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Why care about theories? Innovative ways of theorizing in sustainability science

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The complex nature of sustainability problems and the aim of sustainability science to support emergent processes of transformation require rethinking how we build and make use of theories. We highlight the diversity of ways in which theories, as assemblages of different elements that can serve a variety of purposes, can emerge within inter-disciplinary and trans-disciplinary processes. Such emerging theories are (i) contextualized, constantly changing, and build on a plurality of knowledge from science and practice, (ii) embedded in change-making processes arising when diverse actors try to collectively solve a complex problem. We propose four ideal-typical modes of theorizing, and the notion of 'ecologies of theories', to explicate and further advance theorizing to meet the challenges and needs of sustainability science.

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Introduction

Sustainability science describes itself as a problem-oriented and solution-oriented field that aims to generate knowledge for sustainability transformations [1]. With a focus on problem-solving and action for sustainability transformations, theorizing is often considered secondary or even in competition with action. At the same time and as the field is maturing, the importance of theories and theorizing is increasingly being recognized [2,3••,4], and frameworks, propositions, and concepts abound. In order to resolve this tension and make theories useful for understanding complex sustainability problems and enabling transformative action, it is necessary to reflect on theorizing and the ways theories are being used. In particular, it is important to (i) recognize the diversity of research and engagement practices in the field and their distinct theorizing potentials, (ii) embrace the diversity of purposes and ways to build theories from more traditional scientific theorizing in the social and natural sciences to theorizing through change making processes and (iii) advance innovative ways of theorizing where theories emerge from joint problem solving in transdisciplinary change making processes [5••,6••].

When studying social-ecological phenomena, researchers often either make use of disciplinary theories or employ exploratory strategies with a reluctance to engage with theory. The former may be a consequence of the often disciplinary origins of sustainability researchers, a lack of SES theories, and the difficulties of developing them. The latter may be, among others, because of: a perception of urgency for action where there is no time for theorizing; concerns that existing theories do not fit the complex phenomena of interest and may constrain the search for social-ecological interactions; caution about rushing too quickly into theorizing complex SES and thus returning to the issues with grand theories or silver bullets that the field wants to avoid in the first place; or a stronger focus on developing new empirical data and methods rather than theory. Both, the use of disciplinary theories and the avoidance of theories, can be problematic. With the former, there is a danger of using theories whose assumptions do not fit the complex social-ecological realities of sustainability problems. With the latter one might miss opportunities for consolidating knowledge that emerges from co-production processes that engage with a plurality of understandings and experiences. Finally, while theorizing is part of action and practice, it is rarely seen as such, nor made explicit. Theories often enter policy making and practice implicitly in the form of principles or insights upon which action is then based. This linear application of science to practice risks missing important contextual dimensions and ignores theorizing that happens within practice.

In view of the aspirations and assumptions typical of sustainability science, what is considered theorizing and theories becomes broader than what is traditionally

conceived of as scientific theorizing and scientific theories. Here, we engage in a meta-reflection and synthesis of the existing and potential roles of theories and ways of building theory in sustainability science with the aim to make their contributions more explicit and advance modes of theorizing that support the needs of sustainability science. We do so by clarifying the different ways by which theorizing informs, emerges from, and has the potential to enhance inter-disciplinary and trans-disciplinary research in sustainability science and practice as well as by providing conceptual advances that view theorizing and theories as dynamic and continuously evolving. In so doing, we go beyond recent work that focuses on methodologies for theorizing [e.g. 2,4,7,8], critical elements and relationships [1] or types of causal assumptions [3••] that inform theorizing, work that clarifies the theoretical foundations of concepts or frameworks [9,10••], highlights the challenges of different ontologies and epistemologies in the social and natural science [11] or develops middle-range theories [12,13]. Our work has relevance to future directions for sustainability science in its endeavors to link theory and practice in more complexity-aware manners. Furthermore, by highlighting the potential of novel ways to theorize, this article may inspire new endeavors that mobilize and leverage theoretical work both in disciplinary science and in inter-disciplinary and trans-disciplinary research more generally.

Aspirations of sustainability science and its consequences for theorizing

The complex and intertwined nature of SES (Box 1) as well as the field's mission to contribute to societal transformations challenge us to rethink both *theorizing* as a process and *theories* as the outcomes that result from it. Theorizing in sustainability science can rarely be done from the armchair by a lone scientist, but takes place in collaborative deliberation and learning processes that may involve a diversity of actors across disciplines (interdisciplinary) and beyond science (transdisciplinary). Such collaborative processes, which are often embedded in specific contexts, are important for understanding complex social-ecological interdependencies through deliberation, joint sense-making and acting within the system of investigation [5••], as well as for engaging multiple value and knowledge systems. Theorizing in sustainability science is as much about generating knowledge for understanding and action as it is about working with actors to learn how to address problems, so that solutions can in turn become adaptive through mutual learning. Finally, theorizing is not only done through observation and interaction from the outside as researchers are part of the system they study. Rather, theorizing often emerges when asking where researchers are positioned in relation to the SES they investigate, how they contribute to framing and defining such systems, or how they interact and intervene in them [17,18].

Box 1 A social-ecological systems perspective

Sustainability science encompasses different research arenas that share an interest in creating knowledge relevant for societal transitions towards sustainability [14]. These arenas or subfields have different disciplinary roots and take different perspectives. This paper argues from the position of social-ecological systems (SES) research and the complexity perspective it takes [15]. A complexity worldview entails a relational and dynamic understanding of SES, that is, SES elements, structures and behaviors emerge from social-ecological relations and processes. For instance, the collapse of the cod populations of the Baltic Sea emerged from interactions between fishers, the fish populations, the marine environment, the economy and Swedish fisheries authorities [16••]. SES behaviors are continuously changing, context- and path-dependent, and influenced by feedbacks and processes across multiple levels and scales. The complex and social-ecologically intertwined nature of SES has implications for how we study and engage with them, as it entails dealing with complex causation, irreducible uncertainty, unpredictability, heterogeneity and context-dependence. Research and action are faced with multiple explanations (e.g. equifinality and multifinality); and a plurality of views, values, interests, and power positions. It also implies overcoming the dichotomy between the social and the ecological as well as to reconsider the researcher not only as an external investigator of systems, but also as embedded and part of those systems [17]. The latter changes how knowledge is generated but also how knowledge and action are linked [5••].

The outcomes of theorizing processes in sustainability science, that is the theories, also differ from the rigid constructs of more conventional disciplines. They continuously evolve, and take on many different purposes and shapes. Embedded processes of theorizing result in theories that are bounded based on context specificities and contingencies of place-based sustainability challenges, while also being attentive to the multiple-scale and cross-scale dynamics inherent to SES [12,19]. They are informed by and reflect the diversity of worldviews, values and goals that characterize SES [8]. Importantly, these theories contend with and reflect the complex and intertwined nature of SES by emphasizing social-ecological relations and interactions as foundational for explanation or guiding action. The complexity of SES requires theorizing to contend with alternative explanations for the same phenomenon that may be valid under different conditions [20]. Finally, SES are evolving, with reflexive agents, such that a theoretical explanation or guide for action that was valid in the past may not be in the future.

We are aware that many challenges of complexity are not unique to sustainability science. Yet, the need to integrate theorizing of social and biophysical processes together with the necessity to consider multiple understandings, interests and values in the support of transformation processes pose additional challenges that are quite unique.

Diversity of purposes of theorizing

The aspirations and needs of sustainability science entail a diversity of purposes for which theories are being built.

They range from explanation, description or interpretation of a phenomenon to use for deliberation, decision-making and action (Table 1). Theories used for explanation specify causal mechanisms or relationships between variables, synthesize knowledge, frame the research process, specify conceptual foundations and guide the researcher, explain change or predict system behavior. Theories are also used to inform actions such as policy, management, or a change process or provide principles for generating systemic change. Finally, theories can emerge through action, and theory building may aim to understand and/or improve action itself. Of course, these are ideal-types. In reality, there is no crisp boundary between these categories, but rather a gradient, where a number of theoretical efforts being quite clearly 'explanatory' or 'action' oriented, but also a number of efforts falling somewhere in a grey zone in between (illustrated by the grey area in Table 1). Further, the same theory or set of theories can serve multiple purposes.

Table 1

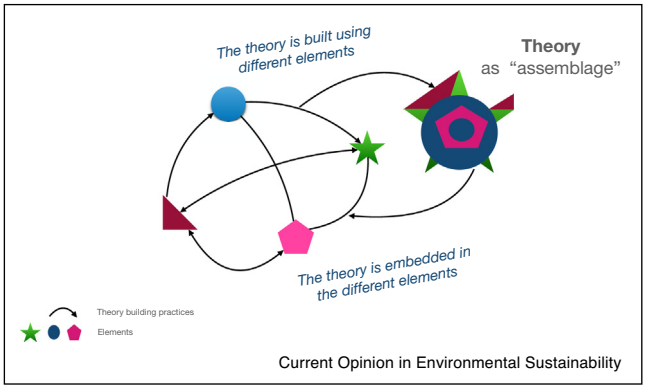
Examples of sustainability theories for different purposes. The grey area illustrates the fact that the boundaries between explanation and action are blurry and there is a gradient from 'explaining how the system works' to 'explaining transformations' to 'guiding and accompanying action'

Example applications of sustainability theories of different types and for different purposes			
General Purpose	Specific purpose	Description	Example
Explanation	Framing or guiding a research process	Theory or framework highlights a set of variables that have proven to be relevant for explaining a specific phenomenon, indicates high level relationships between system elements, and supports hypothesis development and testing	The SES framework: Identifying a common set of variables influencing likelihood of self-organization in local resource use and management [23]. Theory of access identifying the factors that influence how actors access natural resources [24]
	Specifying causal factors or causal mechanisms	Theory that proposes a causal mechanism for explaining a phenomenon	Multi-level poverty traps: Understand causal mechanisms that generate poverty traps and predict outcomes of possible interventions [25] Mechanisms that explain impasses of governance for adaptation [26]
	Predicting system behaviour	Theory used to formulate expected results or outcomes of a process. Theories specify a precise set of conditions under which one or the other outcome can be more likely (noting that unless the set of conditions is exhaustive, this remains a tentative prediction, not a 'law')	Theory specifying the conditions under which land use intensification may result in land sparing versus rebound effect [27]
	Synthesizing knowledge	Theory that synthesizes available knowledge of a particular phenomenon and makes it available for research, for example by identifying a set of key typical, stylized pathways that can summarize much of the empirical reality.	Theories of forest transition [e.g. Ref. 28] Archetypes of social-ecological systems and their dynamics [e.g. Ref. 29] Theories of collapse [30]
	Explaining transitions or transformations	Theories and frameworks that propose key elements and processes and their interactions across levels in socio-technical transitions or social-ecological transformations	Multi-level Perspective [e.g. Ref. 31] Social-ecological transformations [e.g. Ref. 32]
Action	Framing or guiding transitions or transformations	Theories and frameworks that target interdependencies of institutions, technologies, mindsets, and actors to steer complex systems towards sustainability	Leverage points: Identify root causes of unsustainability and realms of leverage points to support transformational sustainability interventions [33].
	Informing interventions	Theories used to develop a theory of change that specifies how an intervention on some specific variables might allow to deliver desired outcomes.	Resilience causal chains: complex SES theories used to design a theory of change to capture complexity of household gender norms and resilience to inform interventions to build resilience capacities in households [34]
	Providing principles for generating systemic change especially in organizations	Theories used to frame processes of change especially in organizations (such as businesses) through management principles that work across organizational contexts.	Management theory for sustainability [35]; Theory of robust action applied to sustainability transformations [36]
	Informing action and change processes in local contexts with multiple actors through learning	Theories that emerge through knowledge co-production and transdisciplinary methodologies involving multiple actors and based on broader theories of individual and social learning aiming to empower and enable actors to create change on their own behalf	Resilience assessments to co-produce understanding of system dynamics for collaborative response options [37,38]

Diversity of positions of researchers in theorizing

Because of its multiple purposes and the complexity of sustainability problems, theorizing in sustainability science may unfold in many different ways. One important distinction is whether the researcher acts as an external observer or is embedded within the system they seek to observe. The former reflects the more conventional way of understanding research and theorizing as from the outside [17]. The latter is common, for instance, in reflexive, participatory and action-oriented research or in sustainability practice. Through collaboration and participation, relationships between researchers and practitioners, but also between participating actors and the SES of interest, are mobilized and thus are not only objects of investigation but become involved in generating theoretical insights. Knowledge in change processes is thus not applied to action, but rather produced and used within a situation, shaped by the outcomes that emerge during the process [5••,6••]. These processes mobilize multiple value and knowledge systems within the system [6••,21] and more often attend to the normative dimensions of sustainability research than when theorizing from the outside [22].

Figure 1



Different elements that support the process of theorizing and how the theory feeds back onto the elements. The shapes on the left side represent various elements used in theorizing; the arrows represent epistemic activities that contribute to theorizing as assembling; the assembled shape on the right visualizes a theory as an assemblage. The thicker lines indicate how the theory emerges from the assemblage while at the same time giving meaning to the elements of the assemblage.

Different modes of theorizing

Theorizing as the process of assembling different elements into a coherent structure

In a general sense, theorizing can be seen as the process of assembling different elements into a coherent, often causal structure that can help to understand a real-world phenomenon and be part of action processes (Figure 1). The elements assembled vary depending on the questions addressed as well as the purpose of theorizing. In more conventional science, the elements are often restricted to concepts, models, existing theories, and empirical observations. In sustainability science, other elements such as people's values, social norms, cultural attitudes, ethical principles, historical and personal narratives also animate the theorizing process. The importance of different elements and their relations during different stages of a theorizing process (triggering, developing, and evaluating a theory) varies depending on the mode of theorizing (see Section 'Different modes of theorizing' below).

The theories, or assemblages, that emerge can be expressed in a multiplicity of ways, such as through narratives, principles, a set of causal relationships, deterministic equations, statistical relationships, or stochastic models. In the case of theories of forest transitions, for example, the concept of *pathway* and models of *transitions* are combined in order to provide a causal understanding of the way forest landscapes change. The theory is empirically based and allows for synthetizing insights from multiple cases into a set of typical pathways. Each element used in the assemblage process (e.g. the model of transition or the concept of pathway), once part of the theory, acquires a specific meaning within the overall theory.

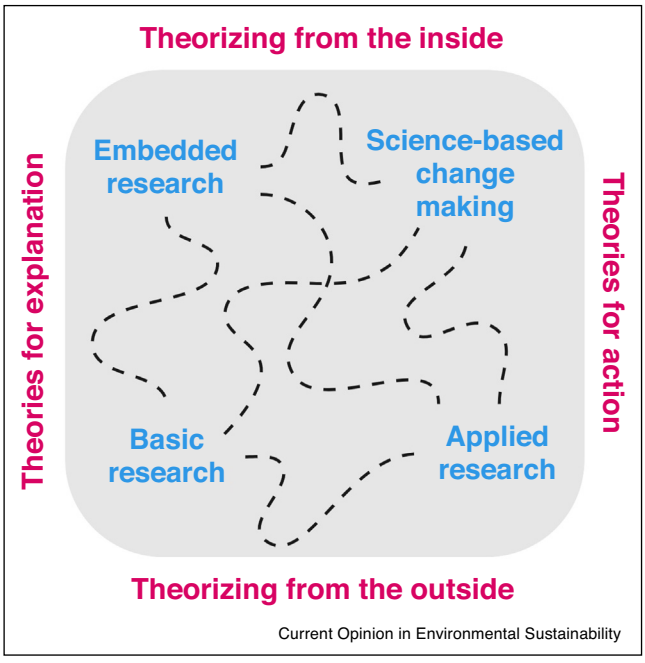
When working with multiple disciplines and knowledge systems the process of assembling has to take into account the deeper level of ontological, epistemological, and axiological assumptions in which the different elements are assembled. This deeper level of theorizing underlies all reasoning and 'problem-solving', and influences what elements might or might not be assembled. Examples of such deeper-level theorizing are knowledge-sharing processes that aim to bridge multiple knowledge systems, such as those of indigenous communities and researchers [39], or fundamental reflections about the relationship of knowledge and action [5••,6••]. Theorizing that engages with these dimensions is particularly important when new needs and phenomena emerge that cannot be accommodated within any existing ones, or when navigating complex social-ecological realities and different ways of doing science at the science-society interface.

Assembling different elements in sustainability science thus comprises not only activities that are typical of more conventional science, such as combining, contrasting, connecting, integrating, linking, generalizing, and abstracting. It may also take the shape of a co-produced process which might include, for instance, embodying, experiencing, as well as imagining. Within individual and collective learning processes, such activities can be fostered through reflection and dialogue.

Different modes of theorizing

Theories as assemblages can be created and used in many different ways. We suggest organizing the landscape of theory-related activities and their interactions in a

Figure 2



Four ideal-typical modes of theorizing within sustainability science. Projects or programs often move between the different modes as indicated by the dotted lines.

theorizing field that is spanned by the two gradients of (i) purposes from explanation to action and (ii) position of the theorizing process from the outside to the inside (Figure 2).

Theorizing from the outside

Basic (or fundamental) and applied research occupy the lower part of the figure as they take place outside of the system or phenomenon to be understood or acted upon through research.

Theorizing in basic research about SES often starts from an empirical problem. Common elements involved in assembling theories in this mode are concepts, models, causal relationships, empirical observations or interpretations, regularities or patterns. Recent theorizing of social-ecological phenomena in this mode has been inspired by social science methodologies, such as the mechanism-based approach from analytical sociology [2,40], or model-centered meta-analysis [3••,41]. There is a focus on middle-range theories that are produced through abductive processes that iterate between empirical research and the emerging theory [e.g. 3••,4,8,13]. Methodologies developed to support such abductive theorizing include collaborative modelling [4] or the identification of archetypes, syndromes or pathways [29,42,43]. Recent examples are the theoretical development of the Multi-level Perspective for socio-technical transitions [10••], the use of evolutionary theories to understand collective action problems [44], theories of system collapse [30], mechanisms of land-use change [45], or policy transitions [46].

Theorizing in applied research includes approaches to theory and theorizing such as policy impact evaluation and scenarios, science-policy advice, intergovernmental assessment processes, knowledge translation and brokering, and other forms of research which aim to propose and assess solutions to address real world problems or situations. The goal of theorizing and theory use here is to support and inform action by theorizing about the course of action to be taken, from outside the system, although usually with the goal of informing actors and stakeholders that are within the system such as policy makers. Often the results are aimed at being policy or practice-relevant rather than prescriptive or embedded in policy or change processes. Examples of theorizing and theory use in applied research are frameworks, models and theories developed within intergovernmental panels such as IPBES [47–49]

Theorizing from the inside

Embedded research and science-based change making occupy the upper part of the figure as they are situated inside the system or problem context.

Theorizing about SES in embedded research refers to processes that run parallel to the mutual learning and knowledge co-production that takes place, for example, in place-based research or forms of real-world experimentation where researchers work together with societal actors to develop an understanding of SES [21,50]. The process of collectively making sense of a phenomenon or problem of interest exposes underlying assumptions and theories of different actors, confronts different perspectives, and can generate novel understanding. Such processes provide opportunities for including tacit theories embedded in local knowledge systems [51,52] and for leveraging different perspectives and competencies to co-produce knowledge about a complex problem under real-world conditions [35,53]. Assembling a theory in this mode implies recognizing the multiplicity of concepts, mental models, and theories different actors might have of the problem addressed. This is followed by engaging with, comparing, negotiating, evaluating, and coordinating these different elements within a structured (although not necessarily unified or shared) understanding of the complex SES under investigation. An example is novel understanding generated about taboo trade-offs in ecosystem services and human well-being, such as those between morally incommensurable values, through integrating ecological simulations with participatory assessments of social-ecological system structure and stakeholders' well-being [54].

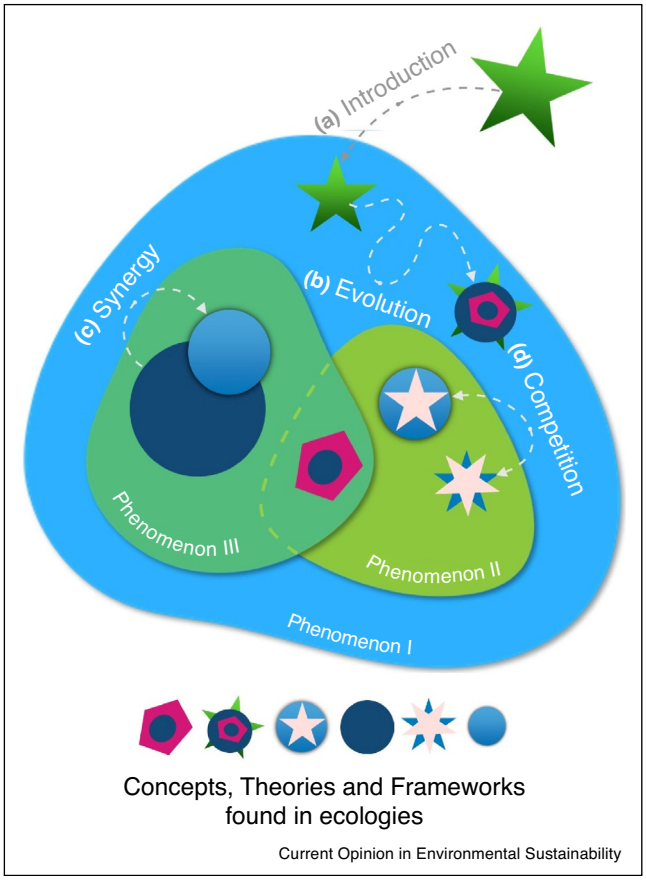
Science-based change making refers to embedded processes of theorizing that aim to move beyond understanding to contributing to change processes in the systems of interest. Theorizing in this mode begins with a process of assembling elements that can help understand and respond to a given problem [39,55••]. In this light, theorizing is not only embedded in a specific context, it is part of the change making process shaping outcomes as well as theories. Assembling a theory in this mode involves building on insights that emerge when collectively engaging in action in a complex problem context, as well as from surfacing the often-implicit concepts, models, and theories used by participants when dealing with enabling, capacity building, and empowering or disempowering dynamics. For example, the design and delivery of a Global Fellowship Program in social innovation used and built novel theories on the role of capacities to navigate emergence and cross-scale systems reflexivity [56]. Theories that emerge in change making processes are theories that are often expressed in the form of principles that guide how knowledge co-production is engaged with multiple value systems and power relationships in order to generate change [57,58]. Other examples include theories about how to manage change within an organization, such as in businesses [35], leverage social norms and mindsets [18,33], work with different knowledge and values systems to create agency for change [6••,14] or engage in dialogues with stakeholders in ways that promote gender empowerment to build resilience capacity [34].

In reality, the modes often overlap and theorizing processes move between different modes, rather than being situated in one corner. Modes may be combined through many possible sequential or simultaneous pathways, as understanding grows and turns to action or change processes (dotted lines in Figure 2). The Bloomington programme of Elinor and Vincent Ostrom, for example, transitioned from an embedded research approach building on anthropological work (upper left) to basic research in the 1980s and 1990s (lower left) to more applied research in recent years (lower right).

Ecologies of theories

A theory that emerges through one of these modes is not an endpoint, it evolves with and shapes its research field. Concepts, theories, and frameworks are embedded in a knowledge context, that is, they become part of an ecology — a set of theories used to understand, explain, or act upon the phenomenon of interest (Figure 3). Theories in such an ecology evolve through application to research and action, and through their interactions with other theories or elements of theories in the form of competition or synergies. This evolution may result in new theories or adaptations of old theories to new phenomena. Examples of theory evolution are the emergence of the Multi-level Perspective (MLP) of socio-technical transitions from various contributing theories that are themselves changing through application [10••], or the evolution of environmental governance theories [59••].

Figure 3



Snapshot of ecologies of theories for three related phenomena such as natural resource management (phenomenon I), collective action (phenomenon II) and collaborative water governance (phenomenon III). Each phenomenon has its own ecology but they may overlap. Theories, produced through different modes of theorizing, may interact within and across ecologies. The ecology changes through a variety of processes: **(a)** A theory may be introduced to an ecology from a different field, for example Coleman's boat has recently been introduced from analytical sociology as a model for the study of mechanisms of adaptive governance by Biesbroek *et al.* [2] **(b)** through application a theory may evolve and gain new elements, such as the social-ecological transformations framework which evolved through borrowing elements from multiple streams theory **(c)** Theories may synergize with each other in explaining a range of phenomena, for example adaptive governance and policy framing theory **(d)** Theories indirectly compete with each other such as Advocacy Coalition Framework which focuses on collaboration of actors with similar beliefs and Resource Dependency theory which highlights opportunistic and resource-focused alliances [61].

The notion of ecologies of theories can serve theory building processes in all four modes as a heuristic to explicate and organize existing knowledge. This is

particularly relevant in sustainability science because of the multidisciplinary nature of the field that draws on a diverse and dynamic body of theories. The emerging landscape of theories is, using this heuristic, conceptualized as a set of constantly changing ecologies that are applicable for understanding or explaining multiple, often nested, phenomena (Figure 3). As we select and apply theories, some theories may become more 'visible' through more frequent application and advancement over time. Concurrently, the interdisciplinary nature of the field and diverse backgrounds of sustainability scientists can often lead to emergence of explanations that borrow concepts and theories from multiple fields.

Mapping theoretical understandings of a phenomenon of interest allows identifying related or competing theories, and supports progress in further theory development [60]. In other words, the heuristic prompts the researcher to search for potentially suitable theories across a broad range of research fields and disciplines. Combining different elements, however, needs to be guided by procedures specific to the different theorizing modes in order to ensure their compatibility. Given the contextual and problem-oriented nature of sustainability science, and the dynamic and contingent nature of SES problems, it is not practical nor desirable for a researcher or practitioner to adhere to any particular theory in all situations and/or at all points in time. Instead, it is more desirable to have a working knowledge of the diversity of theories or conceptual elements that potentially apply to a given problem and/or phenomenon, how multiple theories may apply to the same problem and/or phenomenon but at different points in time (e.g. innovation diffusion and adoption), and the potential for divergence among their explanations or prediction of change. A key objective with our heuristic is thus to facilitate the development of such working knowledge.

Conclusions

Theories play an important role in sustainability science for consolidating and generating knowledge, and as essential elements of both research and action. Theorizing, as the process of assembling different elements into a coherent structure, is already happening in the field today. It is, however, often not called so nor made explicit. We argue that it is important to recognize theorizing, make it more prevalent and to advance modes of theorizing and kinds of theories whose underlying assumptions and processes of knowledge generation are compatible with the complex nature of sustainability problems. Recognizing different modes of theorizing and the plurality and evolving nature of theories are first steps towards reframing the role and potential of theorizing for sustainability science.

There is no blueprint approach to theorizing in the field. Our typology of theorizing modes can help researchers map their approach and make explicit how their research and engagement activities address complexity and the link between research and action. By analyzing theory progress through this typology, it might be easier to overcome some of the current barriers to theory progress; as acknowledging that not every theory should address all the quadrants simultaneously might make it easier for researchers to engage in theory development. The typology also suggests an avenue for innovative theorizing and transdisciplinary theoretical progress through the role of 'theorizing from the inside' that engages with the complexities of SES through mobilizing them in action processes. While parts of sustainability science increasingly aim to co-create knowledge and engage in change processes within the system, the potential for theorizing in transdisciplinary research and change making processes is little recognized so far. Theorizing from the inside might help overcome disciplinary silos by putting solution-oriented views of actors centre stage, that do not necessarily build on disciplinary perspectives and expect solutions notwithstanding a certain methodological or epistemological approach. Collaborative inter-disciplinary or transdisciplinary theorizing processes may, when conducted in a manner that values plurality and supports open dialogue and reflection, facilitate developing genuine social-ecological theories that move beyond ontological or epistemological divides.

The ecology of theories serves as a heuristic to raise awareness and explore the evolving and diverse set of theories for a particular phenomenon of interest. Such an awareness can foster working with plurality of understandings from science and practice through processes of clarification, integration, comparison, and differentiation. While the different modes help navigate through the ecologies, more research is needed to develop guidance and procedures for integrating social and ecological theories for a given purpose within and across different understandings and contexts [integrative pluralism, 62]. We especially acknowledge the need to balance pluralism (of epistemologies, theories and approaches) and their careful integration (across multiple approaches) [62] when advancing sustainability science as a 'progressive programme', that is as a research endeavor that is continuously improved through theoretical advancements and empirical corroboration [63].

Reflexive practices and inter-disciplinary and trans-disciplinary methodologies may be better suited to let theories emerge that accommodate the complexity, uncertainty, and continuous change characteristic of SES and guide forms of interventions or change making. Although the role of multiple knowledge systems and evidence bases is increasingly acknowledged [64,65] and calls for more action-oriented research abound [66,67], the important role of action and embedded and reflexive processes for theory and theorizing are not yet well recognized. These advances in theorizing for explanation and action have the

potential to generate novel theories and theorizing practices that support the needs of sustainability science. Moving in this direction will, however, require restructuring research to realize integrated and transdisciplinary sustainability science [65].

Conflict of interest statement

Nothing declared.

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The paper argues for the need to go beyond linear models of knowledge and action and proposes a relational model where knowledge is used and produced from within complex situations when participants aim to find workable solutions.

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