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ENVIRONMENTAL RESEARCH
LETTERS

TOPICAL REVIEW

Adaptive capacity beyond the household: a systematic review of empirical social-ecological research

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Abstract

The concept of adaptive capacity has received significant attention within social-ecological and environmental change research. Within both the resilience and vulnerability literatures specifically, adaptive capacity has emerged as a fundamental concept for assessing the ability of social-ecological systems to adapt to environmental change. Although methods and indicators used to evaluate adaptive capacity are broad, the focus of existing scholarship has predominately been at the individual- and household- levels. However, the capacities necessary for humans to adapt to global environmental change are often a function of individual and societal characteristics, as well as cumulative and emergent capacities across communities and jurisdictions. In this paper, we apply a systematic literature review and co-citation analysis to investigate empirical research on adaptive capacity that focus on societal levels beyond the household. Our review demonstrates that assessments of adaptive capacity at higher societal levels are increasing in frequency, yet vary widely in approach, framing, and results; analyses focus on adaptive capacity at many different levels (e.g. community, municipality, global region), geographic locations, and cover multiple types of disturbances and their impacts across sectors. We also found that there are considerable challenges with regard to the 'fit' between data collected and analytical methods used in adequately capturing the cross-scale and cross-level determinants of adaptive capacity. Current approaches to assessing adaptive capacity at societal levels beyond the household tend to simply aggregate individual- or household-level data, which we argue oversimplifies and ignores the inherent interactions within and across societal levels of decision-making that shape the capacity of humans to adapt to environmental change across multiple scales. In order for future adaptive capacity research to be more practice-oriented and effectively guide policy, there is a need to develop indicators and assessments that are matched with the levels of potential policy applications.

1. Introduction

The concept of *adaptive capacity* is the source of much debate across the spectrum of social-ecological and environmental change research. Ecologists have defined adaptive capacity as 'the latent potential of an ecosystem to alter resilience in response to change' speaking directly to the properties of an ecosystem that support persistence during or after disturbance (Angeler *et al* 2019, p 4). Social scientists define the concept similarly, but with a focus on the biophysical and socio-economic conditions that underpin the ability of people, both individually and collectively, to anticipate, adapt, and recover from the impacts of

environmental change (Berkes and Jolly 2002, Norris *et al* 2008, Allen and Holling 2010). Although the adaptive capacity concept has been well reviewed in the environmental social sciences (Gupta *et al* 2010, Mortreux and Barnett 2017, Whitney *et al* 2017, Cinner *et al* 2018, Siders 2019), reviewers have not examined how the scholarship accounts for differences in adaptive capacities as they emerge both across spatial and temporal scales, but also across levels of society from the individual, community, nation-state and beyond.

Environmental change impacts people, both individually and collectively, with the most visible impacts often manifesting in personal losses, including the loss of lives, livelihoods, capital, mental well-being, and physical health (Steffen *et al* 2018). Thus, much of the adaptive capacity scholarship in the environmental social sciences has focused on analyses of individuals and households (Siders 2019) without explicit connection to the scalar impacts of the environmental change processes under investigation. This is problematic because many of the most pressing environmental changes today—increased severity and duration of drought, regional vegetation shifts, and sea-level rise, among others—impact landscapes differently across space and time, but also across myriad human-defined jurisdictions of local and regional governance, including the boundaries of local communities and the borders of sovereign nations (Cumming *et al* 2014, Haider *et al* 2018). The capacities necessary for humans to adapt to such manifestations of environmental change are functions of individual and societal characteristics, and often a function of nested capacities across communities and jurisdictions (Adger *et al* 2009, Hill and Engle 2013). Thus, it is critical to evaluate adaptive capacities at levels beyond just individuals and households; levels at which elements such as decision-making authority, institutional structures, infrastructure, and/or coordination or collaborative capacities increase in importance (Allen and Holling 2010), but are often understudied. In this paper, we systematically review environmental social science literature on adaptive capacity with a specific focus on empirical studies performed at levels beyond the individual or household. Our objective is to better understand factors that mediate societal adaptive capacity to environmental change.

Previous reviews of the adaptive capacity research have focused on: the willingness and capabilities of individuals to convert resources into effective adaptive action (Cinner *et al* 2018); fragmentation within existing research (Siders 2019); how research on this concept has changed over time (Mortreux and Barnett 2017); methodological approaches that are often used to study adaptive capacity at multiple spatial scales (Whitney *et al* 2017); and institutional variables that affect adaptive capacity (Gupta *et al* 2010). Building the capacity of social systems to adapt depends in large part on the societal levels at which adaptation decisions are made (Vincent 2007). The majority of existing empirical research has approached assessment and measurement of adaptive capacity at the individual- and household-levels because they are the central locus of decision-making around adaptation actions (Gupta *et al* 2010, Whitney *et al* 2017, Siders 2019). There has been much debate in ecology, across various social science disciplines, and with social-ecological literatures on the definition and meanings of 'scale' and 'level' (see, e.g. Gibson *et al* 2000, Turner and Gardner 2015, Bodin and Norberg 2005, Cumming *et al* 2006, Manson 2008). Herein, we use the term 'scale' to refer to the resolution and extent of space and time specifically in reference to the processes and impacts of global environmental change (i.e. spatially from patches to landscapes to continents; temporally from years to centuries to millennia) (Gibson *et al* 2000). We employ the term 'level' to describe units of society (e.g. individuals, households, communities, jurisdictions, nations) often used in social science research as units of analysis or foci of investigation (Gibson *et al* 2000). We recognize scale and level as distinct but complementary concepts for deepening our understanding of adaptive capacity, yet we also recognize that previous studies have not drawn such clear distinctions, resulting in inconsistencies and contradictions we address in this review.

Here, we assess and discuss differences in methodological approaches, identify important issues for continued empirical investigation, and provide guidance for future social-ecological research on assessing adaptive capacity at levels beyond the household. We also present a co-citation network analysis that maps the connectivity among scholars who have investigated these dimensions of social-ecological adaptive capacity. Analyzing citation patterns provides insight into which theoretical and methodological approaches are most commonly employed and shared among communities of scholars, giving insight into challenges facing current adaptive capacity assessments and promising approaches for future social-ecological research. Our co-citation analysis demonstrates that the theoretical positioning of scholars and choice of theoretical frameworks (vulnerability or community resilience) may influence the indicator selection or method of study in adaptive capacity assessments. As the conceptual underpinnings of adaptive capacity in the social-ecological sciences are rooted in vulnerability and resilience scholarship (Smit and Wandel 2006, Angeler and Allen 2016), we analyzed empirical research articles that relied on vulnerability and resilience frameworks, theories, and methods. The vulnerability scholarship generally defines social adaptive capacity as the set of biophysical and socio-economic conditions that underpin the ability of people to anticipate, adapt, and recover from the impacts of environmental change (Engle 2011).

The resilience scholarship defines community resilience as the collective capacity of a community or system to respond and adapt to an environmental stressor (Berkes and Jolly 2002, Norris *et al* 2008, Allen and Holling 2010). Recognizing the tight conceptual relationships between adaptive capacity, vulnerability, and resilience (Gallopín 2006, Smit and Wandel 2006), we use the term 'adaptive capacity' to refer to the ability of social-ecological systems to adapt to, navigate, and/or recover from the impacts of environmental change.

2. Methods

2.1. Article selection

The goal of our study is to understand how scholars study adaptive capacity at societal levels beyond the individual and household. Therefore, we chose to expand our literature search and review to keywords that attempted to capture the full range of social-ecological and environmental social science research addressing adaptive capacity. Our review includes even those papers not captured with an 'adapt* capac*' term search, as often papers employing the concepts of vulnerability and resilience are clearly linked through the concept of adaptive capacity (Turner *et al* 2003, Eakin and Lemos 2006, Cutter *et al* 2008, Brown and Westaway 2011, Engle 2011).

Our article selection method follows the principles for systematic review proposed by Pullin and Stewart (2006) and Berrang-Ford *et al* (2015). We performed a topic search in the *Scopus* database using search terms used by scholars in community resilience and vulnerability literatures to explore the concept of adaptive capacity in social-ecological systems from 2000 to 2020. Our search included the terms: 'community resilience', 'adaptive capacit*', 'generic capacit*', and 'specific capacit*'. We combined these terms with at least one of the following terms to link the topic of adaptive capacity with environmental change as the target of our intended review: 'climat* chang*', 'soci*-ecological system*', 'soci* system*', and 'SES'. The search was last updated on 06 June 2020. Our search returned 3070 articles.

We acknowledge that there is a large literature that examines the capacities of societies to adapt to environmental change at different levels of decision-making, albeit sometimes using different terms. For example, the term 'community' may not always appear for studies of resilience at higher levels of decision-making. Including additional terms, such as 'transformative capacity', 'security', or 'robustness' may reveal studies that focus on higher levels of societal organization, such as nation states or regional jurisdictions (Hölscher *et al* 2019, Wolfram *et al* 2019, Krueger *et al* 2020). However, these studies will not be explicitly couched in the concept of 'adaptive capacity', which is the central topic of focus in our systematic literature review. These search terms may be more appropriate for a literature review with a research objective focused on understanding how scholars analyzed general system-level properties. The goal of our study is to understand how scholars have carried out explicit adaptive capacity research at larger levels of societal decision-making. Our search terms sufficiently broaden the scope of our study as well as generate an optimal/specific number of articles that are relevant to our research question (Pullin and Stewart 2006). That is, we reviewed all the articles that employed either the vulnerability or resilience frameworks to study adaptive capacity at higher levels of decision-making (3070 papers). It is a recommended practice to use such a conservative approach in selecting search terms so that we retain all articles that are relevant for answering our research question. Including additional search terms to incorporate ecological sciences would have yielded studies that are not relevant to the scope of our review and diminished the effectiveness of our analysis (Pullin and Stewart 2006).

2.2. Inclusion and exclusion criteria

We included papers in the final review if they, (1) contained some element of social science data collection and analysis, even if combined with biophysical data collection and analysis, (2) reported empirical findings based on primary fieldwork, secondary research, or computational modeling (i.e. reviews and opinions excluded), (3) included adaptive capacity as a system driver or outcome (e.g. a study that examined key drivers of social learning, but did not seek to understand how social learning shaped adaptive capacity outcomes would be excluded), and (4) assessed adaptive capacity at societal levels larger than the individual or household (e.g. county, watershed, community, etc). We note that there are interdependencies between environmental change processes and social adaptive capacity. However, given our research objective and questions, we only included studies that analyze the factors that shape the social capacity of social-ecological systems to adapt to environmental change. We excluded articles that solely examined the ecological adaptive capacity of a social-ecological system. Applying these criteria narrowed the review to 287 candidate papers for review (appendix 2 available online at stacks.iop.org/ERL/17/063001/mmedia).

2.3. Co-citation analysis

To determine if and how the empirical research on adaptive capacity relates to theoretical orientation, we employed a co-citation analysis. This method identifies and visually depicts important or central publications as well as cross-linkages both within and between different communities of scholars (Zhao and Strotmann 2015). Constructing a co-citation network involves determining the frequency with which any two publications are cited together by other articles (Small 1973). Clusters of research appear when the

same pairs of articles are co-cited by other publications. The co-cited papers in such clusters often tend to share a common theme and can reveal cross-linkages between different theoretical and conceptual domains. Using the co-citation analysis, we visualized the network of papers reviewed and identified cross-linkages between studies using vulnerability and resilience frameworks. To do this, we imported the articles into R and used the *bibliometrix* package, which generates a co-citation network layout using the Fruchterman-Reingold Algorithm (Fruchterman and Reingold 1991) and clusters nodes based on the density of links (Aria and Cuccurullo 2017, Traag *et al* 2019). Then, we examined the articles within each cluster to determine if they were theoretically or methodologically linked for further analysis of the impact of these communities of scholarship.

2.4. Content analysis

In addition to the co-citation analysis, we used content analysis to further examine the 287 articles selected. For each article, we filled out a pro-forma questionnaire (appendix 3) that included basic information about the study (e.g. study location, environmental change under investigation), questions regarding methods and scale used in data collection and analysis, and open-ended questions about papers' objectives, theoretical framings, and policy implications. Responses to this questionnaire provided critical insight on the theoretical and methodological approaches used to study adaptive capacity at higher societal levels and their applications to policy and practice.

3. Results

3.1. Level of analysis, topical sectors, and geographic distribution

Of the 287 articles reviewed, 70% (201 studies) employed the concept of adaptive capacity and 30% (86 studies) employed the concept of community resilience to measure the capacity of a system to cope with or adapt to environmental stressors (figure 1).

The most common level at which adaptive capacity was analyzed in the sample was the idiosyncratically-defined 'community' level ($n = 76$, 26.5%) (figure 2(A)), although this was often measured as the aggregated adaptive capacity of households (Petheram *et al* 2010, Moreno-Sánchez and Maldonado 2013, Akamani and Hall 2015). The terms 'community' and 'region' were inconsistently defined across the adaptive capacity scholarship. That is, some studies defined 'community' or 'region' based on geographic or political boundaries (e.g. Morzaria-Luna *et al* 2014, Jacobson 2020), which vary greatly in spatial scale from coastal areas within a city (e.g. Huang *et al* 2012) to drought-prone districts within an 'economic region' (e.g. Singh 2020). Other researchers defined these terms as groups of people who share social or environmental attributes such as populations being urban or experience with events such as flood or drought (e.g. Plummer *et al* 2018). This lack of consensus within the adaptive capacity research reflects a broader challenge of defining larger social groups—such as 'community'—a challenge that exists across disciplines, from community-based research in anthropology and sociology to public health (McKeown *et al* 1987, MacQueen *et al* 2001).

With regard to disturbances, nearly 26% of the studies (n = 72) measured the effects of a single environmental disaster (e.g. cyclones, hurricanes, etc) on multiple sectors (e.g. agriculture, urban, energy, etc) and resources (e.g. water, forests, etc) (figure 2(B)). The majority of studies reviewed focused on one specific sector (e.g. tourism) or resource (e.g. water) and examined multiple disturbances to which the social-ecological system under study could or should adapt. Agro-pastoralist systems and/or communities were the most commonly studied sector (n = 56, 20%), followed by urban systems (14%) and the fisheries sector (n = 38, 13.5%). Geographically, the majority of studies reviewed investigated locations in Asia (n = 97, 34%), followed by North America (n = 57, 20%), Europe (n = 43, 15%), Oceania (n = 37, 13%), South America (n = 31, 11%), and Africa (n = 20, 7%) (figure 3). Within each continent, research was dominated by studies in high- to middle-income countries. For example, of the 97 studies conducted in Asia, 32 were conducted in India and 30 in China; 51 of the 58 studies in North America focused on the United States and Canada. These findings mirror the results of previous reviews on the geographic distribution of adaptive capacity research generally (e.g. Siders 2019), reinforcing that a greater focus on adaptive capacity of developing nations is still a pressing need, particularly in light of their high vulnerability to climate change (Klein 2009).

3.2. Data sources and analytical methods

Authors of the 287 studies we reviewed used a wide range of both primary and secondary data in attempts to measure adaptive capacity (figure 4(A)). Primary data collection (e.g. interviews, surveys, focus group discussions) was the most common (51%) method applied, with secondary datasets (e.g. Census, FAO, historical data, etc) used less frequently (35%). Some studies (13%) used a combination of primary and secondary data collection methods to leverage multiple data sources (e.g. Amundsen 2012, Bouroncle *et al* 2017, Andrade and Szlafsztein 2018).

Studies combined multiple primary methods (e.g. interviews, surveys, focus group discussions, etc) to collect data on the specific determinants of adaptive capacity (18.8%) (Cinner *et al* 2012, Bennett *et al* 2014, Akukwe and Ogbodo 2015). Researchers' choice of methods generally followed one of to two research approaches: (1) applying existing frameworks to assess adaptive capacity of a system,

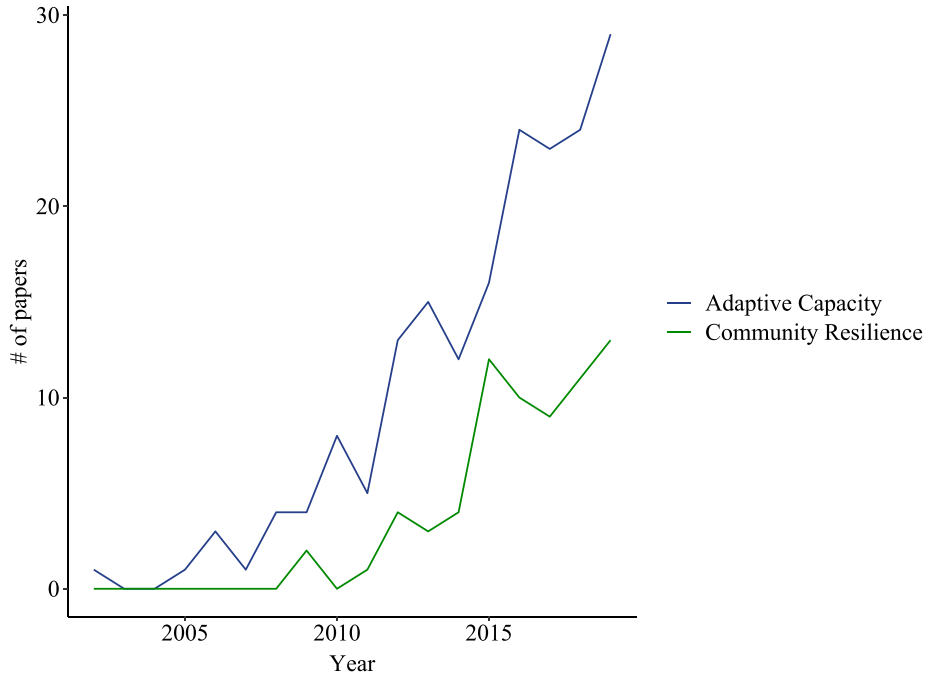

Figure 1. Increase in adaptive capacity publications focused on societal levels higher than the individual or household from 2000–2019.

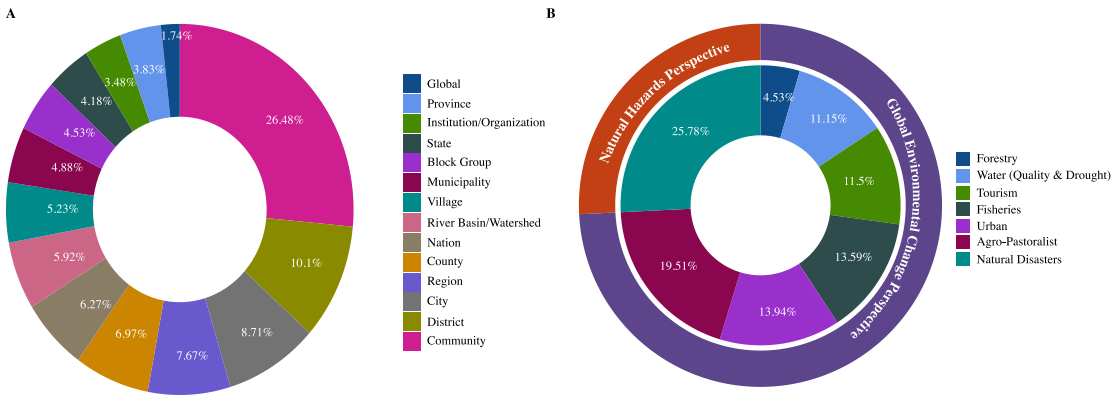

Figure 2. Distribution of (A) levels of analysis and (B) sectors and resources. The topical sector was identified using each study's main focus.

or (2) proposing new frameworks using new indicators and/or methodological approaches. Figure 4(B) shows the broad classifications of types of methods used across the studies reviewed to evaluate the determinants of adaptive capacity as well as an overall measure of adaptive capacity. Quantitative methods (e.g. regressions, simulation modeling) were the most commonly used methods for analysis (53%), followed by qualitative methods (30%), and some studies employed a combination of both quantitative and qualitative methods for analysis (18%).

The methodological approaches used by the studies reviewed can be broadly classified as index-based approaches and proxy-based approaches (figure 5). Index-based approaches typically: (1) identify the determinants of adaptive capacity based on secondary data (Ahumada-Cervantes *et al* 2017, Ducusin *et al* 2019, Azam *et al* 2021) or household surveys and key informant interviews (Cinner *et al* 2012, Quiroga *et al* 2020); (2) use indicators to measure each determinant either quantitatively or qualitatively; and (3) aggregate the indicators into a single metric or index of adaptive capacity either based on weightings derived from expert opinions (Moreno-Sánchez and Maldonado 2013), qualitatively (Gupta *et al* 2010), or through dimensionality reduction methods (e.g. principal component analysis, factor analysis, etc) combined with regressions (Moreno-Sánchez and Maldonado 2013). Within the 287 articles we reviewed, adaptive capacity indices were calculated using quantitative methods (20.6%, e.g. Kotzee and Reyers 2016, Gerrard 2018), qualitative methods (25.5%, e.g. Hurlbert and Gupta 2017), or a combination of quantitative and qualitative

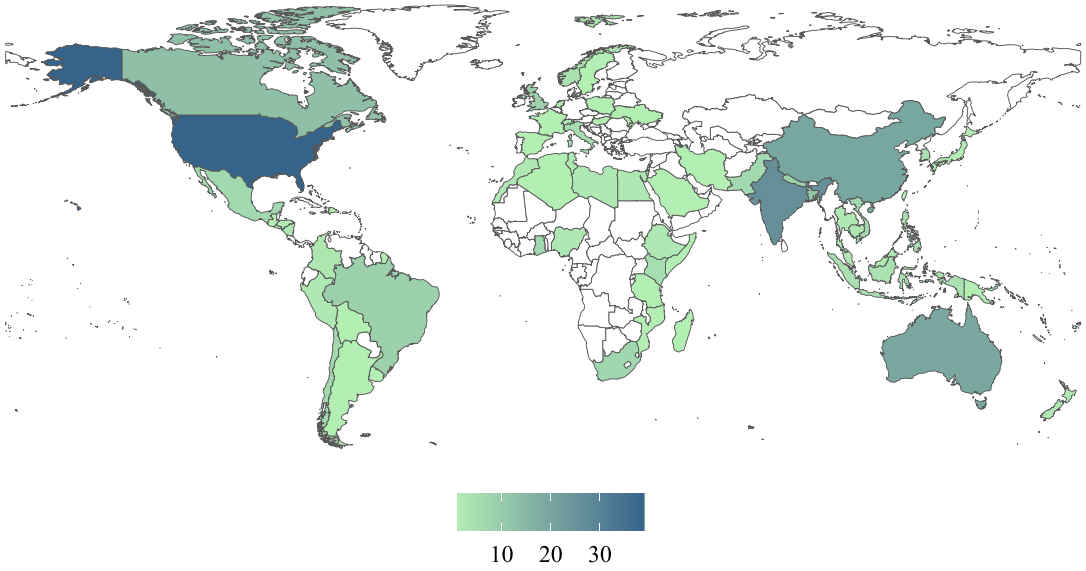

Figure 3. Geographic distribution of adaptive capacity studies. Colors are proportional to the number of studies conducted in a country. For example, 39 studies examined the adaptive capacity of social-ecological systems in USA (dark blue). Several countries (light green) had one study (e.g. Argentina, Bolivia, France, Iran, Japan, etc). The number of studies shown here is less than 287, as some authors conducted studies on a global scale, which are not captured.

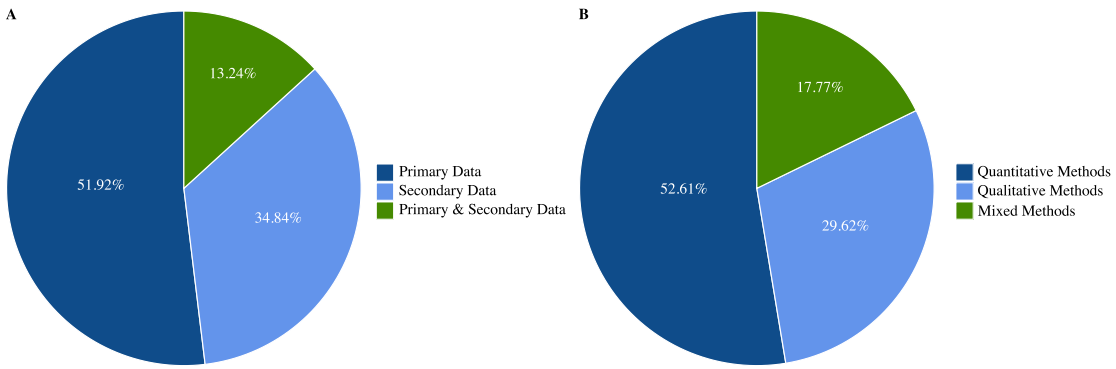

Figure 4. Types of (A) data used, and (B) methods used for data analysis.

methods (8.5%, e.g. Cutter *et al* 2014). The most commonly used frameworks by studies that used index-based approaches were the Vulnerability Livelihood Index (e.g. Ahumada-Cervantes *et al* 2017), Sustainability Livelihood Index (e.g. Islam *et al* 2014), and the Adaptive Capacity Wheel (Gupta *et al* 2010).

In proxy-based approaches, authors typically: (1) identify a proxy for adaptive capacity; (2) identify the determinants of adaptive capacity, measure the determinants using indicators, and evaluate a score for each determinant; and (3) compare the determinant scores with the proxy to determine possible correlation. Proxy-based approaches often use inductive arguments to develop models that explain the observed adaptive capacity through some explanatory variables. For example, if there are data showing that national-level climate change adaptation outcomes are statistically associated with a nation's corruption index, one can infer that the presence of low corruption may indicate high adaptive capacity (Berrang-Ford *et al* 2014). Proxies may include specific social measures, such as the degree of power asymmetry between local community members (Choudhury and Haque 2016, Guarnacci 2016, May 2019), or a specific adaptation practice, such as use of collective-choice arrangements and social learning (Freduah *et al* 2018, Cui and Li 2020), or a specific performance measure, such as agricultural yield (Monterroso-Rivas *et al* 2018, Lawal and Adesope 2019). Within the studies reviewed, proxy-based approaches predominantly used quantitative methods, such as regressions (13.1%, e.g. Brooks *et al* 2005), principal component analysis (10.6%, e.g. Gbetibouo *et al* 2010), simulation models (4.6%, e.g. Chang *et al* 2017), or the combination of multiple quantitative methods (9.3%, e.g.

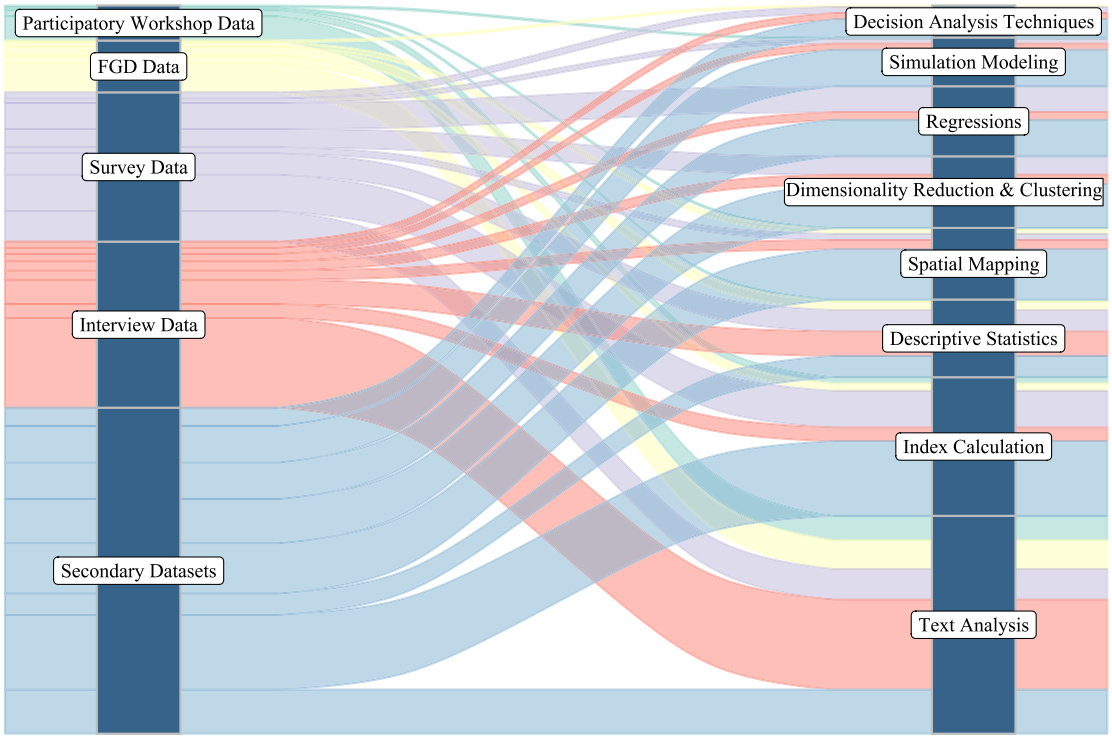

Figure 5. Relationships among data types (left) and the methods used for analysis (right). The widths of the bands are linearly proportional to the number of studies using a particular method for a given data type. Since several papers used multiple data types and methods, there are 389 bands.

Cai *et al* 2016). A few studies used spatial mapping to measure adaptive capacity of the study area (7.8%, e.g. Corobov *et al* 2013).

3.3. Co-citation analysis

The co-citation network (figure 6) allows us to understand the degree to which scholars in the environmental social sciences study adaptive capacity by leveraging concepts from community resilience and vulnerability studies. Although our review only included empirical studies, the majority of papers in figure 6 are conceptual in nature. Each node in the network depicted in figure 6 represents an article that was cited by a paper in our review, and the links (or edges) between nodes connect articles cited jointly by a paper in our review. We measured the density of each cluster by dividing the number of connections between nodes by the total number of possible connections (dyads) within the cluster. We determined the distance between clusters by summing the number of connections between them. The visualization of the co-citation network reveals three distinct scholarly communities related to adaptive capacity: (1) vulnerability literature (red); (2) community resilience studies (green); and (3) papers that draw on both frameworks (blue).

The largest cluster in the co-citation network (red) represents publications that primarily draw on the vulnerability literature to characterize adaptive capacity. Prominent nodes in this cluster were Adger *et al* (2005), Brooks *et al* (2005), Smit and Wandel (2006), Vincent (2007), and Engle (2011). These papers were among the 20 most cited publications by papers in our review. Broadly speaking, these papers review the definitions of adaptive capacity and/or develop methodologies for measuring adaptive capacity at societal levels beyond the household. Smit and Wandel (2006), Vincent (2007), and Engle (2011) are papers that conceptually reviewed the definitions of adaptive capacity of human systems to climate variability.

Engle (2011) reviewed the definitions of adaptive capacity in both the vulnerability and resilience literatures, and called for integrating insights from both these literatures to improve our understanding of the determinants of adaptive capacity. Smit and Wandel (2006) and Vincent (2007) also reviewed the concept of adaptive capacity through the lens of vulnerability and discussed how the determinants of adaptive capacity are level-specific. For example, Vincent (2007) developed two indices to measure adaptive capacity at different levels: the National Adaptive Capacity Index (NACI) for cross-country comparison in Africa; and the Household Adaptive Capacity Index (HACI) for cross-household comparison in the Limpopo Province, South Africa. Both indices were aggregated from the weighted average of a number of composite sub-indices.

Brooks *et al* (2005) was another influential study in which a composite vulnerability index

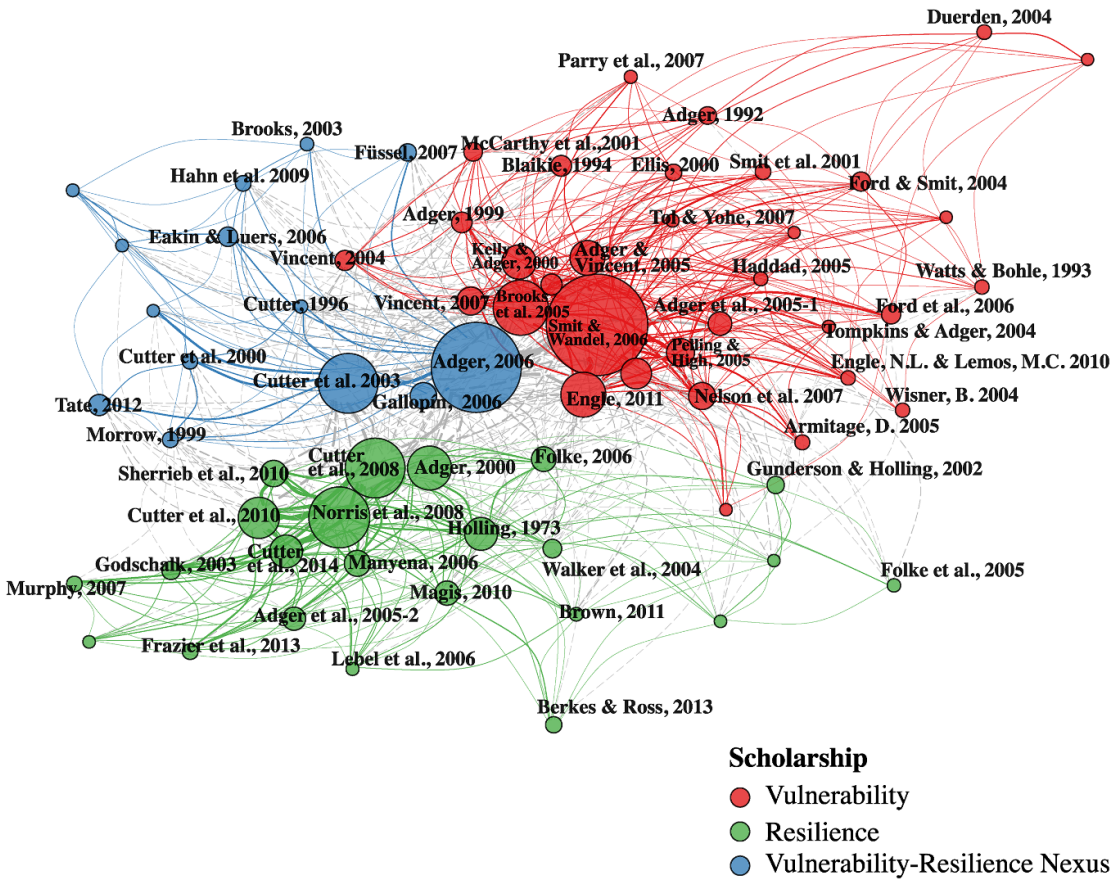

Figure 6. Three scholarly communities of adaptive capacity-community resilience research, 2000–2020. The co-citation network illustrates key publications cited (nodes) in our review of 287 papers. The links between nodes (edges) represent papers that were cited together by any paper in our review. Size of the nodes is based upon degree centrality, such that larger nodes indicate more co-citations. Width of the links represents the number of co-citations between any two nodes. The grey dashed links represent linkages across clusters.

methodology was developed to measure vulnerability and adaptive capacity at the national level on a decadal timescale. The composite index was developed from 46 variables representing structural factors behind vulnerability at the national level. These variables were proxies for national-level economic well-being and inequality, health and nutritional status, education, physical infrastructure, governance, geographic and demographic factors, agriculture, ecosystems and technological capacity.

The resilience cluster (green) focused on the definition and measurement of resilience to hazards and disasters at the community level (figure 6). Research on community resilience has specific foundations in the social-ecological systems literature as well as in mental health and psychology scholarship (Berkes 2007). Community resilience is generally defined as the collective capacity of a community to respond and adapt to an environmental stressor (Berkes and Jolly 2002) or a process that links the network of adaptive capacities in a community in the face of environmental and social change (Norris *et al* 2008). Prominent publications in this cluster included Cutter *et al* (2008), Norris *et al* (2008) and Cutter *et al* (2014). These papers were each among the 20 most cited publications.

Norris *et al* (2008) presented the concept of community resilience as a process linking a network of adaptive capacities to adaptation actions meant to cope with an external disturbance, and argued that a collection of resilient individuals does not guarantee a resilient community. Cutter *et al* (2008) developed a conceptual model to assess resilience to natural disasters at the community level. This paper defined 'community' as a meso-level entity composed of built, natural, social, and economic environments that influence one another in complex ways, recognizing there may be multiple communities within a defined geographic space such as a neighborhood, census tract, city, or county. Model of Cutter *et al* (2008) assesses resilience as a dynamic process that is affected by antecedent conditions and spatial interactions both within and exogenous to the community being studied. Cutter *et al* (2014) developed an empirically-based resilience metric that integrates place-based indicators (e.g. local disaster training, home ownership, local food suppliers, place attachment, etc) and cross-scalar

indicators (e.g. jurisdictional coordination, federal disaster aid, national flood insurance program, etc) of community resilience to natural disasters. The proposed metrics incorporated all facets of a community including infrastructure, governance structures, economy, biophysical attributes, demographics, and social capital.

The smallest of these clusters (blue) comprised studies in adaptive capacity research that focused on linkages between vulnerability and resilience research (figure 6). Many of the prominent authors in this cluster overlapped with those in the vulnerability (red) and resilience (green) clusters. Influential papers in this cluster include Cutter *et al* (2003), Adger (2006), and Gallopín (2006). Adger (2006) reviewed the analytical approaches to vulnerability research in an attempt to improve the synergies between adaptation and resilience literatures. The paper specifically focused on how theories of entitlements and hazards resulted in an apparent lack of convergence of diverse methods and epistemologies in vulnerability research. Ultimately, the paper called for better integration of conceptual frameworks and methods across the domains of vulnerability, adaptation, and resilience.

Cutter *et al* (2003) reviewed research on vulnerability in the hazards field focusing on three methodological approaches to measuring vulnerability: (1) as an exposure (biophysical and structural conditions that make people vulnerable to a hazard); (2) as a social condition (historical, cultural, social, and economic processes that constrain the individual's or society's ability to cope with disasters); and (3) as a 'hazard of place' model (biophysical risk as well as a social response within a specific geographic domain). Similar to Adger (2006), this paper noted how the methodological approaches employed in vulnerability research were highly varied within the vulnerability, adaptation, and resilience literatures. Cutter *et al* (2003) proposed the hazards of place model as a useful construct to bridge theoretical and conceptual gaps between the three bodies of literature and assess vulnerability. Gallopín (2006) analyzed the conceptual linkages between vulnerability, resilience, and adaptive capacity within social-ecological systems. The paper concluded that the vulnerability and resilience domains were conceptually linked to each other through the concept of adaptive capacity. Although the majority of papers in this cluster focused on bridging the research gaps between vulnerability and resilience domains, we found that this group was comparatively more connected to the vulnerability scholarship than the community resilience literature (figure 6).

3.4. Policy applications

Forty-one percent ($n = 119$) of the empirical studies we reviewed provided policy or practical recommendations related to adaptive capacity. These recommendations generally fell into one of two categories: (1) recommendations that identified barriers and opportunities for interventions to increase adaptive capacity or improve the overall resilience of a system (e.g. Bennett *et al* 2014, Yankson *et al* 2017, Younus and Kabir 2018, Tian *et al* 2019); and/or (2) a comparison of relative adaptive capacities within or across levels of decision-making in a social-ecological system to inform policy decisions regarding investment or resource allocations (e.g. Pearsall 2009, Pandey *et al* 2011, Xenarios *et al* 2016). Studies reviewed that also provided policy recommendations were mostly single point-in-time assessments of indicators and metrics relative to past environmental disturbances (e.g. Brooks *et al* 2005, Keys *et al* 2014, Bergstrand *et al* 2015, Schilling *et al* 2020) as opposed to continuous or longitudinal studies of change in adaptive capacity over time (e.g. Chang *et al* 2017).

We found that no studies in our review explicitly addressed specific types of policy problems, or the stage(s) of the policy process a study might inform, e.g. agenda setting, review and formulation of policy instruments, policy legitimization, and policy implementation and evaluation (Sabatier and Weible 2014). All the studies in our review implicitly focused on the 'review and formulation of policy instruments' stage of the policy-making process: recommending policy instruments or solutions as practical guidance to practitioners and stakeholders (e.g. Akamani and Hall 2015, Binder *et al* 2015, Metcalf *et al* 2015, Mthembu and Zwane 2017).

4. Discussion

Our analysis suggests that current approaches to measuring and assessing adaptive capacity at societal levels beyond the household do not match the complexity of the phenomenon. Adaptive capacities of social-ecological systems vary across spatial scales and levels of society, yet the majority of studies we reviewed simply aggregated individual- or household-level data to make assessments of adaptive capacities at higher levels of decision-making (e.g. community, regional jurisdictions, nation state), as well as across scales (e.g. from patches to landscapes). In section 4.1, we discuss how this approach oversimplifies our understanding of social-ecological systems and ignores inherent interactions within and across societal levels of decision-making that shape the capacity of humans to adapt to environmental change. In general, we found that the adaptive capacity literature has done a poor job of handling issues of cross-scale and cross-level interactions, as well as 'fit' between data collected and adaptive capacity analyzed. Greater attention is needed on the role of within- and cross-level interactions in our understanding of adaptive capacities beyond the household. Furthermore, we discuss how adaptive capacity

assessments rely predominantly on static measurements which fail to appreciate (1) how adaptive capacity of a society changes over time, and (2) how feedbacks between environmental processes and social systems domains may shape adaptive capacity over time. In section 4.2, we discuss how the choice of theoretical framing (i.e. vulnerability v. community resilience) may inherently bias whether and how adaptive capacity assessments examine within- and cross-level interactions that shape adaptive capacities of a system under investigation. Last, in section 4.3, we discuss how translating research to actionable solutions for practitioners and policymakers has been constrained by several methodological challenges.

4.1. (Mis-)measuring adaptive capacity beyond the household

Scholars who assess adaptive capacity at societal levels beyond the household often favor collection of individual- and household-level data (e.g. occupational mobility, levels of education, access to information, social networks, etc) and eschew data that might measure interactions across multiple levels of decision-making. Examples of such cross-level data could include measures of inter-governmental resource allocation, joint monitoring, distribution of decision-making authority, and emergence of coordination and cooperation of individuals and groups, or assessments of organizations, infrastructure, and information and technology that spans levels of decision-making.

Previous theoretical and empirical research has concluded that incorporating that such cross-level data is essential for holistically assessing adaptive capacities of social-ecological systems (Scheffer *et al* 2003, Hill and Engle 2013, Garrick and De Stefano 2016, Gunderson *et al* 2017, Whitney *et al* 2017). However, we found very few studies in our review that incorporate such data in their assessments. Of those that did, Cutter *et al* (2008) demonstrated that cross-level indicators like county-level participation in the federal national flood program, coordination between county- and state-level transportation agencies, and coordination of state- and community-level evacuation plans may improve the disaster resilience of a community. In another example, Bunce *et al* (2010) showed that integration of local fishing groups into regional- and national-level agencies is likely to improve the (1) management of river basins in Mozambique and (2) conservation of marine protected areas in Tanzania. Only a handful of other studies we reviewed (e.g. Westerhoff *et al* 2011, Chang *et al* 2017, Tian *et al* 2019, Bangwayo-Skeete and Skeete 2020) included cross-level indicators that shape adaptive capacities of social-ecological systems. This limitation in current research highlights the need for future researchers to explicitly identify and measure the determinants of adaptive capacity that emerge across multiple levels of decision-making.

Adaptive capacity research to date also tends to ignore data that measures how interactions *within* a particular level of decision-making may influence the adaptive capacity of the system under study. For example, scholars have previously argued that successful strategies for bolstering adaptive capacity will engage actors at every level of decision-making if they are to be successful (Brooks *et al* 2005). However, we found that most empirical studies paid little attention to identifying these actors. Moreno and Shaw (2019) provides a rare counter example, concluding that an improved collaboration between private utility companies and public emergency planners in the Talcahuano region in Chile may improve the resilience of communities in that region in the face of earthquakes and tsunamis. In another study, Yankson *et al* (2017) predicted that lack of coordination across coastal towns in the Greater Accra Metropolitan Area of Ghana may impede the implementation of flood adaptation strategies, such as early warning information systems, and decrease the adaptive capacity of the metropolitan area. Apart from these studies, none of the studies we reviewed either (1) identified key actors (organizations, decision makers, government entities, etc) that are instrumental to enhancing adaptive capacity within the level of their study site, or (2) examined how interactions between actors within a particular level of decision-making may shape the overall adaptive capacity of the system.

In practice, evaluating adaptive capacity within and across multiple levels of decision-making necessitates developing and using data to assess governance attributes such as collaboration, accountability, knowledge pluralism, learning, and networks (Armitage 2008). Collecting and assessing data for these kinds of indicators poses practical challenges for researchers because this data is not often readily available, statistically analyzable, and/or requires time consuming data collection methods (e.g. surveys, interviews) to uncover. One way that adaptive capacity researchers have attempted to overcome data availability and collection constraints is by using index-based approaches to aggregate capacities of individuals and/or households (Pandey *et al* 2011, Wilson *et al* 2013, Fernández-Giménez *et al* 2019, Xu *et al* 2020). For example, Moreno-Sánchez and Maldonado (2013) conceptualized adaptive capacity as determined by individual-level endowments as well as their social and human capital. They conducted household surveys to collect information about several determinants of adaptive capacity; then they calculated the scores of these determinants using principal component analysis and aggregated them linearly to construct an adaptive capacity index. Other studies that measure adaptive capacity at higher levels often use nationally aggregated data (e.g. GDP, Gini coefficient, food production index, etc) (Brooks *et al* 2005, Allison *et al* 2009, Cheung *et al* 2015, Himes-Cornell and Kasperski

2015). Table 1 builds on the co-citation analysis (figure 6) to illustrate commonly used determinants and methods by adaptive capacity studies at higher levels of decision-making. The table demonstrates how studies that draw on the community resilience framework do a better job of incorporating cross-level indicators.

A common critique of aggregated research is that it is focused on the analysis of higher levels and fails to incorporate the sub-national indicators at smaller levels of decision-making, such as local knowledge, or household capacities, that mediate the capacity to adapt (Cutter *et al* 2003, Whitney *et al* 2017). The use of both index-based approaches and nationally aggregated data have resulted in insufficient attention to key issues such as the coordination between institutions and organizations and power relations within networks and actors that may affect adaptive capacities of communities (MacKinnon *et al* 2009, Yates 2012). Furthermore, aggregating the capacities from individual or household levels to higher levels fails because environmental change disproportionately impacts different levels of society (Janssen *et al* 2007), and human responses at a particular level have varied effects at different spatial scales (from patch to landscape) across the environment (Adger *et al* 2005). Adaptive capacity scholars have tended to focus on either spatial scale (e.g. continent, ecological region, landscape, etc) or social level (e.g. city, province, nation) significance, with limited efforts to explicitly align the two (Whitney *et al* 2017).

Another data limitation of adaptive capacity research at higher levels of decision-making is the lack of longitudinal studies. Social-ecological systems are dynamic systems that change continuously in response to environmental and socio-economic stressors (Scheffer *et al* 2009). Feedbacks between the social and ecological systems determine the effectiveness of adaptation strategies (Carpenter and Brock 2008, Schlüter *et al* 2014) and consequently the ability of these systems to cope with internal demands and external stressors (Vallury *et al* 2020). Environmental processes, such as climate change, occur at multiple scales and feedbacks have been observed across multiple levels of decision-making (Berkes 2007, Adger *et al* 2009). Thus, adaptive capacity assessments need to examine how these feedbacks—and consequently human responses—change over time, if they are to provide insight for bolstering present and future capacities to respond. Few studies in our review used quantitative models to examine the feedbacks between environmental processes and social systems as well as predict how these feedbacks may affect the system's capacity to adapt to change in the long-run (e.g. Chang *et al* 2017, Bangwayo-Skeete and Skeete 2020). Additionally, the majority of studies reviewed treated community resilience and adaptive capacity as static phenomena for the purposes of measurement. Without greater understanding of feedbacks across levels through either formal models or longitudinal studies, our understanding of how the adaptive capacity of a system will change in the long-run will remain limited in the face of increasing challenges from environmental stressors.

The limitations of current adaptive capacity research we discuss here may indeed apply to lower levels of decision-making as well. For example, previous reviews describe the lack of consistency around selection of indicators in adaptive capacity research because of data availability constraints and high fragmentation within the academic field (Siders 2019). However, we argue that these limitations are more pronounced at higher levels of decision-making. This is because the factors that underpin adaptation decisions become more diverse and complex as one moves from smaller spatial scales and lower levels of decision-making to larger spatial scales and higher levels of decision-making (Adger *et al* 2009). In addition, barriers such as institutional inertia, cultures of risk denial, etc may preclude adaptation at higher levels of decision-making (Termeer *et al* 2010, Gupta *et al* 2013, Eisenack *et al* 2014, Herrfahrdt-Pähle *et al* 2020).

Although many of the impacts of environmental change are felt locally (e.g. loss of livelihoods), the underlying biophysical processes driving change at larger spatial and temporal scales necessitate a societal-level response. Researchers who examine adaptive capacities at societal levels beyond the household are likely to advance future research by ensuring their indicators, determinants, and methods align with the level of their study site and their research motivations. Thus, researchers designing empirical studies should aspire to: (a) ensure that indicators and methods capture cross-level interactions, (b) capture temporal variation and feedbacks in their study, and (c) address the challenge of enhancing adaptive capacities at societal levels beyond the household.

4.2. The importance of theoretical orientation

Our analysis suggests that the inclusion and measurement of cross-level indicators in adaptive capacity assessments is often related to the theoretical frameworks (vulnerability or community resilience) that underpin the research, as shown through the co-citation analysis of our sample (figure 6). We found that the community resilience literature often did a better job of incorporating cross-level determinants of adaptive capacities at societal levels larger than the household. Building on the co-citation analysis in section 3.3, we posit that one reason for this may be because of the inherent focus of the resilience framework on the dynamic processes that affect spatial and temporal interactions both within and exogenous to the system being studied. In this section, we discuss how theoretical orientation may be facilitating or constraining the

Table 1. Illustrative examples of adaptive capacity research at higher levels of decision-making, categorized by theoretical frameworks.

Index	Example	Framework	Dimensions	Methods
Adaptive capacity post-tsunami	Paton *et al* (2008)	Vulnerability	1. Organization 2. Responsibility 3. Cooperation	Data was collected through respondent surveys in affected communities. PCA of Likert-scale based responses was conducted to determine the highest factor that determined collective capacity.
Adaptive capacity index of fishing communities	Moreno-Sánchez and Maldonado (2013), Maldonado and Moreno-Sánchez (2014)	Vulnerability	1. Economic Resources 2. Information & Skills 3. Infrastructure 4. Institutions	Indicators were scored based on surveys of stakeholders. Additive aggregation with equal weighting for the indicators was used to calculate an index.
Adaptive capacity of water resources system in river basins	Pandey *et al* (2011)	Vulnerability	1. Natural capacity 2. Physical capacity 3. Human capital 4. Economic capacity	Data was collected through several secondary data sources. The adaptive capacity index was calculated as an aggregate indicators. Weights of each of the parameters was calculated using the Analytical Hierarchy Process.
Adaptive capacity to coastal hazards	Lam *et al* (2016)	Resilience	1. Socioeconomics 2. Infrastructure 3. Economic resilience 4. Community capital 5. Institutional resilience 6. Infrastructural resilience 7. Environmental resilience	Data was collected through secondary data sources. Indicators were weighted and aggregated to calculate an adaptive capacity index.
Quantification of natural disaster resilience	Frazier *et al* (2013)	Resilience	1. Demographics 2. Transportation 3. Cross-agency coordination 4. Infrastructure 5. Regulatory	Data was collected through primary and secondary data sources. Differential weighting of resilience indicators and spatial autocorrelation techniques (Moran's I and LISA analysis) were used to calculate resilience index.

examination of within- and cross-level interactions at higher levels of decision-making in adaptive capacity assessments.

The application of a vulnerability framework is often applied to assess the impacts of global environmental change on humans and their ability to adapt at local levels (i.e. individual or household). As a result, this research is subject to the 'sin of particularism' (Head 2010), which prioritizes the role of the individual or household and assumes adaptive capacity is a universal process capable of being reproduced independently at different predetermined levels (Hulme 2010). The conceptual challenge with this approach is that this research treats 'level' as a fixed, predetermined 'partitioned geography' (MacKinnon 2011, p 24) or analytical frame (Marston *et al* 2005), often leading scholars to aggregate individual-level indicators to assess adaptive capacity at levels beyond those which the chosen indicators were designed to address. As a result, vulnerability approaches fail to examine relational determinants of adaptive capacity between levels of decision-making, such as jurisdictional coordination, power relationships, and so on (Osbahr *et al* 2008).

In contrast, community resilience scholarship often assumes that impacts of global environmental change are localized and specific to a level of societal decision-making. In terms of the community resilience approach, a 'community' is defined as a social system that is 'composed of built, natural, social, and economic environments that influence one another in complex ways' (Norris *et al* 2008, p 128). Central to the definition of a community is the notion that there can be multiple communities within a defined geographic space (e.g. neighborhood, city, regional jurisdiction, nation-state, etc) and each community may have different degrees of resilience to change partially driven by cross-scale and cross-level determinants of adaptive capacities (Cutter *et al* 2008). Moreover, community resilience research often notes that the 'whole is more than the sum of its parts' (Norris *et al* 2008, p 128), meaning that the aggregation of individual capacities that support resilience does not guarantee a resilient community (Pfefferbaum *et al* 2007). Thus, scholars with this theoretical orientation emphasize that an examination of both individual-level and higher-level indicators are important for measuring adaptive capacity (Cutter *et al* 2008, Fekete *et al* 2010, Magis 2010, Frazier *et al* 2013). For example, studies using the human capitals approach evaluate how different types of social capital (bridging, bonding, and linking) shape community resilience (Magis 2010). These capitals specifically focus on the relationships between groups and heterogeneities in power and resources between groups in a community (Wickes *et al* 2015, May 2019, Jacobson 2020). This emphasis resonates with our call for the development and use of indicators that reflect social processes and interactions at multiple levels to meaningfully assess the adaptive capacity of a system.

The community resilience literature has focused more on including cross-level indicators to measure resilience of communities to environmental change (Füssel 2007, Berkes and Ross 2013). This may be because from the perspective of community resilience, societal level is often defined based on socio-economic and social-ecological activity that is empirically relevant, rather than as a predetermined frame of analysis. Consequently, models of community resilience often incorporate place-based indicators as well as spatial dependencies based on relationships or linkages with other places (Frazier *et al* 2013, Cutter *et al* 2014). For example, the resilience of a coastal community to storm events such as cyclones and hurricanes is determined by factors within the community (e.g. beach nourishment projects, community organizations active in disaster (COAD) agencies, hospitals, etc) as well as county-level factors (e.g. road & communication infrastructure, emergency reserve funds, public shelters, etc) (Cutter *et al* 2010, Frazier *et al* 2013). This emphasis on cross-level determinants has also resulted in different methodologies for data collection and analysis in the community resilience scholarship (table 1). In order to continue aligning the design and methods of future empirical studies to meaningfully examine adaptive capacity across societal levels, questions that scholars may consider in their research design include: *does the theoretical framework used to assess adaptive capacity require level-, scale-, and context-specific assessment methods?; how does the framework incorporate within- and cross-scale interactions that underpin adaptive capacity?; and does the framework examine relational determinants of adaptive capacity between levels of decision-making?*

4.3. Bridging adaptive capacity research and policy

Adaptive capacity research is to some degree a practice-oriented field, concerned with uncovering insights that can aid practitioners and policymakers in efforts to prepare for, mitigate, adapt to, and recover from impacts of environmental change. In this context, scholarly assessments of adaptive capacity can be used to prioritize policy interventions across levels of decision making to strengthen factors that enable and reinforce adaptive capacity, and/or reduce constraints to the emergence and activation of adaptive capacity. However, translating research to actionable solutions or insights for policy has been constrained by several methodological and practical challenges, as well as disconnects between researchers and practitioners (Mortreux and Barnett 2017, Siders 2019). None of the studies stated the types of policy problems they were addressing or what stage of the policy-making process that assessments might inform (e.g. Leykin *et al* 2013, Morley *et al* 2016). Consequently, the methods and data used by studies in our sample were not chosen with the end goal

of policy application in mind. Furthermore, there were no studies in our sample that compared situations where adaptive capacity was successfully activated versus cases where adaptive capacity remained latent, despite the need to adapt.

We identified several factors that complicate the policy applications of research evaluating adaptive capacity at levels beyond the household. First, just as mismatches between spatial scale and societal level have implications for research design, there are also consequences for developing policy from research results. For example, Cohen *et al* (2016) concludes that limits to education, physical mobility, and agency results in differential adaptive capacities for women and men in rural communities in Solomon Islands that are often exposed to large-scale ecological stressors such as earthquakes, cyclones, and flooding. These findings are important for understanding the drivers of individual-level adaptive capacities. However, developing policy that enables communities adapt to such large-scale ecological processes often requires responses at higher levels of decision-making, such as coordination between centralized and provincial government departments, and institutions that promote decentralization and local empowerment beyond the individual and household (Cumming *et al* 2006). None of the studies we reviewed developed or used indicators that matched with the levels of potential policy applications of their adaptive capacity assessments. We argue that a greater focus on individual- and household-level indicators in adaptive capacity research has largely constrained the degree to which research may generate actionable management and policy solutions at larger levels of decision-making.

Second, adaptive capacity in any social-ecological system is a moving target, especially related to higher levels of decision-making where complex and often unpredictable social processes emerge, such as the need for coordination, collective action, and/or the development of institutions to guide societal response to environmental change. Despite this, except a handful of studies (e.g. Chang *et al* 2017, Bangwayo-Skeete and Skeete 2020), most of the studies we reviewed used static measurements or indicators to assess the dynamic processes and feedbacks that shape adaptive capacity (e.g. Burton 2015, Weis *et al* 2016, Phan *et al* 2019), and thus this scholarship likely does not reach practitioners or policy makers who may be able to learn and act based on the evaluation of adaptive capacity over time (Hinkel 2011).

We found that the theoretical frameworks that underpin the research (i.e. vulnerability and community resilience) also clearly shape the policy applications of adaptive capacity assessments. For example, the vulnerability scholarship in our review predominantly focused on policy interventions at the individual and household levels to enhance their adaptive capacities (e.g. Pearsall 2009, Xenarios *et al* 2016, Yankson *et al* 2017). In contrast, the community resilience scholarship does a relatively better job of identifying how specific governmental agencies and/or policy actors at higher levels of decision-making (e.g. municipal entities, regulatory agencies, neighborhood associations) helped communities maintain and improve their adaptive capacities over time (e.g. Frazier *et al* 2010, Thompson *et al* 2014, May 2019). For example, Frazier *et al* (2013) examined the indicators of community resilience and identified hazard mitigation strategies in Sarasota County, Florida. In addition to identifying socio-economic and infrastructural drivers of community resilience, the authors concluded that coordination between agencies that operate socio-political jurisdictions is critical for mitigating the impacts of natural hazards (e.g. debris management and COAD agencies that provide assistance during hurricanes, floods, and wildfire emergencies).

An important direction for future adaptive capacity scholarship is to explicitly identify policy questions and situate research design clearly in a stage of the policy making process in order for studies to have relevant impact. Key questions we encourage future scholars to consider in their research design are: *what are the policy problems the study seeks to address? which stage in the policy process is the study likely to generate implications for? is the study conducive to evaluating adaptive capacity (and change in adaptive capacity) over time to inform policy development?* Furthermore, by identifying key actors that may enhance adaptive capacities and the scope or level of their decision-making, researchers may address both the 'why' of their research and the 'how' of policy solutions, and contribute more effectively to produce actionable outcomes.

5. Conclusion

Rapid global environmental change continues to impact the capacity of social-ecological systems to respond to, cope with, and adapt to change at all societal levels, individual, household, and those beyond. Most research on adaptive capacity to date has focused (either implicitly or explicitly) on individual and household assessments; herein, we provide the first systematic review of adaptive capacity research that explicitly engages higher levels of societal decision-making, those beyond the household including community, province, nation-state, etc. Existing reviews provide limited understanding of the measurements and methods required to conduct adaptive capacity research at these levels. Several important points emerge from our review of adaptive capacity research that provide new insights and promote new directions for future research.

First, both the scale of environmental processes and the level of societal analysis matter. Adaptive capacities in social-ecological systems vary across

levels of decision-making, and their effectiveness and impact depends on a series of complex cross-scale and cross-level interactions (Klein *et al* 2015). Thus, assessments of adaptive capacity should measure indicators of both level-specific as well as cross-level aspects of adaptive capacity. Simply aggregating individual- or household-level measures does not adequately capture the full range or dynamic nature of adaptive capacities potentially responding to environmental change.

Second, there is a need for better integration of adaptive capacity research across the community resilience and vulnerability scholarships. Our co-citation analysis demonstrates that the choice of theoretical frameworks that underpin adaptive capacity may influence whether or not adaptive capacity research incorporates cross-level indicators. Although the vulnerability scholarship has done extensive work on individual capitals that affect adaptive capacity (Cinner *et al* 2018), key gaps exist in incorporating cross-level indicators that measure coordination and collaboration between key stakeholders (decision-makers, policymakers, etc). On the other hand, the community resilience scholarship has often examined both within-level and cross-level factors that may enhance the adaptive capacity of a community (Cutter *et al* 2014). Thus, there is a need for better integration and cross-pollination between these literatures to improve the application of indicators and methodological approaches toward more comparative and effective assessments of adaptive capacity at societal levels beyond the household.

Last, there are limited examples that demonstrate how the results of assessments can foster and build adaptive capacity in society. It is a critical time to understand how research methods can best evaluate and better understand adaptive capacity at higher levels and contribute to informing desirable adaptation action. While current approaches have resulted in a proliferation of definitions, indicators, and methods, there has been limited success in translating research into action-oriented outcomes for communities (Siders 2019). In order for future research to effectively generate actionable outcomes, we suggest that researchers need to identify the policy questions they seek to address as well as key actors at the societal level of their study that are positioned to enhance adaptive capacity. Identifying key policy actors across multiple levels of decision-making can particularly help navigate institutional complexity and increase the adaptive capacity of social-ecological systems (Andersson and Ostrom 2008, Lubell and Morrison 2021). Furthermore, we suggest that it is critical for adaptive capacity researchers to utilize longitudinal studies to better understand feedbacks across levels and across spatial scales and over time. Adaptive capacity research of the future should meaningfully contribute to answering the question of how will the adaptive capacity of the social-ecological systems change over time with the impacts of environmental change, and what policy tools will best bolster adaptive capacity at different levels of society.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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