

Review

# Putting power in perspective: a systematic review of power dynamics in social-ecological traps

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## Abstract

This paper explores the use of power and politics in empirical literature on social-ecological traps. Social-ecological traps describe conditions where self-reinforcing interactions between social and ecological elements perpetuate a system in an unfavorable or undesirable state. Researchers across disciplines have theorized the nature and composition of social-ecological traps. In this connection, critical viewpoints on resilience have recognized a growing need to investigate political context, power relations, and the unequal distribution of risks and benefits contributing to the capacity of communities to manage changing conditions. However, it remains unclear to what extent empirical studies support any theorized way of power and politics influencing trap dynamics. This paper reviews power dynamics in the existing literature and offers insight into how power influences the emergence and persistence of social-ecological traps. Through a systematic literature review, we examined how the concept of power has been used, explicitly and implicitly, in empirical social-ecological trap research. The review identified 40 publications, focusing mainly on coastal ecosystems and cultivated areas within Latin America, Sub-Saharan Africa, and Asia. Our results suggest that power is still poorly understood from both a conceptual and operational perspective within the social-ecological trap literature. A few studies that do center power in their analyses demonstrate that despite limited attention, there are clear instances where power intersects with social-ecological system dynamics to perpetuate resilient, yet undesirable outcomes. We point to the absence of empirical studies that systematically analyze power relationships and dynamics and highlight the need for further research that bridges socio-political and ecological analyses.

## 1 Introduction

Integrating resilience into sustainability strategies has become a focal point in recent research, as it addresses how systems can persist and continue providing ecosystem services despite various stressors and shocks [1]. The linkage between resilience and sustainability is rooted in the idea that sustainable practices must not only safeguard resources<sup>1</sup> but also foster the resilience of social-ecological systems (SES) against future uncertainties [3–5].

<sup>1</sup> Resources refer to people, assets, materials or capital – including human, mental, monetary, artifactual and natural resources – utilized to achieve a specific objective [2]

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The concept of SES refers to integrated and complex systems that encompass both ecological and social components, where humans and nature interact dynamically and interdependently [6]. Understanding SES involves recognizing that social and ecological systems are intertwined, with feedbacks and interactions that shape the overall behavior and outcomes of the system [7]. The SES approach describes social-ecological systems as complex systems characterized by multi-scalar dynamics, with ecological and social processes that co-produce resilient outcomes [8].

Resilience, in the context of SES, refers to the capacity of a system to absorb and adapt to disturbances while maintaining its essential functions, structures, identity, and feedback mechanisms [1]. The concept of resilience highlights how SES can withstand shocks and stresses while maintaining the capacity to provide ecosystem services and support human well-being [1]. Resilience theory emphasizes the importance of adaptability, learning, and transformation in response to social and environmental changes [9, 10].

Despite its valuable insights, resilience thinking often incorporates underlying assumptions about resilience as an inherently desirable property [11–13]. However what constitutes a desirable state is often unclear and seldom debated, because perceptions of desirability are influenced by diverse and competing factors such as political agendas, economic priorities, and cultural values [11, 13]. Furthermore, the capacity to determine what is and is not desirable often lies with those who hold power [12, 14]. There is a need to understand how power relations determine desirability and influence which perspectives are prioritized and which are marginalized. The ecological underpinnings behind resilience approaches have been critiqued for their homogenization of social complexity, adopting methods that overlook power relations, assuming uniform interests among actors in a system, and obscuring or giving preference to certain perspectives and values. Consequently, concerns have emerged over power imbalances surfacing both during interventions and as outcomes of those actions [15].

Power, or a lack thereof, can translate to differential access to and control over resources, amplifying existing inequalities and power hierarchies, ultimately raising questions about whether the needs of people and communities are being met [16, 17]. Disparities in power can result in scenarios where marginalized communities and local ecosystems bear the brunt of environmental and social stresses [18]. When adverse social and environmental outcomes interact, they can force a system into a social-ecological trap. Perspectives on how power manifests vary; some scholars view power as embedded in social relations among stakeholders [19], while others identify power within interactions among social and ecological system components [12]. By influencing both social relations and system interactions, power dynamics can lead to adverse social and environmental outcomes that interact and reinforce each other. When such reinforcing dynamics occur, the system can become entrenched in a social-ecological trap.

Social-ecological traps describe conditions where self-reinforcing feedbacks between social and ecological factors keep a system in an undesirable state, threatening its long-term sustainability [20]. The concept evolved from development economics, particularly from theories on poverty traps that increasingly recognized the integral role of ecological dynamics in human-nature relationships [21]. Building on this foundation, empirical research in coupled human-natural systems has revealed that human actors and institutions actively foster feedbacks in social-ecological systems, altering the environment's ability to generate key ecosystem services upon which human health and well-being depend [8]. By demonstrating how reinforcing feedback mechanisms can hinder adaptive capacity and the system's ability to recover from disturbances, social-ecological traps highlight the challenges in sustaining resilience and achieving long-term sustainability [22].

Understanding how social-ecological systems become caught in undesirable states necessitates a framework that accounts for dynamic interactions across different scales and times. Panarchy theory offers such a framework by conceptualizing systems as undergoing recurring cycles of growth, accumulation, restructuring, and renewal, highlighting the adaptive and transformative capacities of social-ecological systems [23]. Panarchy emphasizes that changes at one scale can influence other scales, leading to cascading effects throughout the system. Key to panarchy is the concept of path dependency, which suggests that historical events and decisions can set systems on particular trajectories that are resistant to change. Path dependency means that past processes and institutional arrangements influence present and future states of the system, making it challenging to make changes that deviate from established patterns. In this connection, critical junctures—periods of significant change or crisis—can either reinforce existing paths or open opportunities for transformation [24]. In the context of social-ecological traps, understanding how path dependency and critical junctures shape system dynamics is essential for identifying leverage points to initiate change towards sustainability.

Power dynamics significantly influence processes within panarchy cycles, as actors in positions of authority can affect the system's trajectory, potentially reinforcing feedbacks that maintain undesirable states. Integrating panarchy theory with an understanding of power relations enables a better comprehension of how social-ecological systems become

trapped and allows for the identification of opportunities for transformative change. The literature identifies four main types of traps within panarchy theory each representing specific conditions that hinder the ability of a system to adapt and transform:

*Poverty Trap:* This trap occurs when a system lacks sufficient resources or capital to initiate change, leading to persistent underdevelopment [20, 25]. Limited potential and low levels of cooperation among actors prevent the system from progressing, trapping it in a state of stagnation.

*Rigidity Trap:* Systems in a rigidity trap are characterized by excessive connectedness and inflexibility, making them resistant to change and innovation [26, 27]. Strong adherence to established norms and structures hinders adaptation, leaving the system vulnerable to external shocks.

*Lock-In Trap:* A lock-in trap emerges when maladaptive behaviors are maintained due to entrenched relationships and institutional resilience [27]. The system's high connectedness reinforces existing practices, while a lack of alternative options limits the potential for transformation. Whereas a rigidity trap has high potential for change, lock-in traps cannot change because such low potential exists.

*Chaos Trap:* In a chaos trap, significant potential exists within the system, but a lack of organization and connectivity prevents this potential from being realized [28]. Low resilience means that minor disturbances can lead to unpredictable and chaotic dynamics, impeding the system's development.

Although the four identified traps may manifest in diverse ways within social-ecological systems, it is important to recognize that traps can originate exclusively from social factors or exclusively from ecological factors, without necessarily involving both.

Social-ecological traps represent a specific area within SES research where the role of power requires deeper exploration. Studies suggest that power relations contribute to the formation and persistence of social-ecological traps by influencing resource dynamics, decision-making processes, and access to adaptive capacities at local and regional levels [29, 30]. However, the specific mechanisms by which power dynamics hinder or facilitate the ability of people, communities, institutions, and social-ecological systems to initiate and guide desirable changes remain poorly understood [31].

Without investigating the presence of power disparities, efforts focused on building resilience may fail to address the root causes of vulnerability or may inadvertently reinforce existing inequalities. Incorporating analyses of power into resilience research can lead to more effective and just interventions, enabling transformations toward sustainability that consider the needs and aspirations of all stakeholders. Consequently, exploring how power relations contribute to specific challenges within social-ecological systems, such as the persistence of social-ecological traps, can inform more equitable policy-making and resource management practices, helping to dismantle barriers that prevent communities from achieving sustainable, just and desirable outcomes.

Existing literature has laid considerable theoretical groundwork on the structure and function of social-ecological traps, often drawing from the broader resilience literature. Studies have shown the diversity of trap conceptualization across disciplines, emphasizing the dynamics and feedback mechanisms relevant to social-ecological systems [20], and identified how social dilemmas such as conflicting interests and collective action failures drive resource degradation [32]. Increasingly, authors have pointed to the importance of identifying leverage points and pathways out of trapped systems [33–35]. Remedying a trapped system requires significant shifts in governance and power structures to enable transformations toward more sustainable and just social-ecological systems. Additionally, concentrating on singular elements may result in short-term fixes that fail to address underlying root causes. Whereas siloed or disciplinary approaches may risk worsening traps, social-ecological systems thinking has been recognized for its delineation between intricately connected social and natural systems [36].

In complex SES, the multitude of interacting factors, actors, and dynamic processes makes it exceedingly difficult to establish clear, direct cause-and-effect relationships between specific actions and specific undesirable outcomes [29]. Accordingly, the influence of power dynamics on SES resilience—particularly in enabling people, communities, and institutions to initiate and guide positive change—remains unclear [31]. Though power and politics are gaining attention in resilience research [31], a systematic review of how power has been empirically studied within social-ecological traps literature appears to be absent. This review aims to fill that gap by fostering a deeper understanding about how authors use power in empirical studies to investigate the emergence, persistence, and resolution of social-ecological traps. To address this, our review is guided by three research questions:

- 1) In what contexts has social-ecological traps research been conducted and by whom?

- 2) To what extent are social power and politics defined and addressed within social-ecological traps literature?
- 3) How is power analyzed across the social-ecological trap literature?

This review is driven by three primary objectives. First, the review aims to examine authorship and theme trends in social-ecological trap studies, with an emphasis on determining if there are power structures capable of influencing research results. Second, we aim to explore the challenges in defining and conceptualizing power in social-ecological traps, focusing on its role in driving and maintaining undesirable states, and its potential as a leverage point for transformation. Third, we aim to address how studies operationalize and measure different dimensions of power within the social-ecological trap context. Finally, we seek to highlight the strengths and gaps in empirical studies on social-ecological traps and power, with the intention of fostering a deeper understanding of how these dynamics can be meaningfully captured in research.

The rest of the paper is structured as follows. In the next section, we present a theoretical framing of power in the context of social-ecological interactions. We then outline our materials and methods used for data collection and analysis. Subsequently, we present specific results through a quantitative investigation and analysis of titles, keywords, and abstracts using Scopus and Web of Science. The final section takes these observations and integrates them within the larger social-ecological trap framework, highlighting significant gaps in research and proposing further avenues for exploration.

## 2 Theoretical background

Researchers have long recognized the centrality of power in shaping social-ecological systems. Early approaches often treated power as a static attribute held by individuals or groups, focusing on who holds power and how it is exercised [37]. Various conceptual frameworks have been employed to understand power, ranging from relational and productive power to structural and material power, each offering unique insights into the complexities of human-nature interactions. Over time, scholars from various disciplines began to explore power as a dynamic and relational phenomenon embedded in social interactions and practices [38, 39]. This shift was driven by the recognition that power is not merely a possession [40] but is continually constructed and reconstructed through interactions [41]. Increasingly, researchers have agreed that power can be conceptualized as a family of related yet distinct dimensions, allowing for the inclusion of a diversity of power relations and incorporating different perspectives and experiences [42, 43].

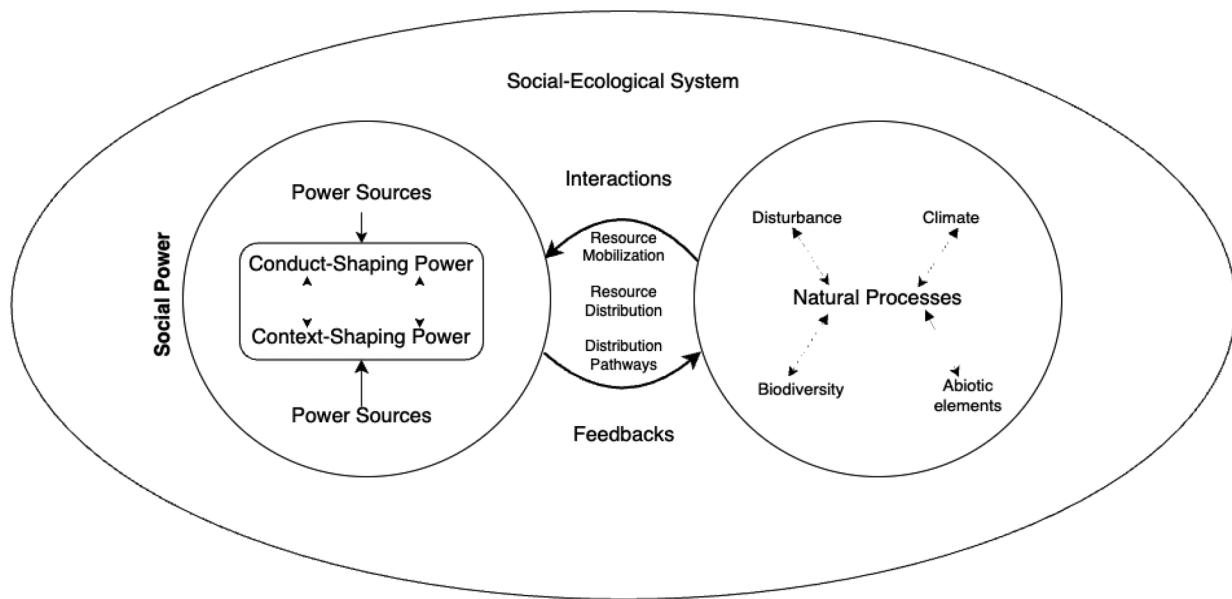
Despite these strides to understand power, its complexity continues to present substantial conceptual challenges. Power in social-ecological systems is not uniformly defined or understood across disciplines. Some scholars view power as a capacity to act [44, 45]—encompassing resilience, adaptability, and transformability—while others see it as a relational dynamic that shapes and is shaped by social-ecological interactions [46].

Studies that use a complex adaptive systems (CAS) perspective usually focus on entities like systems, structures, and networks rather than individuals, and examine their causal impacts on social-ecological interactions [47, 48]. As a result, the CAS perspective, as well as systems thinking in general, often views problems like inequality, fairness, or unsustainability as emergent properties of the entire social-ecological system [49, 50]. One issue with this perspective is that these issues are not just isolated or random occurrences but are embedded within the way the system functions as a whole.

Notions of embeddedness raise important questions about the role of power within the system, particularly whether power dynamics function as inherent properties of the system, are driven by individual actors, or reflect some combination of the two. Differentiating between power as a systemic property and power as a characteristic of individual actors is crucial because it helps assign responsibility and understand the moral and political implications of power dynamics [29]. Recognizing these distinctions enables researchers to better identify who or what holds power, how it is exercised, and what the impacts of these power dynamics are on human and environmental systems [12]. This differentiation is essential for developing strategies to address and mitigate the inequalities and unsustainable practices perpetuated by these power dynamics.

This study develops a comprehensive framework reflecting the complexity of power dynamics, moving beyond the limitations of single-dimensional approaches. We draw on existing frameworks [2, 29, 51, 52] to explore how power has been treated in empirical studies. Our integrated approach centers power as a key component in social-ecological interactions, highlighting the diverse ways in which power is derived and exercised.

In our analysis, we aim to identify three interconnected levels of power: social power, context-shaping power, and conduct-shaping power, which are supported by various attributes of that power, referred to as sources [29] (see Fig. 1).



**Fig. 1** Diagram of power dynamics in a social-ecological system, depicting how power sources (monetary, artifactual, natural, human, mental) feed into both conduct-shaping and context-shaping power. Power relations influence system dynamics through three mechanisms we refer to as powering processes—resource mobilization, resource distribution, and distribution pathways. Through these powering processes, power is exerted over natural system components like climate, biodiversity, and abiotic elements. Interactions between social power and natural processes can create feedback loops, eventually contributing to the formation of a social-ecological trap (adapted and modified from [2, 29, 52])

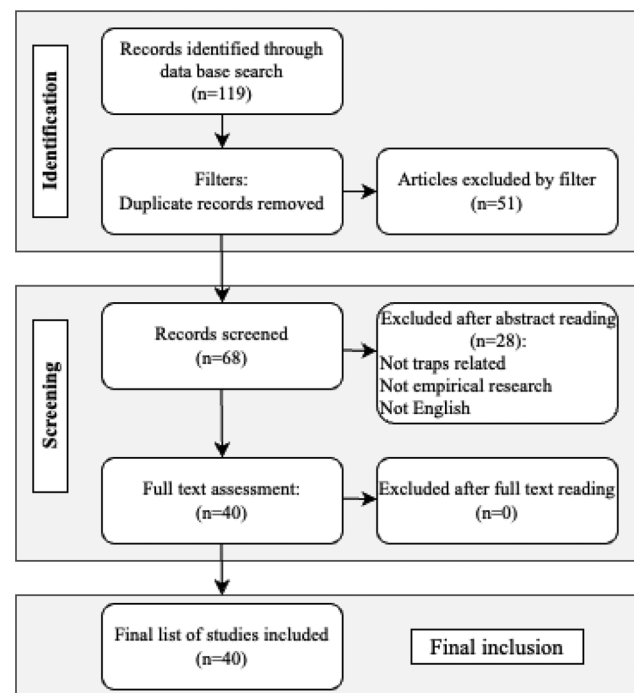
At the first or basic level, social power is the capacity to determine conduct and context. This level encompasses the overarching influence an actor has within the social-ecological system. In the next, secondary level, context-shaping power relates to the capacity of actors to shape the structural conditions and rules that govern their interactions and decision-making processes. In parallel, conduct-shaping power pertains to the capacity of actors to act within—and potentially alter—these frameworks through their actions and decisions [53, 54]. Finally, the third level includes the attributes of context-shaping and conduct-shaping power, referred to as sources of power, encompassing the diverse origins or bases from which actors derive their ability to influence outcomes. Sources of power correspond to diverse resource types including: human (e.g., leadership, social networks), mental (e.g., knowledge, expertise), monetary (e.g., financial resources), artifactual (e.g., technology, infrastructure), and natural (e.g., human authority and control over and access to natural resources) [2]. Linking each level to its corresponding sources and attributes clarifies how the ability to shape contexts and conduct is enabled by specific resources.

Social power interacts with natural processes in a social-ecological system through ‘powering’ processes, deeply embedded in socio-material and social-ecological configurations [51]. In turn, powering processes influence system dynamics via mechanisms of resource mobilization, resource distribution, and distribution pathways, shaping the ways in which actors and institutions access and utilize resources. Resource mobilization refers to the ways in which actors gather and allocate resources to exert influence. Resource distribution involves the methods by which resources are spread across different actors and groups, often reflecting existing power dynamics. Distribution pathways are the routes through which resources flow, determining who has access and control. Understanding these dynamics offers insights into the construction of solutions or the deconstruction of practices contributing to the persistence of social-ecological traps. Powering processes embody the effect of power relations in heterogeneous networks, highlighting the complex nature of power in shaping systemic change.

### 3 Materials and methods

Our decision to use a systematic literature review was driven by its well-known extensive coverage and capabilities for detailed analysis, thanks to its structured methodology, rigorous selection criteria, and ability to synthesize and integrate diverse findings from empirical studies [55, 56]. The systematic literature review approach reduces bias and

**Fig. 2** Flow chart of the review method



increases reliability, thereby facilitating the identification of patterns and gaps in the literature, capturing the diversity of power conceptualizations relevant to social-ecological traps from a range of disciplines, regions, and methodologies. This method's broad yet rigorous approach enables us to look across diverse empirical social-ecological contexts to pinpoint salient research gaps across diverse empirical studies. This systematic literature review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [57] (Fig. 2).

### 3.1 Literature search

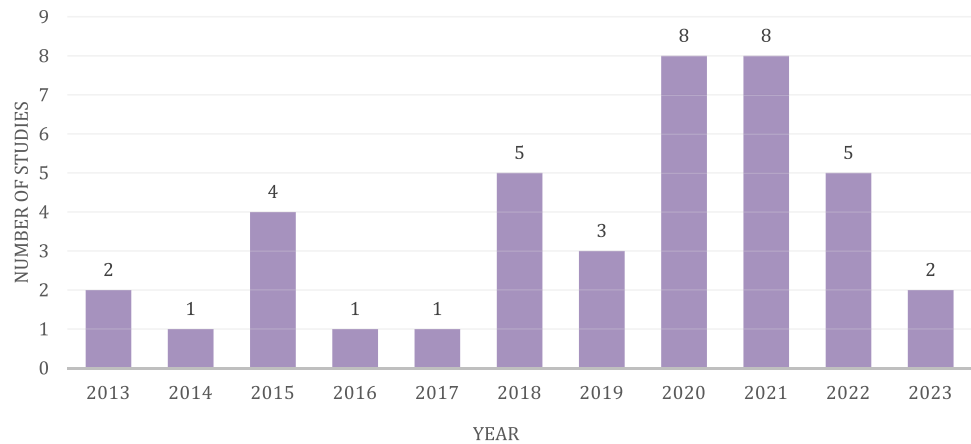
To identify relevant literature, we conducted a bibliographic search of the Scopus and Web of Science databases, as they have extensive coverage and recognized authority in providing quality, relevant scholarly content [58]. Only papers explicitly using the concept of social-ecological traps were considered for review. The bibliographical search was limited to any peer-reviewed publication published with the following terms in the title, keywords, or abstract: "social-ecological trap" or "social-ecological lock-in" or "social-ecological shift" or "social-ecological poverty trap" or "social ecological systems trap," including singular and plural forms of all key words. By focusing on peer-reviewed literature, the review builds upon a body of work that adheres to standardized research methodologies, which can make comparisons and synthesis across studies more coherent. No specific timeframe for publication was required. As of 11/20/23, a total of 119 articles were found, with 51 duplicates removed, resulting in 68 publications for the first step of the literature search (Fig. 2).

Two authors independently engaged in the screening and selection of documents for inclusion or exclusion. The screening process involved evaluating titles and abstracts to ensure alignment with the inclusion criteria, which focused on empirical studies related to social-ecological traps. Exclusions were made for several reasons (refer to Fig. 2 for details), including: (1) the study did not pertain to social-ecological traps; (2) the research lacked empirical analysis, such as in the case of reviews or opinion pieces; (3) the search terms were applied in an unrelated context; or (4) the paper was not written in English. If there was uncertainty about a paper's relevance, a full-text review was conducted before making a decision. The extracted data were then validated to check accuracy using the Mixed Methods Appraisal Tool (MMAT). This process resulted in the rejection of 28 articles. A total of 40 articles were ultimately included in our analysis.

### 3.2 Data extraction and analysis

The codebook for data extraction was developed iteratively, guided by an initial set of indicative literature, which also served as the basis for creating the search terms and inclusion/exclusion criteria (See Supplementary material for details). The iterative selection process focused on using practical indicators of power and its various dimensions that have broad

**Fig. 3** The number of peer-reviewed empirical studies on social-ecological traps and publication trends over time (up to November 2023)



applicability across various academic disciplines. This focus was guided by the observability and empirical nature of various resources and their dynamics in social-ecological systems, which can be more concrete and measurable than abstract conceptualizations of power. In line with the social power framework (Fig. 1), we first searched for codes relevant to sources of power before deciding if those sources were context or conduct shaping for further categorization.

Topics included in the coding covered basic descriptors (e.g. ecosystem, geography, trap type), the depth and characteristics of social power, the range of methods used to analyze power in traps, and outcomes of how power interacts with social-ecological trap dynamics. The temporal focus, referring to the specific time frames employed to study trap dynamics, were considered for selecting codes.

The dimensions of power in social-ecological traps studied follow the social power framework. The final indicator list includes: sources of power (monetary, natural, artifactual, human and mental), conduct- and context-shaping power, social-ecological feedbacks, and powering processes. The codebook categorized the level of focus on specific dimensions as follows: “analyzed” (i.e. the article includes empirical data on sources of power and systematically analyzes this data to draw conclusions related to conduct-shaping or context-shaping power), “discussed” (the dimension was included only as a discussion point or underlying factor, without empirical analysis), or “not included.” Full text data extraction was performed in accordance with the coding framework and using the application DistillerSR.

The approach to data analysis employed in this review combines both qualitative and quantitative methodologies, known as a mixed methods approach, ensuring the validity and reliability of our findings. We applied descriptive statistics to provide a quantitative summary of the collected data. Meanwhile, qualitative data were used to illustrate and substantiate key statistical observations, contributing to a more holistic understanding inclusive of qualitative dimensions of the complexity underlying social-ecological trap dynamics.

## 4 Results

### 4.1 The evolving science of social-ecological traps

Social-ecological traps are slowly emerging as a distinct topic in recent scientific literature (Fig. 3). From 2013 to 2023, there was a notable increase in studies, peaking in both 2020 and 2021 ( $n=8$ ). Of the 40 studies reviewed, more studies featured locations in Latin America and the Caribbean (48%,  $n=19$ ), Sub-Saharan Africa (38%,  $n=15$ ), and Asia (28%,  $n=11$ ). Fewer studies included locations in Europe (18%,  $n=7$ ), North America (15%,  $n=6$ ), and Central Asia (3%,  $n=1$ ) (Fig. 4). Notably, there are no studies from Oceania or the Middle East and North Africa, indicating unexplored areas for potential future research. The majority of first authors in these studies hail from institutions in Sweden (15%,  $n=6$ ), the USA (12%,  $n=5$ ), and Argentina (10%,  $n=4$ ), with Canada, Spain, Chile, and Germany each contributing 7% ( $n=3$ ). International collaboration is notably present, with half of the studies (50%,  $n=20$ ) featuring authors from multiple countries. Collaboration between Global North and Global South institutions occurred in 35% of the studies ( $n=14$ ).

Articles spanned a total of 24 different journals, with only four journals publishing more than one article: Ecology and Society (30%,  $n=12$ ), Sustainability Science (7.5%,  $n=3$ ), Global Environmental Change (5%,  $n=2$ ), and Marine Policy (5%,  $n=2$ ).

Ecosystem types were identified based on the International Union for Conservation of Nature and Natural Resources (IUCN) Global Ecosystem Topology framework [2020]. Coastal ecosystems make up the most studied social-ecological systems (40%,  $n = 16$ ), followed by cultivated areas (32.5%,  $n = 13$ ), marine ecosystems (22.5%,  $n = 9$ ) and forests (15%,  $n = 6$ ). Other ecosystems represented in the research include inland waters (15%,  $n = 6$ ), grasslands (12.5%,  $n = 5$ ), mountains (12.5%,  $n = 5$ ), urban areas (10%,  $n = 4$ ), and shrublands (2.5%,  $n = 1$ ), with some studies covering multiple ecosystem categories.

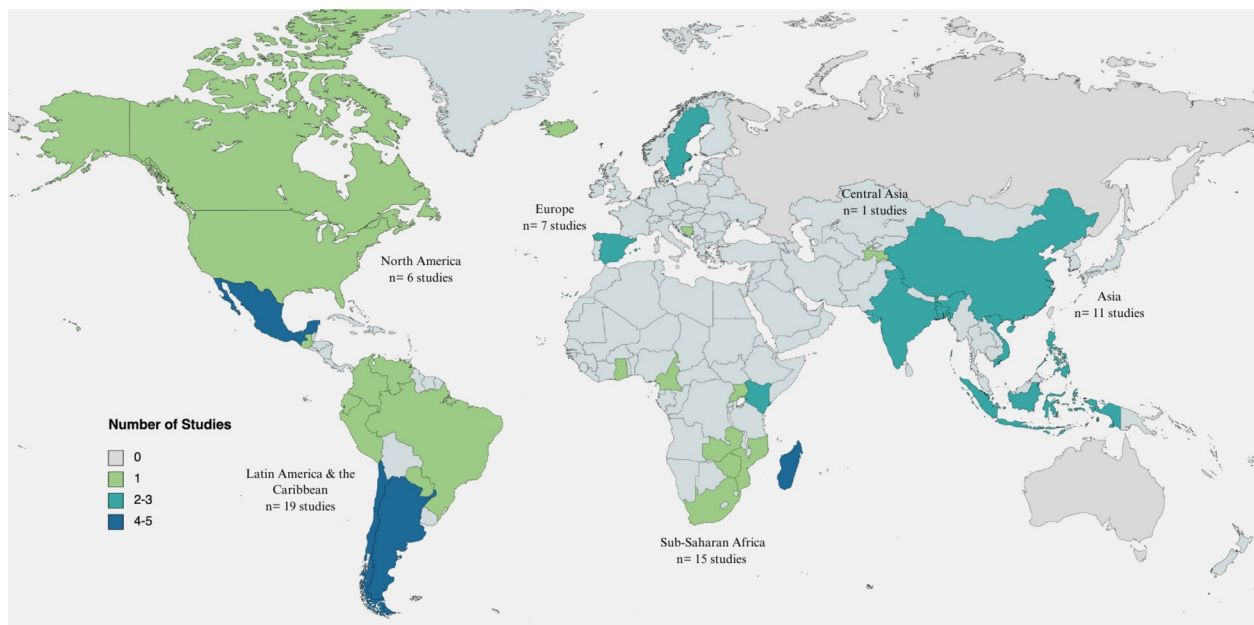
Articles were primarily focused at the subnational (45%,  $n = 18$ ) and local (40%,  $n = 16$ ) scales, while 10% of studies ( $n = 4$ ) focused on the regional scale and 7% of studies ( $n = 3$ ) at the national level. One study was framed globally. Cross-scale dynamics are a key qualifier for social-ecological traps [20, 59, 60], yet cross-scale comparisons were only mentioned in 20% of studies ( $n = 8$ ). Furthermore, aligning local objectives with global targets, such as the Sustainable Development Goals or Global Biodiversity Framework, can enhance the contribution of local actions to broader conservation and sustainability efforts, but only 17% of studies ( $n = 7$ ) in the review mentioned this connection.

We also identified other types of traps and lock-ins in the reviewed literature that were mentioned alongside social-ecological traps to document the mechanisms driving persistence. Poverty traps, referring to conditions where structural constraints limit the ability of the poor to improve their living standards [61], were mentioned most frequently alongside social-ecological traps ( $n = 13$ ). This was followed by rigidity traps (20%,  $n = 8$ ), then lock-in traps where systems become resistant to change due to established practices and structures, which appeared in 5% of the studies ( $n = 2$ ). Sunk-cost traps, where past investments lead to continued commitment to a failing course of action, were mentioned in one study. Nearly half of the studies ( $n = 17$ ) made no mention of other types of traps.

## 4.2 Dimensions of power in social-ecological traps research

Out of the 40 studies included in our review, almost half included power in either their analyses or discussions (45%,  $n = 18$ ). The number of studies specifically analyzing power in the context of social-ecological traps (25%,  $n = 10$ ) was slightly higher than those in which power was in some way discussed (20%,  $n = 8$ ). The remaining studies (22.5%,  $n = 22$ ) did not discuss power in any capacity.

Only one study provided an explicit framework conceptualizing power [62]. The rest of the literature did not define power nor was it broken down into any subcomponents. To identify how power operates within social-ecological traps, we examined the variables authors used in the ten studies that analyzed power and assessed how each study determined how power was both acquired and exercised (Fig. 5). We first identified whether power dynamics were context-shaping



**Fig. 4** Geographical map of study location ( $n = 59$ ; note that various studies include multiple countries). Dark blue shading shows countries with the highest representation



Study	Conduct-shaping power					Context-shaping power				
	Human	Mental	Monetary	Artifactual	Natural	Human	Mental	Monetary	Artifactual	Natural
A social-ecological trap perspective to explain the emergence and persistence of illegal fishing in small-scale fisheries [84]	●	●	●	●		●	●	●		●
Understanding the governance of sustainability pathways: hydraulic megaprojects, social-ecological traps, and power in networks of action situations [85]	●		●	●		●	●		●	●
Escaping social-ecological traps through tribal stewardship on national forest lands in the Pacific Northwest, United States of America [86]	●	●	●			●	●		●	●
Assessing Sustainability Aspects of Mud Crab ( <i>Scylla</i> sp.) Fishery and Its Link to Social-Ecological Traps in the Bangladesh Sundarbans [87]		●	●	●		●		●		
Mangroves, fishers, and the struggle for adaptive comanagement: Applying the social-ecological systems framework to a marine extractive reserve (Resex) in Brazil [88]	●		●	●		●	●			
Linking inequalities and ecosystem services in Latin America [89]	●		●	●		●		●		
Postharvest fish losses and unequal gender relations: Drivers of the social-ecological trap in the Barotse Floodplain fishery, Zambia [90]		●	●	●		●			●	
Community-based aquaculture in the western Indian Ocean: Challenges and opportunities for developing sustainable coastal livelihoods [91]	●	●	●			●		●	●	
Reimagining large-scale open-water fisheries governance through adaptive comanagement in hilsa shad sanctuaries [92]	●	●	●			●	●		●	
Climate resilience and risks of rigidity traps in Iceland's fisheries [93]	●					●	●	●		●

**Fig. 5** Power-related dimensions covered by the studies that specifically analyze power in social-ecological traps

or conduct-shaping and then explored the specific sources from which that power originated (Fig. 1). Within the ten identified articles, conduct-shaping power most frequently surfaced through monetary sources, appearing in 90% of the studies ( $n=9$ ). Human sources were present in 80% of the studies ( $n=8$ ). Mental and artifactual sources each emerged in 60% of the studies ( $n=6$ ). Natural sources were not identified in any of the studies ( $n=0$ ). Overall, conduct-shaping power was empirically analyzed in 80% of the studies ( $n=8$ ) and mentioned in discussion in an additional 20% of the studies ( $n=2$ ).

Within the same ten articles, context-shaping power most frequently surfaced through human sources, appearing in all of the studies ( $n=10$ ). Mental sources were present in 60% of the studies ( $n=6$ ). Monetary and artifactual sources each emerged in 50% of the studies ( $n=5$ ), while natural sources were noted in 40% of the studies ( $n=4$ ). Overall, context-shaping power was empirically examined in 80% of the studies ( $n=8$ ) and mentioned in discussion in an additional 20% ( $n=2$ ).

In examining how social power is exercised, we identified powering processes to determine how resources are mobilized, distributed, and directed within social-ecological systems. Our review found that resource distribution, resource mobilization, and distribution pathways were each mentioned in all of the studies ( $n=10$ ).

Information was collected on whether studies described feedbacks between power dynamics and natural processes (Additional findings are presented in Appendix 1). The findings indicate that positive or reinforcing feedbacks, where power dynamics and ecological outcomes mutually reinforce each other, are well described across all studies ( $n=10$ ). Negative or balancing feedbacks, which depict scenarios where power dynamics and ecological impacts counteract each other, were less frequently noted. Negative feedbacks were analyzed in 20% of studies ( $n=2$ ) and discussed in some detail in 70% of studies ( $n=7$ ). In the studies where negative feedbacks were discussed, potential stabilizing pathways for the system were mentioned, but the role of power dynamics in these processes was not clearly explained.

### 4.3 Temporal and methodological approaches to power analysis

Temporal focus refers to the time frames researchers employ to analyze the dynamics of power within social-ecological systems. The time frames considered for analysis differed considerably among the reviewed studies. Of the 18 studies discussing or analyzing power, 50% ( $n=9$ ) were singularly present-focused. Studies only incorporating retrospective analysis consisted of 11% of studies ( $n=2$ ). Less than half the studies (39%,  $n=7$ ) incorporated both retrospective and present-focused analyses. No studies employed any prospective or future-focused methods.

Exactly half of the papers studying power conducted historical analysis ( $n=9$ ). We distinguish historical analysis from retrospective studies by defining historical analysis as requiring the study to either pinpoint the time and place where a social-ecological trap emerged or identify one or more critical junctures that contributed to the trap's emergence. In contrast, a retrospective study reviews past events without necessarily determining specific emergence points or critical junctures.

Mixed methods and qualitative methods were each utilized in 44% ( $n=8$ ) of the studies. There were no studies employing purely quantitative or spatial methods.

In 27% of the papers reviewed ( $n=5$ ), researchers differentiated between different social, economic or environmental variables in their analysis. Within these studies, 22% of studies ( $n=4$ ) stratified economic variables like income, 22% of studies ( $n=4$ ) measured socio-demographic variables such as gender and ethnicity, and 11% ( $n=2$ ) included measurement of environmental variables like ecosystem services and biophysical properties. It is important to note that some studies disaggregated across multiple types of variables, accounting for these overlapping percentages.

## 5 Discussion

### 5.1 Key gaps

#### 5.1.1 Geographic trends

Research on social-ecological traps predominantly centers on regions within the 'Global South,' such as Latin America, Sub-Saharan Africa, and Asia. However, a significant portion of this literature is authored by scholars from institutions in the 'global north,' including Europe, North America, and Australia, often without co-authorship from 'global south' institutions. This trend suggests potential gaps in how external perspectives may shape the narrative and understanding of social-ecological traps and raises concerns about whether the research reflects the local realities, priorities, and knowledge systems of the affected communities. Disciplinary background can influence how researchers perceive and frame traps, including what variables they use to capture and assess entrapment, affecting the outcome of a study [63]. Researchers without firsthand local knowledge may benefit from the involvement of local collaborators with in-depth knowledge of the political power structures and historical events that coalesced to drive trap conditions.

Moreover, while research has mainly focused on developing regions, there is a notable lack of studies from Europe, North America and Australia. Expanding research into Global North contexts could yield valuable insights, particularly in understanding how social-ecological traps manifest in developed economies where governance structures and resource use differ from those in the Global South. Such research could explore issues like technological lock-ins or urbanization challenges, enriching our understanding of traps across diverse socio-economic and political systems.

The concept of social-ecological traps draws heavily from development economics, particularly the idea of poverty traps, where individuals or communities are locked into self-reinforcing cycles of poverty due to a lack of resources or opportunities [21]. This theoretical foundation may explain why much of the empirical research on social-ecological traps has focused on the Global South, where poverty, resource dependency, and environmental degradation intersect, as exemplified in studies of fisheries, agriculture, and deforestation [20, 64]. Consequently, the narrative around social-ecological traps tends to prioritize regions with acute development challenges, potentially overshadowing social-ecological dynamics in the Global North, where traps may take on different characteristics [65].

### 5.1.2 Ambiguity in power definitions

Despite extensive theoretical literature identifying multiple dimensions of power [14, 29, 65], our analysis revealed that only one study [62] explicitly defined power at the outset. Given its polymorphous nature, studies focusing on specific dimensions of power without a clear definition might provide a narrow purview of how that power is situated within a broader social-ecological system. While the empirical literature on social-ecological traps has largely adopted a narrower view of social power as presented in theoretical discussions, this may reflect the complexity and polymorphous nature of power itself, making a unified approach difficult to achieve. Simplifying the analysis by focusing on specific dimensions of power can provide clarity in individual studies, but it risks overlooking the broader, multi-dimensional aspects that could be crucial for understanding power's full impact within social-ecological system. A majority of the literature examined power dynamics and relationships without a clear definition of either, leaving readers to infer the meaning of 'power' from the context and usage within the paper, which can lead to varied interpretations. Heterogeneity in descriptions of power may contribute to inconsistencies in analysis, especially in the determination of the extent to which the utilization of power impacts other factors within a system. While standardizing a definition might be difficult due to the nature of power as a family resemblance concept, framing power within the context of a given study can reduce ambiguity and misunderstandings, allowing for researchers to better identify leverage points for intervention and develop targeted strategies.

### 5.1.3 Clarifying the operational use of power

Our review of power dynamics in social-ecological traps reveals significant gaps concerning the complex nature of social-ecological interactions. Although power is discussed in nearly half of the empirical literature we studied, authors often do not explore in depth how power functions as a mechanism reinforcing trap dynamics. Furthermore, in cases where power is the primary focus of analysis, that examination is often shaped by the specific context of the study.

Researchers may define and analyze power based on factors such as cultural norms, historical background, or local governance structures, which often vary significantly between studies. A variety of contextual influences can lead to diverse interpretations and analytical approaches to power dynamics because they shape the lens through which researchers view power, affecting the assumptions, frameworks, and methodologies used. As a result, we often had to rely on inference to piece together disparate findings from various studies and to draw connections that support the results in our review.

Within the current scope of literature our findings suggest that power dynamics influence both social and ecological outcomes, acting through various power sources and processes. Multiple studies described social-social or social-ecological feedback mechanisms in which some iteration of power acted as a driver of trap formation or as a key mechanism for the persistence of an existing trap. The review indicates that sources of power manifest in a variety of scenarios, acting on both conduct and context. We also see that power is utilized in terms of resource distribution and resource mobilization across multiple distribution pathways. However there still remains a gap in understanding the path of social power from source to feedback to system outcome. In most cases it was unclear the specific ways in which disparate parts of the social power continuum connected, and the degree to which social-ecological feedbacks were reinforced.

Our results indicate a broad range of sources of power that shape conduct and context. However, there is still a significant gap in understanding if and how those various sources influence one another. This gap mirrors findings from the broader theoretical literature, which has highlighted the failure in current research to elucidate the relationships between different dimensions and sources of power [42, 43, 51]. Identifying the boundaries and interdependencies of the social power subsystem is key to understanding the conditions under which feedback loops arise and persist [66].

Boundaries within social-ecological systems define the limits of influence and interaction, with power sources serving as an illustrative example of a social-subsystem [67]. Distinct power sources, drawn from human, mental, monetary, artifactual, and natural resources, affect decisions, actions, or outcomes within the system and may amplify or dampen one another. Clarifying boundaries helps determine where power dynamics intersect and delineate the scope of different actors' influence on feedback loops.

Identifying interdependencies among subsystems of power can reveal how interactions between sources contribute to sustaining social-ecological traps [66]. For instance, power derived through human resources like leadership and social networks might be amplified by monetary resources, leading to entrenched inequalities that are resistant to change. Conversely, power derived through knowledge and expertise (mental sources of power) could be constrained by the natural environment, in cases where access to resources is limited by ecological conditions, creating vulnerabilities in

the system. Recognizing how these sources of power interact can help identify leverage points where small interventions can have cascading effects across the system, potentially transforming feedback loops from reinforcing traps to enabling adaptive capacity and resilience.

#### 5.1.4 Methodological gaps

A diverse set of power conceptualizations corresponds to varied strategies for analysis. The use of multiple methodologies in the reviewed studies highlights the effectiveness of interdisciplinary approaches for examining complex social issues, such as power dynamics alongside ecological factors. Studies that adhered to a single methodology relied exclusively on qualitative methods, exposing a gap in the use of quantitative data for complementary analysis. Additionally, participatory approaches were lacking despite the context-dependency of social-ecological traps. Participation of local stakeholders may have deeper insights in the political history preceding feedbacks, with unique insight on moments like critical junctures where systems become ensnared.

All retrospective studies in our review identified key moments in the past where a social-ecological trap emerged or became more entrenched. Analyzing the embedded power in historical processes reveals how power shapes access, resource use and management of social-ecological systems [68]. Identifying critical junctures where power relations and social-ecological elements converge can be a key tool for understanding how to alleviate current trap conditions.

The importance of historical analysis is highlighted in a study from the review on the hilsa shad fisheries in Bangladesh [69]. Historically, the introduction of incentive-based fisheries management aimed to address declining hilsa shad stocks through compensation for compliance with seasonal fishing bans. Initially, this policy decision led to the recovery of fish stocks. However, over time, it became evident that while fish populations improved, the policy failed to address underlying power dynamics and social inequalities. Fishing households remained in cycles of poverty and political disempowerment because the management approach did not consider the historical accumulation of debt, lack of representation in decision-making processes, and unequal access to fishery resources. As a result, these communities continued to experience economic hardship and limited political influence, perpetuating their trapped state. The combined historical context of debt accumulation, evolving power dynamics, and long-term impacts of past policies reveal a cycle of entrenchment. Highlighting how past trajectories influence current conditions can be an essential tool for determining the causes of trap dynamics.

While historical analysis provides critical insights into the root causes of social-ecological traps, there is also a need for methodological approaches that capture the varied impacts on different social groups within these systems. Systems thinking techniques that determine feedback loops using aggregate measures can end up masking the nuanced experiences and impacts of traps on different social groups [70]. Within many of the reviewed studies it is often lost who bears the brunt of a trap, even when poverty is one of the central social outcomes. Very few studies clearly differentiate between the powerful and the powerless, as well as the mechanisms and pathways that allowed for such relationships to evolve. Disaggregation of data can be an effective tool to break down information into detailed categories, such as socio-economic status, gender, and ethnicity, to uncover varied impacts on social groups and delineate complex economic and ecological influences within social-ecological traps. Disaggregating data reveals how benefits and burdens are distributed among diverse groups, highlighting equity issues and providing insights into the socio-economic and environmental indicators that influence power dynamics [71].

While a system level focus can probably be attributed to the steps in which social-ecological traps are investigated—the existence of the trap should first be confirmed—it illuminates that trapped systems may require additional scrutiny in order to reveal hidden inequities and inequalities. Recent quantitative approaches suggest a path forward. For example, Wang et al. [35] use a composite index to track the overall condition of a social-ecological system over time, incorporating variables such as net income per capita, ecosystem goods supply, and environmental indicators. The strengths of this approach lie in its ability to capture system dynamics in space and time. An environmental justice perspective may build on these discoveries and ask whether vulnerable populations experience the trap differently over time, what kind of disparities exist between social groups, and whether interventions equitably address all affected groups within the system.

## 5.2 Looking ahead

To address the identified gaps and advance the field, we recommend that social-ecological traps researchers focus on three primary topics: clarify the definition of power, understand how power drives and perpetuates feedback loops, and employ a diverse range of methods to capture power in trapped systems.

### 5.2.1 Clarifying operational definitions of power

Studies of social-ecological traps often lacked explicit definitions of social power. Understanding the various forms and dimensions of power is important for identifying spaces where participation can foster social change [43]. Given that traps are path-dependent processes that usually span decades or longer, defining power relations from the perspective of local stakeholders may yield key insights on historical legacies of power. By drawing on their lived experiences, local stakeholders may have nuanced opinions on the historical complexity of a trap's formation. In research, participatory approaches to defining power can democratize development by involving local communities and stakeholders in decision-making processes, potentially leading to more equitable and effective outcomes. This doesn't mean blanket participation is one size fits all. While participatory processes can enable the exercise of agency and reconfigure power relations, they can also inadvertently reinforce existing power hierarchies if not thoughtfully designed [72]. Participatory methods have the potential to promote social inclusion, but they must genuinely redistribute power rather than replicate existing inequalities [73]. To achieve their empowering potential, participatory approaches should be carefully designed and implemented to avoid reinforcing current power structures. When participatory approaches are effectively implemented, they build a sense of ownership among stakeholders, fostering greater commitment and ensuring that development initiatives are sustained and adapted over time [74–76]. In the context of entrenched social-ecological traps, ownership may translate into a lever for transformation [33]. As communities gain ownership, they can influence decision-making processes and implement solutions that address the root causes of traps, shifting the balance of power and fostering more equitable and resilient outcomes.

### 5.2.2 Locating power in systems

The examination of causal links between power and entrapment has been minimal, though such analysis could highlight leverage points for change. Resilience studies try to explain the evolution of social-ecological systems by analyzing causality through the lens of social-ecological interaction. Knowing the causal links between actions and outcomes allows for the design of targeted interventions that address root causes rather than symptoms [76]. Causality in SES refers to understanding how interactions between social and ecological components lead to specific outcomes and how these outcomes feed back into the system, affecting future interactions. Causality in SES is often emergent, meaning that outcomes arise from interactions that are not easily predictable from individual components alone [77]. In analyzing power, social causality can be revealed, demonstrating how individual and collective abilities influence outcomes.

Trap dynamics can be distinguished from causal analysis as an emergent outcome of complex social-ecological interactions. Therefore, locating power as it relates to trap emergence or persistence can act as an important first step in determining causality. In terms of emergence, power can act as a driver, one of the underlying factors or conditions that initiate or exacerbate the conditions leading to a trap. Drivers can either be internal or external to the system. Haider et al. [20] discuss how external drivers, including historical legacies and socio-political structures, often precipitate or maintain trap dynamics. Recognizing power as a driver can help unpack how certain actors or institutions wield influence over resource distribution and decision-making, which can sustain or exacerbate conditions of entrapment. In terms of persistence, social power may also operate as a mechanism, a process or structure within a system that perpetuates a particular state, often through feedback loops. Mechanisms thus maintain a trap by reinforcing the conditions that led to its formation. Little is known about how social power interacts with other mechanisms in traps.

Explicitly determining how power is influencing a trap, whether it is contributing to the formation of a trap or perpetuating trap conditions by feeding back into other factors, can enable a deeper analysis and the formulation of targeted remediation strategies. Considering power as a broad spectrum of dimensions, from where and how that power is derived to the different processes in which it is utilized can help to clarify the complexity in social-ecological systems. Additionally, linking power with external factors, such as the social dimensions of resilience exemplified in Cinner and Barnes [31], can help uncover the path-dependent nature of social-ecological systems. Power dynamics, when further broadened to include ecological factors, can also reveal how feedback loops are maintained not just by social decisions but also by ecological constraints or opportunities [29]. Rather than looking at power solely in terms of human interaction but expanding that to interactions with humans and their environment can shed light on the role that nature plays in regulating trap dynamics.

Where resilience thinking has faced scrutiny for its limited attention to power structures and relationships [12], political ecology has increasingly been recognized as a potential complementary framework to investigate power dynamics in human–environment interactions. As an explanatory field, political ecology frames social-ecological systems as complex,

power-laden spaces [78] where political legacies and equity issues intersect in particular geographic and historical settings [18, 79]. By framing social-ecological systems in this way, political ecology suggests that wicked problems are not solely the result of unsustainable practices by certain communities or organizations. Instead, they are the result of complex interactions between overlapping biophysical, social, economic, and political processes operating at various interconnected scales, from the local level to the global stage [80, 81].

### 5.2.3 Bridging the gap with quantitative analysis

Few studies utilized quantitative analyses of power, indicating the need to explore how quantitative data might offer complementary insights. Yet, as our framework above demonstrates, power is inherently relational, existing within interactions between individuals or groups or even between humans and nature. This makes it challenging to isolate and measure power since it is not a fixed attribute but a dynamic interplay between actors [38]. Recent studies have employed methods like agent-based modeling [82], social-ecological network analysis [35] to study human–environment interactions. Others have employed methods like structural equation modeling [83] to explore power in social-ecological systems, particularly in terms of how access of individuals and groups is determined by power. Quantitative analyses may also reveal the strengths of feedbacks arising from interactions between power and other social-ecological elements of a system, indicating among leverage points where pressure should be exerted most.

## 5.3 Conclusions

The review emphasizes the patterns in research focus within the region, often centered on the global south, which can shape the conceptualization, framing, and assessment of power. Improving clarity and providing explicit definitions of power and its beneficiaries will enhance the transparency of assertions regarding relationships within social-ecological traps. In addition, the use of clear definitions will facilitate the organization of studies in a manner that best addresses multiple conceptualizations of power, utilizing appropriate methodologies and acquiring comprehensive data.

Notwithstanding the substantial theoretical endeavors to refine these concepts, empirical research has not uniformly assimilated these advancements. Articulating rationales for why studies focus on specific dimensions of power or even specific outcomes will provide deeper insights. The inclusion of these additional factors can serve to illustrate the potential consequences that may arise from diverse power dynamics within traps, and the ways in which they may either complement or contradict each other, along with the underlying rationale.

The continued call for more interdisciplinary research in order to understand complex issues in sustainability represents a window for researchers to broaden their methodological approaches. However, studies should focus on conceptual clarity regarding power dynamics from the outset. If research aims to show that negotiating power dynamics leads to more effective management of social-ecological traps, it should integrate appropriate ecological and social measures. Additionally, interdisciplinarity should extend across research methods and teams, in order to ensure a more balanced perspective.

Integrating the study of social-ecological traps with other research fields can help broaden our understanding and reveal the underlying mechanisms behind persistence. Incorporating power and politics into analyses of social-ecological traps can provide actor-oriented analyses of the trade-offs associated with certain environmental changes and assist in determining which system state is desirable for whom. The field of political ecology is one area that can guide this endeavor. Political ecologists emphasize the importance of historical context, which provides insight into how the legacy of past actions, policies, and social structures on current environmental and social conditions. This perspective is important for unraveling the historical roots of social-ecological traps and for recognizing the long-term impacts of colonialism, resource extraction, and land-use changes on resilience and sustainability. Leveraging political ecology as a tool can highlight the importance of considering diverse voices and forces in environmental decision-making and stresses the need for equitable and sustainable management practices that can help communities navigate and eventually dismantle traps.

Overall, giving more attention to defining power, understanding the contexts underlying these definitions, and critically considering if these definitions reflect what power means in context are crucial steps forward in linking power dynamics with social-ecological traps in both research and practice.

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**Data availability** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Competing interests** The authors declare no competing interests.

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