



Social dimensions of adaptation to climate change in rangelands: a systematic literature review

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Abstract

Rangeland social-ecological systems (SESSs), which make up vast tracts of Earth's terrestrial surface, are facing unprecedented change—from climate change and vegetation transitions to large-scale shifts in human land use and changing social and economic conditions. Understanding how people who manage and depend on rangeland resources are adapting to change has been the focus of a rapidly growing body of research, which has the potential to provide important insights for climate change adaptation policy and practice. Here, we use quantitative, qualitative, and bibliometric analyses to systematically review the scope, methods, and findings of 56 studies that examine the social dimensions of adaptation in rangeland SESSs. Our review focuses on studies within the climate adaptation, adaptive capacity, and adaptive decision-making sub-fields, finding that this body of research is highly diverse in its disciplinary roots and theoretical origins, and therefore uses a wide range of frameworks and indicators to evaluate adaptation processes. Bibliometric analyses revealed that the field is fragmented into distinct scholarly communities that use either adaptive capacity or adaptive decision-making frameworks, with a lack of cross-field citation. Given the strengths (and weaknesses) inherent in each sub-field, this review suggests that greater cross-pollination across the scholarship could lead to new insights, particularly for capturing cross-scale interactions related to adaptation on rangelands. Results also showed that a majority of studies that examine adaptation in either “ranching” or “rangeland” systems are geographically concentrated in few, high-income countries (i.e., USA, Australia, China), demonstrating a need to extend future research efforts to understudied regions of the globe with rangeland-based livelihoods. Finally, our review highlights the need for more translational rangeland science, where policy- and practice-relevant frameworks evaluating adaptation in rangeland SESSs might be developed by co-producing research working with rangeland communities.

Keywords Climate adaptation · Rangelands · Adaptive capacity · Adaptive decision-making · Social-ecological systems · Co-citation analysis

1 Introduction

Rangelands comprise approximately 25–40% of the earth's terrestrial area and are home to millions of people who derive their livelihoods from livestock grazing (Asner et al. 2004; Reid et al. 2014; Sayre et al. 2013). These diverse working landscapes are critical for safeguarding ecosystem services, producing food and fiber, protecting open spaces, contributing to local and regional economies, and maintaining cultures and knowledges across the globe (Brunson & Huntsinger, 2008; Sayre et al. 2012).

Rangelands are often described as “social-ecological systems” (SESs) because of the interconnectedness of humans (and their values, organizations, and institutions) with ecological processes (Hruska et al. 2017; Roche 2021). Rangelands are tightly coupled and highly diverse SESs, where ranchers and rangeland managers are seasoned to adapting their management goals and practices to reduce their risks in the face of increased complexity and uncertainty (Sayre et al. 2012). At the same time, rapid environmental and socio-economic changes on rangelands today—particularly climate change—present novel challenges for ranchers and rangeland managers (here forward referred to as “ranchers”). Thus, the ability for ranchers to adapt in new ways is becoming increasingly important (Briske et al. 2015; Joyce and Marshall 2017; Roche 2021).

There is a growing recognition among academic scholars that a focus on the social dimensions of rangeland SESs is important for understanding and supporting desirable adaptation into the future (Reid et al. 2021; Roche 2021; Wilmer et al. 2018). Yet, this scholarship is diverse in its disciplinary roots and dispersed across a wide range of scholarly communities. Thus, it is timely to consider how this rapidly growing body of adaptation scholarship has progressed and where the field needs to go in order to inform policy and practice for rangeland management. Specifically, our objective in this systematic literature review is to use a combination of qualitative and bibliometric analysis techniques to examine scholarship that uses climate adaptation, adaptive capacity, and adaptive decision-making frameworks to understand the social dimensions of adaptation in rangeland SESs. To that end, we wanted to understand how each of these three concepts has been employed in the literature with the aim of identifying research gaps and suggesting ways to advance current lines of research to bridge analyses with actionable recommendations that support desirable adaptation outcomes in rangeland SESs.

1.1 Approaches to understanding adaptation in rangeland social-ecological systems

Adaptation is recognized as a vital approach for reducing vulnerability and building resilience in rangeland social-ecological systems (Adger 2006; Adger et al. 2007; Briske et al. 2015; Karimi et al. 2018). In the broadest sense, adaptation describes “adjustments made to changed environmental circumstances that take place naturally within biological systems and with some deliberation or intent in social systems” (Adger et al. 2009; Gallopin 2006). In the climate change literature, adaptation refers to adjusting practices, processes, and capital responses to the threat of climate change (Adger et al. 2007). Adaptation involves both individual choice or “agency” as well as agency that exists within a context of structures, governance, and institutions (Berrang-Ford et al. 2011). For example, as the impacts of climate change manifest in rangelands, ranchers may shift to dynamic grazing practices that are driven by forage availability rather than fixed dates, establish drought contingency

plans, or utilize government programs to mitigate risk or help support ecosystem function in light of drought and other extreme climate events (Haigh et al., 2021; Joyce and Marshall 2017; Sayre et al. 2012; Yung et al., 2015).

SES scholars have taken various approaches to examine adaptation to changing social and ecological dynamics on working rangelands. In this review, we focused on studies that used three common concepts—climate adaptation, adaptive capacity, and adaptive decision-making—for examining the social dimensions of adaptation in rangeland SESs. Figure 1 depicts the nested relationship between these concepts. Within the climate adaptation and adaptive capacity literatures, adaptation takes place predominately in response to climate change or its manifestations (e.g., drought), while some studies examining adaptive management and decision-making look at adaptation processes in the context of environmental and social change more broadly (e.g. Lubell et al. 2013; Roche et al. 2015; Wilmer and Sturrock 2020). As we describe in the following sections (and as Fig. 1 shows), these concepts have emerged as distinct bodies of literature, yet are closely interlinked both conceptually and in reality. As such, studies in our review sometimes describe a combination of concepts (e.g., adaptive capacity and adaptive decision-making), but tend to use just one as their framework for analysis. Throughout this review, we refer to people who manage livestock on rangelands as “ranchers” and these systems as “working rangelands” with the recognition that some studies included in this review take place in pastoralist and herding rangeland SESs. We follow Huntsinger et al. (2010) and Reid et al. (2014) in their view that while each place-based system, including within ranching systems, has distinct and

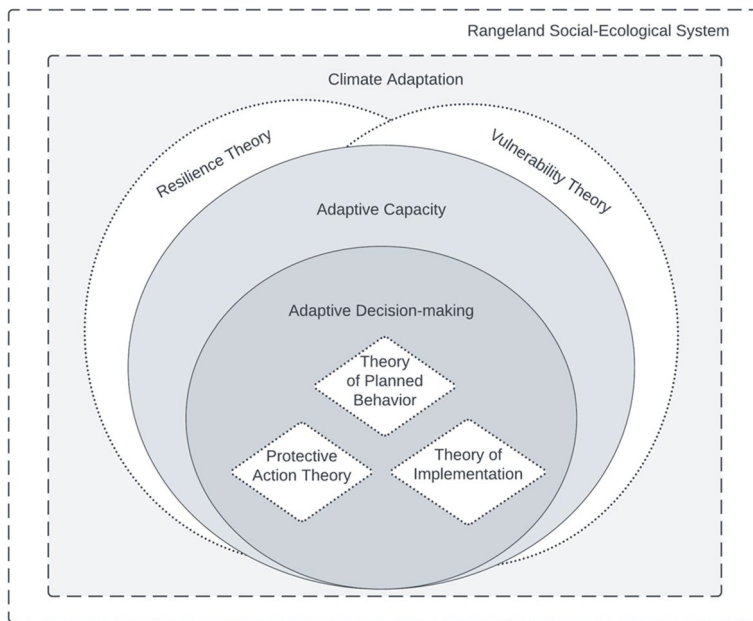


Fig. 1 This diagram depicts the nested relationship between the concepts of rangeland SESs, climate adaptation, adaptive capacity, and adaptive decision-making. Adaptive capacity scholarship has its theoretical roots in resilience theory and vulnerability theory, which are often applied at a system-level scale, while adaptive decision-making studies tend to be informed by theories (such as those depicted) operating at the individual level

unique ways of managing rangeland SES, there are strong commonalities between pastoralists and ranchers (i.e., both pastoralists and ranchers make their living primarily from herding livestock, but may also use other resources in diverse arrangements) (Reid et al. 2014). We chose to focus our search terms (Table 1) to include studies that examine adaptation in either “ranching” or “rangeland” systems—using those terms specifically. By keeping the scope of our search terms narrow, we hope that the results of this review speak directly to the rapidly growing field of rangeland social science—and particularly North American rangeland social science—in which “rancher” is the most common terminology used to refer to range livestock producers (Reid et al. 2014) (Sayre, 2017; Bruno et al. 2020).

1.2 Climate adaptation

Climatic conditions are rapidly changing rangeland ecosystem processes and properties (Polley et al. 2013). In recent decades, research that examines climate adaptation among rangeland resource-dependent communities has expanded from an initial focus on ecological and economic impacts and adaptation strategies to a broader vision that includes the social dimensions of adaptation (Briske et al. 2015; Joyce and Marshall 2017). In this review, climate adaptation was used as a keyword to identify studies that explored how ranchers are adapting to climate change and what factors enable and constrain adaptation strategies/behaviors (outside of the adaptive capacity and adaptive decision-making literatures). Climate adaptation studies tend to examine specific practices used by ranchers in order to mitigate the effects of drought and climate-related events, and examined factors influenced the adoption of those practices (e.g., Karimi et al. 2018). For example, climate adaptation strategies used by ranchers may include the adoption of different grazing strategies (e.g., rotational grazing, renting crop residues for postharvest grazing) as a response to declined quantity and quality of forage due to drought or climate variability, developing areas on-ranch for shade and water to reduce heat stress, changing forage and animal species/breeds to match the changing environmental context, or adjusting stocking rates to account for the impacts of climate change on rangeland forage (Coppock, 2011; Haigh et al., 2019; Karimi et al. 2018).

1.3 Adaptive capacity

Adaptive capacity is a concept that has been used widely in the SES, resilience, and vulnerability literature as an analytical framework to understand and assess the interplay between structure, agency, and other factors that make up the preconditions for adaptive behavior across diverse contexts and scales (Engle 2011; Siders 2019; Vallury et al. 2022). While conceptualizations of adaptive capacity have crossed many disciplines, adaptive capacity has been described as preconditions that influence peoples’ ability to anticipate and

Table 1 Web of Science Query

Query

TS = ((“adaptive capacit*” OR “adaptive management” OR “adaptive decision-making” OR “climate adaptation” OR “climate change adaptation” OR “rancher decision making” OR “rangeland decision making”) AND (“rangeland*” OR “ranch*”))
671 results

respond to perceived or current stresses by mobilizing and managing scarce resources for resilience (Adger et al. 2007; Cinner et al. 2015; Engle 2011). Importantly, within both the resilience and vulnerability literature, governance and institutions, which includes both formal governmental policies and informal social patterns, have been cited as critical variables affecting adaptive capacity, recognizing that they can either enable or constrain the agency of actors within the system (Berman et al. 2012; Cinner and Barnes 2019; Engle 2011; Gupta et al. 2010). In rangeland contexts, factors influencing adaptive capacity include ranchers' individual capacities to plan, learn, and reorganize in light of climate change (Marshall 2010); access to diverse sources of information and opportunities for knowledge exchange within ranching communities that may help mobilize ranchers to act collectively in preparing for climate events (Fernández-Giménez et al. 2015); and access to government resources, such as funding for drought relief (Crimp et al. 2010). Thus, adaptive capacity assessments have been used to illuminate preconditions, or factors, at both the individual level (e.g., access to assets) and beyond individual (e.g., social networks) or institutional level (e.g., governance and institutions) that promote or inhibit adaptation within a given system. Figure 2 shows common categories of indicators (not an exhaustive list) used to evaluate adaptive capacity.

Although adaptive capacity assessments can help clarify the various dimensions that enable or constrain successful adaptations in the face of environmental change, considerable gaps in adaptive capacity application exist. Critiques include the diversity (or lack of standardization) of methods and indicators used to evaluate it, a lack of understanding of cross scale (i.e., individual to institutional) interactions (e.g., between local contexts and

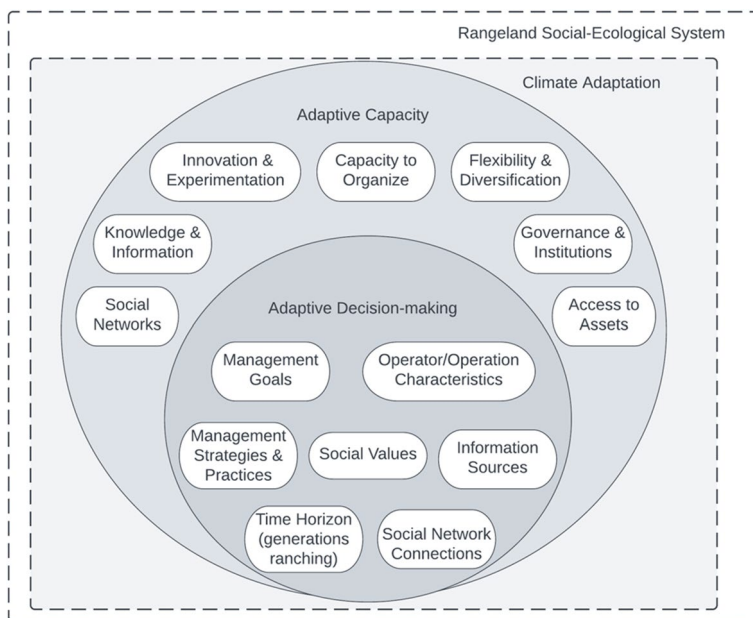


Fig. 2 We conceptualize rangeland SESs and climate adaptation as the framings within which scholars examine adaptive capacity and adaptive decision-making. The figure depicts common categories of indicators used to evaluate adaptive capacity (adapted from Engle (2011) Cinner and Barnes (2019), Gupta et al. (2010), and adaptive decision-making is also shown (adapted from Lubell et al. (2013))

global processes), and the challenge of designing research that is practice-oriented and at policy-relevant timescales (Siders 2019.; Vallury et al. 2022; Whitney et al., 2017). Further, while adaptive capacity is a rapidly growing concept, a relatively small number of studies have examined adaptive capacity in rangeland SES contexts specifically. Yet, rangeland SESs across the globe are experiencing the impacts of climate change (Briske et al. 2015; Joyce et al. 2013; Joyce and Marshall 2017), demonstrating the need for research that can help identify capacity building strategies for rangeland dependent industries, livelihoods, and communities.

1.4 Adaptive decision-making

While adaptive capacity provides a theoretical framework for assessing the myriad factors that influence ranchers' ability to respond to climate change, the *capacity* to act is different than adaptive *action*. There is a growing body of research using adaptive decision-making frameworks to understand what ranchers are doing to reduce economic and ecological risk and what factors influence or drive the decision-making process (Wilmer and Fernández-Giménez 2015; Wilmer and Sturrock 2020; Wilmer et al. 2016). For example, given that ranchers are highly dependent on sufficient and timely rainfall for rangeland forage production, they may decide to either adopt conservative long-term stocking strategies as a hedge against drought or practice a more dynamic approach in which they vary stocking rates and supplemental feed in response to drought (Shrum et al. 2018; Haigh et al., 2021). Other examples of adaptive decision-making might include destocking practices (through culling, early weaning, ending grazing contracts, sending cattle to a feedlot, etc.) (Haigh et al., 2021) or decisions around diversifying on-ranch enterprises, earning off-farm income, or participating in conservation-related programs to augment ranch income (Kachergis et al., 2014; Lubell et al. 2013).

Studies that examine adaptive rangeland decision-making tend to focus on individual-level factors (e.g., operator/operation characteristics, information sources, social values) (Lubell et al. 2013) and look at adaptation in the context of smaller scale ecological processes (e.g., regional drought, ranch-level ecological indicators). However, there is also some acknowledgement of the important drivers at socioeconomic scales that exist beyond the individual rancher, including globally integrated commodity markets, agricultural policies and regulations, and broader geographic shifts in agricultural industries (Wilmer et al. 2018). Figure 2 shows the conceptual relationship between adaptive capacity and adaptive decision-making in and depicts common categories of indicators used to examine adaptive decision-making for rangeland management (adapted from Lubell et al. 2013).

2 Research questions

To examine and synthesize existing scholarship that explores the social dimensions of adaptation in rangeland SESs, we asked:

1. Which of the three concepts of focus in this review (climate adaptation, adaptive capacity, and adaptive decision-making) is most commonly used to evaluate adaptation in rangeland SESs?
2. What methods and indicators are used to evaluate climate adaptation, adaptive capacity, and adaptive decision-making?

3. What is the scale of analysis used across this scholarship?
4. What are the implications for communities (i.e., recommendations for policy or practice) emerging from this scholarship?

3 Methods

3.1 Article selection

The article selection method we used 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 Web of Science database using search terms from the climate adaptation, adaptive capacity, and adaptive decision-making literatures to explore the concept of adaptation in rangeland social-ecological systems (Table 1). Our search included the terms “adaptive capacit*,” “adaptive management,” “adaptive decision-making,” “climate adaptation,” “climate change adaptation,” “rancher decision making,” and “rangeland decision making.” These terms were combined with “rangeland” and/or “ranch” to link these concepts with rangeland systems as the focus of our review. The search was last updated in February 2022 and returned 671 articles.

This suite of search terms resulted in a sufficiently broad scope of research while also generating an optimal number of articles that are relevant to our research questions and context (Pullin and Stewart 2006). It is a recommended practice to use a conservative approach in selecting search terms in order to retain all articles that are relevant for answering our research question. Still, there were articles that examine the drivers of adaptation processes in rangeland contexts that were not captured by this search and rangeland literature (see Sect. 5 for more on study limitations). For example, studies on pastoralism were not fully represented. In addition, we did not search terms specific to ecological adaptation, as that would have yielded studies that are not relevant to the scope of our review (focusing on social science studies) and diminished the effectiveness of our analysis (Pullin and Stewart 2006).

3.2 Inclusion and exclusion criteria

Articles were included in the final review if they examined social factors, drivers, or predictors that influence adaptive capacity, adaptive decision-making, or climate adaptation strategies among ranchers in livestock-based rangeland SESs. The lead author used four questions to guide the inclusion/exclusion decision-making process, summarized in Table 2.

The process for inclusion/exclusion was iterative and included three rounds of reviewing abstracts and then full articles, starting with the initial sample of 671 papers. Figure 3 shows the resulting number of papers after each round of inclusion/exclusion, which resulted in a final sample of 56 papers. See Table A2 for the complete list of articles included in this review, categorized by concept (i.e., adaptive capacity, adaptive decision-making, or climate adaptation).

Table 2 Inclusion/exclusion questions

Question	Description
<i>Question 1: Does the paper have a social science focus?</i>	While there are interdependencies between environmental change processes and human adaptation, we only included studies with a social science focus. In other words, all studies included analyze the factors that shape the human component of rangeland SESs in response to environmental change. Papers were excluded if adaptation examined was predominantly due to social, cultural, or economic dynamics (or a combination), and not directly related to environmental change.
<i>Question 2: Is the paper focused on human adaptation (not ecological) to an environmental stressor?</i>	We included studies focused on human adaptation to an environmental stressor (e.g., climate change, drought, vegetation shifts). We excluded articles that solely examined the ecological outcomes of “adaptive management” treatments to study sites, but that did not address the social determinants or drivers of those decision-making processes. Similarly, we excluded papers if they simply inventory climate adaptation strategies but did not evaluate drivers or factors influencing the adoption of those strategies.
<i>Question 3: Does the paper evaluate, assess, measure or characterize adaptive capacity, adaptive decision-making or climate adaptation? In other words, is it empirical (not a review)?</i>	Studies were included if they reported empirical findings based on primary fieldwork or secondary research (i.e., reviews and opinions excluded) examining adaptive capacity, adaptive decision-making, or climate adaptation as a system driver or outcome. A study that examined key drivers of different grazing management types but did not seek to understand how grazing management shaped adaptive capacity outcomes would be excluded.
<i>Question 4: Is the paper focused on rangeland managers/ranchers (this includes papers that focus on pastoralists and/or use the term livestock producers)?</i>	Studies included focused on social dimensions of rangeland managers or ranchers. We included studies that used the terms livestock producers or pastoralists. Papers focusing on landowners in general were excluded.

3.3 Content analysis

Following the inclusion/exclusion process, we used content analysis to examine the final sample of 56 articles in greater detail. For each article, the lead author filled out a pro-forma questionnaire (Table 3) that included basic information about the study (e.g., study location, scale of analysis); questions regarding methods, frameworks, and indicators used in data collection and analysis; and open-ended questions about papers’ objectives and implications for policy or practice. Responses to this questionnaire provided insight on the theoretical and methodological approaches used to study adaptation on rangelands as well as the research applications of this body of scholarship.

After filling out the questionnaire for all 56 articles, we examined the responses across the literature and took notes on themes and patterns in a separate document. The questions driving this phase of content analysis related primarily to questions 5–7 and were as follows: (1) What are common methods, frameworks, and indicators evaluated

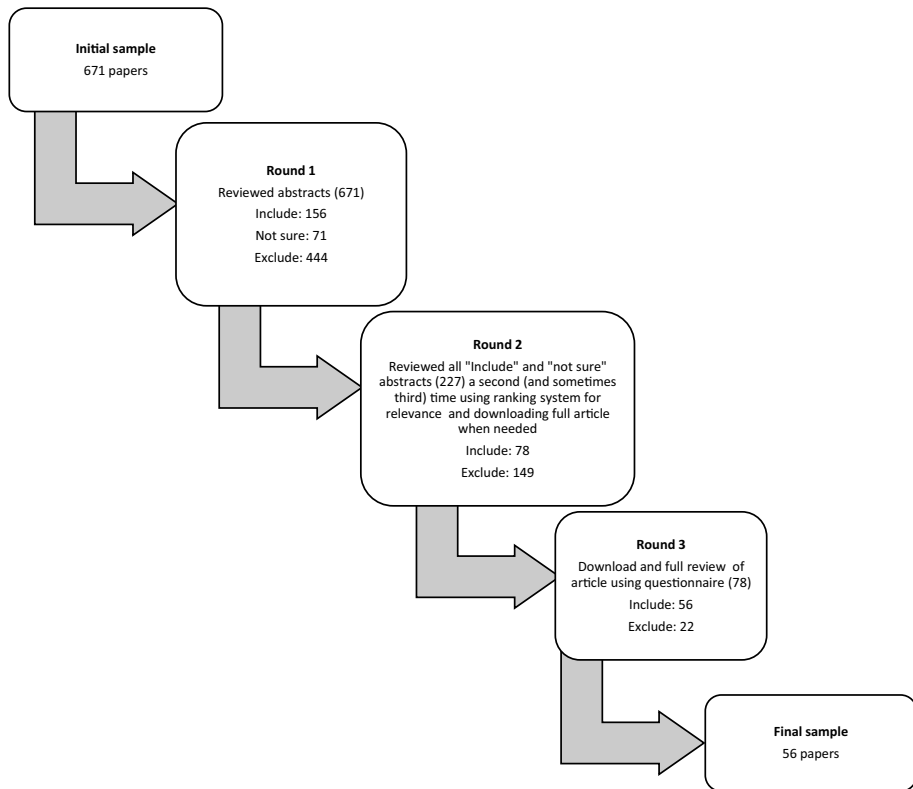


Fig. 3 Summary of iterative rounds of inclusion/exclusion

Table 3 Questionnaire for content analysis

1. Aim of the study
2. Study location
3. What SES stressor(s) are ranchers adapting to?
4. At what scale is adaptive capacity, adaptive decision-making or climate adaptation being studied in this paper?
5. Methods: What methods were used to collect data? What methods were used to analyze data?
6. Indicators: What framework (if any) and/or indicators were used to evaluate CA/AC/AD?
7. Study findings: In particular, what policy or practice-oriented solutions emerged from the study? How have or how can the results be integrated into decision-making? What are the implications for communities of interest in the study (e.g., of the process, outcomes, or recommendations)?

for understanding adaptation in rangelands/among rangeland managers? (2) Do the indicators and methods capture cross-scale interactions (i.e., individual and beyond-individual level factors influencing adaptation) and do they align with the scale action is needed to address environmental stressors? (3) What insights related to policy and practice emerged from the study? What are key areas of inquiry for more action-oriented future research? We used basic descriptive statistical analysis to understand patterns across questions 1–4.

3.4 Bibliometrics and co-citation analysis

In order to understand and organize this body of research further, we used bibliometric analyses. Bibliometric analyses offer a structured method for analyzing large body of information, to infer trends over time, to examine themes researched, and to identify conceptual and theoretical shifts within scholarly fields (Aria and Cuccurullo 2017; Crane 1972). Co-citation analysis, a common analysis in bibliometrics, uses citation counts to identify and visually depict important or central authors, publications, and journals within a body of literature (Zhao and Strotmann 2015). Co-citation involves tracking pairs of papers that are cited together in the sample of articles (Small 1973). When the same pairs of papers are co-cited by many authors, clusters of research begin to form. Of the final 56 articles in our sample, we were unable to access the necessary data fields (i.e., cited references) through the WoS core collection for two articles (Snaibi et al., 2021 and Wilmer and Sturrock 2020), resulting in a sample of 54 for the bibliometric analyses. We used the *bibliometrix* package to generate the network data (Aria and Cuccurullo 2017; R Core Team 2016) and created the co-citation network plots using VOSviewer. We used the Fruchterman-Reingold algorithm (Fruchterman and Reingold 1991) for the network layout and clustered nodes based on average degree (Aria and Cuccurullo 2017; Traag et al. 2019). The co-cited papers, authors, or journals that show up as clusters on co-citation maps tend to share a common theme and can reveal different theoretical and conceptual domains.

4 Results

4.1 Mapping the literature: concepts, geographic distribution, and scale of analysis

Of the 56 articles reviewed, 22 (39%) employed the concept of adaptive capacity, 20 (36%) employed the concept of adaptive decision-making, and 14 (25%) examined climate adaptation to understand adaptation in rangeland SESs across the globe (Fig. 4). Over half of the articles reviewed studied adaptation at the regional level ($n = 29$, 51.8%), followed by

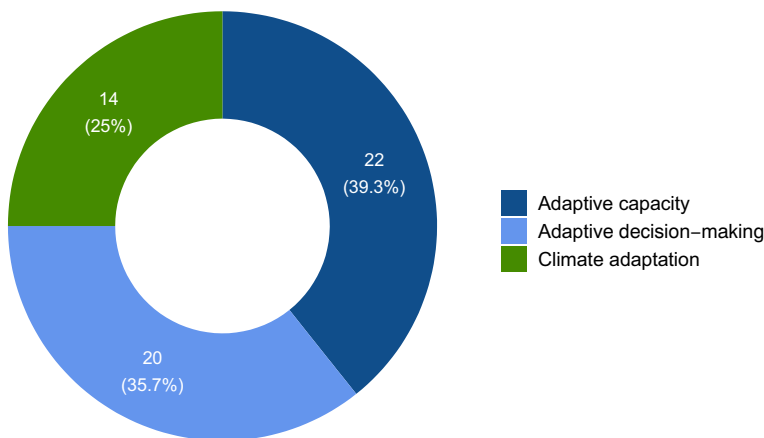


Fig. 4 Distribution of frameworks/concepts used in studies ($n = 56$) understand adaptation in rangeland social-ecological systems

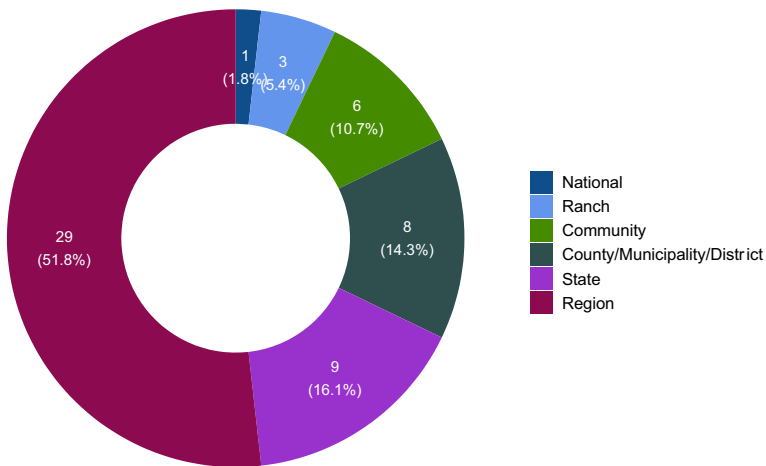


Fig. 5 Scale of analysis that adaptive capacity, adaptive decision-making, or climate adaptation was studied ($n = 56$)

state ($n = 9$, 16%), county/municipality/district ($n = 8$, 14%), community ($n = 6$, 11%), ranch ($n = 3$, 5%), and national ($n = 1$, 2%) levels (Fig. 5). See Table A2 for the full list of articles included in this review.

Studies defined “region” and “community” in different ways. That is, some studies defined community or region based on geographic or political boundaries, which vary greatly in spatial scale, from smaller natural resource management areas such as the Upper Burdekin “dry tropics” region studies by Marshall et al. (2011) to the Inner Mongolia Autonomous Region examined in Tan et al.’s (2018) study. Other studies defined regions based on watershed boundaries (e.g., Fang et al. 2011; Habron 2004) or by a combination of climate vulnerability and agricultural production, such as the Murray-Darling Basin in Australia that is vulnerable to climate change and important for livestock production (Crimp et al. 2010). This lack of consistency in defining larger social groups is a known challenge in the social science literature (McKeown et al. 1987; MacQueen et al. 2001). Importantly, while the scale of analysis may have been “region” or “state,” it was common that the unit of analysis within these studies was the household or individual, which was then aggregated for a final assessment or measure of adaptation.

The majority of the studies ($n = 31$, 55%) examined adaptation of humans (i.e., ranchers, communities) to climate change, followed by broad social-ecological change or a combination of environmental and social stressors ($n = 12$, 21%). A significant portion of studies also explored ranchers’ adaptation to drought specifically ($n = 11$, 20%) and two studies examined human adaptation to other specific climate change manifestations (i.e., the *dzud*, winter storms, in Fernández-Giménez et al. 2015 and changes in “frozen soil” change in Fang et al. 2011).

Geographically, studies investigating adaptation in rangeland SESs were conducted predominantly in the USA ($n = 23$, 41%), followed by Australia ($n = 11$, 20%), China (including the Tibetan Autonomous Region) ($n = 6$, 11%), Mongolia ($n = 3$, 5%), South Africa ($n = 3$, 5%), Kenya, Iran, and Ethiopia with two studies each ($n = 2$, 4%), and Uganda, Morocco, Tanzania, and Spain with one study each ($n = 1$, 2%). Figure 6 shows the geographic distribution of where research took place across the 56 studies.

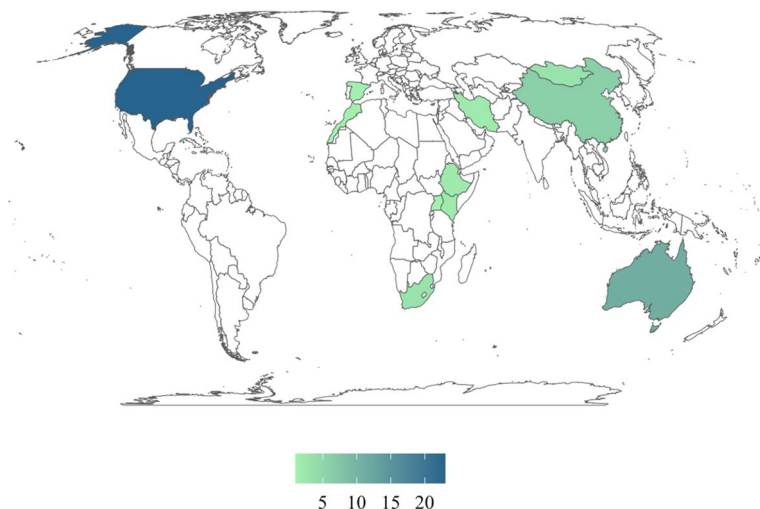


Fig. 6 Geographic distribution of studies. Colors reflect the number of studies conducted in a country. For example, 23 studies examined adaptation in rangeland social-ecological systems in the USA (dark blue). Several countries (light green) had one study (i.e., Uganda, Morocco, Tanzania, Spain). No studies were conducted at a global scale

4.2 Conceptual and intellectual knowledge structures (K-structures) using bibliometric analyses

The co-citation analysis and resulting co-citation network map revealed distinct intellectual structures, or groupings, within this literature. The network map of co-cited papers, which reflects papers that have been cited together by articles in our sample, shows three distinct clusters (Fig. 7). One cluster (blue) includes papers focusing on adaptive capacity emerging from the resilience and vulnerability literatures (e.g. Smit & Wandel (Smit and Wandel

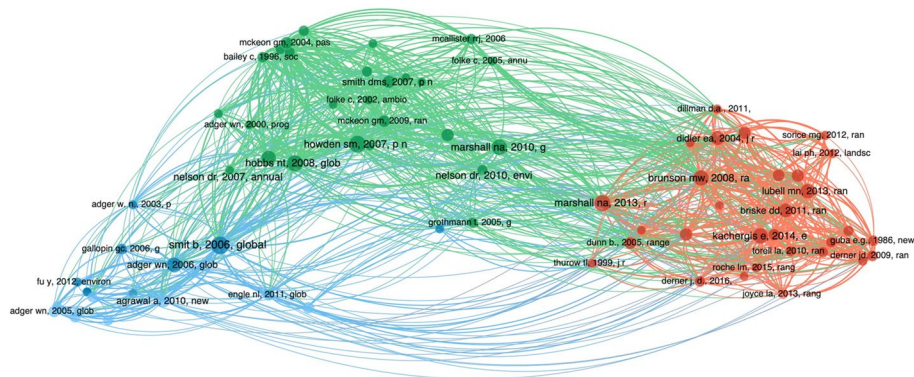


Fig. 7 Co-citation network map of co-cited papers. The size of nodes reflects the number of times papers are cited in the reference lists of articles in our sample ($n = 54$). When the same pairs of papers are co-cited by many authors, that is represented by the linkages and proximity between nodes, and clusters of research sharing common themes begin to form

2006; Adger 2006; Engle 2011). The second cluster (green) highlights a distinct grouping of co-cited papers that focus on adaptation and adaptive capacity primarily in rangelands and agricultural contexts (e.g., Marshall 2010; Marshall et al. 2011). The third cluster (red) depicts a grouping of co-cited papers that tend to focus on the concepts of adaptive management and decision-making in rangelands (e.g., Roche et al. 2015; Lubell et al. 2013) with the exception of one key paper, Marshall and Smajgl (2013), which focuses on adaptive capacity in rangelands and creates a strong bridge between the green and red clusters. Prominent nodes such as Marshall and Smajgl (2013) represent papers that have accumulated many citations over time and have large out-degrees, creating links to other clusters of literature, likely forming the backbone of the network over time. In the blue cluster, the top two cited papers—or key nodes—are Smit and Wandel (2006) titled “Adaptation, adaptive capacity and vulnerability” and “Vulnerability” by paper Adger (2006). In the green cluster, the key nodes are Howden et al. (2007), “Adapting agriculture to climate change” and Marshall (2010), “Understanding social resilience to climate variability in primary enterprises and industries.” In the red cluster, in addition to Marshall and Smajgl (2013), “Understanding variability in adaptive capacity on rangelands,” a paper by Brunson and Huntsinger (2008) titled “Ranching as a conservation strategy: Can old ranchers save the New West?” is a key node that, as Fig. 7 depicts, is highly cited both within the red cluster and also has a large number of out-degrees to the green and blue clusters.

4.3 Methods, frameworks, and indicators

Authors used a range of methods for data collection and analysis. Nearly all the research in this review involved primary data collection (e.g., interviews, quantitative surveys) ($n = 55$, 85%) with only one study (Crimp et al. 2010) using exclusively secondary data. Some studies used a combination of primary and secondary data collection methods to leverage multiple data sources (e.g., Fang et al. 2011; Goldman and Riosmena 2013). Quantitative surveys were the most common method used in this literature ($n = 25$, 45%) to examine adaptation in rangeland SESs, followed by structured or semi-structured interviews ($n = 21$, 37%), which were analyzed using both quantitative (e.g., Ndiritu 2021) and qualitative approaches (e.g., Lien et al. 2021). Both survey and interview data were collected in three of the studies and seven studies that used other methods other than surveys or interviews to evaluate adaptation in rangeland systems, including policy/document analysis, the use of expert knowledge, stakeholder workshops, participatory and ethnographic approaches, computational modelling, or a combination of multiple methods.

One common approach used to evaluate adaptive capacity in rangeland SESs was frameworks that conceptualize adaptive capacity as an emergent property of the diverse forms of capital (human, social, natural, physical, and financial) from which livelihoods are derived. This includes Rural Livelihoods framework developed by Ellis (2000) and built upon Adger (2006) and Cinner et al. (2009), the Sustainable Livelihoods Framework (SLF) (King et al. 2018), the Adaptation, Institutions, and Livelihood (AIL) framework developed by Agrawal and Perrin (2009), and the Adaptive Capacity Index (ACI) developed by Tan et al. (2018). These approaches typically evaluate indicators representing each “capital” using qualitative or quantitative analyses (e.g., dimensionality reduction methods such as principal component analysis and/or combined with regressions). Other studies used custom frameworks to examine adaptive capacity in rangeland systems (Fernández-Giménez et al. 2015; Marshall 2010; Marshall et al. 2011; Marshall and Smajgl 2013) (see Table A1 for examples).

A diverse suite of indicators was also used to evaluate adaptive decision-making among ranchers. Unlike the adaptive capacity scholarship, indicators for adaptive decision-making often emerged out of behavioral and psychological theories (e.g., Theory of Planned Behavior and the Diffusion of Innovation Theory in Lubell et al. 2013) and often measured individual-level attributes (e.g., operation characteristics, off-ranch income sources, social values) (see Table A1). Methodologically, adaptive decision-making studies often used statistical analysis of survey data where dependent variables were adaptive behaviors (as a proxy for adaptive decision-making) and independent variables were a diverse range of factors hypothesized to influence these behaviors (Haigh et al., 2021; Kachergis et al., 2014; Lubell et al. 2013). Some studies also used qualitative methods such as interviews and participant observation to identify key themes and drivers of the decision-making process for ranchers (e.g., Wilmer and Sturrock 2020; Wilmer and Fernández-Giménez 2015).

Climate adaptation studies used a wide range of indicators to evaluate adaptation behaviors among ranchers as well. The theoretical foundations of this scholarship were similarly diverse, from climate vulnerability and resilience (Haigh et al., 2019) to risk management (Coppock, 2011). The most common methodological approach used among the climate adaptation studies was quantitative survey research where researchers employed statistical analyses to understand the relationship between climate adaptation behaviors (dependent variables) and factors thought to influence these behaviors (independent variables). Researchers used a suite of statistical techniques to understand these relationships, including basic descriptive statistics, directional change tests, principal component analysis (PCA), cluster analysis, and logistic regression (e.g., Coppock, 2011). See Table A1 for a list of selected studies and the diverse indicators used to evaluate adaptive capacity, adaptive decision-making, or climate adaptation in rangeland contexts and Table A2 for the full list of studies included in this review.

4.4 Implications for policy and practice

An examination of implications for policy and practice across this literature revealed that studies tend to either (1) provide an assessment that compares regions/communities within a rangeland SES to inform policy focus or resource allocations (e.g., Crimp et al. 2010; Cobon et al. 2009; Wang et al., 2013) or (2) provide recommendations for policies or programs in response to current adaptation processes (and their determinants) (e.g., King et al. 2018; Lubell et al. 2013; Marshall et al. 2011; Ndiritu 2021) or as a way to promote future adaptation pathways (e.g., Liao. 2018; Wilmer et al. 2018). Studies falling into the second category were diverse in terms of their specificity/generalizability of policy recommendations and covered a wide range of policy needs for improved adaptation within rangeland SESs.

5 Discussion

5.1 “Linking the literatures” to capture cross-scale interactions

Adaptation involves both individual agency as well as individual agency that exist within a context of existing structures, governance, and institutions (Cinner et al. 2015; Giddens 1984; Gupta et al. 2010). To holistically assess adaptation in rangeland SESs, then, there is a need for studies that use methods and indicators that capture cross-scale interactions

(Garrick and De Stefano 2016; Hill and Engle 2013; Whitney et al., 2017). Yet, the majority of studies reviewed used individual-level indicators (i.e., factors related to “agency”) and lack an examination of the structural factors that enable and constrain adaptation in rangeland SESs. Specifically, adaptive capacity scholarship often recognizes the importance of structural factors for determining the pre-conditions for adaptation, but studies using this concept often favored using index-based approaches where individual and/or household level (i.e., levels of education, access to information, and social networks) indicators were aggregated into an adaptive capacity “score” or measure (see Table A1). Many of these studies did not use indicators that reflect important—and well established—factors such as governance, institutions, and collective organization/capitals (Gupta et al. 2010; Vallury et al. 2022). At the same time, the adaptive management and decision-making literatures also tended to lack an examination of the structural factors that influence individual-level decisions. In part, this may be a reflection of the predominately social-psychological theories that inform these studies and tend to focus on individual-level factors (e.g., Protective Action Theory and Theory of Implementation Intention in Haigh et al., 2021), resulting in variables of interest that are also at the individual level (e.g., aspects of operation/operator characteristics, social values) (see Table A1). Recognizing that there are practical challenges associated with collecting and analyzing data on the wide range of factors influencing adaptation across scales, we argue that there is a need for scholarship that attempts to capture these interactions, particularly regarding factors operating beyond the individual level that influence the options and ability of ranchers and rangeland managers to adapt to change.

The results of our bibliometric analyses also point to the need for greater exchange across scholarly communities (e.g., adaptive capacity and adaptive decision-making scholars) to expand and transform the way we examine and evaluate adaptation in rangeland SESs. The three distinct clusters depicted in the co-citation network (Fig. 7) for this body of research reinforces that there could be greater connectivity between scholarship employing (and citing other papers that employ the use of) the concepts of climate adaptation and adaptive capacity with those focused on adaptive management and decision-making in their work. In other words, the co-citation map helps to visually show that while we may *conceptualize* adaptive capacity and adaptive decision-making as related (Figs. 1 and 2), the intellectual communities using (and citing) these concepts are distinct.

We argue that creating stronger linkages between these scholarly communities might encourage the development of more holistic, cross-scale assessments and lead to new methodological insights related to studying adaptation in rangeland SESs. For example, Lubell et al. (2013), one of the prominent nodes in the red cluster, focuses on evaluating adaptive decision-making, using primarily indicators at the individual level. However, one could envision an expansion of their framework that includes more “external” or “structural” factors that resemble frameworks more commonly used (and cited) in the resilience and adaptive capacity scholarship (e.g., governance, regulations, markets). At the same time, adaptive capacity scholars who take a “capital” approach (e.g., Crimp et al. (2010), King et al. (2018) Wang et al (2016), see Table A1) might consider looking at the well-established theories of agricultural decision-making (e.g., Theory of Planned behavior or Diffusion of Innovation in Lubell et al. 2013) to develop more nuanced or more meaningful indicators for measuring “social capital” or “human capital” that speak to social values, networks, or operation/operator characteristics known to be influential to individual-level adaptation behaviors (Lubell et al. 2013). Integrating the strengths from different sub-fields could help move the needle forward for understanding the cross-scale suite of factors influencing adaptation in rangeland SESs.

At the same time, bridging scholarly communities has practical challenges and potential intellectual tradeoffs that should be considered. First, moving beyond siloed fields to incorporate knowledge and methods from multiple disciplines may require more time and resources than conventional, discipline-specific research. For instance, effective interdisciplinary work will require interdisciplinary training for emerging scholars, but at what costs? For a graduate student, for example, there may be an opportunity cost associated with choosing interdisciplinary training over time spent gaining disciplinary expertise. More broadly, what are the tradeoffs of having a more interdisciplinary network of scholars? For instance, overly connected research disciplines may result in the homogenization of ideas and frameworks, whereas maintaining distinct disciplines (and their associated concepts, frameworks, and methods for evaluating adaptation) could be more useful for generating new ideas and encouraging innovation. While understanding adaptation in rangeland SESs will inherently require an integration of social and ecological sciences, it is also important to consider the “how” of integration and communication across research disciplines to avoid potential pitfalls and to maintain the disciplinary expertise (e.g., rangeland ecology, animal sciences, economics, sociology, psychology) necessary for informing meaningful research questions, indicators, and assessments.

In light of these questions and considerations, we suggest as others have (e.g., Roche 2021) that rangeland science needs scholars who are equipped with disciplinary expertise and provided opportunities to learn about other knowledge systems that will help foster successful and integrative collaborations. We posit that greater intellectual proximity could be facilitated simply through opportunities for closer physical proximity among scholars of different disciplines. Institutions are often designed in ways that quite literally contribute to scholars (and their ideas) remaining in disciplinary “silos” (Goldstein 2006). Advancing a culture of meaningful collaboration across scholarly communities could be facilitated by innovative changes to campus building design and architecture that facilitates conversations and connections among researchers. Finally, we argue that there is a need for consistent funding that supports collaborative research efforts. Overland and Sovacool (2020) found that, over 30 years of climate change research funding, the natural sciences received ~ 770% more funding than the social sciences. This highlights a major constraint, given what we know about the critical need to integrate social science to understand adaptation behavior in rangeland SESs (Briske et al. 2015; Joyce and Marshall 2017; Roche 2021).

5.2 Expanding the geographic reach of research on adaptation in rangeland SESs

Although rangeland SESs are critical in supporting ecosystem services and the livelihoods of people across the world (FAO 2022; Sayre et al. 2012), the results from this review revealed that research on the social dimensions of adaptation in these systems is predominantly concentrated in the USA and Australia (Fig. 6). We acknowledge that a major limitation of this study for capturing the full extent of this research was that we narrowed the second requirement of our search query (Table 1) to the terms “ranch” or “rangeland” instead of broadening the scope to “pastoralist,” “pastoralism,” “transhumance,” or “livestock producer.” Even in light of this limitation, the complete absence of studies in vast regions of the world both characterized by rangelands (e.g., northern African, see Hoffman and Vogel 2008) and by ranching systems (referred to and/or translated as such, e.g., Brazil, Argentina, Mexico) that would have resulted from the keywords we did include in our search, may reveal significant inattention to the social dimensions of adaptation in these areas.

We argue that expanding research on the social dimensions of adaptation processes in understudied rangeland SESs could provide insight on where and how resources might be allocated to enable place-based and culturally relevant adaptation that improves social and ecological outcomes. Just this year, the United Nations (UN) has declared 2026 the International Year of Rangelands and Pastoralists in order to increase investment in and build the adaptive capacity of rangeland and pastoral communities in light of climate change and other pressures (FAO 2022). An emphasis on social science research in these areas could help international organizations such as the UN identify where investments are made, for whom, and toward what adaptation measures, strategies, and outcomes. Along with these considerations, it is critical that as researchers expand into new and potentially unfamiliar research contexts that they reflect on how their own “frames of power,” power mechanisms, and other structures may shape the research process, outcomes, and broader adaptation-power relations (Klein 2009; Woroniecki et al. 2019).

5.3 From assessment to application: making research more actionable across scales

While there has been a rapid increase in scientific papers on adaptation in recent years (Berang-Ford et al. 2011; Vallury et al. 2022), the need for a focus on the social dimensions of adaptation in rangeland contexts is as present as ever (Briske et al. 2015; Reid et al. 2021; Roche 2021). Specifically, while both science *of* adaptation and science *for* adaptation are important (Swart et al. 2014), there is a need for rangeland social science scholarship that provides actionable insights that can aid ranchers, policymakers, and other stakeholders in adaptation planning and implementation. In a recent review of North American rangeland social science, Bruno et al. (2020) highlight the need to leverage diverse methods, draw on a diversity of social science disciplinary traditions, and consider a broader diversity of stakeholders in order to advance the field. Other rangeland social science scholars have pointed to the need to transcend disciplinary approaches in order address climate change and other SES risks in rangelands (Roche 2021). Following these calls, we argue that effectively addressing issues related to adaptation in rangeland SESs and connecting research to societal needs (i.e., for both policy and practice) today will require more participatory and translational rangeland science approaches, where scientists involve non-scientific stakeholders in the process of co-defining societally relevant questions, co-producing relevant knowledge, and co-learning from the research process (Reid et al. 2021; Roche 2021).

A few studies in this review provide good examples of research taking a translational approach. First are papers that emerged out of the Collaborative Adaptive Rangeland Management (CARM) project (e.g., Wilmer et al. 2018; Wilmer and Fernández-Giménez 2015) which started in 2012 as a large, 10-year, ranch-scale participatory grazing experiment, where the team’s goal was to intensively experiment with contrasting grazing practices and then adapt as they learned. From the beginning, the project engaged diverse stakeholders on the research team in co-production of knowledge and evaluation of outcomes that resulted in deep reflection, changing mental models and epistemologies, and learning together (Wilmer et al. 2018; Fernández-Giménez et al. 2019b). As a result of the project, Wilmer et al. (2018) found that future collaborative adaptive management efforts will benefit from exchange among managers’ different experiences and knowledge and from long-term research in time and funding to social, as well as experimental, processes that promote trust building among stakeholders and researchers over time.

Another example of translational research is a study by Fernández-Giménez et al. (2015, 2019a), which was part of the MOR2 (Mongolian Rangelands and Resilience) project started

in 2008 as a large, 8-year, national-scale project investigating the role of formal community-based natural resource management (CBNRM) in responding and adapting to climate change impacts. The study found that CBNRM herders demonstrated greater adaptive capacity than non-CBNRM herders (due to greater knowledge exchange, information access, linking social capital, and proactive behavior), advancing our understanding of the role of local institutions (specifically donor-initiated CBNRM institutions) in climate adaptation, which has important implications for policy. In this project, the team engaged in yearly meetings with practitioners and government decision-makers at the national-level, regional workshops with local and regional decision-makers at the end of the project and evaluation of MOR2 learning opportunities (Reid et al. 2021). The project is exemplary of the inclusion of both Mongolian and American scientists and resulted in deep reflections about the team science conducted by this project (Fernández-Giménez et al. 2019a, 2019b).

These studies show that successful translational research involves designing projects with collaborators and end-users in mind from the very beginning, rather than as an afterthought. In each of these projects, methods emphasized trust-building and an integration of knowledges as scientists worked side by side with stakeholders, beginning with ranchers and rangeland managers, to understand their on-the-ground experiences and challenges. Taking this kind of research approach means recognizing that within ranching communities, there is deep, experiential knowledge (and knowledge networks) that are critical to helping inform our understanding of adaptive capacity, decision-making, and climate adaptation on rangelands (Roche 2021). Moreover, these studies demonstrate that, at the heart of translational research approaches is relationship building to identify, define, and solve collective problems.

By embracing translational research approaches, we argue that more meaningful and policy-relevant frameworks and indicators for adaptive capacity, adaptive decision-making will emerge. While this scholarship (particularly adaptive capacity research) has been criticized for lacking consensus on what frameworks and indicators are best for assessment (Siders 2019), we argue that standardization of evaluation frameworks would not necessarily make research more useful “on the ground.” Rather, there is a need for using translational research approaches to co-produce diverse, place-based, indicators or metrics for evaluating adaptation to inform policy and practice. While these approaches may be more “messy,” than using existing frameworks, by leaning in to the complexity of decision-making and adaptation contexts of rangeland communities, we will improve the relevance of our science to managers working in real-world conditions (Porensky 2021). In addition, there is a need for more longitudinal and long-term studies that foster science-management partnerships, build trust, and develop our understanding of adaptation over time (Wilmer et al. 2018). As shown in this review, studies that provided policy recommendations were almost entirely single point-in-time assessments, highlighting that there is a need for more research that tracks changes in adaptation capacities, strategies, and processes (capacity, decision-making) based on community experiences, knowledges, and learning over time. While developing more actionable science will undoubtedly be a challenge, it is a critical time for more “transformative science with society” as Reid et al. (2021) suggest, and it is exciting to think of the new methods, approaches, and strategies that might be developed by co-producing research working with rangeland communities.

6 Conclusion

In this systematic literature review, we used qualitative and bibliometric analyses to document the scope, methods, and findings of studies that examine the social dimensions of adaptation in rangeland SESs. Within the climate adaptation, adaptive capacity, and adaptive decision-making sub-fields, we found that this body of research uses a wide range of frameworks and indicators to evaluate adaptation processes, and that there is a need across these approaches for more policy- and practice-relevant assessments. Bibliometric analyses further revealed that studies employing the concepts of climate adaptation and adaptive capacity tend to emerge out of (and speak to) the resilience and vulnerability scholarship, whereas studies using adaptive decision-making tend to be embedded within applied science and management-oriented fields. We also found that this body of research is geographically concentrated relative to the vast tracts of globe where rangeland-based livelihoods exist. To advance existing lines of scholarship on adaptation in rangeland SESs, we suggest that scholars consider the following questions:

- To better understand the cross-scale factors influencing adaptation in my rangeland SES of focus, what combination of concepts, frameworks, and indicators are most useful and relevant to inform policy and/or practice? By choosing one conceptual lens and/or suite of indicators over others, what factors influencing adaptation might be missed? At what scale? Where will there be blind spots?
- Who are the non-scientific stakeholders, and potential partners, in my rangeland SES of focus? And, how can I involve them in the process of co-defining my research questions, co-producing relevant knowledge, and co-learning from the research process?
- For my research to help support ongoing science-management partnerships, what possibilities exist for conducting a longitudinal or long-term study that iteratively tracks changes in adaptation capacities, strategies, and processes (management, decision-making) over time?

We suggest that bridging the strengths of the diverse, rapidly growing, sub-fields of scholarship reviewed in this paper will lead to a more holistic understanding of cross-scale factors influencing adaptation in rangeland SESs across the globe. And, through more collaborative and translational research efforts, new insights on adaptation opportunities and challenges in rangeland SESs might emerge.

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

Declarations

Competing interests The authors declare no competing interests.

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