The relevance of case studies in climate change research: a review of policy recommendations

Jose Daniel Teodoro¹ · Donal S. O'Leary III¹ · Siobhan E. Kerr² · Eva Peskin³ · Julie A. Silva¹

© Springer Nature Switzerland AG 2019

Abstract

In the age of big data, case studies build the foundation for the large-scale models that are increasingly being used for decision and policymaking. In this systematic literature review, we investigated the geographic, methodological, and conceptual characteristics of case studies in climate change science to evaluate the extent they provide policy recommendations to answer the questions: *how can researchers best gather and report policy-relevant information for climate change adaptation, resilience, and/or recovery? What are the current themes within the literature, and how can these areas best advance as policy-relevant fields within climate change science?* Findings highlight that policy recommendations were more robust, and significantly more likely, in case studies that employ participatory research methods; and geographic characteristics and use of theoretical frameworks are associated with providing policy recommendations. On the other hand, studies that focus on biophysical parameters of climate change offered weak or no policy recommendations. Thus, we conclude that local-level case study research can serve as validation and calibration data for large-scale models as long as they accurately represent the local values and perceptions of the people in the study area. We elaborate on the opportunities that exist in non-human, biophysical, research for communicating findings to policy-friendly audiences.

Keywords Case study research · Systematic review · Climate change · Adaptation · Resilience

1 Introduction

Anthropogenic climate change is a threat to all humans, causing risk to land quality, personal property, and livelihoods [1, p. 80, 2]. The human capacity to adapt to these changes, remain resilient, and recover from climate disturbance is critical for the survival of communities, cultures, and countries in the twenty first century. In such a pursuit, scientists have ventured in studying different ways in which communities around the world mitigate and adapt to climate change's dangerous impacts, such as novel forms of participatory governance [3], finding adaptation and mitigation synergies that increase carbon

sequestration potential [4], understanding the role of social networks in climate communication [5, 6], and identifying the benefits of community driven natural resource conservation programs [7]. Designing and enforcing policies that address the severity of climate change impacts is a complex process, and despite the abundance of examples in the literature policymakers may be hesitant to implement new regulations without practical and actionable evidence in support of their efforts [8]. As a result, there has been an increasing interest in policy-relevant scientific research supporting climate change resilience and adaptation at the local and global scales [9, 10].

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s42452-019-1221-x>) contains supplementary material, which is available to authorized users.

✉ Jose Daniel Teodoro, teodoro@umd.edu | ¹Department of Geographical Sciences, University of Maryland, 2138 Samuel J. LeFrak Hall, College Park, MD 20742, USA. ²School of Public Policy, University of Maryland, College Park, MD 20742, USA. ³Department of Women's Studies, University of Maryland, College Park, MD 20742, USA.

SN Applied Sciences (2019) 1:1197 | <https://doi.org/10.1007/s42452-019-1221-x>

Received: 7 June 2019 / Accepted: 3 September 2019 / Published online: 10 September 2019

With the beginning of the digital revolution, policy-makers have been increasingly recognizing the potential of big data analytical methods to support their decisions, including climate-forecasting global circulation models [11, p. 159], natural resource life cycle modelling [12], and social networking models [13]. The advancement of such models and techniques offers an unprecedented insight into regional and global phenomena [14]. Still, models like these are still in the earlier stages of development and require calibration and validation through the comparison with local data, which are most often generated through fieldwork and case study research [e.g., 15]. Such case studies run the gamut from systematic evaluations of timber harvest efficiency and succession [16], to local and regional surveys regarding human health and well-being [17]. The policy implications of a new landscape of small and big data are yet to be fully materialized. However, the degree and quality of policy engagement in recently published climate change research begin to unravel the role local-level data can play in policy-making in the digital age.

In this article, we systematically review case studies in climate change science to evaluate the relationship between the methodological characteristics of a study and the extent they provide implementable policy recommendations to answer the questions: *In what ways is (case study) research design associated with reporting policy-relevant information for climate change adaptation, resilience, and/or recovery? What themes stand out within the literature in relation to engaging with climate change adaptation or mitigation policies, and how can these areas best advance as policy-driven foci within climate change science?* The review includes a meta-analysis of climate change research on adaptation, resilience, and recovery that involve field data from case studies or study sites (e.g., sample plots) published between 2012 and 2017. The objectives of the systematic review were (1) to syn-

of the research team embodied interdisciplinary perspectives used to review and analyze the existing body of literature. Our results aim to inform researchers who desire to make explicit linkages between scientific findings and policy formulation, whether they are ‘foot soldiers’ collecting data in the field, or ‘big data’ analysts working to inform their models using case study data.

2 Methods

This review article blends systematic meta-analysis [18] with a focused qualitative approach [e.g., 19] in order to provide both statistical analysis of the evaluated literature and a nuanced qualitative assessment of some selected themes that emerged from the reviewed work. An interdisciplinary research team representing ecology, geography, public policy, and women’s studies conducted the review of climate change research involving case studies of human populations and/or the collection of biophysical field data. The research team met weekly from January to May, in 2017, to develop consensus regarding classification schemes, harmonize data collection, discuss findings, and engage in team-building exercises to facilitate interdisciplinary collaboration. The following section describes the article selection process, including the inclusion and exclusion criteria, the process used to make the final determination of the article sample, data collection, statistical analysis and thematic foci for the qualitative review component.

2.1 Document selection and review

The title, abstract, and keywords of all peer-reviewed English articles indexed in the Web of Science SCI-EXPANDED, SSCI search engines were searched using the following code:

TS = (“Climate Change” AND(Adaptation OR Resilienc* OR Recovery)AND (“Case Study” OR “Study Area”))

synthesize recent climate change research using case study or field site data to provide a general description of this body of literature; (2) gauge the extent to which research involving case and field study data provide policy recommendations, and how this varies by study characteristics; (3) assess how researchers integrate local-level data with secondary sources and; (4) qualitatively describe insights in case study research based on nuanced themes within the reviewed articles.

Our study stands out in two specific ways: First, our approach combines analysis of studies involving human and non-human actors. Second, the unique composition

For the purposes of our analysis, case studies were defined following Yin [20, p. 13] as an empirical inquiry investigating a contemporary issue within its real-life context by collecting data from individuals. The term study area was used to allow for the inclusion of research conducted in a specific geographically delimited area because it is representative of a larger ecological system.

Fig. 1 Flow chart of the article selection and screening phases

The search was restricted to include only articles published between 2012 and 2017 in journals classified in at least one of the following Web of Science categories:

the research team with the most demonstrated expertise in that area. The member of the team with the broadest range of research experience reviewed all articles, which

WC = (Environmental Sciences OR Environmental Studies OR Geography OR Geography,
Physical OR Social Sciences, Interdisciplinary OR Planning and Development
OR Ecology OR Area Studies OR Urban Studies OR Forestry)

The basis for the journal classification selection involved an assessment of the journal outlets publishing climate change research involving case studies and other field data collection by both social and physical scientists. Figure 1 outlines the selection and review process in 5 phases. All potentially relevant articles identified in phase 1 were segmented into four categories using the bibliometric and visualization software VOSviewer [21]. This method clustered articles based on similarities between the works cited. Bibliometric clustering resulted in four article groupings unified by overarching themes. The team identified the main themes of each cluster based on a joint review of cited references and ten randomly sampled articles from each. The four clusters were assigned to members of

ensured independent data screening by two analysts in all subsequent steps.

Drawing on the methodology described by Brandt et al. [22], two readers reviewed each abstract based on questions to identify relevant articles (Fig. 1). Team members discussed assessments of the inclusion criteria at weekly team meetings to ensure consistent interpretations. Questionable cases that arose throughout the process were discussed and cleared during meetings. In cases where a decision of inclusion/exclusion for a specific article differed between the two independent readers, additional time was allocated to arrive at a consensus-based decision. After completing the initial review of the abstracts, the team collectively reassigned some select papers based

on their thematic area. During the previous phase, both reviewers noted when the topic of an article fell within the area of expertise of another member of the research team. All reassignments were based on team discussions and consensus.

All articles included in the sample were then downloaded and assessed independently by two reviewers using a pre-designed rubric to capture quantitative, qualitative, close-ended categorical data, and open-ended notes or comments (Supplementary Material 1). The rubric included questions regarding the characteristics of the author(s), the case studies conducted, the data collection and analytical methods employed, the stated policy implications of the research, and other factors. As in phase 3, the second reviewer read all articles in the sample in order to ensure continuity between the four different thematic clusters. In addition, some articles were excluded from the sample if the team determined, after a review of the full article, that it failed to meet the inclusion criteria outlined in phase 3. As with the previous phase, team members had weekly discussions regarding any questions that arose during the coding process to ensure a uniform analysis. A final sample of 155 articles was selected for coding and analysis (Supplementary Material 2).

2.2 Analytical approach

2.2.1 Systematic meta-analysis review

After the article selection and coding process was completed, data from the review rubric were entered into a database for analysis. Descriptive statistics were used to describe the overall sample of articles. Cross-tabulations were used to examine how article characteristics (e.g., geographic region of study, spatial scope, rural or urban focus, data collection techniques, and methodological approaches) varied for articles employing case studies, field studies, or a combination of both. Chi square (χ^2) and

Fisher's exact tests were conducted to identify statistically significant associations between article characteristics and the inclusion of policy recommendations. All p values refer to χ^2 tests unless otherwise indicated. The software SAS was used for all statistical analyses.

2.2.2 A qualitative review of selected themes

Following the example of Brown [19], this review discusses selective themes that emerged from the overall sample to illustrate in more detail the associations found in the analysis. This component of the review involved four team members from different disciplines conducting separate, in-depth assessments of selected articles which were then discussed and synthesized into a collective discussion below. The approach taken for the qualitative review allowed the team members, each with different disciplinary perspectives and backgrounds, to critically reflect on the literature they found to be illustrative of an insightful theme that emerged during the systematic review of the articles. Team members discussed the content of the qualitative reviews at weekly team meetings.

3 Results

3.1 Descriptive characteristics of the dataset

Descriptive statistics of the final sample ($n=155$) show that 73% of the articles exclusively collected and analyzed primary data from individuals (In this article, we call these human studies), 15% focused on biophysical data from field sites (non-human studies), and the remaining 12% used both types of data (coupled studies). Figure 2 summarizes the geographical focus of the reviewed articles using the World Bank's regional classification system. Figure 3 shows the relationship between the first author's geographic region, the type of study, and the region where

Fig. 2 Geographic distribution of the affiliation of first authors (top) and region where the study took place (bottom)

Fig. 3 Descriptive distribution of **a** country of the first author, **b** type of article (i.e., human, biophysical, or coupled studies), and **c** country where the study took place

the study took place. From our sample, 70% of articles discussed the policy implications of their research or made recommendations decision-makers based on presented findings; although the degree to which articles engaged with policy varied substantially across the sample.

In broad geographical terms, the majority of first authors were affiliated with institutions in Europe or Central Asia (36%), followed by East Asia and the Pacific (mainly Australia) and North America (25% and 25%, respectively). These three regions accounted for the majority of first authors in all subcategories, with almost half of the natural systems studies (48%) first authored by someone with institutional affiliation in Europe or Central Asia. When looking at where studies took place, East Asia and the Pacific had the greatest overall coverage (26%) and this region was the focus of the largest share of human systems studies (26%) and the second largest share of coupled human-natural systems studies (23%). The largest number of natural systems studies focused on locations within Europe and Central Asia (33%). Of the reviewed articles, only 1% had a study area located in the Middle East or in North Africa; only two human studies taking place in this regional grouping.

3.2 Statistical relationships

Few geographic characteristics have statistically significant associations with whether or not the article provided policy recommendations. Articles involving a case study or field site within Sub-Saharan Africa ($p=0.034$) or a first author with an institutional affiliation there ($p=0.033$, Fischer) were more likely to include policy recommendations. Indeed, all ten papers first authored by someone affiliated with the region did so. The opposite relationship was true for articles with study areas located in Europe and Central Asia ($p=0.008$) or first authors affiliated with institutions in

this region ($p=0.004$). Despite the common critique that case studies prioritize the local level [23, 24], 70% of the articles conducted research at the regional scale (extra-local but still subnational). The relationship between the scale of analysis (i.e., local or regional) and providing policy recommendations was not significant.

Scientific collaboration across fields was prevalent in our sample. Multidisciplinary teams authored 60% of the articles and 78% of the biophysical systems studies. The majority of articles had at least one author with an institutional affiliation where the study took place (79%), and that figure is even higher for biophysical systems studies (96%). Nevertheless, there was no statistical association between the multidisciplinary composition of authors, their institutional affiliation, and providing policy recommendations.

Methodological characteristics, like analytical frameworks and data collection, emerged as important characteristics associated with policy recommendations. Methodological representation was evenly divided between studies using quantitative approaches (33%), qualitative approaches (35%), or a blend of both (32%). However, as would be expected given the use of biophysical data, all non-human studies employed quantitative methodologies. Overall, studies using quantitative methodologies ($p=0.000$) were less likely to highlight the policy relevance of the reported research. In contrast, data collection and methodological approaches associated with human studies, such as the participatory activities/exercises ($p=0.003$), focus groups ($p=0.001$), and the use of ethnographic techniques ($p=0.002$) were all more likely to discuss policy. Human studies ($p=0.000$) were more likely than natural or coupled studies to include policy recommendations or discuss the policy implications of the research.

Exactly half of the articles explicitly mentioned the theory or conceptual framework guiding the research.

These articles that referenced the theory or conceptual framework ($p=0.008$) or discuss power asymmetries or structural inequalities that exacerbate the impacts of climate change ($p=0.084$) were more likely to provide policy recommendations, but these characteristics were almost exclusively found in human studies.

When analyzing only the subset of human studies articles, a research methodology that included some kind of participatory activities ($p=0.079$) and focus groups ($p=0.029$) remain significantly more likely to provide policy recommendations. Only one relationship emerged as statistically significant within the human studies subset while insignificant for the overall sample: urban versus rural focus. Articles with case studies in rural areas ($p=0.019$, Fischer) were more likely to make policy recommendations than those exclusively focused on urban areas.

The overall sample was evenly split between studies using only primary data (50%) and those integrating primary and secondary data sources (50%). However, the type of data had no significant association with policy engagement. This was true for the entire sample and for all three of the study subsets (i.e., human, biophysical, and coupled). Core concepts did display an association with policy engagement, with articles addressing adaptation ($p=0.003$) more likely to do so and those addressing recovery ($p=0.019$, Fischer) were less likely. However, most of these associations were not statistically significant within the three study subsets.

4 Emerging themes in the literature

The results from the meta-analysis broadly suggest that geographic location of study and affiliation of authors, the methodology employed, theoretically-framed research, and the type of data collected are all significant characteristics that are associated with research-policy integration through policy recommendations. The most apparent finding is the clear distinction between human and non-human studies, with the former being more likely to provide policy recommendations than the latter. The qualitative assessment of trends and themes in climate change adaptation and resilience literature is a useful mechanism to unpack these associations with nuance and with the aim of synthesizing our findings.

4.1 Human-oriented studies most likely to offer policy recommendations

When unpacking the significant characteristics of the human studies, Gibson-Graham's [25] formulation of the "ethics of the local" is a helpful conceptual tool to imagine

how locally focused research can have broader social and economic transformative significance. The Ethics of the Local primarily acknowledges the particularity of the "local" recognizing the difference and otherness with the intention of cultivating local capacity [25]. Particularity and contingency were demonstrated by reviewed studies that employed ethnographic methodologies that helped understand specific circumstances of different communities around the world [7, 26, 27]. Some case studies include clear policy recommendations that aimed at cultivating local capacity and reducing vulnerability [e.g., 28], while increasing the participation of local stakeholders in the research process. In this sense, these case studies sought not only to describe a scientific reality but also to influence and transform the social-environmental regime of that locality. Evidently, each case study highlights findings which are to some degree generalizable yet reinforce the specific conditions of each place.

Within the human studies sub-sample, a clear divide emerged between articles focused on urban high-income or rural low-income communities. In particular, researcher differed in the way elicited knowledge and perceptions from local inhabitants regarding climate change. In the former, researchers generally asked respondents to consider climate change as a broad, long-term scientific phenomenon, while in the latter the focus was more on asking about recent changes in the weather. Many of the studies conducted in rural or low-income study areas asked respondents questions such as whether they had observed rising temperatures [29], if rainfall had become more variable [30] or if drought was more frequent [31]. When researching rural low-income communities, the authors did not acknowledge or justify their decision to focus on observable variability rather than on long-term trends. This may be related to the way people understand climate change effects based on geographical location. Regardless, the apparent lack of consistency in methodology presents challenges to researchers or policy-makers who wish to understand how climate change is affecting livelihoods in a broader sense. Given this inconsistency, attempts to compare research results from different geographic areas will become increasingly challenging. Thus, designing and enforcing climate adaptation policy may broadly benefit from a greater integration of lessons learned from urban high-income and rural low-income communities.

4.2 Participatory methods are associated with policy recommendations

Data collection methods that are most commonly associated with human studies include interviews, surveys, focus groups and workshops, all of these are significantly associated with providing policy recommendations. These

methods were employed in articles which engaged with communities and investigated how changes in climate are experienced by people at the local level. Based on the reviewed literature, it is clear that the weather today presents more and different challenges than it did in the past. These findings show that, overall, people quite accurately perceive the degree and magnitude of changes in the weather [32–34]. Case studies that used historical meteorological data for validation found that weather changes described by the community were generally correct [28, 35, 36]. This suggests that case study research have the potential to provide valuable information for climate change science, particularly in areas with limited long-term meteorological data. As such, participatory methods have the capacity to uncover relevant aspects of the local social life [37].

Some of the methods employed target local perceptions as a way to understand local values and past experiences that influence the way communities engage with governance structures and how they ultimately address climate change impacts [38, 39]. Our analysis shows the importance of using local-level perception data to inform regional adaptation policies in ways that account for local priorities and needs [38, 40, 41]. Research in this area highlights the long-term benefits of employing participatory methods that support adaptive environmental management [38, 42, 43]. Openness to a diversity of views and perceptions can empower marginalized stakeholders and promote learning among diverse stakeholders about the trade-offs and benefits of different adaptation options. In addition, participatory research that facilitates the interaction among stakeholders with different views may contribute to building cooperation between individuals or groups with opposing interests [44, 45].

Participatory research methods also promote local participation in areas where there are contentious, often opposing, views on how to address climate change risks and vulnerability [46, 47]. Case study research that brings together scientists, policymakers, and local inhabitants through participatory methodologies like focus groups and workshops tend to provide opportunities to incorporate local knowledge into management processes [48, 49]. These approaches have gained attention in policy and practitioner circles for their capacity to engage with multiple stakeholders and direct research in ways that benefit the overall community [10]. Moreover, these approaches have the potential to help identify awareness and information gaps among stakeholders, which may help in crafting tailored communication across different types of stakeholders and support the successful implementation of adaptation strategies [49].

Taken together, the human studies reviewed in this article that employ participatory research methods are

strongly associated with providing policy recommendations. Further research is necessary to unpack and understand this trend. Nonetheless, integrating local participation in climate change adaptation is likely to facilitate discussion and learning on the appropriate responses to climate impacts.

4.3 Policy potential for carbon sequestration

Even though biophysical, non-human, studies did not have a statistically significant association with providing policy recommendations, some did employ qualitative forms of engagement with local actors. Within the biophysical subsample, carbon sequestration emerged as a prominent research focus. While local efforts to mitigate carbon emissions make a small difference to the global carbon budget, the potential for wide-reaching policies to make an impact remains large. There are three studies that focused on the decision-making process behind forest carbon management, though they found that carbon-smart policies were implemented with varying levels of success [7, 50, 51]. Each of the three studies interviewed forest managers, gaining insight into the on-the-ground management practices that drive long-term carbon retention and sequestration. Ellenwood et al. [50] interviewed federal forest managers in Durango, Colorado, USA and found that, while there is widespread interest in carbon sequestration, few management decisions are focused on these goals. Milad et al. [51] found similar results when interviewing forest managers across Germany.

Pandey et al. [7] focused on a set of community forests, rather than exclusive nationally-controlled forests (as in the USA and Germany), in Nepal, as they implemented new Reduced Emissions from Deforestation and forest Degradation (REDD+) policies. Their study combined interviews with field measurements of below- and above-ground forest carbon density as they studied the carbon sequestration effects of a locally-empowering policy shift. They found that by implementing carbon-smart strategies they were able to sequester more carbon while simultaneously empowering the poorest farmers; a true win–win. In this comparison, it was the developing country (Nepal) that had a far more effective carbon-smart forest management practice, compared to the two developed nations (USA and Germany). These findings suggest that, while national-level policies have the potential to make a large impact, they can be slow to implement. Conversely, community-level management can be quick to adapt to changing management goals and may offer faster, albeit smaller, results. These studies show that combining carbon sequestration objectives and active adaptation strategies into synergistic policies can effectively sequester atmospheric carbon while simultaneously building local

capacity for climate change adaptation, particularly within the developing world.

Forestry as a practice has a rich literature where it is understood that large-scale forest management activities such as harvest, replanting, thinning, and burning have significant impacts on the carbon balance [52]. Countries such as Indonesia and Costa Rica act as a carbon source because they are undergoing deforestation in service of palm oil plantations, while the eastern United States is acting as a carbon sink as it regenerates from deforestation that occurred in the nineteenth and twentieth centuries [53]. It is critical for nations, states, and communities to properly account for carbon emissions and sequestration if they seek to reach carbon-mitigation policy goals [e.g., 54]. Several papers found within our analysis report the effects of management activities on carbon storage, with examples from major forestry centers, including Australia [55], Canada [56], Nepal [7] and the United States [57]. Taken together, these papers demonstrate the need for quantifying carbon within a variety of forested ecosystems. While these reports are valuable for land managers as they inform carbon-smart strategies, ecosystem modelers need the rate of carbon sequestration and ecosystem recovery for their time-and-space sensitive analyses. Before they can be used to inform policy decisions, these models must be properly calibrated using field data derived from case studies. Some of the reviewed articles provide this information in detail [56] and others even provide a growth rate curve that is essential to most ecosystem models [55].

Carbon management within pastures is highly dependent upon SOM, which sequesters far more carbon than the above-ground fraction of the ecosystem [58]. Soil resilience is therefore critical to carbon sequestration success in the face of disturbances such as flood, erosion, and soil degradation [59]. Two papers studying pasture management of carbon report metrics such as biological diversity, SOM [59], carbon allocation, and macronutrients [60]. For agriculture practitioners, these metrics are of the utmost importance for management, and it is helpful that these papers display their results in terms that are familiar to farmers and scientists alike. These papers come from ecologically distinct, but regionally similar areas of Tibet [59] and Inner Mongolia [60], emphasizing the need for additional research in different geographic locations. Still, by framing their results with land management in mind, their findings are directly applicable to pasture managers who seek to maintain the quality of their soils while retaining carbon sequestered below ground.

This review also found a number of discussions of specialized agricultural practices and their impact on the carbon budget. Studies concerning the carbon sequestration benefits of small-scale farming practices in Ethiopia [15], intensive aquaculture in The Philippines [61], and cork

production in Portugal [62] all provide useful quantifications of carbon as a result of management practices. The studies concerning farming and aquaculture appear to be highly applicable to other locales, however, some studies may be limited in their overall reach if their focus is highly localized in small industries with the relatively low potential for carbon sequestration [e.g., 62].

Taken together, these papers regarding carbon were less focused on framing their results to inform policy than the other papers within the review sample. Perhaps this is explained, in part, by papers that did discuss policy through interviews with land managers, which suggest that carbon sequestration land management practices have yet to be fully accepted within the policy world [50, 51]. To improve this integration, future carbon sequestration studies should frame their results to appeal to land managers by including carbon sequestration potential, reproducible best management practices, quantified uncertainty, and economic analysis on return on investment or incentives.

For many biophysical researchers, implementing policy may be impossible, and advocating for policy change may be socially and professionally risky. There have even been recent directives from the executive branch of the United States government to limit scientist interaction with the media to ensure a unified public discourse [63]. Therefore, it would be understandable if federally-funded biophysical scientists are hesitant to recommend policy changes in the literature, or public media, as this could adversely affect the career of a federal land management employee. Still, there is ample opportunity for biophysical researchers to generate new information that can be useful in advising carbon-smart policies. As mentioned above, by quantifying and reporting the particular biophysical parameters that govern carbon in the ecosystem (along with other climate-sensitive compounds such as methane, aerosols, and pollutants) researchers are able to build a solid foundation for policy recommendations once this information gets to the appropriate decision-makers. Furthermore, by quantifying metrics such as the rate of carbon sequestration in forests [55, 56] biophysical researchers can support higher-level research objectives, such as NASA's global carbon monitoring system [64].

4.4 Opportunities and challenges for biophysical studies

The majority of non-human focused papers did not recommend any policies (20 out of 25). Of the five that did, policy recommendations were generally brief and vague. There was one non-human focused paper that gave specific policy recommendations, Boateng [65]; which is a single-authored paper by a civil engineer, that recommended

policies to stabilize and protect the eastern coastline of Ghana. This example highlights the central role engineers play in the science-policy interface. Particularly in geographies where extreme climate-related events and sea level rise pose significant risks to infrastructure. Still, the strong majority of non-human focused papers did not make a policy recommendation.

4.5 The prominence of multidisciplinary teams

The call for a multidisciplinary approach to research is not new [66, 67]. In climate change research, complex global problems warrant integrated scientific approaches to help understand the drivers and impacts from multiple perspectives [68]. Surprisingly, multidisciplinary author teams were not significantly associated with providing policy recommendations. This may be explained, in part, by the lack of academic integration found in multidisciplinary research, compared to research employing transdisciplinary methods that also include non-academic practitioners at multiple phases of the research [66].

In the case of this article, the author team was deliberately multidisciplinary involving geography, ecology, women's studies, and public policy in an attempt to review the existing literature with a multidisciplinary perspective. This composition brought challenges while undergoing this project and required that the team spend hours synthesizing common definitions and learning how different scientific fields use different interpretations of similar concepts. These challenges are presumably akin to those encountered by authors of multidisciplinary papers included in our review, who may have found it difficult to reach a common understanding in research design and use of analytical methods. These challenges resonate with previous assessments of multidisciplinary work in sustainability science [69]. It is presumed that as research methods become more translatable across fields, and more non-academic stakeholders are involved in the research design process, multidisciplinary teams may increase their association with policy recommendations.

As mentioned above, the multidisciplinary composition of the team intentionally brought to the fore the known challenges of communicating climate science in different scientific disciplines. Even though two readers had to be in agreement on their interpretation and coding of a paper, some aspects of the paper remained reliant on each reviewer's subjective judgment (e.g., understanding of national and subnational scope, number of 'communities' involved, and the extent a policy recommendation was concrete or vague).

Case study research that engages with local and community-defined geographies bares the ethical

responsibility to capture and accurately represent those communities' climate challenges. Future work may investigate the ethical components of community engagement, specifically the relationship between to the author's national affiliation and the country where the study took place. Future work may also benefit from a closer look at the different methodological approaches that elicit climate change perceptions based on the urban-high-income country and rural-low-income country contexts. If case study data focusing on climate change impacts is to be incorporated into regional or global models, a detailed understanding of the comparison and contrast of those approaches will help researchers understand the implications of their methods.

This review used VOSviewer bibliometric and visualization software to cluster articles based on bibliometric similarities [21]. This method was a useful way to organize the articles into meaningful clusters, which facilitated the distribution of tasks among team members. It is possible that a larger number of clusters could have altered the review process, which is something future reviews that use this software may be able to explore. This review may serve as a guide for researchers who desire to engage in case study research on adaptation, recovery, and resilience to climate changes in both developing and developed countries and focused on human, natural, or coupled systems.

5 Conclusions

We conducted a systematic meta-review of 155 articles concerning climate change adaptation, resilience, and recovery from across the literature. Our aim was to characterize the aspects of case study research that are associated with providing policy recommendations. We found that policy recommendations were more robust, and significantly more likely, in papers that used methodologies focused on human subjects. Non-human, biophysical, studies make only 15% of our sample and they were not likely to provide policy recommendations. Methodological characteristics have a significant effect on the degree studies engaged with policy. Studies using quantitative methodologies were less likely to highlight the policy relevance of their research. In contrast, data collection and methodological approaches associated with human studies, such as the participatory research, focus groups, and the use of ethnographic techniques were all more likely to discuss policy. Within the human studies subset, we found that articles with case studies in rural areas were more likely to make policy recommendations than those exclusively focused on urban areas. Geographical characteristics, such as the country where the study takes place

and the affiliation of the first author, also show significant associations with providing policy recommendations. Most notably, we found that studies conducted in Sub-Saharan Africa and studies first-authored by a person affiliated with that region were more likely to provide policy recommendations.

We also conducted a qualitative assessment of our sample in order to identify emerging themes in the literature and provide our own recommendations for researchers or decision-makers who wish to narrow the gap between science and policy. We emphasize the following conclusions based on the main themes within the literature: First, effective climate mitigation and adaptation are essentially local processes, therefore researchers must embrace the uniqueness of each locality at all stages of the research project. Second, trust in the governance institutions charged with addressing climate impacts is an important ingredient of effective participation and social learning [44]. Thus, large-scale models can rely on small-scale data validation approaches that are perceived to legitimately represent the uniqueness of the locality. Third, engagement of local populations and stakeholders is essential for effective and sustainable policy formation [7]. Fourth, studies that focus on biophysical parameters often lack policy recommendations, though the results of such studies provide essential supporting evidence for policymakers [55, 56, 64].

As climate change proceeds, developing countries will be hit the hardest [2]. By leveraging the big data era, researchers have an opportunity to inform policies that effectively mitigate the worst of these changes. Identifying the biophysical properties underlying, and the socio-political solutions to, these changes must be informed through case studies in a local context. Therefore, we must engage the locales of interest with care if researchers seek to improve their climate change prognosis and inform large-scale climate policy.

Funding Funding was provided by the Department of Geographical Sciences, University of Maryland.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

- Hayhoe K, Wuebbles DJ, Easterling DR, Fahey DW, Doherty S, Kossin J et al (2018) Our changing climate. In: Impacts, risks, and adaptation in the United States: fourth national climate assessment, vol II. Washington. <https://doi.org/10.7930/NCA4.2018.CH2>
- Hallegatte S, Bangalore M, Bonzanigo L, Fay M, Kane T, Narloch U et al (2015) Shock waves: managing the impacts of climate change on poverty. The World Bank, Washington
- Juhola S (2013) Adaptation to climate change in the private and the third sector: case study of governance of the Helsinki metropolitan region. *Environ Plan C Gov Policy* 5:911–925. <https://doi.org/10.1068/c11326>
- Chandra A, Dargusch P, McNamara KE (2016) How might adaptation to climate change by smallholder farming communities contribute to climate change mitigation outcomes? A case study from Timor-Leste, Southeast Asia. *Sustain Sci* 3:477–492. <https://doi.org/10.1007/s11625-016-0361-9>
- Cunningham R, Cvitanovic C, Measham T, Jacobs B, Dowd A-M, Harman B (2016) Engaging communities in climate adaptation: the potential of social networks. *Clim Policy* 7:894–908. <https://doi.org/10.1080/14693062.2015.1052955>
- Malone EL, Kinnear S (2015) How and why: complementary analyses of social network structures and cultural values: improving flood response networks in Queensland, Australia. *Qual Quant* 1:203–220. <https://doi.org/10.1007/s11135-013-9982-6>
- Pandey SS, Cockfield G, Maraseni TN (2016) Assessing the roles of community forestry in climate change mitigation and adaptation: a case study from Nepal. *For Ecol Manag* 360:400–407. <https://doi.org/10.1016/j.foreco.2015.09.040>
- Swanson D, Barg S, Tyler S, Venema H, Tomar S, Bhadwal S et al (2010) Seven tools for creating adaptive policies. *Technol Forecast Soc Change* 6:924–939. <https://doi.org/10.1016/J.TECHFORE.2010.04.005>
- Simon D, Schiemer F (2015) Crossing boundaries: complex systems, transdisciplinarity and applied impact agendas. *Curr Opin Environ Sustain* 12:6–11. <https://doi.org/10.1016/j.cosust.2014.08.007>
- Meadow AM, Ferguson DB, Guido Z, Horangic A, Owen G, Wall T (2015) Moving toward the deliberate coproduction of climate science knowledge. *Weather Clim Soc* 2:179–191. <https://doi.org/10.1175/WCAS-D-14-00050.1>
- IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. In: Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
- Dewulf J, Benini L, Mancini L, Sala S, Blengini GA, Ardenne F et al (2015) Rethinking the area of protection natural resources in life cycle assessment. *Am Chem Soc Environ Sci Technol* 9:5310–5317. <https://doi.org/10.1021/acs.est.5b00734>
- Piedrahita P, Borge-Holthoefer J, Moreno Y, González-Bailón S (2017) The contagion effects of repeated activation in social networks. *Soc Netw*. <https://doi.org/10.1016/J.SOCNET.2017.11.001>
- Fatehkia M, Kashyap R, Weber I (2018) Using facebook ad data to track the global digital gender gap. *World Dev* 107:189–209. <https://doi.org/10.1016/J.WORLDDEV.2018.03.007>
- Mengistu D, Bewket W, Lal R (2016) Conservation effects on soil quality and climate change adaptability of Ethiopian watersheds: soil and water conservation soil quality mitigation adaptation. *Land Degrad Dev* 6:1603–1621. <https://doi.org/10.1002/ldr.2376>
- Jandl R, Lindner M, Vesterdal L, Bauwens B, Baritz R, Hagedorn F et al (2007) How strongly can forest management influence soil carbon sequestration? *Geoderma* 3–4:253–268. <https://doi.org/10.1016/j.geoderma.2006.09.003>
- Victor B, Fischer EF, Cooil B, Vergara A, Mukolo A, Blevins M (2013) Frustrated freedom: the effects of agency and wealth on wellbeing in rural Mozambique. *World Dev* 47:30–41. <https://doi.org/10.1016/j.worlddev.2013.02.005>
- Berrang-Ford L, Pearce T, Ford JD (2015) Systematic review approaches for climate change adaptation research. *Reg*

- Environ Change 5:755–769. <https://doi.org/10.1007/s10113-014-0708-7>
19. Brown K (2014) Global environmental change I: A social turn for resilience? *Prog Hum Geogr* 1:107–117. <https://doi.org/10.1177/0309132513498837>
  20. Yin RK (2003) Case study research design and methods, 3rd edn. Sage Publications Inc, Thousand Oaks
  21. Van Eck NJ, Waltman L (2014) Visualizing bibliometric networks. In: Ding Y, Rousseau R, Wolfram D (eds) *Measuring scholarly impact: Methods and practice*. Springer, Cham, pp 285–320
  22. Brandt P, Ernst A, Gralla F, Luederitz C, Lang DJ, Newig J et al (2013) A review of transdisciplinary research in sustainability science. *Ecol Econ* 92:1–15
  23. Noor K (2008) Case study: a strategic research methodology. *Am J Appl Sci* 11:1602–1604. <https://doi.org/10.3844/ajassp.2008.1602.1604>
  24. Barzelay M (1993) The single case study as intellectually ambitious inquiry. *J Public Adm Res Theory* 3:305–318
  25. Gibson-Graham JK (2003) An ethics of the local. *Rethink Marx* 1:49–74. <https://doi.org/10.1080/0893569032000063583>
  26. Gore ML, Lute ML, Ratsimbazafy JH, Rajaonson A (2016) Local perspectives on environmental insecurity and its influence on illegal biodiversity exploitation. *PLoS ONE* 4:e0150337. <https://doi.org/10.1371/journal.pone.0150337>
  27. Shijin W, Dahe Q (2015) Mountain inhabitants' perspectives on climate change, and its impacts and adaptation based on temporal and spatial characteristics analysis: a case study of Mt. Yulong Snow, Southeastern Tibetan Plateau. *Environ Hazards* 2:122–136. <https://doi.org/10.1080/17477891.2014.1003776>
  28. Tesfaye W, Seifu L (2016) Climate change perception and choice of adaptation strategies. *Int J Clim Change Strateg Manag* 2:253–270. <https://doi.org/10.1108/IJCCSM-01-2014-0017>
  29. McDowell JZ, Hess JJ (2012) Accessing adaptation: multiple stressors on livelihoods in the Bolivian highlands under a changing climate. *Glob Environ Change* 2:342–352. <https://doi.org/10.1016/j.gloenvcha.2011.11.002>
  30. Below TB, Schmid JC, Sieber S (2015) Farmers' knowledge and perception of climatic risks and options for climate change adaptation: a case study from two Tanzanian villages. *Reg Environ Change* 7:1169–1180. <https://doi.org/10.1007/s10113-014-0620-1>
  31. McDowell G, Ford JD, Lehner B, Berrang-Ford L, Sherpa A (2013) Climate-related hydrological change and human vulnerability in remote mountain regions: a case study from Khumbu, Nepal. *Reg Environ Change* 2:299–310. <https://doi.org/10.1007/s10113-012-0333-2>
  32. Biggs EM, Tompkins EL, Allen J, Moon C, Allen R (2013) Agricultural adaptation to climate change: observations from the Mid-Hills of Nepal. *Clim Dev* 2:165–173. <https://doi.org/10.1080/17565529.2013.789791>
  33. Comoé H, Siegrist M (2015) Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: a case study of two regions in Côte d'Ivoire. *Mitig Adapt Strateg Glob Change* 2:179–199. <https://doi.org/10.1007/s11027-013-9486-7>
  34. Elgin-Stuczynski IR, Batterbury S (2014) Perceptions of climate variability and dairy farmer adaptations in Corangamite Shire, Victoria, Australia. *Int J Clim Change Strateg Manag* 1:85–107. <https://doi.org/10.1108/IJCCSM-03-2013-0039>
  35. Amos E, Akpan U, Ogunjobi K (2015) Households' perception and livelihood vulnerability to climate change in a coastal area of Akwa Ibom State, Nigeria. *Environ Dev Sustain* 4:887–908. <https://doi.org/10.1007/s10668-014-9580-3>
  36. Sujakhu NM, Ranjitkar S, Niraula RR, Pokharel BK, Schmidt-Vogt D, Xu J (2016) Farmers' perceptions of and adaptations to changing climate in the Melamchi Valley of Nepal. *Mt Res Dev* 1:15–30. <https://doi.org/10.1659/MRD-JOURNAL-D-15-00032.1>
  37. Regmi BR, Star C, Leal Filho W (2016) An overview of the opportunities and challenges of promoting climate change adaptation at the local level: a case study from a community adaptation planning in Nepal. *Clim Change* 3–4:537–550. <https://doi.org/10.1007/s10584-016-1765-3>
  38. Campos M, Velázquez A, McCall M (2014) Adaptation strategies to climatic variability: a case study of small-scale farmers in rural Mexico. *Land Use Policy* 38:533–540. <https://doi.org/10.1016/j.landusepol.2013.12.017>
  39. Leonard S, Parsons M, Olawsky K, Kofod F (2013) The role of culture and traditional knowledge in climate change adaptation: insights from East Kimberley, Australia. *Glob Environ Change* 3:623–632. <https://doi.org/10.1016/j.gloenvcha.2013.02.012>
  40. Alexander SM, Andrachuk M, Armitage D (2016) Navigating governance networks for community-based conservation. *Front Ecol Environ* 3:155–164. <https://doi.org/10.1002/fee.1251>
  41. Wells MP, McShane TO (2004) Integrating protected area management with local needs and aspirations. *AMBIO J Hum Environ* 8:513–519. <https://doi.org/10.1579/0044-7447-33.8.513>
  42. Carlsson L, Berkes F (2005) Co-management: concepts and methodological implications. *J Environ Manag* 1:65–76. <https://doi.org/10.1016/j.jenvman.2004.11.008>
  43. Metcalf SJ, van Putten EI, Frusher SD, Tull M, Marshall N (2014) Adaptation options for marine industries and coastal communities using community structure and dynamics. *Sustain Sci* 3:247–261. <https://doi.org/10.1007/s11625-013-0239-z>
  44. Cooper SJ, Wheeler T (2015) Adaptive governance: livelihood innovation for climate resilience in Uganda. *Geoforum* 65:96–107. <https://doi.org/10.1016/j.geoforum.2015.07.015>
  45. Petzold J (2016) Limitations and opportunities of social capital for adaptation to climate change: a case study on the Isles of Scilly. *Geogr J* 2:123–134. <https://doi.org/10.1111/geoj.12154>
  46. Gómez-Baggethun E, Reyes-García V, Olsson P, Montes C (2012) Traditional ecological knowledge and community resilience to environmental extremes: a case study in Doñana, SW Spain. *Glob Environ Change* 22:640–650. <https://doi.org/10.1016/j.gloenvcha.2012.02.005>
  47. Picketts IM, Déry SJ, Curry JA (2014) Incorporating climate change adaptation into local plans. *J Environ Plan Manag* 7:984–1002. <https://doi.org/10.1080/09640568.2013.776951>
  48. Mandryk M, Reidsma P, Kartikasari K, van Ittersum M, Arts B (2015) Institutional constraints for adaptive capacity to climate change in Flevoland's agriculture. *Environ Sci Policy* 48:147–162. <https://doi.org/10.1016/j.envsci.2015.01.001>
  49. Nursey-Bray M, Pecl GT, Frusher S, Gardner C, Haward M, Hobday AJ et al (2012) Communicating climate change: climate change risk perceptions and rock lobster fishers, Tasmania. *Mar Policy* 36:753–759. <https://doi.org/10.1016/j.marpol.2011.10.015>
  50. Ellenwood MS, Dilling L, Milford JB (2012) Managing United States public lands in response to climate change: a view from the ground up. *Environ Manag* 5:954–967. <https://doi.org/10.1007/s00267-012-9829-2>
  51. Milad M, Schaich H, Konold W (2013) How is adaptation to climate change reflected in current practice of forest management and conservation? A case study from Germany. *Biodivers Conserv* 5:1181–1202. <https://doi.org/10.1007/s10531-012-0337-8>
  52. Malhi Y, Baldocchi DD, Jarvis PG (1999) The carbon balance of tropical, temperate and boreal forests. *Plant Cell Environ* 6:715–740. <https://doi.org/10.1046/j.1365-3040.1999.00453.x>
  53. Hurr GC, Pacala SW, Moorcroft PR, Caspersen J, Shevliakova E, Houghton RA et al (2002) Projecting the future of the U.S. carbon sink. *Proc Natl Acad Sci* 3:1389–1394. <https://doi.org/10.1073/pnas.012249999>
  54. City of Boulder (2017) Boulder's climate commitment: rising to the climate challenge, powering a vibrant future

55. Keith H, Lindenmayer D, Mackey B, Blair D, Carter L, McBurney L et al (2014) Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks. *Ecosphere*. <https://doi.org/10.1890/ES14-00051.1>
56. Lindgren PMF, Sullivan TP (2013) Long-term responses of tree and stand growth of young lodgepole pine to pre-commercial thinning and repeated fertilization. *For Ecol Manag* 307:155–164. <https://doi.org/10.1016/j.foreco.2013.06.058>
57. Kerhoulas LP, Kolb TE, Hurteau MD, Koch GW (2013) Managing climate change adaptation in forests: a case study from the U.S. Southwest. *J Appl Ecol* 6:1311–1320. <https://doi.org/10.1111/1365-2664.12139>
58. Lal R (2005) Forest soils and carbon sequestration. *For Ecol Manag* 1–3:242–258. <https://doi.org/10.1016/j.foreco.2005.08.015>
59. He S, Richards K (2015) Impact of meadow degradation on soil water status and pasture management—a case study in Tibet: Tibetan meadow degradation and pasture management. *Land Degrad Dev* 5:468–479. <https://doi.org/10.1002/ldr.2358>
60. Xiao C, Janssens IA, Zhou Y, Su J, Liang Y, Guenet B (2015) Strong stoichiometric resilience after litter manipulation experiments: a case study in a Chinese grassland. *Biogeosci Discuss* 3:757–767. <https://doi.org/10.5194/bg-12-757-2015>
61. Duncan C, Primavera JH, Pettolelli N, Thompson JR, Loma RJA, Koldewey HJ (2016) Rehabilitating mangrove ecosystem services: a case study on the relative benefits of abandoned pond reversion from Panay Island, Philippines. *Mar Pollut Bull* 2:772–782. <https://doi.org/10.1016/j.marpolbul.2016.05.049>
62. Palma JHN, Paulo JA, Faías SP, García-Gonzalo J, Borges JG, Tomé M (2015) Adaptive management and debarking schedule optimization of *Quercus suber* L. stands under climate change: case study in Chamusca, Portugal. *Reg Environ Change* 8:1569–1580. <https://doi.org/10.1007/s10113-015-0818-x>
63. Maron DF (2017) Trump administration restricts news from federal scientists at USDA, EPA. <https://www.scientificamerican.com/article/trump-administration-restricts-news-from-federal-scientists-at-usda-epa/>. Accessed 17 Dec 2018
64. NASA-CMS NASA Carbon Monitoring System (2018)
65. Boateng I (2012) An assessment of the physical impacts of sea-level rise and coastal adaptation: a case study of the eastern coast of Ghana. *Clim Change* 2:273–293. <https://doi.org/10.1007/s10584-011-0394-0>
66. Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Moore H (2013) Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr Opin Environ Sustain* 3:420–431. <https://doi.org/10.1016/j.cosust.2013.07.001>
67. Tress G, Tress B, Fry G (2005) Clarifying integrative research concepts in landscape ecology. *Landsc Ecol* 4:479–493. <https://doi.org/10.1007/s10980-004-3290-4>
68. Weaver CP, Mooney S, Allen D, Beller-Simms N, Fish T, Grambsch AE et al (2014) From global change science to action with social sciences. *Nat Clim Change* 8:656. <https://doi.org/10.1038/nclimate2319>
69. Palmer MA, Kramer JG, Boyd J, Hawthorne D (2016) Practices for facilitating interdisciplinary synthetic research: the National Socio-Environmental Synthesis Center (SESYNC). *Curr Opin Environ Sustain* 19:111–122. <https://doi.org/10.1016/j.cosust.2016.01.002>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.