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Sociology for sustainability science

Stefano B. Longo, Ellinor Isgren, Brett Clark, Andrew K. Jorgenson, Anne Jerneck, Lennart Olsson, Orla M. Kelly, David Harnesk, Richard York

Discussion Research ID	DPR-2026-1337
Year	2021
Field	Environmental Science
DOI	10.1007/s43621-021-00056-5
Author ORCID	0000-0002-6409-8399
Licence	CC-BY
Original source	Discover Sustainability
Permanent link	https://discussionpublishers.com/research/8b4e578d-80da-4a08-8f3a-160979880ec9
Publisher	Discussion Publishers discussionpublishers.com

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Cite as: Stefano B. Longo, Ellinor Isgren, Brett Clark, Andrew K. Jor (2021). Sociology for sustainability science. Discussion Pub

Discover Sustainability

Discover

Perspective

Sociology for sustainability science

Stefano B. Longo[1,2] · Ellinor Isgren[3] · Brett Clark[4] · Andrew K. Jorgenson[5] · Anne Jerneck[3] · Lennart Olsson[3] · Orla M. Kelly[6] · David Harnesk[3] · Richard York[7]

Received: 26 August 2021 / Accepted: 20 October 2021
Published online: 27 October 2021
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Abstract
Sociological insights are often underutilized in sustainability science. To further strengthen its commitment to interdisciplinary problem-driven, solutions-oriented research, sustainability science can better incorporate fundamental sociological conceptions into its core. We highlight four aspects of sociological thought that we consider crucial for advancing sustainability science research: (1) social construction and critical realism, (2) structure and agency, (3) historical specificity, and (4) collective action. We draw on examples from sociology to support a dynamic understanding of how social relations interact with the bio-geo-physical world. This necessary integration of sociological insights, we argue, is critical to generate comprehensive assessments of the causes and consequences of human-induced environmental change, and tend to be overlooked or oversimplified within the field of sustainability science. Beyond that, it can stimulate the development and implementation of viable solutions to sustainability challenges.

Keywords Critical realism · Social structure · Collective action · Social relations · Environmental sociology

1 Introduction

Sustainability science emerged as a response to the numerous sustainability challenges that people and societies face. These involve nature-society interactions across spatial and temporal scales that can undermine the biophysical entities and processes on which humans and non-humans rely, such as a livable climate, clean water, healthy ecosystems, and productive soils. With its problem-driven and solutions-oriented agenda, sustainability science is committed to addressing concerns that are not necessarily defined by disciplinary traditions. To tackle the many complex and diverse socioecological challenges, it is therefore widely recognized that sustainability science research must be interdisciplinary[1] [1, 2]. As a result, the field has become diverse in terms of theory, methodology, and engagement with stakeholders. It uses a variety of frameworks and integrated approaches to develop distinct knowledge about sustainability issues and is gaining profound understanding of how to pursue such work [3, 4].

[1] There are many discussions in sustainability science regarding the benefits of transdisciplinary research. While we are familiar with these issues, we limit our discussion here to the widely agreed upon interdisciplinary nature of the field.

✉ Stefano B. Longo, stefano.longo@soc.lu.se | [1]Department of Sociology, Lund University, Box 114, 221 00 Lund, Sweden. [2]Department of Sociology and Anthropology, North Carolina State University, Raleigh, NC, USA. [3]Lund University Centre for Sustainability Science (LUCSUS), Lund University, Lund, Sweden. [4]Department of Sociology, University of Utah, Salt Lake City, UT, USA. [5]Department of Sociology and Environmental Studies, Boston College, Boston, MA, USA. [6]Department of Social Policy, Social Work, and Social Justice, University College, Dublin, Ireland. [7]Department of Sociology and Environmental Studies, University of Oregon, Eugene, OR, USA.

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While sociology is applied in sustainability science to some degree, we propose that a more consistent integration and systematic uptake would enrich the field in substantial ways. Sustainability challenges are essentially sociological in their origin in that they arise out of social structures, drivers, and dynamics, and call for changes in human behavior and social processes. Environmental problems, such as pollution of air, soils, and water, are undesirable, so why do they persist? Sociology offers useful conceptual tools and analyses to help answer this seemingly simple, but foundational question. Broadening and deepening our understanding of why and how environmental problems occur also improve the chances of effectively addressing them.

Sociologists study social relations in the context of structures and institutions where humans interact with each other and the larger world guided by norms, rules, regulations, and values. While sociology in general needs to do a better job acknowledging the natural bases of social life, we can extend its insights about social relations, processes, structures, and institutions to study society-environment dynamics. Since its emergence in the 1970s, the subdiscipline of environmental sociology has developed a research agenda and scholarly work that examine the deep and tangled roots of environmental problems in the social fabric. It can provide essential concepts and tools for sustainability research [5].

Given that it is seriously committed to critical interdisciplinary problem-solving, sustainability science must incorporate into its core the fundamental insights from the various disciplines it deems genuinely relevant. This clearly includes sociology because most solutions are social [6]. Pointing to sociology's role in sustainability science in this way is no more controversial than indicating that sustainability science researchers need to consistently draw on fundamental insights from biology or geoscience. Sociological contributions are essential for a robust, insightful, and efficacious sustainability science.

Yet, sociology is not a homogenous discipline [7–9]. What we emphasize here is critical conceptual and methodological thinking that is widely shared in sociology and invaluable for sustainability science. Foremost, we suggest four particular aspects where sociology provides insights that are indispensable for analyzing the causes and consequences of unsustainability and for developing viable solutions: (1) social construction and critical realism; (2) structure and agency dynamics; (3) historical specificity; and (4) the necessity of collective action for problem-solving. While other insights from the discipline can surely be considered useful, we argue that the overlapping and combined integration of these four aspects is analytically indispensable for understanding and addressing sustainability concerns.

Sustainability science is a dynamic and relevant field of research, generating knowledge on an array of sustainability challenges. Overall, our aim here is to briefly clarify how the aforementioned aspects of a sociological approach can be fruitful when analyzing sustainability concerns and why fundamental sociological insights are crucial for the continued advancement of sustainability science. A deeper, more consistent, and combined assimilation of these key sociological insights can improve understanding of and promote action on these increasingly weighty matters.

2 A sociological approach

Broadly speaking, sociology is a social science that pursues the systematic study of social settings, social aggregations, and social institutions, including the study of people's lives, groups, communities, and societies. Sociology is a methodologically pluralistic discipline, with empirical work consisting of a range of quantitative and qualitative approaches, and often with a combination of different methods and research designs. A key emphasis of the sociological approach, however, is social context, or the broad circumstances in which humans interact, make decisions, and behave. Institutions are the social fabric on which societies are built, and are central to producing social contextual conditions. In various intricate combinations, they constitute the sedimented structures of society and are generally quite durable. These institutions are the social entities through which humans move throughout their lives, from family, to work, to education, to political bodies, to spiritual communities and religious organizations. Institutions are a central locus of the norms and values upon which humans gain their social bearings, worldviews, and act upon the larger world [10]. Sociology emphasizes the significance of different and nested levels of analysis, from the micro, individual-level to the macro, aggregate-level. Yet, even at the micro level, structural conditions play a central role in developing knowledge [11].

Classical sociologists established the foundation for the science of sociology. Emile Durkheim defined it as a study of social facts, and Max Weber as the analysis of social action [12, 13]. They described the ways in which society shapes individual experiences and actions and how individuals coalesce into collectives. Durkheim stressed that social arrangements are not simply an outcome of numerous discrete individual acts. Rather, there are supra-individual social forces that exist independent of actors, *sui generis,* and exert real effects. These forces are "external to the individual, and endowed with a power of coercion," constraining the ways agents think and act [12]. W.E.B. Du Bois made clear that the social realm can

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be examined and understood in its own distinct terms, and, thus, sociological analyses produce a specific contribution to understanding the historical development of matters of the human condition, including social divisions and pathways to change [14]. Later, C. Wright Mills called this approach the "sociological imagination," which starts by understanding how peoples' biographies are formed by and rooted in both contemporary and historical structural contexts [15]. Starting from these foundational premises, sociologists generate insights on how social structural forces and processes affect human behavior and also transform conditions.

3 Advancing sociological analysis in sustainability science

Social sciences approaches, such as sociology, are regularly championed in the sustainability field as crucial for developing the types of analysis that are necessary for addressing the complex, or so-called "wicked," problems in the environmental realm [16]. Some scholarship in the field seeks to highlight sociological thought, for example in the ways technological systems are developed, adopted, and adapted, or examining consumer behavior in relation to sustainability concerns [17–20]. However, our intervention is motivated by the minimal engagement and integration of key sociological insights in much prominent sustainability science research. Concretely, this is evident in the magnitude of research focusing on individual responsibility, psychology, and lifestyle choices [21, 22], corporate responsibility and stewardship [23, 24], technological drivers and solutions [25], and consensus-based processes of stakeholder co-production [26, 27].

Research on these issues makes significant contributions to sustainability science and some of this work is presented as sociologically discerning. However, it is both problematic and telling that a recent review of sustainability science excludes environmental sociology as influential for building the field [28]. This is problematic in that it discounts a sociological perspective, particularly the key aspects we highlight here, as a useful basis for developing and enhancing sustainability research, and overlooks relevant sociological research on various socioecological relationships. It is telling in that it correctly demonstrates that the influence of sociology on the field's development is not as significant as it potentially could be, and, we argue, ought to be.

Most fundamentally, recognizing sociology as a core discipline within sustainability science can help: a) provide a more comprehensive evidence base on the nature of socioecological relations that avoids "reinventing the wheel"—that is, ending up with conclusions that, from a sociological perspective, are rather banal and should instead serve as a starting point for analysis; b) preclude conclusions and recommendations that, due to overlooked social dynamics, risk leading to paradoxical outcomes from a sustainability point of view; and c) ensure that strategies to promote sustainability are socially just and account for intersecting forms of inequality. Such outcomes are entirely consistent with the ambitions of sustainability science, a rich field that seeks to provide effective and robust solutions to complex but urgent sustainability problems, with an emphasis on socially tenable and just outcomes.

More specifically, a sociological approach can both enhance the potential for sustainable solutions and address some shortcomings in sustainability science research by moving beyond the individual; better emphasizing and accounting for social structure, institutions, and culture; highlighting taken-for-granted assumptions about human behavior; and analyzing social processes in ways that reveal the social bases of sustainability challenges. In what follows, we discuss the aforementioned four overlapping aspects of sociological thought that—if drawn on and integrated effectively—can play a valuable role in the continued advancement of sustainability science.

3.1 Social constructionism and critical realism

Sociology highlights that the norms, values, and generalized assumptions that often appear as common sense to most people are socially produced or constructed and particular to specific times and places. Peter Berger and Thomas Luckmann explain that "the developing human being not only interrelates with a particular natural environment, but with a specific cultural and social order." This conceptual method underscores the "social construction of reality," or the processes by which sociocultural systems shape ways of knowing and acting in the world [29]. The insights gained from this approach are essential for enhancing our understanding of socially mediated knowledge and practices, as distinct from biological or physical realities. The emphases on culture, knowledge construction, meaning, framing, and beliefs indicate the relativity of social phenomena, an indispensable feature of sociological and sustainability research alike [30, 31].

The social constructionist approach is applied to various aspects of social life, including the production of knowledge and processes of science. However, for sustainability science, social constructionism alone is insufficient. Firstly, sustainability concerns include physical environmental changes, which can—and do—have concrete effects on people's bodies

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and lives. That is, they are not only social in character, but necessarily have material dimensions. Secondly, the material dimension of life is the basis of society. It is well known that sustainability science requires an approach that spans and interconnects social and material elements, nature and culture [32].

In an influential article that details meta-theoretical orientations for understanding risks, environmental sociologist Eugene Rosa argues that a realist ontology accepts as a starting point that "a world exists independent of percipient human observations" [33]. The physical world is ontologically prior to our understanding of it. That is, the objective biophysical reality operates irrespective of human knowledge or interpretations. This approach maintains a commitment to materialism and the assumption that "the world is explained in terms of itself, by reference to material conditions, natural laws, and contingent, emergent phenomena" [34]. Realist orientations are often associated with an epistemology based in the natural sciences. As such, these postulations are familiar to most practicing sustainability scientists.

The distinct meta-theoretical assumptions of realism and constructionism, seemingly at odds, are brought together under a philosophy of science called critical realism[2] [35]. To clarify the power of such an approach, Rosa explains that it allows for the congruence of competing paradigms or meta-theoretical orientations (e.g., individualist, holist, culturalist, positivist). Significant here is the recognition that humans come to understand the world through socially constructed processes and conceptual tools, but that there exist, what Roy Bhaskar calls, "intransitive objects of knowledge" [35]. That is, these objects are "in general invariant to our knowledge of them." The world we understand is a representation of the world itself, but this representation is not all that there is. Conflating what we (can) *know* with what *is*, or reducing ontology to epistemology, is what Bhaskar refers to as the "epistemic fallacy" [35].

These distinctions are crucial for developing analytical insights in sustainability science. We argue that sustainability science must recognize that there is a socially constructed reality, but, of course, that this is not all. There is a world beyond our perception of it. Critically important is that this includes both a physical world and a social world structured by people and institutions, which opens up opportunities to further integrate knowledge across the epistemological divide between the natural sciences and social sciences. The material basis of life is the foundation for human social processes and has implications for their development and how humans construct sociocultural practices [36]. One-sided constructionist or realist approaches will often miss necessary analytical insights for effective sustainability analyses [37]. While the critical realist approach may, at times, be implied in sustainability science research programs, its explicit application requires a direct engagement with the ongoing interactions between social and natural systems—cultural constructs and biophysical condition—and provides an orienting foundation for the latter three components we discuss below.

Research in environmental sociology makes use of the social construction of reality and critical realism in a variety of ways. A well-developed research stream is the analysis of climate change denial. One version of denial does not necessarily deny that the climate is changing, but rather denies that climate change is a very serious problem. This view reflects a promethean cultural propensity identified by environmental sociologists as "human exemptionalism," whereby it is assumed that human ingenuity and technology can generally overcome natural limits or biophysical constraints; i.e., that humans are essentially "exempt" from such limitations [38]. Sociologists analyze how prevalent human exemptionalist views are formed and how they shape public perceptions and attitudes regarding environmental problems, which often serve to undermine support for climate mitigation and adaptation policies [39].

Another version of climate change denialism is based on challenging the validity of scientific knowledge, which highlights how public perceptions are—to a notable extent—socially constructed, being influenced by not only material reality, but also cultural processes. Thus, sociologists investigate how political and economic relations mediate knowledge of climate change and climate actions; how power and values shape the scientific process; how individual history and experiences influence knowledge; how ideologically motivated foundations and think tanks mobilize to shape public opinion; how media coverage of climate has changed through the years; and how social movements frame climate change [40]. On this front, sociology provides necessary insights regarding the plurality of conditions, relationships, and processes that influence understandings of climate change, which then affect public concerns, doubt, support, behaviors, and mobilization [39, 41–44]. It also reveals the organizations and means through which groups have marshalled to deny climate change or to delay institutional action [45, 46]. Sociological analyses, rooted in social constructionism and critical realism, examine how knowledge is generated in relation to changes in climate. This work illuminates how

[2] Here we specifically discuss critical realism, but the important aspects of this approach that we emphasize in this paper—notably bridging the social and natural—are often considered under different monikers such as cautious constructionism, critical materialism, or, as Rosa put it, hierarchical epistemology-realist ontology (HERO), among others.

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the everyday experiences of culture and climate interact and vary, in relation to social locations such as gender, race, ethnicity, indigeneity, and class [47].

In a broad way, critical realism motivates much research in environmental sociology, which recognizes that socially created circumstances must be analyzed in a manner that identifies the material bases of society and ongoing interactions with the biophysical world. This work advances research that integrates material conditions and processes into social analyses, and provides structural insights into numerous environmental issues and problems, including those associated with fisheries and pollution, among many others, and is often associated with an approach called "structural human ecology" [34, 48–50]. Thus, it provides the bases of a sociological approach that is easily assimilated into sustainability science.

A critical realist lens is an essential component for developing interdisciplinary research in sustainability science. It values both the natural and social sciences, and offers "a conceptual framework through which to view nature-society relations" [37]. This approach noticeably requires a reflexive stance from researchers on what constitutes best available scientific knowledge and practice. Critical realism presents opportunities for better integrating sociological analysis that can aid sustainability science in examining the interpenetration of the sociocultural and the biophysical realms within a broader dynamic whole, thus giving appropriate analytical emphases to both socially constructed and material components of sustainability challenges.

3.2 Structure and agency dynamics

Social structures exist and they are both socially constructed and real. They are "recursively organized sets of rules and resources" that are socially produced, reproduced, and patterned across space and time [51]. Sociological thought begins from the recognition that social forces act upon individuals in ways that are beyond immediate recognition and often taken for granted [52]. For example, we develop a collection of values and norms not entirely of our own making, but largely inherited from the past. This is of course true in the broader social world, but also, as a critical realist approach highlights and directly relevant to our discussion here, does not exclude scientists and researchers. These institutional realities structure societies and the experiences of individuals and groups, but can also be challenged, resisted, transformed, and transcended.

As with any structure, the social order that emerges shapes, constrains, and advances distinct conditions and possibilities. Humans are complex creatures capable of evaluating the world, making decisions, developing knowledge, and using that information to reflect on personal choices and those of others. The recognition that social structures are real and that they shape human behavior does not supplant the fact that individuals have agency, and that this is not a purely imposed agency. Sociologist Anthony Giddens clarifies that situated social actors reflexively and sometimes strategically "draw upon rules and resources in the diversity of action contexts," displaying social practices and monitoring others [51]. These processes contribute to the maintenance and formations of social structure [52]. But society is not simply the direct conscious product of human actions. As Durkheim highlighted in his classical work on religion, social structures emerge and exist independent of deliberate action, or the recognition of their role in human affairs [53].

Sustainability scientists must recognize the analytical importance of social structure, and should not proceed as if humans act only as a collection of separate individuals operating largely independent of social relations or structures. With analytical emphasis on individuals and discrete aggregates thereof (methodological individualism) including their actions, beliefs, needs, and preferences, we risk explaining the central drivers of sustainability problems and postulating the locus of solutions within each individual, or even within the individual's mind [54]. These common assumptions are often adapted from rational actor models. Such conceptions also buttress the information deficit model, which assumes that sustainability problems exist largely because of a lack of appropriate or effective knowledge. This position is not proven to be empirically useful, especially in regard to addressing climate change [55]. An approach that centers on individuals elides the powerful socio-historical forces that present us with a distinct (and often limited) range of conditions, choices, and potential actions, as well as important emergent properties, non-linearities, and conflicts of interest [56].

Sociology offers sustainability science theories and methods that put social-contextual matters, such as culture, economic conditions and processes, political systems and settings, and relationships within and between societies, front and center, integrating and emphasizing their necessity for analyzing outcomes [57]. In particular, structural approaches in environmental sociology investigate the macro-level processes that are key for understanding the broad relevance of social conditions for environmental concerns. This involves accentuating contextual factors, such as political-economic power and control, structural inequalities (within and between groups/societies), cultural processes, and norms when seeking to better understand sustainability problems and identify potential solutions. Studies that do so may draw on quantitative methods such as longitudinal and macro-level analyses of political-economic processes and trends and/or

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qualitative methods such as interviews and focus groups designed to capture specific socio-cultural dynamics, or case studies that can examine social institutions in depth. A structural approach reveals the significance of social institutions for behavioral actions, and avoids isolating individuals as ahistorical rational actors. It offers sustainability science further opportunities to develop more comprehensive assessments of sustainability concerns.

Thus, sociology provides key insights regarding the specific character, organization, and operations of systems and structures, which mediate the relationship between humans and the larger biophysical world [58–61]. Here, prominent structural approaches examine the various social drivers of environmental change, including general tendencies and patterns. Treadmill of production and metabolic rift research, for example, focus on how an economic system predicated on constant growth, whereby profits are reinvested to expand overall production, requires an ever-increasing expansion of resources in the form of matter and energy [62, 63]. The economic growth imperative, which generates revenue for firms and taxes for the state, produces a type of path dependency, in which profits are elevated to a primary goal of society, as seen in the people, profits, and planet conception of sustainability [64].

Sociological analyses dig into the "enduring conflict" between the economy and the environment, focusing on the conditions that generate an array of contradictions and paradoxes [62, 65–68]. For instance, technological innovation is often proposed as a means to reduce energy consumption through gains made in energy efficiency. This relationship, however, is more complicated. Improving efficiency often generates additional savings, which tend to be reinvested in ways that expand production and can eventually lead to more energy consumption, manifesting in the rebound or backfire effect. Social-structural analyses, which situate technological developments within the operations of the growth-dependent economy, help explain how such results can arise, providing a critical inquiry into why policies focused largely on improving efficiency are not necessarily sufficient to address sustainability issues, such as climate change [69, 70]. Further, sociological research on ecological modernization—while sometimes overemphasizing the role of technology—takes into consideration necessary structural factors, such as those stemming from politics and culture, that interact with and shape social change and its sustainability implications [71].

Sociological work in the ecologically unequal exchange tradition focuses on how inequalities in the structure of global production and trade networks contribute to more affluent nations in the global North outsourcing their consumption-based environmental impacts to less affluent nations in the global South, which increases forms of environmental degradation within the latter's borders [72]. Structural sociological research also demonstrates that economic development tends to have uneven effects on the environment, in for example fisheries, with less-affluent nations more likely to bear heavier burdens [73]. Sociological insights can also facilitate sustainability science research that elaborates on the scope and restrictions of human agency in the face of interlinked natural and social stressors, like climate change, conflict, poverty, and gender, racial, and ethnic inequalities [74, 75]. Drawing on sociology to study the ways in which intersecting social inequalities are associated with environmental problems is an essential component for advancing sustainability science and the promotion of equitable solutions.

Finally, another useful illustration of social structural impediments to sustainability is the growing body of sociological research on how the structure of the world's militaries, even in times of peace, generates an expansionary dynamic and serves as a major driver of environmental degradation. Militarism is a form of resource-intensive, coercive power for societies. Structural factors, including the need to continually transport, operate, maintain, and train on military equipment, are part of the reason that the Pentagon is perhaps the world's "leading consumer of petroleum" [76]. Sociological research also documents how militarism in the United States creates distinct patterns of environmental injustice, as the storage and disposal of its toxic wastes tend to be adjacent to Indigenous lands [77].

We do not suggest that these structural dynamics are completely ignored in sustainability science research. However, we argue that sociostructural forces are much more powerful and relevant than is often recognized, and hence unsustainable outcomes cannot be overcome just by changing individual behaviors or, for that matter, individual polices. Structural sociological theory and methods such as these can reveal the limits of approaches to sustainability that, for example, center on individual choices, technological innovation, stakeholder collaboration, or corporate stewardship, and bring us to our third foundational aspect.

3.3 Historical analysis and historical specificity

Analyzing structure and agency are crucial for understanding individual behavior in the social order, what Mills referred to as the relationship between "history and biography" [15]. Social structures involve historical processes that emerge, persist, and change and, in that sense, they are sedimented institutions. The work of the founders of sociological thought, especially those who focused on the importance of structural conditions and social relations—from Karl Marx to Max

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Weber to Charlotte Perkins Gilman to W.E.B Du Bois—were steeped in historical analyses. Understanding this importance, Mills argued that "No social science can be assumed to transcend history. All sociology worthy of its name is 'historical sociology'"[15]. Although historical analysis is foundational to sociological research, even in sociology its influence has receded in recent decades. Thus, we highlight here a useful methodological component that is not only relevant to sustainability scientists, but also environmental sociologists, and to which there is need for increased analytical attention.

Sociologist Craig Calhoun describes the power of a historical analysis as rooted in three essential insights brought out by historical specificity: (1) the importance of studying social change; (2) the problem associated with projecting "an illusory set of universal [social] laws" and the value of dispelling assumptions of "false necessity"; and (3) understanding the context for the production and application of analytic categories [78, 79]. Incorporating historical specificity helps illuminate social patterns and their transformations, which are "important to clarifying a trajectory that includes the present and understanding the options open, the paths closed, and the forces at work." Further, a focus on history and historical specificity is an effective "way of demonstrating what happens to be [i.e., socially speaking,] is not what must be" and avoids the analytical traps associated with taking for granted the necessity or inevitability of the current social conditions [78]. It aids in understanding why the social order is the way it is, instead of being slightly different, or, for that matter, very different [80].

Categories of scientific analysis are shaped by their historical settings [79, 81]. They must be understood and scrutinized, particularly in relation to the aforementioned point about false necessities [82]. For example, if sustainability analysts take the given social order and its institutional conditions to be a functional necessity (i.e., a functionalist position[3]), given that attention is paid to only one specific starting point or a limited historical period, then certain analytical categories might appear quite logical, even when—sociohistorically—they are not. Consider how ahistorical the conception of the economy is within the notion of the three pillars of sustainable development, where the growth-oriented market system is usually naturalized and removed from social relations [84]. In order to avoid these types of "common sense" oversimplifications, it is crucial for sustainability science research to recognize historically specific developments, such as the structural dynamics and social relation associated with capitalist economic development [85]. Further, the historical roots of social phenomena or structures can also be understood using theories of path dependence. By tracing "reaction sequences," defined as chains of temporally ordered and causally connected events, we can better explain what otherwise may be thought of as aberrant or exceptional phenomena [86, 87].

The implication of these points further highlights that social (structural) conditions influence the ways we interact with the rest of nature, but also that this changes over time. It suggests that sustainability scientists must be reflexive in considering their analytical categories, starting points, and critical events; which questions they ask and why; and what assumptions are inherent within theories and methodologies. This can help alleviate affinities toward functionalist or mechanistic analyses of society, which have a tendency to manifest in "a view of society as a self-regulating sociological order" [88]. More recently, this has been reproduced by the dominant discourse on the resilience of coupled social-ecological systems [89].

Sociological research using historical analysis can offer rich contextual case studies that provide valuable comparative insights, especially related to questions of continuity and discontinuity, stability and change. World-systems research, in particular, is crucial in this regard, as a central aspect of the analysis is the Braudelian notion of the *longue durée*, which accentuates extensive time periods or eras, and the broad social conditions produced, reproduced, and transformed over time [90–92]. Scholars in this tradition examine socioecological changes over centuries and even millennia [93–95]. For example, Stephen Bunker's path-breaking work on the Amazon provides a sociological analysis of the changing historical conditions in Brazil dating back to the era of European colonial control [96, 97]. This research reveals the significance of understanding how the broad structural conditions associated with colonialism, economic development, and "underdevelopment in the periphery" affected the extraction of resources, the social relations with nature, and the lasting social and environmental implications of these historical processes.

Sociologists have also examined long-term social conditions and relations associated with forestation and deforestation. This work indicates that the spatial and historical inequalities between nations, trade agreements, development policies, and the globalization of labor and commodities are central drivers of changes in forest ecosystems [98, 99]. Scholarship focused on landscape change, whether forest or urban, which incorporates the sociohistorical dimensions

[3] While functionalism has a long history in sociological thought—including structural-functionalism—it has been strongly criticized for its lack of political-economic analysis, presenting the social system as "intrinsically harmonious" [15, 83].

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of these processes, attempts to remedy ahistorical examinations "by providing convincing accounts for both *who* and *when* people have built roads that have triggered landscape transformations" [100].

Research focusing on the historical processes associated with commodity production generates distinctive insights regarding the ways that production systems change over time and their environmental implications. For example, in examining fisheries and aquaculture, the tragedy of the commodity approach details specific patterns of development, whereby extractive and productive operations are increasingly geared toward economically efficient processes, with vast ecological consequences in the modern era [101]. As a sociological response to the widely used tragedy of the commons thesis, it details how historical structural conditions associated with capitalist development, trade, consumption, and certain cultural practices change over time, leading to specific transformations in socioecological processes associated with marine systems. Such outcomes are quite common, presenting significant challenges to sustainability. For example, even though fossil fuels provided potential substitutes for whale oil (the main commodity from whaling), paradoxically the rapid growth of fossil fuel industry in the nineteenth and twentieth centuries accelerated whaling, because fossil fuel powered ships could catch far more whales than was possible by older technologies [102]. Accounting for these historical developments and interrelationships provides a richer understanding for the persistence of various contradictory outcomes in regard to sustainability goals.

Sociological research on social metabolism also offers critical insights on the changing nature of socioecological processes [103]. Drawing on the historical-materialist tradition, this research emphasizes that the dominant political-economic conditions influence the interconnection and interchange of matter and energy within and between society and nature. For example, major social shifts, such as the establishment of a feudal order or the rise of capitalist development have profound socioecological effects. The ways that societies, as part of the rest of nature, affect bio-geo-chemical processes changes over time, sometimes quite dramatically. These changes are structured by systems of production and consumption, which mediate the exchanges. Sociological research on social metabolism examines how the dynamics of capital shape the ways modern human society interacts with the rest of nature, and how this affects social and natural history. This scholarship identifies specific social and historical drivers of, for example, soil exhaustion, climate change, deforestation, pollution, and fisheries decline [104–107].

By emphasizing the historically specific character of conditions associated with environmental change, sociological research identifies persistent conditions that exert a broad influence on socioecological relationships. At the same time, this work illuminates historical transformations, revealing that social change and social stability are ongoing processes. Thus, it is also necessary to consider sociological insights regarding the role that collective action plays in advancing sustainable solutions.

3.4 The necessity of collective action

As a solutions-oriented field, sustainability science underscores the potential for social change and transformations for meeting sustainability goals. The centrality of social structures in generating and perpetuating sustainability problems, and the limited capacity of individuals in isolation to change social structures, means that addressing sustainability problems often necessitates "shared agency" or what in sociology is more often referred to as collective action [26]. Social structures can and do change over time, sometimes slowly, and often via incremental institutional change—and not necessarily in a direction that enhances sustainability. But throughout history it is shown that problems rooted in social structures can be successfully revealed and addressed through strategic collective action, and sometimes social change can be relatively rapid [108].

When it comes to tackling sustainability challenges, we further highlight collective action in the form of social movements. We do so given their capacity for putting new issues on the political agenda and their potential to bring about changes that in the absence of pressure from (many) citizens would be highly unlikely, due to misalignment between those changes and the interests of powerful individuals and groups [109]. Emphasizing the importance of social movements for addressing sustainability challenges provides openings beyond familiar recommendations of good governance or corporate stewardship [23, 110]. While the role of social movements is largely overlooked within sustainability science, there are signs that this is changing, resulting from a realization that sustainable development requires more profound transformational change than commonly seen today [111–113].

Sociological analyses in this realm are constructive for producing a richer understanding of when and why different forms of collective action emerge and persist (or not), and what factors help explain and shape their relative successes or failures in mobilization and achievement of specific outcomes [114]. Here, micro-, meso-, and macro-sociological approaches and their established sets of methods all have much to offer. The first emphasizes social psychology and

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enables understanding of what motivates and enables people to partake in collective action (or discourages them from doing so) through focusing on processes of social interaction, learning, and identity formation within and around social movements [115–117]. Macro-sociological perspectives target questions of how structural forces shape the emergence and evolution of collective action, which in turn may generate changes at a structural level [118]. Here, needed conceptual tools are provided by political process theory and its particular attention to the issue of political opportunity structures [119]. Much research also concentrates on the role of formal social movement organizations and their interactions with each other and their surroundings, especially from the perspective of resource mobilization, examining these matters at what could be referred to as the meso-level [120, 121].

Over time, this area of research has moved towards more synthesizing relational approaches aimed at understanding interlinkages and interactions between different processes and levels of analysis [122–124]. Applying such a relational lens to climate change, Doug McAdam, for example, analyzes barriers to grassroots activism in the contemporary United States. He points to three key issues: climate change awareness emerged during an inopportune political period, characterized by polarization and increased lobbying; the dominance of highly institutionalized and mostly moderate environmental organizations; and difficulties in developing a strategic frame and collective identity [118].

Other scholars examine notable mobilization efforts, for example, to understand the relationship between different activist tactics and tangible environmental outcomes [114]. Linking back to the discussion on social construction, it is further shown that social movements—whether "reactionary" or "progressive"—are also sites of knowledge production and contestation around contentious issues, such as the long-standing discussion on rural development and more recent debates on climate change [125, 126]. Among the many implications, this calls for the development of arenas where scientists and citizens are able to meaningfully interact [127].

Finally, critical insights regarding collective action for sustainability are found in work on environmental justice and equity, which (academically speaking) has its roots in sociology [128]. Most fundamentally, environmental justice movements and the surrounding literature highlight the interactions between environmental problems and different forms of inequality [129, 130]. They reveal the lack of adequate attention to the analytical categories of race, ethnicity, indigeneity, gender, and class within mainstream environmental movements and how these intersect in complex ways [131]. By highlighting how experiences of environmental issues are often socially differentiated and linked to persistent inequality, they also demonstrate how more salient frames that explicitly acknowledge these linkages can draw new groups to engage with sustainability issues [132, 133]. This aspect of sociological work is necessary for furthering sustainable solutions and just transitions.

4 Conclusion

With few exceptions, sustainability science's engagement with sociology is marginal [134]. We highlighted four overlapping conceptual and methodological aspects within sociology for integration into the core of sustainability science analysis and research: (1) the role of social construction and critical realism; (2) the dynamic between structure and agency; (3) historical specificity; and (4) the necessity of collective action. These aspects of sociological analysis bring forward the complex interchange within and between different scales and levels of organization, the social context and fabric that influence knowledge and actions, the way that human lives are nested within and between social institutions, the structural conditions that serve as social drivers of environmental degradation or restoration, and the obstacles and avenues for facilitating social change for sustainability. They reveal why human beings are not able to escape global environmental crises by mere technological solutions, or by simply changing individual behavior or specific policies. Instead, viable sustainability solutions require grappling with the complex social relationships and social structures that shape history. Through a more effective utilization of these sociological insights, a richer and more comprehensive sustainability science is possible.

The natural sciences are obviously essential for developing sustainability science research, and so are the social sciences [1, 3, 4, 6, 28, 135]. As the field has progressed, more work analyzes the social realm and socially oriented solutions—offering important contributions—as these are central elements in the practice of sustainability science. But a robust integration of crucial sociological insights is still limited. Further, sociologically based research—particularly insights from environmental sociology—has not been systematically incorporated into prominent research programs within sustainability science [28]. There are likely numerous reasons for this insufficient uptake. We suggest, however, that this is generally related to a lack of experience in and rigorous engagement with social theory, and inadequate recognition of the centrality of social forces when examining sustainability concerns. Other social sciences are also clearly

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important for studying these matters, but we contend that the integration of the aspects of sociological research that we highlighted here will further enrich investigation and understanding of the social dimensions of sustainability. While our contribution is largely programmatic, recently there have been attempts to develop heuristics for sustainability research built on sociological foundations, which illustrate how such integration can be done methodologically [136].

It is outside the scope of this paper to apply our suggestions to systematically scrutinize specific strands of sustainability science research. However, as previously noted, several prominent approaches in the field lack attention to or awareness of one or more of the four key aspects we have discussed—namely work that centers on individual consumer choices or technological innovation in ways that underplay structural forces and obscures the potential for collective action, or falsely portrays historically specific and socially constructed (albeit real) conditions essentially as inevitabilities. There is a need for increased reflection on the treatment of social conditions in sustainability science, which too often simplify social dynamics into functionalist terms and mechanistic processes and offer explanations overly reliant on rational choice theory [89]. What we propose here, as far as the integration of critical aspects of sociology into sustainability science, is very much in line with advancing the development of a reflexive science. There is precedent within science, and in particular sustainability science, for questioning dominant disciplinary assumptions and methodologies. Notably, the subfields of "post-normal" and "mode 2" science have long advocated for increased scientific engagement with non-traditional methodologies and audiences, to better account for the context specific complexities and uncertainties associated with global environmental change [79, 137, 138].

While not the focus here, other fields including sociology would also be wise to better integrate knowledge from sustainability science research—especially to break away from the human exemptionalism that remains all too pervasive in the center of many social science disciplines. Environmental sociology has a problem-focused legacy, largely examining the human drivers of environmental change, as well as their inequitable consequences. It could greatly benefit from deep engagements with solutions-oriented insights from sustainability science. In addition, some aspects of environmental sociology could enhance engagement with the natural sciences to better inform analyses and provide foundations and inroads into sustainability science. While cultural analyses of environmental issues in sociology have produced valuable contributions to our knowledge on these matters, sociologists could heighten their attention to biophysical questions in ways that are better suited towards sustainability science. Further integrations of these types are crucial for forging comprehensive sciences, advancing sustainability research, and addressing the world's socioecological problems.

Authors' contributions All authors contributed to the manuscript. The article was conceived and conceptualized by SBL and EI. The first draft of the manuscript was written by SBL, EI, BC, and AJ and all authors contributed and commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open access funding provided by Lund University. SBL received financial support from Lund University and The Swedish Research Council [grant number 2019–05766].

Data availability N/A.

Code availability N/A.

Declarations

Competing interests The authors declare no competing interests.

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