Overall, these observations on (non-)cumulation can be integrated under the rubric of "fragmented adhocracy" introduced by Whitley (2006) as one of seven major types of scientific fields. Referring to social sciences such as management studies, sociology and political studies, "fragmented adhocracies" denote fields in which "research is rather personal, idiosyncratic, and only weakly coordinated across research sites," where "scientists do not have to produce specific contributions which fit in to those of others in a clear and relatively unambiguous manner. Rather, they tend to make relatively diffuse contributions to broad and fluid goals which are highly contingent upon local exigencies and environmental pressures" (p. 159).

The aforementioned observations may lead us to conclude that the culture and structure of the academic system inhibit the production of cumulative knowledge—and which, therefore, would warrant reform (e.g., Davis 1994). Notwithstanding, there is a long-standing discussion as to whether the nature of social sciences, in being different from natural sciences, in fact allows for cumulative knowledge to be produced. Many acknowledge that social sciences cannot cumulate in quite the same way as the natural sciences (Ostrom 2006; Gerring et al. 2020). With human interactions as its subjects of study, social science research often does not permit experimental research and replication of studies (Gerring et al. 2020). Moreover, social realities change quickly and therefore require new conceptual framings, which constrain long-term comparisons (Gerring et al. 2020). Overall, the complex dynamics of human societies make universal law-like theories unattainable.

Taking an extreme position, Flyvbjerg (2001) asserts that "the natural sciences are relatively cumulative and predictive, while the social sciences are not and never have been" (p. 29), because, he argues, social science must be context-dependent by its very object, whereas cumulation would require context-free theory. Others have countered this assertion. For example, Ostrom (2006) argues that it is both desirable and possible to study complex social processes in fruitful ways, such as by identifying building blocks and understanding "structures and resulting processes and how specific combinations of elements affect the likely outcomes of these processes," so that cumulative knowledge emerges. Thus, even though social science appears to produce less cumulative knowledge than desired, this does not mean it cannot and will not cumulate.

2.2 | Specificities of Environmental Governance Research

While at its core a field of social science, EGR bears several peculiarities to be taken into account in the project of assessing knowledge cumulation. First, perhaps more than other fields of social science, EGR aspires to be practically relevant (Earth System Governance Project 2018). This may be related to the fact that governance—from Greek *kubernaein*, "to steer"—is about intervening into society (Mayntz 2022). Hence, in order for governance practice to contribute to problem-solving, it is important that EGR provide the cumulative knowledge necessary to do so (Schoenefeld 2023).

Second, EGR constitutes an interdisciplinary research field, relating inter alia to political science, international relations, public administration, sociology, planning, institutional economics, human geography, human ecology, innovation studies, and law. According to diverse governance scholarship (Kooiman 2003; Lemos and Agrawal 2006; Driessen et al. 2012; Challies and Newig 2019; Rose and Newig 2023), governance refers to the complex structures and interactive processes through which societies organize, coordinate, and manage their affairs, and operate toward reaching societal goals. Governing human–environment interactions through collective action, environmental governance arrangements may operate across spatial and formal-jurisdictional scales toward a range of causes such as the conservation and management of natural resources and social-ecological systems as well as the protection of human health. Much of EGR is guided by the idea of sustainability, acknowledging environmental limits, the needs of future generations, and the global impacts of local action (e.g., Biermann et al. 2010). EGR is young but rapidly growing, with no Scopus-listed publication before 1990; 41 publications in the 1990s, 665 in the 2000s, and 3073 in the 2010s (with the term "environmental governance" appearing in title, abstract or keywords).

Given its interdisciplinarity and young age, EGR has been characterized as relatively fragmented and not (yet) consolidated

as a field (Visseren-Hamakers 2015; Newig and Rose 2020; Khmara 2025). The call has been made for EGR to become more established as a study area of its own, with its own identity and methods (Tacconi 2011). Growing attempts at institutionalization are restricted to subfields of EGR. According to Cashore and Bernstein (2023), two important research communities exist in EGR: first, the "Earth System Governance" network (Biermann et al. 2019), with regular international conferences since 2009, a secretariat in Utrecht (NL), a related journal founded in 2019, and an elaborate institutional structure; and second, the "Environmental Politics and Governance" network, founded by Elinor Ostrom's student Aseem Prakash (Seattle, US), with a mailing list and annual international conferences since 2015. Both interdisciplinarity and young age may pose certain challenges to knowledge cumulation within EGR. Yet, interdisciplinarity also offers opportunities to cumulate around topical areas through knowledge integration (Tacconi 2011; Stafford 2018; Khmara 2025). Imagine, for example, that political science scholars investigate the national implementation of an international agreement on halting deforestation; they collaborate with scholars from public administration and anthropology who assess how local administrators, perhaps subject to corruption, do (not) enforce these rules; while ecologists and geographers use satellite data to help to determine local land-use changes as biophysical outcomes of the international agreements of interest. Hence, a plurality of disciplinary orientations, perspectives, and methods can be indeed beneficial to knowledge cumulation on shared topics of research (Bschir and Lohse 2024).

3 | So What Is Knowledge Cumulation, and How to Measure It?

Summing up so far, in many areas of research, and with respect to EGR in particular, lacking knowledge cumulation is bemoaned. Yet, there does not appear to be consensus on what exactly constitutes "knowledge cumulation" because this question has not yet been systematically investigated, let alone empirically measured. However, based on existing literature, the following aspects are emerging as important.

> In the broadest sense scientific results are cumulative if empirical laws and theoretical structures build on one another so that later developments extend and unify earlier work (Hedges 1987, 443).

There seems some consensus that knowledge cumulation is not equivalent to the mere production of new knowledge (Mahoney 2003). Regarding terminology, the term "cumulation" of knowledge seems preferable to the term "accumulation," even though the literature tends to use both terms interchangeably. According to (Abbott 2006, 6), "accumulation" is associated with "simply piling things up," whereas "cumulation involves commensurability, a building directly on things before, which implies in turn the mutual translatability—if not, indeed, the identity—of concepts, measures, and so on."

Following Davis (1994); Mahoney (2003); Mears and Stafford (2002) and Newig and Rose (2020), knowledge may cumulate on descriptive data and empirical findings, causation, and theories. While methodological knowledge can also cumulate, this is of less importance to EGR, which essentially draws from general social science methodology. Building on the above-mentioned literature, three basic forms or mechanisms can be distinguished through which academic scholarship can produce cumulative knowledge: (i) adding to existing research in the sense of confirming findings or widening their spatial, temporal, or topical scope/applicability/validity; (ii) challenging existing research in the sense of falsifying or rejecting prior research based on new findings or arguments (thus raising questions about quality or replicability, or the scope conditions under which prior and new findings may hold, or logical coherence); (iii) refining existing research by specifying scope conditions, causal mechanisms, amending sets of variables, or generating new hypotheses. While these may overlap to some degree, all pathways require that academic publications systematically relate to prior knowledge. Knowledge cumulation is thus about adding to, deepening, broadening, contextualizing, questioning, or rejecting existing empirical evidence and theoretical knowledge—on specific objects of research. Hence, the cumulation of knowledge requires—on the level of the research community—sufficiently similar research topics, concepts, research questions, and units of analysis (see, e.g., Bouvier 2009; Campbell 2019). Furthermore, in order to allow for cumulation, publications must exhibit sufficient "quality" (e.g., clarity of concepts and research questions, appropriate engagement with existing research findings, appropriate research design).

For assessing knowledge cumulation, we should hence distinguish between the level of individual academic publications and the level of a research community that provides the environment in which research activities and publications take place and that is, in turn, shaped by the activities and outputs of its members.

How, then, can we assess and "measure" knowledge cumulation at these levels? At the level of *individual academic publications*, we would need to identify evidence of one or more of the three mechanisms mentioned above—whether a study adds to, challenges, or refines existing research. However, this would necessitate an in-depth qualitative analysis of all publications under review. Given these constraints, our exploratory analysis adopts a more modest approach: Studying how research articles meet quality standards and the extent to which they engage with previous literature, e.g., through using existing frameworks, theories, or datasets, allows us to appraise their potential for knowledge cumulation. Beyond this, we also identify explicit efforts to synthesize existing, perhaps unconnected research, such as through systematic reviews or meta-analysis, as clear indicators of the actual production of cumulative knowledge.

At the "collective" level of *research communities*, we need to identify the prevalence of commonly accepted or shared frameworks, theories, concepts and datasets and sufficiently similar research topics, concepts, and research questions—for without these, knowledge production would occur in isolation, hampering knowledge cumulation. As Pfeffer (1993), 611 put it: "Without some minimal level of consensus about research questions and methods, fields can scarcely expect to produce knowledge in a cumulative, developmental process."

These considerations suggest that for a semi-quantitative exploration of knowledge cumulation, we may have to resort to

TABLE 1 | Metrics to characterize the extent to which research communities and individual articles enable knowledge cumulation.

Level of knowledge cumulation	Preconditions of knowledge cumulation	Facilitators of knowledge cumulation	Actual knowledge cumulation
Research community	• Shared concepts • Shared objects of research • Shared research questions	• Shared journals • Shared bodies of literature • Shared authorships • Shared frameworks • Shared variables • Shared datasets	• Empirically saturated theories[a]
Individual publications	• Scientific quality standards	• Replication • Comparative research design • Use of existing frameworks • Use of existing theories • Use of existing datasets • Data sharing • Engagement with the state of the art	• Synthesis (e.g., meta-analysis). • Thorough engagement with existing research to add to, refute, or amend existing research[a]

[a]Metrics not covered in this study.

proxies that capture the potentials for knowledge cumulation, its preconditions, and facilitators. Table 1 presents our initial effort to systematize metrics accordingly for both individual publications and research communities. To this end, we suggest distinguishing "preconditions" and "facilitators" for knowledge cumulation in the following ways. Preconditions' for knowledge cumulation include essential practices without which knowledge cumulation appears unlikely, whereas "facilitators" include practices that potentially enable and strengthen knowledge production without being necessary conditions.

For our study of knowledge cumulation and cumulability, the basic unit of analysis is the academic publication. While the process of cumulating knowledge—like that of research in general—may occur and be facilitated through exchange in different media, including through research collaborations and academic conferences, we adhere here to the widely accepted standard that produced knowledge materializes in the published record, specifically in academic outlets. Our research object is therefore knowledge cumulation in and through academic publications—both individually and as larger ensembles constituting a research community.

Based on the above considerations, we propose a number of metrics to characterize the extent to which research communities and individual articles enable (or inhibit) knowledge cumulation.

3.1 | Metrics Characterizing the Potential for Knowledge Cumulation in the Research Community

3.1.1 | Shared Set of Journals

Journals are joint references of research communities for publications and debates within and across journal editions. A high degree of publication centralization, e.g., in few journals linked to or edited by the community, facilitates publications that build on each other, so knowledge can cumulate. A strong fragmentation of publications across dozens or hundreds of journals, however, inhibits mutual reference. At the same time, publication centralization can also be too high and become detrimental to knowledge cumulation. This may happen when there are only a few recognized journals that act as gatekeepers to a siloed community and marginalize voices that challenge the established state of the art.

3.1.2 | Shared Body of Literature

A shared body of literature that is referenced and built upon is indicated by works that are cited by many community members and are serving as a joint frame of reference. A research community is more coherent the more of these joint references exist, the more of these joint references originate from this very community, and the more cross-citations among community members we observe, all of which facilitate knowledge cumulation. By contrast, loose citation networks indicate fragmentation of knowledge (Goyal and Howlett 2018). At the same time, a research community must not isolate itself from research originating from other communities, and citing (highly cited) joint references should indicate engagement and not a mere ritual of belonging (Mandard 2022).

3.1.3 | Shared Authorships

Knowledge cumulation is inhibited by a high number of small "research silos" that "do their own thing," talking past each other (Goyal and Howlett 2018; Turner 1991). However, if members of a research community avoid silos by collaborating on joint research and publications, knowledge from different research groups can relate more easily, and joint research programs can be established, both of which facilitates knowledge cumulation.

3.1.4 | Shared Objects of Research and Scientific Concepts

We distinguish *concepts*, i.e., conceptual abstractions of empirical phenomena; *topics*, i.e., topical contents of papers; and *objects of research*, i.e., instances of a paper's units of analysis. Sharing those can be considered a precondition of knowledge cumulation

(Mahoney 2003; Mears and Stafford 2002). Against the background of ubiquitous concept stretching, shared concepts also require shared—or at least similar—definitions. Different from many concepts in the "hard" sciences (e.g., energy, speed, photosynthesis), most, if not all, social science concepts can be interpreted in different ways and hence lack an unambiguous collectively agreed-on definition (Ansell 2021). It is therefore good scientific practice to define concepts used, and indeed this facilitates—and may even be indispensable for—the cumulation of knowledge. Inconsistent uses, or concepts that are so broad that they encompass very heterogeneous phenomena, however, limit knowledge cumulation (Jordan 2008; Newig and Rose 2020).

3.1.5 | Shared Research Questions

Knowledge can cumulate on shared research questions jointly pursued in a research community. This metric does not imply a narrow or homogeneous set of research questions in the community, but emphasizes the benefit of having research questions that are pursued by multiple authors and papers for cumulability.

3.1.6 | Shared Theories, Analytical Frameworks and Variables

As pointed out earlier, knowledge cumulation often happens around theory formation and the use of shared analytical frameworks. If the members of a research community continue to provide empirical evidence on shared middle-range theories and contribute to their joint further development, knowledge can cumulate (Freese 1972; Mahoney 2003; Newig and Rose 2020). Moreover, if research within a community draws on shared analytical frameworks and variables, this facilitates knowledge cumulation as knowledge can potentially cumulate around these variables and can support theory formation when the functions of the shared variables (i.e., independent, dependent and context variables) are considered as well (Mears and Stafford 2002). To quote Elinor (Ostrom 2009, 419), "without a common framework to organize findings, isolated knowledge does not cumulate."

3.1.7 | Shared Datasets

The same is true for shared datasets. A research community can build joint databases to facilitate the cumulation of empirical knowledge, which might also contribute to cumulating evidence on middle-range theories. This applies to both quantitative and qualitative data (Alexander et al. 2020). A lack of shared data sources, by contrast, inhibits knowledge cumulation (Flechtner and Sánchez-Ancochea 2022).

3.2 | Metrics Characterizing Individual Publications' Potential for Knowledge Cumulation

3.2.1 | Types of Articles and Research Designs

Some types of articles can be understood as particularly clear instances of *knowledge cumulation*. In particular, meta-analyses and (systematic) literature reviews serve to cumulate and synthesize existing knowledge (see, e.g., Jensen and Rodgers 2001; Rudel 2008). Replication studies serve to test and thus confirm or challenge existing research. Similarly, comparative case studies have the potential to cumulate knowledge around particular research questions. Individual case studies, too, may serve to cumulate knowledge if demonstrating how they add to or challenge existing knowledge. Some individual case studies, however, are idiosyncratic to an extent less inclined to knowledge cumulation (Blatter and Haverland 2014).

3.2.2 | Use of Middle-Range Theories and Existing Analytical Frameworks

To contribute to knowledge cumulation through theories, individual publications can empirically test theories and confirm, refine, or refute them. Moreover, they can contribute to theory formation through new data or new ideas. Furthermore, facilitating knowledge cumulation, employing an existing analytical framework for empirical analyses allows future research to cumulate empirical research in a structured way and may eventually benefit evidence-based theory development (Newig and Rose 2020; Richardson 2018).

3.2.3 | Use and Extension of Existing Datasets and Open Data

To facilitate the cumulation of empirical data and the resulting empirical analyses, the authors may use existing datasets, extend existing datasets, and provide their own data and its documentation for further studies (Pauliuk 2020). Data sharing and transparency can also be enhanced in qualitative research (Kapiszewski and Karcher 2020).

3.2.4 | Engagement With the Relevant Literature

To cumulate knowledge, authors have to consider all relevant literature and state how they contribute to it (Richardson 2018). They can do so by identifying gaps in the literature, stating where they might challenge the existing state of the art, or otherwise engaging deeply with existing works—instead of simply naming "predecessors who (presumably) wrote on the same topic" (Davis 1994, 183). As mentioned above, particular forms of engaging with existing literature are synthesis papers (systematic reviews and meta-analyses) and replication studies that test and strengthen or weaken the credibility of previous research.

3.2.5 | Scientific Quality Criteria for Cumulability

To allow other researchers to evaluate and build on their research (e.g., through well-embedded follow-up original research, replication or meta-analyses), the authors should meet widely agreed scientific quality criteria, among them clear definitions of concepts and variables, a clear description of methods (including case selection), the discussion of limitations, and the development of main conclusions that are fully based on the analysis (Mears and Stafford 2002). Hence, the

standardization and transparency of research procedures are key for knowledge cumulation (Gerring 2011, 91).

4 | Data and Methods

4.1 | The Earth System Governance (ESG) Community as Empirical Case

Research communities form a "natural" locus for knowledge cumulation (Becher and Trowler 2001). Here, exchange occurs, topics are formed and discussed, and relations are built. Regular conferences play a key role in academic exchange and the production of knowledge (Gross and Fleming 2011). Within the broader field of EGR, a number of research communities have been emerging, building their own institutionalized structures, partly also linked to specific journals, conferences, e-mail lists, and so on, typically embodying a particular set of authors (who may also associate and contribute to multiple communities).

As an empirical case, we select the ESG community, which counts as a paradigmatic example of an interdisciplinary, yet political-science-driven research association addressing environmental challenges (Cashore and Bernstein 2023; see Figure 1). For an interdisciplinary research community, regular meetings are particularly important to increase mutual understanding, integrate knowledge, and initiate cross-cutting collaboration, all of which facilitate knowledge cumulation. Since 2007, the ESG community has been holding regular (mostly annual) conferences in all world regions, which attract on average some 200 paper presentations. Seeing itself as a project, ESG has published science and implementation plans (Earth System Governance Project 2018; Biermann et al. 2019), making it an especially promising community for knowledge cumulation.

4.2 | Constructing a Database of 362 Published Articles From the ESG Community

To determine the body of literature emerging from the ESG community, we identified those publications that emerged from presentations at the ESG conferences. Hence, we define the body of ESG research as all journal articles that can be attributed to the abstracts accepted at ESG conferences. The challenging task was to correctly identify publications that sufficiently match the originally submitted conference abstracts. In the process from submitted abstract to published article, the set of authors, the title, and the content may change, following feedback at the conference or peer review in the publication process.

We developed a methodology to match conference presentations with published articles. We restricted our search and analysis to journal articles listed in Scopus, the world's most comprehensive curated database, covering the largest share of social science journals, and providing—unlike Google Scholar—structured meta-data (Gusenbauer and Haddaway 2020). Allowing for a five-year time lag from conference to publication, we included articles emerging from the first seven ESG conferences: Amsterdam (2007 and 2009), Colorado (2011), Lund (2012), Tokyo (2013), Norwich (2014), and Canberra (2015).

We conducted a careful comparison of (1) authors, titles, and conference abstracts with (2) potential journal publications listed in Scopus, independently done by two researchers (for the complete screening and matching guideline, see Newig and Rose 2021b). From a total of 1210 conference presentations, we identified 444 potentially matching Scopus publications. For every pair of "matched" papers, we calculated an average similarity index (0%–100%). To validate our matching effort, we contacted a random sample of 100 presenters of the first conference in Amsterdam 2007, asking them to identify the publication(s) resulting from their conference presentation, if any. From the returned 80 responses, we calibrated our matching, resulting in a cut-off value of 55% similarity. This way, we excluded 71 articles with similarity below 55%, yielding 373 Scopus-listed publications. We excluded a further 11 publications that appeared as duplicates because they matched multiple conference presentations (it is, in fact, not uncommon that a paper is presented at multiple conferences before or even after submitted to a journal). Hence, we arrived at a final dataset of 362 unique matching publications, which we define as the published journal output of the seven studied ESG conferences[1].

For bibliographic and citation analyses, we exported a data table from Scopus that contains the relevant meta-data (authors, year, title, keywords, abstracts, and also all cited references).

From the 362 journal articles, we drew a random sample of 100 articles that were independently coded by three researchers each, as the coding sometimes places high demands on

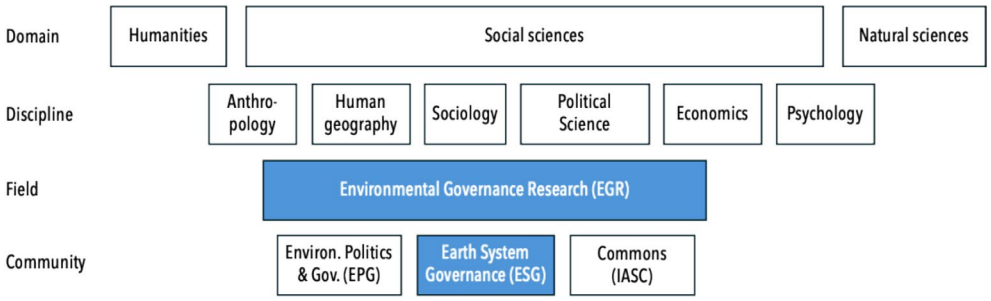

FIGURE 1 | The empirical case of the earth system governance (ESG) community as part of the field of environmental governance research, embedded in the broader science system. Note that this illustration is not an attempt to systematically map the science system.

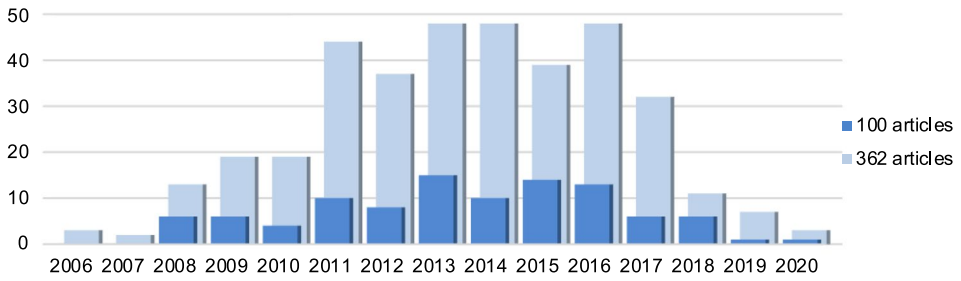

FIGURE 2 | Number of articles by year of publication in the whole dataset of 362 articles and in the random sample of 100 articles.

interpretation. We followed a comprehensive coding scheme (Newig and Rose 2021a), covering the metrics mentioned above in Section 3. Most items were coded on a three-point scale from 0 (absence or no importance) to 0.5 (partial or secondary importance) to 1 (full presence or primary importance). Coders met to discuss differences in coding but did not need to force consensus. For every item, the arithmetic mean across all three codes was calculated. Where appropriate, we will offer additional methodological details in the below presentation of our findings.

5 | Results and Discussion

Our sample of 100 randomly selected journal articles emerging from the ESG conference of the years 2007–2015 comprises journal articles published in the years 2008–2020 (Figure 2). For our subsequent analyses, we mostly use the sample of 100 coded publications. Where simple meta-data are available, we also draw on the full dataset of 362 articles.

Among the 100 articles, most (75%) are predominantly empirical studies, followed by 14% of conceptual studies, with only 5% literature reviews and another 5% perspective, commentary, or agenda-setting articles. We find no predominantly methodological or philosophical articles, no replication studies, and no meta-analyses.

5.1 | Cumulation-Relevant Characteristics of the Whole Research Community

5.1.1 | Shared Set of Journals

Table 2 shows the 10 most commonly used journals in the set of 362 articles, covering 40% of the publications (the top-five covering 29% of articles), while the remaining 60% are spread across a further 148 journals. While the ESG community has established its own journal, *Earth System Governance*, in late 2018, none of the articles in our datasets have yet appeared in this journal. In sum, the ESG community publishes its research in a broad journal landscape, with the exception of a few core journals, five of which each collect 20 or more articles from the community. However, even these "core" journals are not specific for the community, i.e., most papers published there are not clearly linked to the ESG community (Table 2, right column). From our own observation as practitioners in the field, we can confirm that it is not obvious which are the "top" journals or "standard" journals in the field; rather, journal choice appears very much contingent on concrete topics, opportunity (e.g., special issues), and, increasingly, impact

TABLE 2 | Most commonly used journals in the set of 362 publications, restricted to the publication years 2008–2018, in which 96% (347) of articles were published.

Journal name	ESG articles in our set	Total articles in journal	Percent ESG articles in journal
Global environmental politics	23	311	7.4%
International environmental agreements: politics, law and economics	21	327	6.4%
Global environmental change	20	1371	1.5%
Environmental science and policy	20	1664	1.2%
Ecology and society	20	1830	0.9%
Ecological economics	13	3086	0.4%
Environmental politics	8	586	1.4%
Marine policy	7	2549	0.3%
Regional environmental change	7	1306	0.5%
Environmental policy and governance	6	340	1.8%

Note: The table depicts the numbers of articles that appeared in each journal; the total number of articles per journal from 2008 to 2018; and the percentage of ESG articles of the total number of articles that appeared in a journal from 2008 to 2018, indicating the specific ESG relevance for a journal.

factor. These considerations, taken together, suggest to us a relatively fragmented journal landscape as regards ESG publications.

5.1.2 | Shared Body of Literature

Of the 20 scholarly works most frequently cited by the 362 articles (with the top-three cited works collecting 46, 28, and 27 citations within our ESG set, respectively), only three are part of the 362 ESG articles (Table 3). Whereas the number of citations indicates the *importance* of a work, its *specificity* for the ESG community set is expressed by the number of citations by ESG literature divided by the total number of citations in Scopus. In terms of specificity, the article by Biermann and Gupta (2011) scores highest (while being on rank eighth of the top-20 list and not part of the ESG set), with 12.6% of all its citations stemming from the ESG articles (Table 3).

The top 20 scholarly works cited in the ESG set can be attributed to six different literatures: (1) Social-ecological systems (Folke, Olsson, Smit), associated with the Stockholm Resilience Center; (2) global environmental governance (Young, Keohane, Haas), with ESG as a particular subfield (Biermann, Gupta); (3) institutional economics, as associated with the Ostrom workshop in Political Theory and Policy Analysis; (4) general public policy (Kingdon); (5) general environmental politics (Hajer); and (6) Earth system science (Rockström, Crutzen).

These findings suggest, first, that there is hardly a "core" body of literature that ESG research refers to. Only 11 scholarly works are cited by more than 5% of articles in the set, with the top one (Folke et al. 2005) cited by only 12.7% (Table 3). Second, none of the cited scholarly works are truly specific to the community, with the most specific article (Biermann and Gupta 2011) receiving 87.4% of its Scopus-listed citations outside the ESG set. Third, the intellectual basis, as expressed through the cited works, is truly broad and reflects the community's interdisciplinary nature, ranging from international relations and institutional economics to natural science. Thus, it is perhaps not surprising that the most-cited works pertain to a genuinely interdisciplinary literature (i.e., that of social-ecological systems research).

TABLE 3 | Scholarly works most cited by articles in the set of 362 ESG articles.

Reference	Articles in set?	No. of cites in set	Percent articles citing	No. of cites in scopus	Specificity
Folke et al. (2005)	No	46	12.7%	2779	1.7%
Biermann et al. (2009)	Yes	28	7.7%	514	5.4%
Stern (2007)	No	27	7.4%	5700	0.5%
Biermann (2007)	No	26	7.2%	341	7.6%
Ostrom (1990)	No	26	7.2%	15,963	0.2%
Young (2002)	No	22	6.1%	1163	1.9%
Ostrom (2005)	No	21	5.8%	1655	1.3%
Biermann and Gupta (2011)	No	20	5.5%	159	12.6%
Keohane and Victor (2011)	No	20	5.5%	682	2.9%
Dietz et al. (2003)	No	20	5.5%	2287	0.9%
Olsson et al. (2006)	Yes	19	5.2%	805	2.4%
Ostrom (2010)	No	17	4.7%	937	1.8%
Smit and Wandel (2006)	No	17	4.7%	2601	0.7%
Kingdon (1984)	No	17	4.7%	9440	0.2%
Gupta et al. (2010)	Yes	16	4.4%	417	3.8%
Hajer (1997)	No	16	4.4%	3995	0.4%
Rockström et al. (2013)	No	16	4.4%	5334	0.3%
Haas (2004)	No	13	3.6%	155	8.4%
Crutzen (2002)	No	11	3.0%	2112	0.5%
Rockström et al. (2009)	No	11	3.0%	2316	0.5%

Note: Column 1: Cited work; Column 2: Cited work's membership in the ESG article set; Column 3: Number of citations in the set of 362; Column 4: Share of articles in the ESG article set citing the work; Column 5: Total citations in Scopus until the year 2020 (i.e., the last year for which we have articles in our set); Column 6: Percent specificity of citations, expressed as cites in the ESG set divided by total cites in Scopus. *Methodological note:* We identified the most-cited references using the Scopus citation table. Since Scopus does not provide unambiguous references, we utilized VOS Viewer 1.6.20 and the AI application Julius to identify the top 50 most-cited references. The lists generated by both tools showed variations in the references and their citation counts. On this basis, we employed Excel's COUNTIF function to search the Scopus citation table for both sets of top-50 references, ultimately retaining the 20 most-cited references.

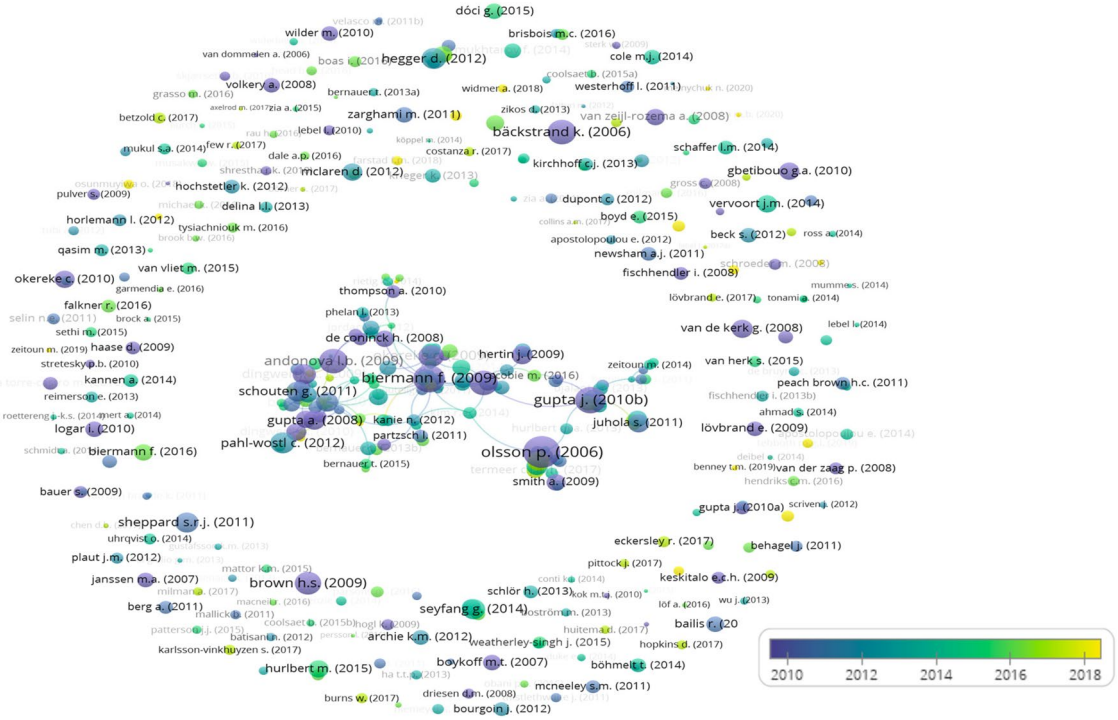

FIGURE 3 | Citation network of the set of 362 articles. Dots represent articles, with dot size indicating the total number of citations. Created with VOS Viewer 1.6.17.

The analysis of the citation network (Figure 3) yields a core network of 135 articles in the set that are well-connected through citations (even though there are, as mentioned above, no dominating highly cited articles in the set), while a large periphery is largely unconnected. Only 178 articles (49%) cite or are cited by others in the set. These results indicate a community with a smaller core of articles that build on one another and a larger periphery of articles that do not.

5.1.3 | Shared Authorships

Figure 4 shows the network of co-authorship among the set of 362 ESG articles. While the isolated clustered dots indicate individual (co-authored) articles, the largest connected set involves only 204 (=27%) of the authors. In addition, several medium-sized clusters are visible. However, our data cannot show whether co-authorships bridge potential silos. Overall, once more, there appears to be a "core" group of authors who are linked by various co-authored pieces, with a large "periphery" of author collaborations that are otherwise unconnected.

5.1.4 | Shared Objects of Research and Scientific Concepts

Table 4 displays the most-researched topics in the set of 362 articles, highlighting a pronounced focus on climate change-related issues, with 45% of articles addressing this broad area. On closer inspection, the articles cover a variety of individual climate-related topics, with 16% of all articles addressing climate change adaptation and 12% carbon or greenhouse gas emissions. The remaining climate-related articles primarily address climate change more indirectly, such as examining climate change salience in party manifestos or studying general tendencies in sustainability within the context of the climate crisis. Overall, the spectrum of issues, sectors, actors, structures, and specific policies is broad. In principle, the set of articles on specific topics—such as climate change adaptation—could provide an excellent basis for knowledge cumulation. We shall later see whether this is the case. However, the wide variety of studied topics in the ESG community may pose challenges for achieving genuine knowledge cumulation.

More precise than research topics are specific units of analysis. If articles address the same research objects as their unit of analysis, knowledge can cumulate. We find that in the set of 100 coded articles, most objects of research are unique. Thirteen research objects are shared by two or more articles (Appendix Table S1). The most common research objects include governance arrangements regarding climate-related issues (five articles on global climate governance, three articles on adaptation, two each on REDD+ and the Clean Development Mechanism) and water-related issues (three each on flood risk management and local water governance, two each on water governance in a German region, on national water governance, on water governance in Israel and Palestine, and on hydropower policy arrangements in Turkey).

Another important precondition for cumulating knowledge is the shared use of concepts. In contrast to *topics*, we study *concepts* as abstract ideas or theoretical constructs that help explain or analyze a phenomenon. Table 5 displays the most frequently used concepts across the set of 100 articles and the number of articles that use these as central concepts. Numerous articles use the relatively broad concepts of "governance" and "policy." As they can encompass a very broad

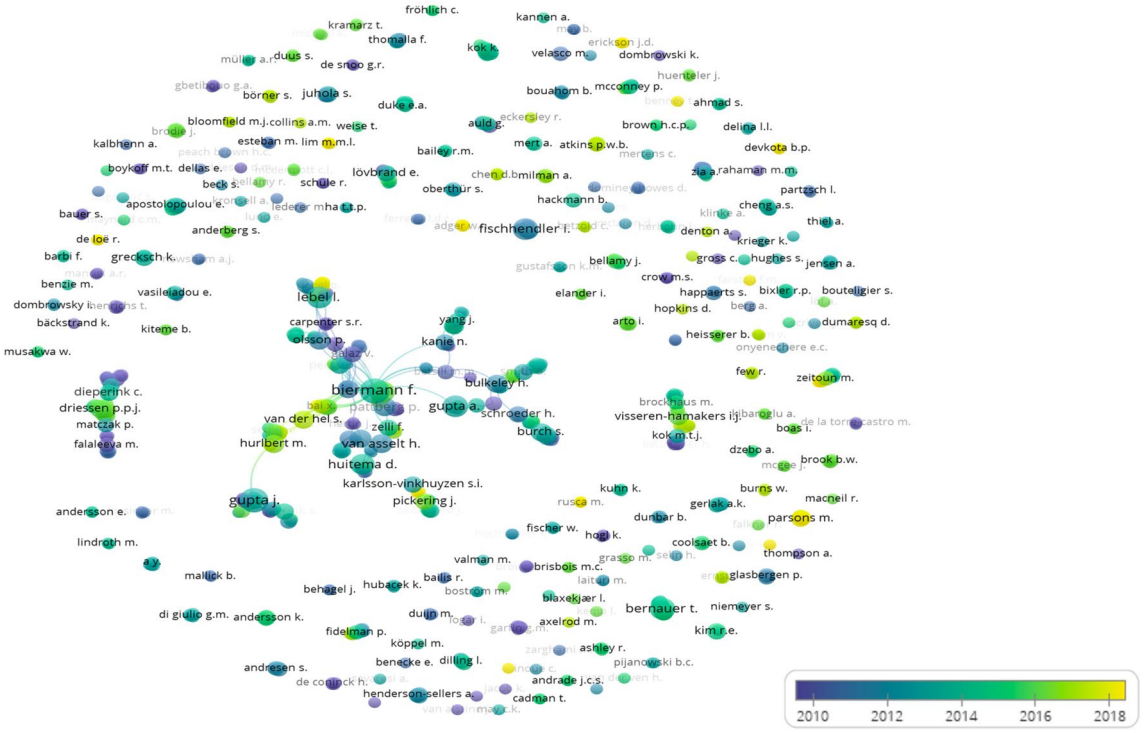

FIGURE 4 | Co-authorship network of the set of 362 articles. Dots represent authors, and connections denote co-authorship. Dot size indicates the number of co-authored articles. Due to technical reasons, not all authors have a name label. Colored shading indicates the year of publication. Created with VOS Viewer 1.6.17.

range of phenomena, they are not well suited for knowledge cumulation. Most other, more specific concepts are central to less than 10% of articles each. Hence, we may conclude that there is hardly a shared set of common concepts used across the studied articles.

Strikingly, we find that more than two-thirds of all concepts deemed important to the articles in which they appear remained undefined (Table 6). 25% of the articles' central concepts were defined by directly applying or adjusting existing definitions from the literature (Table 6).

5.1.5 | Shared Research Questions

In order to assess research questions (RQs), coders first extracted relevant text passages from the articles that mentioned RQs; if none were stated explicitly, coders identified text on the research aims or contributions of an article. In a second step, all RQs were manually grouped and compared for general similarity. A pair of RQs would count as similar if they approached the same governance topic with a similar perspective. For example, articles studying the emergence of environmental NGOs would count as having similar RQs; the same for articles studying factors leading to greenhouse gas emission reductions, or for articles on the benefits of collaborative governance—all regardless of the particular empirical object under study (particular NGOs, particular countries, etc.). Doing so, we did not quantify "similarity" or "difference" among RQs but only looked for RQs that were shared across papers.

Our analysis of 100 coded articles shows an extreme diversity among them, with almost every study posing a unique RQ. By way of example, we consider more closely the issue of climate change (cc) adaptation—one of the most-mentioned specific topics (Table 4). Keyword search within the 100 coded articles yields a total of nine articles on adaptation to climate change (Appendix Table S2). Three of these, all co-authored by K. Grecksch, share almost identical research questions (here: research aims, more precisely), namely to assess the adaptive capacity of a region's environmental governance sectors (articles 3–5 in Appendix Table S2). Two of these also aim to test the conceptual framework of the "Adaptive Capacity Wheel." These certainly present excellent opportunities for knowledge cumulation across different regional settings, drawing on the same conceptual framework, and by partly identical authors. Two further articles (7 and 8) have somewhat similar RQs. All other articles (1, 2 and 6) show quite different RQs (Appendix Table S2). So, even within the same studied issue, we find little common RQs.

5.1.6 | Shared Theories, Analytical Frameworks and Variables

If scientific communities use shared theories, analytical frameworks and variables, these can become anchor points of knowledge cumulation (Mears and Stafford 2002). An analysis of the 100 coded articles shows that there are only seven theories and two analytical frameworks each shared by at least two articles. Among the theories, deliberative democracy and discourse

TABLE 4 | Most-researched topics in the set of 362 articles.

Issues and sectors		
Climate	163	45%
Climate change adaptation	59	16%
Water and river basin governance	48	13%
Carbon/greenhouse gas	45	12%
Forests	32	9%
Cultural	32	9%
Natural resources	29	8%
Agriculture	26	7%
Conservation	23	6%
Ecosystem	22	6%
Mining	22	6%
Trade	20	6%
Biodiversity	19	5%
Flood	18	5%
Long term	17	5%
Coast	15	4%
Marine	14	4%
Food	13	4%
Consumption	12	3%
Renewable energy	11	3%
Specific international agreements		
UNFCCC	24	7%
REDD	15	4%
Actors and structures		
Cities	84	23%
Stakeholder	49	14%
Participation	47	13%
Negotiation	29	8%
Democracy	28	8%
United Nations	28	8%
Corporate/business	26	7%
NGOs	23	6%
Deliberation	19	5%
Partnership	15	4%
Civil society	14	4%
Agencies	11	3%

Note: Numbers indicate the number of articles that address the listed topic. Only topics addressed by more than 10 articles are listed. *Methodological note:* Topics were identified through text search in the title, abstract, and keywords of published articles.

TABLE 5 | Most frequently used concepts across the set of 100 articles.

Concept	Number of articles
Governance	37
Policy	15
Adaptation/adaptive	11
Sustainability/sustainable	10
Network	10
Participation/participatory	9
Power	9
Communities/community	9
Institution	8
Legitimacy	8
Public	7
Decision-making	7
Effective(ness)	6
Knowledge	6
Implementation	5
Regime	3
Capacity	2

Note: Included are concepts mentioned by at least 10 articles. Depicted are the number of articles in which the respective concept was used in an "important" way (importance score > 0.6 on a scale from 0 to 1).

TABLE 6 | Ways in which articles in the set of 100 define (or not) the concepts they use.

Kind of definition	Frequency
No definition	69%
Article's own definition	6%
Definition based on literature but with substantial adjustments	4%
Direct application of definition existing in the literature	21%

theory/discursive institutionalism are used four times each, and among the frameworks, the Adaptive Capacity Wheel is used three times. Overall, we observe that there are no dominating theories or frameworks that would act as common reference points for the whole community (see Appendix Table S3 for further details).

A similar picture results with regard to the variables employed in the set of 100 articles. We identified a total of 188 different variables through bottom-up coding, including only variables mentioned by two or more coders, with aggregation of very similarly termed variables. On average, each variable was employed

only 1.78 times across our dataset, with the vast majority of variables used only once (Figure 5). The top-5 variables, occurring seven times or more, are defined on a relatively abstract level: *adaptation/adaptability, participation, governance, justice*, and *policies*. The variables in our set are mostly employed as independent (213 times) or dependent (102 times) variables (Appendix Table S4).

When searching for joint variable constellations, we find that the three articles co-authored by K. Grecksch on adaptive capacities not only share a similar research question (see above), but also similar constellations of independent and dependent variables, reinforcing these articles' potential for knowledge cumulation. Apart from two other articles that share *legitimacy* as their dependent and *participation* as an independent variable, our sample does not include further instances in which multiple articles share two or more variables in the same function (dependent, independent, etc.). For example, there are seven articles which study some form of justice as their dependent variable (Appendix Table S4), but they all use different independent variables, including features of decision-making processes, people's economic status, geographic location, and actors' framings. What is more, the studied aspects of justice also vary across articles, including procedural justice, distributive justice, and multi-dimensional aspects of justice. While of course, justice is a complex concept, the differences in meanings studied across the seven articles and the different independent variables studied make it difficult to fruitfully compare, synthesize, or integrate—in short: cumulate—justice-related research findings across these articles.

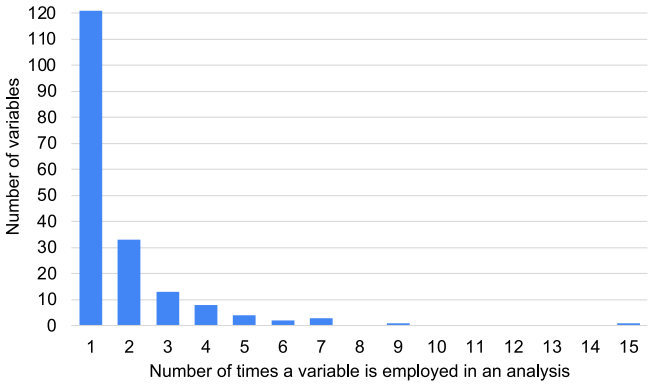

FIGURE 5 | Distribution of variables across analyses in the set of 100 articles.

5.1.7 | Shared Datasets

Shared datasets could facilitate knowledge cumulation within a community; however, none of the datasets used in the 100 coded articles are used by more than one article.

5.2 | Cumulation-Relevant Characteristics of Individual Publications

Details on the operationalization of the cumulation-relevant characteristics of individual publications are available in Appendix Table S5.

5.2.1 | Types of Articles and Research Designs

Among the 100 coded articles, there are no meta-analyses or replication studies, but five literature reviews, among them three systematic literature reviews. Review topics include regime complexity in global environmental governance (Visseren-Hamakers 2015), flood risk governance (Dieperink et al. 2016) and transnational governance in the minerals and mining sector (Auld et al. 2018). Across the 75 empirical articles in our sample, we identified 84 distinguishable analyses (which means than some articles present more than one analysis). Of these, 39 are single case studies (Figure 6). As regards the objects of analysis, governance arrangements are most often analyzed, followed by jurisdictional units and governance processes, with only a few analyses focusing on individual, corporate, or collective actors (Figure 6).

While comparative studies lend themselves more naturally to knowledge cumulation, this is not to say that single case studies cannot contribute to cumulative knowledge. A well-designed case study, when carefully embedded within existing literature, can yield significant insights. Comparing the potential of different types of studies to produce cumulative knowledge, we find that articles studying multiple cases achieve an average "cumulability" score of 0.46 (on a scale from 0 to 1), while single case studies score an average of 0.39 (see around Figure 10 for details on the "cumulability" index).

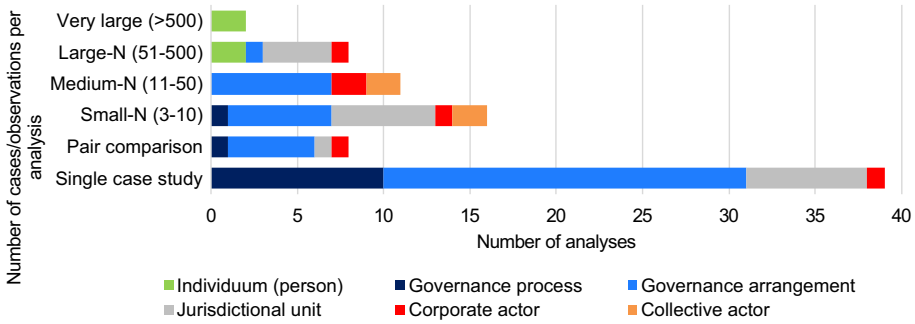

FIGURE 6 | Small-N versus large-N research designs: Number of analyses in the set of 100 articles, organized by number of cases/observations. (Every article can have up to three analyses.)

5.2.2 | Use of Middle-Range Theories and Existing Analytical Frameworks

ESG publications are mostly non-theoretical, i.e., most of them do not contribute to knowledge cumulation through theory development. Of the 100 coded articles, only six articles empirically tested and confirmed or refined existing theories, while no articles engaged in refuting theories or in building theories inductively from empirical research. No theories were further developed in a non-empirical manner, and only one article synthesized existing theories. Sixteen articles used theories to guide or interpret their empirical analysis without any substantial theoretical engagement as described above. The relative absence of theoretical engagement might be due to the interdisciplinary nature of the field of EGR, which tends to favor problem-driven empirical research at the expense of theory-guided research. Comparatively more empirical articles—23 of 75—directly applied or adjusted an already existing analytical framework.

5.2.3 | Use and Extension of Existing Datasets and Open Data

Of the 75 coded empirical articles, 13 use one or more existing datasets, while none extends an existing dataset. Twenty-eight articles provide the data they used, and another two justify why they cannot provide their data. Therefore, the majority of articles inhibit data-driven knowledge cumulation, as they neither provide their own data nor build on existing datasets.

5.2.4 | Engagement With the Relevant Literature

Within the set of 100 coded articles, 51 identify gaps in the literature and 28 explicitly state where and how they challenge the existing state of the art[2]. While 41 articles neither challenge the state of the art nor identify gaps in the literature, 14 of these engage with the literature in that they apply an existing framework, and one of these uses existing theory in a meaningful way (confirming, refining or refuting theory). None of the coded articles attempt replication of previous research (see above).

5.2.5 | Scientific Quality Criteria for Cumulability

A precondition of knowledge cumulation is that articles meet certain scientific quality criteria. We therefore developed a basic scientific quality index that we apply to our subset of coded empirical articles ($N = 75$) to allow for meaningful comparisons across articles and indicators (Figure 7).

With a mean value of 0.78 and a median of 0.81 (see Appendix Figure S1 for the distribution of values), articles' scientific quality does not appear to be a clear obstacle to knowledge cumulation. However, many articles are relatively weak on the transparency of their methods and, most strikingly, with regard to reflecting the limitations of their research (Figure 7). Over time, the scientific quality index remains almost stable, showing a slight increase (Figure 8).

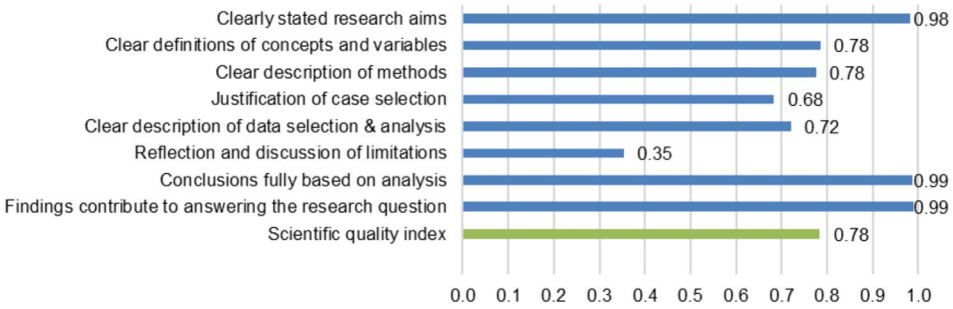

FIGURE 7 | Components of the scientific quality index and their mean values e[0;1].

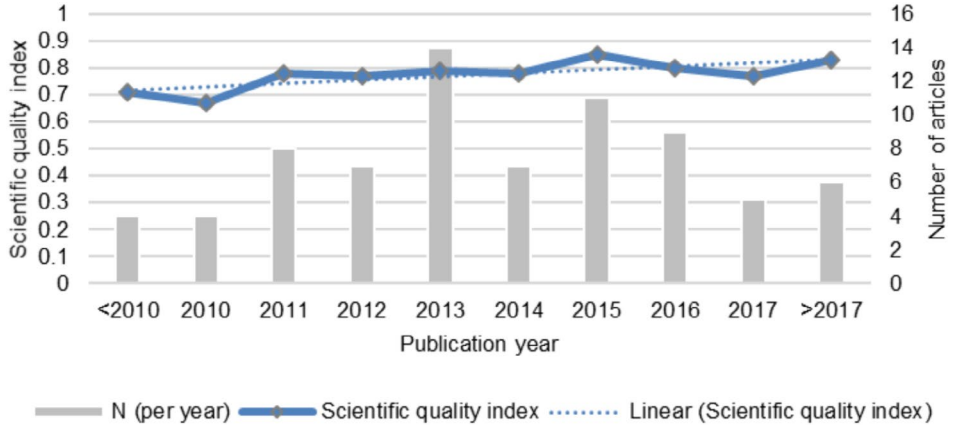

FIGURE 8 | Trend of the scientific quality index.

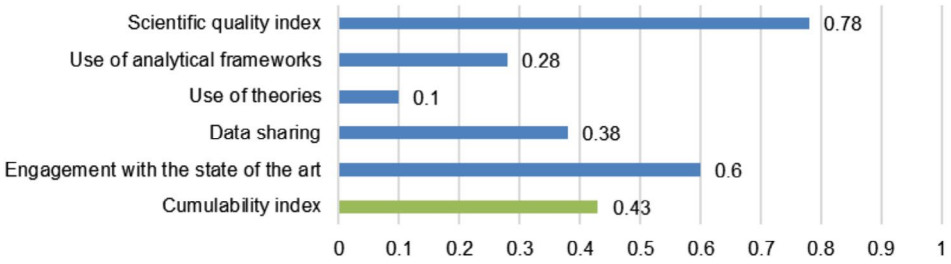

FIGURE 9 | Components of the cumulability index and their mean values e[0;1].

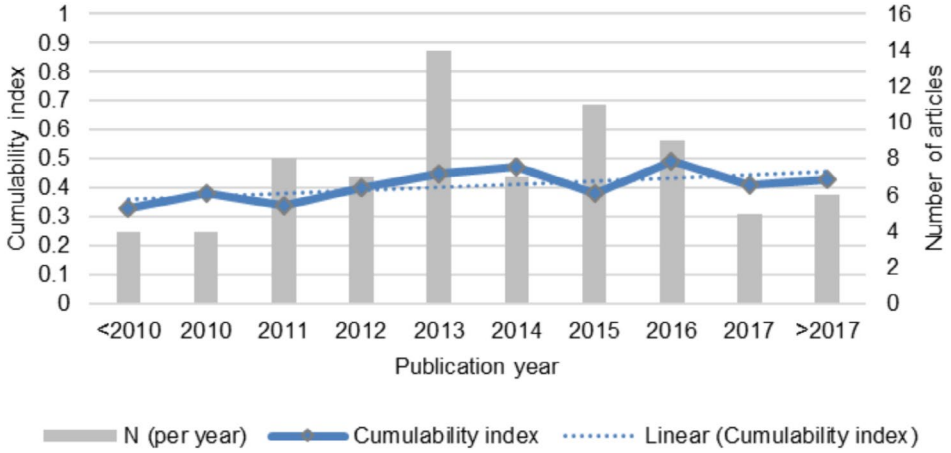

FIGURE 10 | Trend of the cumulability index.

5.2.6 | Cumulability Index

To summarize, we developed a cumulability index that measures the degree to which the research presented in empirical articles lends itself to knowledge cumulation. The cumulability index (e[0;1]) combines—by calculating an unweighted mean value—the arithmetic mean of the scientific quality index, the use of analytical frameworks (direct or adjusted application), the use of theories (empirically confirm, refine or refute a theory or build theory from empirical analysis), data sharing (proving data or a justification in case of non-provision), and the engagement with the state of the art (challenge previous literature or identify research gaps) (Figure 9).

The cumulability index is roughly normally distributed, varying between 0.12 and 0.77, with an average value of only 0.43 (Figures 9 and S2). The cumulability index increases slightly over time (Figure 10). The majority of articles' relatively low cumulability index is mostly due to a lack of use of theory and analytical frameworks, and the lack of data sharing.

The number of authors positively affects cumulability (correlation coefficient of 0.25), peaking at four authors (Figure 11). This suggests that to some degree, collaborative research benefits cumulability.

To a small degree (correlation coefficient of 0.16), the cumulability index positively correlates with the number of citations an article receives in a timeframe of 1 year prior to publication to 3 years after the publication year (Figure 12). This suggests that research that lends itself to knowledge cumulation also increases its take-up in future research.

6 | Conclusions

Many have critiqued EGR as non-cumulative, while highlighting that cumulative knowledge is essential for evidence-informed public decision-making to combat global unsustainability (Earth System Governance Project 2018; Newig and Rose 2020; Cumming et al. 2020). This begs questions of the actual (non-)cumulative nature of EGR and, with it, the challenge of defining, measuring, and assessing knowledge cumulation. This research presents, as far as we are aware, the first systematic effort at (1) conceptualizing knowledge cumulation and (2) measuring the extent to which knowledge produced in a research community lends itself to knowledge cumulation, taking the literature on ESG as an empirical testbed.

Drawing on a wide range of social science literature (Turner 1991; Gans 1992; Davis 1994; Mahoney 2003; Walliser 2009a; Gerring et al. 2020), we understand knowledge cumulation as a precondition of scientific progress. Knowledge cumulates by adding to, deepening, broadening, contextualizing, questioning, or rejecting existing empirical evidence and theoretical knowledge on specific objects of research. Knowledge may cumulate through individual contributions that build on previous research; through explicit efforts to synthesize existing research, and on the "collective" level of communities, topics, or fields of research.

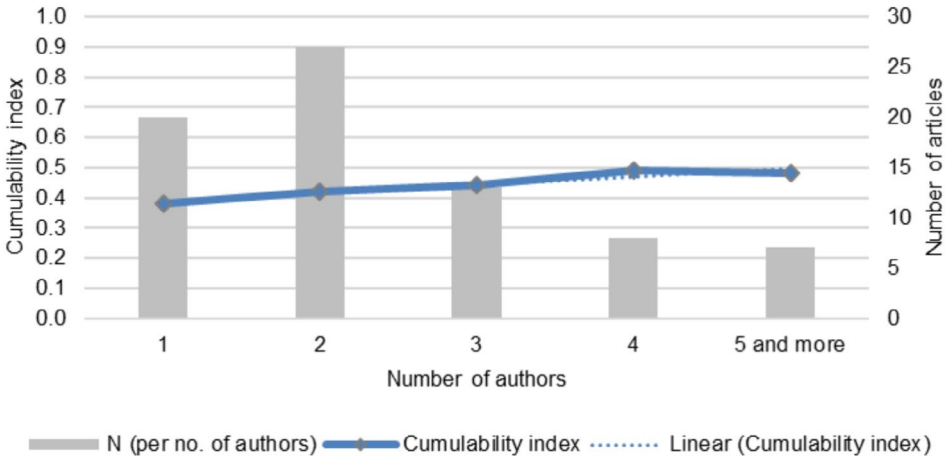

FIGURE 11 | Cumulability index per number of authors.

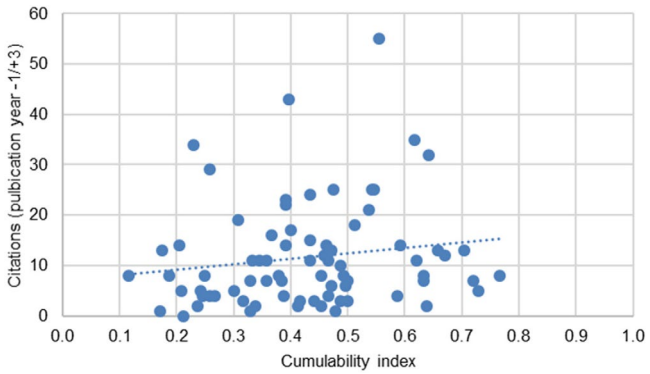

FIGURE 12 | Cumulation and citation per article.

To assess the cumulability of knowledge in a research community, we developed metrics for the community level and the level of individual articles, which we translated into an extensive coding scheme applied independently by three researchers for each article.

By the metrics developed in this study, our findings suggest limited potential for knowledge cumulation within more than a decade of publications by the ESG community.

On the community level, we found a core-periphery structure—both for the journals in which ESG research is published and the citation and co-authorship networks—with the periphery of largely unconnected authors, articles, and journals clearly dominating in quantitative terms. The most-cited scholarly works originate from different and usually interdisciplinary schools of thought and are relatively unspecific to the ESG community, indicating a lack of shared reference works that could facilitate knowledge cumulation. Concepts used in the studied articles remain to a large extent undefined. We find an enormous heterogeneity of research questions and topics, concepts, units of analysis, variables, theories, analytical frameworks, and datasets. While there are small thematic clusters on climate and water-related issues, this research largely operates with idiosyncratic research questions and sets of variables, hence offering little opportunity for knowledge cumulation.

On the level of individual articles, we found research designs to be dominated by individual case studies. Among the 100 coded articles, there are five literature reviews and no meta-analyses. While most articles meet basic standards of scientific quality, few articles contribute to theory testing and theory formation, and a minority of empirical articles use existing analytical frameworks or share their datasets. Two out of five articles neither challenge the state of the art nor identify gaps in the existing literature. Findings on an aggregative cumulability index suggest that middle-sized author teams best advance cumulability. Moreover, we found that articles' cumulability is positively associated with the number of citations they receive, which confirms the expectation that articles with higher potential for cumulative knowledge production are indeed more frequently built upon in subsequent knowledge production.

Taken together, our analysis confirms virtually all of the apprehensions on the relatively low potential for knowledge cumulation in an interdisciplinary community of EGR. Therefore, we may indeed label the ESG community as a "fragmented adhocracy" (Whitley 2006), characterized by practices of "do-your-own-thingism" (Turner 1991). Through the lens of Kuhn (1962), we could characterize the community as "pre-paradigmatic," in which there is no consensus on shared theories, assumptions or research questions. According to our analysis, the community's approaches, concepts, research questions and variables are so diverse that research contributions appears to talk past each other. Concepts are seldom used consistently across studies. The field is dominated by single case studies wanting synthesis and integration. Shared theories, datasets and analytical frameworks are rare. And while the works of others are of course cited, existing research is rarely truly challenged or built upon in such a way that genuine knowledge cumulation would emerge, with a few exceptions proving the rule.

The so-described nature of an EGR community contrasts with other fields of social science. Economics, perhaps the other extreme of the spectrum, is said to benefit from strong formal models, a unified ontology, and empirical accessibility, making it a highly cumulative field (Walliser 2009b). Of course, whether or not this outweighs the theoretical limitations of economics is another matter.

While our study is the first to explore knowledge cumulation with clearly defined metrics, it also has limitations. First, our research object allows only tentative conclusions on EGR as a whole. Despite significant efforts to match published articles with corresponding conference presentations, this process may not be perfect, potentially resulting in some false negatives and false positives. Then, we only coded a random sample of the ESG literature, which may have led us to underestimate knowledge cumulation at the community level. Moreover, our methodology does not capture ESG-relevant publications that were not previously presented at an ESG conference. However, we are not aware of any systematic distortions that would significantly alter our assessment of knowledge cumulation within our set of articles. Similarly, as we restrict our dataset to Scopus-listed English journal articles, we are missing book publications and articles written in other languages as a further literature basis for cumulative knowledge. We also did not consider products of the "Harvesting Initiative" of the ESG community that aimed to collect key research results primarily in book publications (https://www.earthsystemgovernance.org/research-findings-2). Finally, we have no indication to what extent our findings on the ESG community are generalizable to EGR more broadly.

Second, our metrics of gauging the potential for knowledge cumulation in the body of ESG research present only a first attempt at a systematic assessment. The extant literature on knowledge cumulation and scientific progress stresses the importance of (at least minimal levels of) consensus on concepts and research questions, common publication outlets, shared datasets, and so forth. Therefore, many of our metrics were designed to capture coherence or similarity within the studied body of research. This approach, however, has limitations because it disregards the problem of "too much" coherence, similarity, or concentration. Considering our findings of a highly disaggregated research community, this problem may seem hypothetical for the time being. Yet it is a fundamental question of just how much consensus and commonness is right for knowledge to cumulate. For example, while we found ESG research to be published in a relatively fragmented journal landscape, there is no standard as to what would constitute a "suitable" size of core journals and with what level of specificity to the community. For sure, a narrow journal landscape of a few highly specific key journals risks supporting silo building. However, exchange across research fields is essential for cross-fertilization and avoiding that the same topics are independently researched under different labels in separate communities.

What to conclude for cumulative knowledge production—both by individual research articles and across the research community? On the level of individual research articles, we observe a gradual increase in cumulability, while a significant fraction of articles do not fully meet standards of good scientific practice. Authors, supervisors, journal editors, and funders could and should put more emphasis on submitting, publishing, and funding high-quality research that thoroughly engages with the empirical and theoretical state of the art. Nonetheless, even articles that do not use existing datasets, analytical frameworks, or theory, or that are not particularly explicit about their contributions to the literature, could play important roles in knowledge cumulation—for example, through meta-analyses of case studies.

On the level of the community, it may be that we its value reaches beyond the immediate production of cumulative knowledge cumulation. Perhaps it is the "weak ties" (evidenced by what we identified as the large periphery in several of our metrics) that facilitate inspiration and productive exchange, which may ultimately benefit scientific progress. This would underscore ESG's role as a "bridging" community that brings together researchers from more specialized communities. Furthermore, we may also be witnessing what Pfeffer (1993) described as a trade-off between "values of inclusiveness and theoretical and methodological diversity," on the one hand, and cumulative knowledge production and scientific progress, on the other. These considerations beg questions on the role of research communities, academic conferences and other institutionalized forms of academic exchange for the production of cumulative knowledge.

We hope our research will stimulate debate on assessing knowledge cumulation. Next to the mostly quantitative metrics presented here, qualitative inquiries into how publications engage with existing literature will yield more robust evidence on actual knowledge cumulation. Further insights can be gained by comparing different communities within EGR. Future research may test our metrics in different fields and engage in comparative research by assessing knowledge cumulation and cumulability in other research communities. Moreover, studies with longer time frames can yield insights into the effects of community institutionalization and maturation on knowledge cumulation. Finally, further studies are needed to understand the links between cumulative knowledge and the practice of environmental policy and governance.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

[1] An alternative approach to defining the body of ESG-related literature would be to search for the term "Earth System Governance." This, however, yields only 85 articles in Scopus until the year 2020 that use the term in title, abstract, or keywords, whereas we identified 362 articles.

[2] While our analysis specifically focused on these two dimensions of engagement with the literature, they are widely recognized as key

mechanisms for advancing knowledge by pushing theoretical boundaries and addressing unanswered questions. However, we acknowledge that articles can contribute to cumulative knowledge through other means, such as through deep engagement with existing research. These modes of engagement are not captured by our coding framework and thus fall outside the scope of our analysis. Despite this limitation, our findings provide insights into the extent to which the articles in our sample actively contribute to cumulative knowledge by explicitly driving innovation or addressing gaps.

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