

Community-level climate change vulnerability research: trends, progress, and future directions

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Environmental Research Letters



TOPICAL REVIEW

Community-level climate change vulnerability research: trends, progress, and future directions

OPEN ACCESS

RECEIVED

12 August 2015

REVISED

10 February 2016

ACCEPTED FOR PUBLICATION

15 February 2016

PUBLISHED

4 March 2016

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**Abstract**

This study systematically identifies, characterizes, and critically evaluates community-level climate change vulnerability assessments published over the last 25 years ($n = 274$). We find that while the field has advanced considerably in terms of conceptual framing and methodological approaches, key shortcomings remain in how vulnerability is being studied at the community-level. We argue that vulnerability research needs to more critically engage with the following: methods for evaluating future vulnerability, the relevance of vulnerability research for decision-making, interdependencies between social and ecological systems, attention to researcher / subject power dynamics, critical interpretation of key terms, and consideration of the potentially positive opportunities presented by a changing climate. Addressing these research needs is necessary for generating knowledge that supports climate-affected communities in navigating the challenges and opportunities ahead.

1. Introduction

Research examining vulnerability is central to the human dimensions of climate change scholarship, and plays a critical role in revealing where, how, and why people are affected by changes in the climate system (Smit and Wandel 2006). The importance of such work is now widely recognized (Moss *et al* 2013, Ribot 2014), with observed and projected climatic changes adding urgency to the need for understanding the implications of a rapidly changing climate (IPCC 2013). To this end, community-level vulnerability assessments have proliferated over the last 25 years, contributing to a growing body of evidence about the pathways through which climate change affects human systems (Wang *et al* 2014). Community-level assessments have received particular attention, reflecting the critical role of place-based studies in revealing how human and biophysical stresses interact to affect vulnerability as well as the importance of community-level studies in problem identification

and supporting/developing effective adaptation strategies (Schröter *et al* 2005, Forsyth 2013, Ribot 2014, Schipper *et al* 2014). A number of keystone papers theorizing how to best study climate change vulnerability were published in the early to mid-2000s (Turner *et al* 2003, Adger 2006, Füssel and Klein 2006, Smit and Wandel 2006). However, since these seminal papers there have been few attempts to examine the state of the field. This study addresses this gap, systematically identifying, characterizing and critically evaluating community-level vulnerability research published since 1990.

In reviewing the state of the climate change vulnerability field, the paper contributes to a growing body of environmental change scholarship that seeks to systematically and transparently assess the state of knowledge in a given area (Ford and Pearce 2010, Ford *et al* 2012, Lorenz *et al* 2014, McDowell *et al* 2014, Porter *et al* 2014, Berrang-Ford *et al* 2015, Ford *et al* 2015, Sud *et al* 2015). Such review work is of particular importance for the vulnerability scholarship, where

Table 1. Questionnaire sections.

Theme	Topics evaluated
1. Bibliometric information	Year published, author institutional affiliation, author country
2. Vulnerability assessment information	Study community details, sectors examined, relevant climatic and non-climatic stressors, nature of assessment findings
3. Conceptual information	Treatment of socio-economic/political dimensions of vulnerability, differential vulnerability, and cross-scale dynamics
4. Methodological information	Methods used, including details of stakeholder involvement
5. Usability information	Extent to which studies were designed to contribute to decision making processes and inform policy
6. Vulnerability assessment versus critiques of vulnerability science	Engagement with interdependencies between social and ecological systems, researcher/subject power dynamics, critical interpretation of key terms, opportunities presented by climate change

rapid increases in publishing across disciplines have made it difficult for individual researchers and research teams to keep abreast of key developments.

2. Methods

This study utilized systematic review methods (Berang-Ford *et al* 2015). Data were obtained from peer-reviewed, English language journal articles published between 1 January 1990 and 31 December 2014. Searches were performed in Web of Science, Scopus, and PubMed, to ensure coverage of the socio-economic/political, technical/engineering, and health literature.

An inclusion/exclusion criteria was used to evaluate the relevance of each article collected, where included articles had to be focused on the human dimensions of climate change, to utilize a vulnerability perspective, and to examine vulnerability at the community-level (i.e. community-based or community-focused case studies). Article titles were scanned for fidelity to these criteria, and clearly irrelevant articles were removed; abstract screening and full text skimming was conducted with the remaining articles. In total, 274 articles were included for thorough full text review. The majority of excluded articles were not community based or community-focused, concentrated on climate change adaptation, or only evaluated impacts in biological communities.

A questionnaire, accompanied by a codebook defining all terms and possible responses, was used to standardize data extraction. The questionnaire contained 43 questions (134 possible answers), and was organized into six sections (table 1). The first two sections focused on capturing bibliometric information and developing insights on the nature of the study reported in the article. The remaining sections were designed to evaluate the literature based on criteria representing what is now considered 'best practice' in community-level vulnerability assessment. This benchmark includes emphasis on exposure,

sensitivity, and adaptive capacity; attention to cross-scale dynamics in affecting vulnerability; recognition of feedbacks and nonlinearities in system responses; evaluation of the usability of science; attention to coupled human–environmental system dynamics; and a focus on both present day and future vulnerabilities (e.g. Ford and Smit 2004, Fussel and Klein 2006, Smit and Wandel 2006, O'Brien *et al* 2007, Ford *et al* 2010, Haalboom and Natcher 2012, Lemos *et al* 2012, Tschakert *et al* 2014).

Question responses from all 274 articles were entered into a database (36 716 data points), and basic summary statistics were performed for all possible responses. The supplementary materials provide full details of the research protocol, complete questionnaire and codebook, data analysis results, and a bibliography for all articles reviewed.

3. Results

3.1. Community-level vulnerability studies have expanded rapidly over the last quarter century, and are primarily led by developed nation academics

Community-level climate change vulnerability assessments first appear in the peer-reviewed, English language literature in 1996 ($n = 2$), with publications not exceeding $n = 6$ until 2006. Thereafter, a steady rise in annual publications is evident, peaking in 2014 ($n = 55$) (figure 1). More studies were published between 2012 and 2014 than all other years combined. Based on analysis of the affiliation of lead authors at the time of publication, studies are authored by individuals based in 49 countries, although most are from developed nations; namely, the United States (23%, $n = 63$), Canada (15%, $n = 42$), Australia (9%, $n = 26$), and the UK (8%, $n = 22$). The absolute number of authors is high, with no single author leading more than 3% ($n = 8$) of the articles reviewed.

University-based groups (77%, $n = 212$) and government (10%, $n = 27$) lead most community-level vulnerability assessments, but NGOs (7%, $n = 18$),

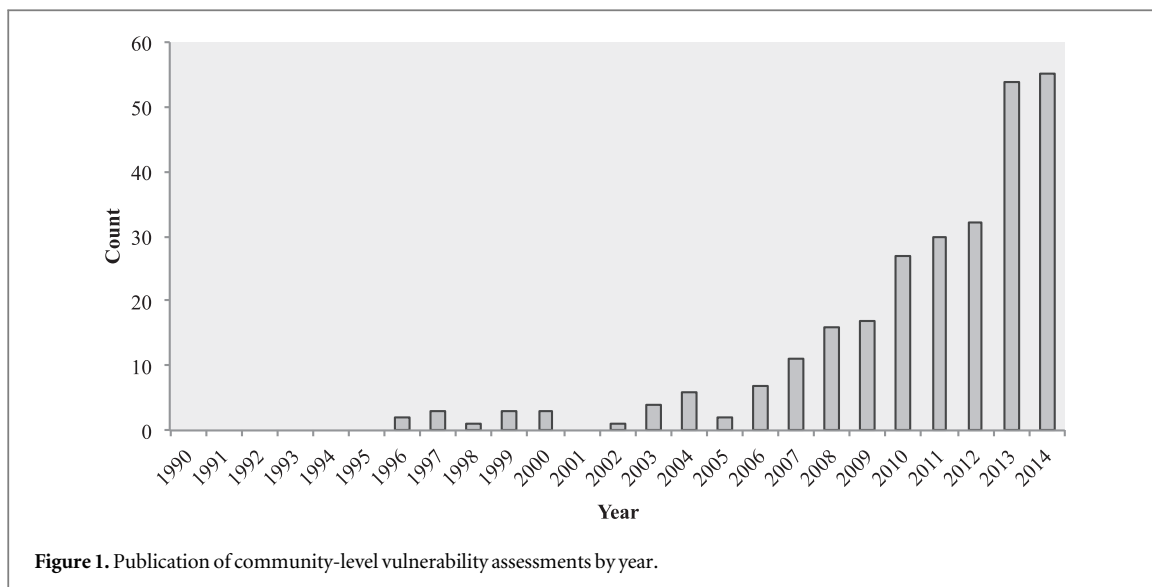


Figure 1. Publication of community-level vulnerability assessments by year.

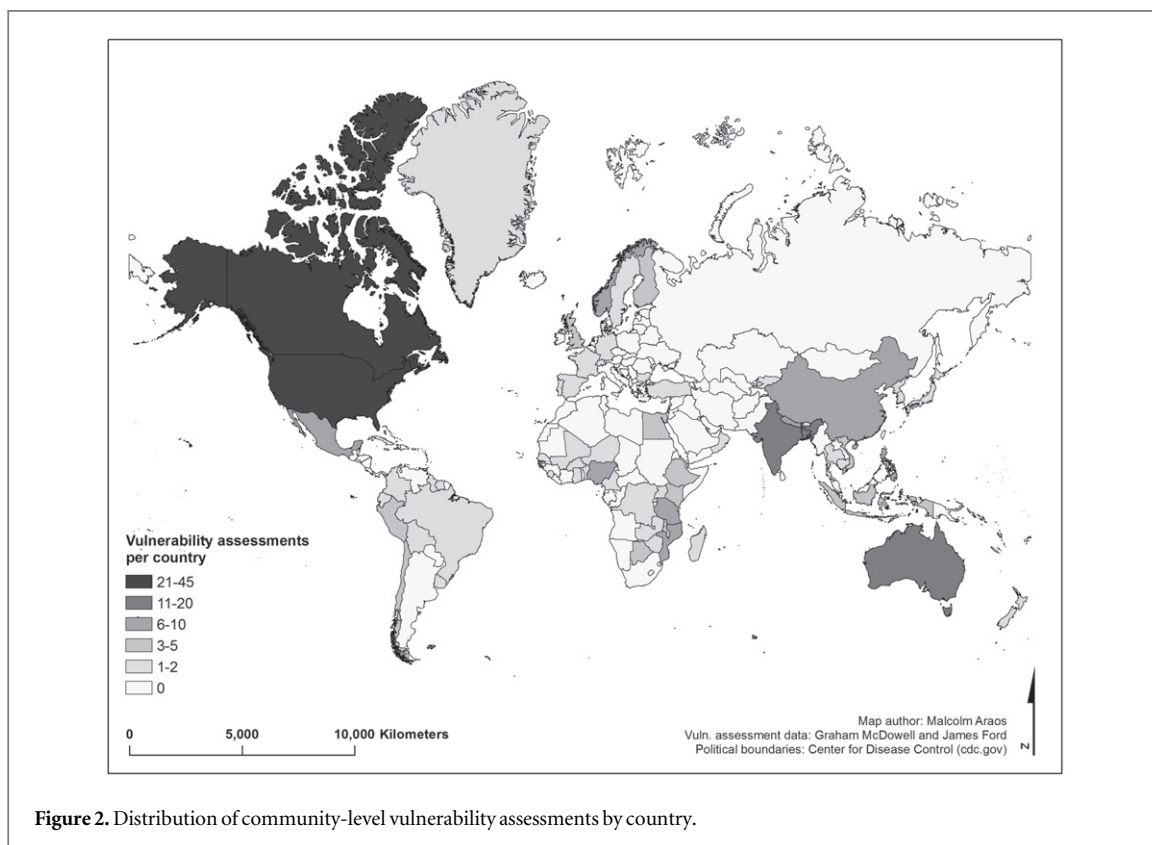


Figure 2. Distribution of community-level vulnerability assessments by country.

intergovernmental organizations (3%, $n = 7$), and the private sector (1%, $n = 2$) also register. NGO and intergovernmental organization led publications are only documented between 2007 and 2013. From a regional perspective, Africa, South America, and South/Southeast Asia have the most diversity in terms of the groups leading assessments (i.e. university-based, government, NGO, and intergovernmental organizations). Central/Eastern Asia has the largest proportion of assessments led by government, and private sector leadership is restricted to assessments conducted in Western Europe and North America.

3.2. There is an uneven distribution of vulnerability studies by region, a focus on small rural communities, and an increasing diversity of risks being studied

The reviewed articles report on community-level vulnerability assessments conducted in 73 countries (figure 2). Five countries account for 45% of the assessments to date: the United States (16%, $n = 43$), Canada (11%, $n = 30$), India (7%, $n = 20$), Australia (7%, $n = 18$), and Bangladesh (4%, $n = 11$). This geographical distribution highlights notable gaps for many countries where community-level vulnerability

is thought to be significant, particularly low- and middle-income nations. Regionally, most studies have been conducted in North America (29%, $n = 80$), Africa (19%, $n = 52$), and South/Central Asia (17%, $n = 46$). In comparison, research in Central/Eastern Asia (4%, $n = 11$), the Middle East (3%, $n = 9$), and Eastern Europe (<1%, $n = 1$) is limited.

The largest proportion of studies evaluate vulnerability in one community (32%, $n = 89$); articles focusing on one to three communities comprise 55% ($n = 150$) of the sample. Studies evaluating four to twelve communities account for 22% ($n = 60$) of reviewed articles. The maximum number of communities in a study was 428 (Mendoza *et al* 2014). Across regions, the majority of studies focus on rural communities, except in the Middle East and Eastern Europe where a focus on urban areas dominates. While the absolute number of studies per year is increasing for all study community types, proportionally there is a trend towards greater emphasis on rural communities. Of studies where information is available on the population of study communities ($n = 167$), 65% ($n = 108$) focused on small communities (<10 000 residents), 8% ($n = 13$) on medium sized communities (10 001–100 000 residents), and 34% ($n = 56$) focused on large communities (>100 000 residents). This pattern is consistent across regions, except in the Middle East and Central/Easter Asia, where a focus on large communities dominates.

Most of the reviewed studies focus on one or more sectors to examine specific aspects of climate vulnerability (90%, $n = 247$), with the most commonly evaluated sectors being agriculture (33%, $n = 91$), health (24%, $n = 65$), culture, arts, and heritage (19%, $n = 53$), coastal management (16%, $n = 43$), and water (15%, $n = 41$). However, the sectoral focus in assessments varies across time and space. For example, evaluations of culture, arts, and heritage are considered in 9%–29% of assessments per year since 2006, signaling a shift from the pre-2006 scholarship where this focus is absent. This is consistent with increasing emphasis on the cultural dimensions of climate change (Adger *et al* 2013). Conversely, although the total number of assessments examining the coastal management sector is large, the yearly proportion of studies evaluating this sector is declining over time (focus was dominant in the late 1990s). Regionally, agriculture and development sectors are the most common focus in Africa, health sector evaluations occur most frequently in Western Europe and North America, and a focus on the water sector is seen most often in South America and the Middle East.

The most commonly reported climate-related risks from vulnerability case studies were extreme events (e.g. floods) (59%, $n = 162$), temperature increase (53%, $n = 145$), sea level rise and coastal erosion (27%, $n = 74$), weather uncertainty (26%, $n = 71$), and seasonality change (23%, $n = 63$). Reporting on climate-related changes has evolved in

important ways over time. Extreme events and temperature increase are the only climatic stimuli reported for the first third of the study period. Not until 2006 do other climatic risks begin to be studied, after which time the diversity of reported risk increases significantly. For example, after 2006, cryospheric change (i.e. reductions in sea extent and duration, glacial change, and thawing of frozen ground) and changes in wildlife distribution and behavior begin to emerge as important additional climate-related factors affecting vulnerability.

Most vulnerability case studies also consider non-climatic factors in influencing vulnerability (96%, $n = 263$), with economic stress (e.g. inability to access credit for adaptive actions) (60%, $n = 164$), livelihood diversification (e.g. multiple sources of income, which often reduces susceptibility to harm) (30%, $n = 83$), marginalization (e.g. economic and ethnic stratification) (29%, $n = 79$), health-related factors (e.g. pre-existing pulmonary conditions that increase sensitivity to heat stress) (24%, $n = 65$), and cultural change (e.g. erosion of traditional knowledge) (20%, $n = 56$) of note in many assessments. Quantified under the heading of 'Other' (68%, $n = 187$), education, gender, age, governance/policy, and remittances were also cited for their influence on vulnerability in many cases. While marginalization, food insecurity, and displacement and conflict were not the most significant factors numerically, they were often associated with high vulnerability. Marginalization is most commonly reported in the Middle East and South/Southeast Asia, food insecurity is most prevalent in studies from Africa and the Middle East, and displacement and conflict is a common concern in the Middle East and Central/Eastern Asia. Overall, the Middle East emerges as a hotspot for these concerning non-climatic drivers of vulnerability.

3.3. Most community studies use a 2nd generation vulnerability framing, and emphasize cross-scale determinants of vulnerability

Reviewed articles were coded according to the conceptual and methodological framing adopted. Twenty one percent ($n = 57$) of studies were classified as 1st generation or endpoint approaches to vulnerability assessments, where community-level vulnerability is conceptualized as a direct outcome of biophysical changes (Füssel and Klein 2006, O'Brien *et al* 2007). Work using this framing has decreased over the observation period, although such studies comprise no less than 9% of studies in any given year since 1996. Second generation or starting point approaches to vulnerability assessment, where vulnerability is conceptualized as emerging from the complex interplay of climatic and non-climatic factors (*ibid.*) has been dominant since 2000, and accounts for 68% ($n = 186$) of the assessments reviewed. However, the review also reveals that 12% ($n = 34$) of studies claiming to use a

2nd generation conceptualization of vulnerability did not actually do so in practice; instead they primarily examined biophysical drivers of vulnerability. By region, 2nd generation assessments are most common in Africa, whereas 1st generation assessments are dominant in Eastern and Western Europe (slightly increasing as a proportion of studies in a given year in Western Europe, driven in part by recent heat wave assessments). Fifty-eight percent ($n = 159$) of assessments examined differential vulnerability, but an additional 20% ($n = 55$) of assessments claiming to examine differential vulnerability demonstrated no meaningful engagement with social differentiation.

Cross-scale dynamics relevant to community-level vulnerability were captured in 70% ($n = 191$) of the studies reviewed, observable based on whether studies assessed the effects of local and distal processes and events on vulnerability. Cross-scale dynamics were a focus in at least 57% of studies per year from 2003 onwards, and were prominent in all regions except Central/Eastern Asia. The main arguments made by articles with regards to scale in vulnerability assessment are that larger scale/distal processes substantially affect smaller scale/local processes (17%, $n = 46$), that cross-scale factors play a key role in influencing vulnerability (44%, $n = 120$), and that scale must be considered in climate change policies (47%, $n = 30$).

3.4. Local perspectives and knowledge are important sources of information in community-level vulnerability assessments, but most studies do not use principles of participatory design

The majority (77%, $n = 211$) of community-level assessments incorporate local perspectives and knowledge (e.g. interviews, focus groups with community members and stakeholders), although in 2% ($n = 5$) of studies claiming local inclusion this was not evident based upon what was reported in the article. Twenty-eight percent ($n = 78$) of studies reviewed reported co-developing the research with local stakeholders and/or involving locals substantively in research activities. First explicitly reported in 2004, the use of such participatory approaches has generally increased over time, peaking proportionally in 2007 (46% of studies in year, $n = 3$) and absolutely in 2013 ($n = 21$). North America (primarily work northern Canada and Alaska, 40% of studies in region, $n = 32$) and South/Southeast Asia (30% of studies in region, $n = 14$) are above average in terms of the use of such approaches. Most case studies report engaging between 61 and 150 participants (21%, $n = 58$), followed by 151–500 (19%, $n = 52$), and 31–60 (11%, $n = 30$), respectively. The number of study participants could not be determined or was not applicable for 34% ($n = 92$) of assessments reviewed (e.g. no-grounded research).

3.5. A diversity of methodological approaches are used in community-level vulnerability research, although scoring/index approaches are most common

The reviewed studies utilized several methodological approaches. Temporal analog, where experiences of environmental change at one time are used to identify potential impacts in a future period of time, were utilized in 12% ($n = 33$) of studies overall, but aside from small spikes in 2009 and 2011 have decreased in popularity. Spatial analog methods, where experiences of environmental change in one area are used to identify potential impacts in another area, were documented in only 1% ($n = 2$) of the articles reviewed (Hayhoe *et al* 2010, Mark *et al* 2010). Longitudinal approaches, where vulnerability is tracked over time, were evident in 9% ($n = 25$) of case studies, mostly in Central/Eastern Asia. For example, integrating multiple field site visits with long-term data records to track the effects of drought over time in Southwestern China (Su *et al* 2012). Aside from a peak in 2005, the use of longitudinal methods is declining. Examples of real time monitoring of vulnerability are limited (6% of studies, $n = 17$), and are primarily utilized in indigenous communities in the North American Arctic ($n = 3$).

The use of vulnerability scoring/index approaches is relatively common, representing 30% ($n = 82$) of the sample. As a proportion of methodological approaches used in a given year, scoring/index approaches peaked in 1998 and 2002, then declined until 2009, after which time there has been an increase in use absolutely and proportionally. The use of vulnerability scoring/indices is most common in studies from South/Southeast Asia (48% of studies in region, $n = 22$) and North America (35% of studies in region, $n = 28$).

3.6. Future scenarios of climatic and socio-economic change are rarely used in community-level vulnerability studies

Climate change modeling projections were incorporated explicitly in 14% ($n = 37$) of studies. In some cases projections were used to identify and characterize direct impacts such as areas inundated by future sea level rise (i.e. 1st generation assessments) (Kumar 2006). In other cases, projections were part of a suite of methods used to evaluate complex socio-ecological dynamics (e.g. Alessa *et al* 2008). Relative to the number of studies in a given year, the use of climate change projections has declined strongly over time. Few studies utilized modeling projections of social change (6%, $n = 16$). Like studies incorporating climate change projections, studies using projections of social change are most often conducted in Western Europe and North American studies. Most modeling studies have projection timelines of >50 years and, often evaluate change to 2100.

3.7. A key goal of the majority of studies is to inform decision making on vulnerability reduction, but few are explicitly designed according to principles of usable science

We used Ford *et al*'s (2013) framework to determine the extent to which studies produced usable information. Here, usable science can be characterized by the extent to which: (i) research investigates factors under the influence of decision makers (pertinence); (ii) research is trusted and valued by decision makers, and therefore likelihood of being acted upon (quality); and (iii) the extent to which information is available in time for decision makers (timeliness).

The majority (82%, $n = 225$) of reviewed articles explicitly articulated a goal of informing decision making on vulnerability reduction. However, based on the information available in articles, few demonstrated evidence of being explicitly designed to integrate key principles of usable science (i.e. pertinence, quality, timing). Only 14% ($n = 38$) of reviewed studies indicated that research objectives were developed in consultation with stakeholders (i.e. pertinence); the largest proportion of these studies were conducted in North America (29% of all studies, $n = 23$). Central/Eastern Asia and Eastern Europe perform worst in this regard, with no studies with this focus. Stakeholder involvement in research question development first registers in 2004, declining thereafter until 2011; it peaks again in 2013 (24%, $n = 13$).

Studies perform poorly on the quality attribute of usable science based on information provided in the articles examined, with only 15% ($n = 42$) of articles reporting involvement of stakeholders in making judgments regarding the quality of results. Articles describing the involvement of stakeholders in evaluating results appear first in 2006; since 2010 such studies are generally declining as a proportion of studies conducted in a given year. North America again emerges as a leader in this aspect of usability (31% of studies in region, $n = 25$), with work in Arctic regions with Indigenous groups commonly involving stakeholders in evaluating results.

Few of the reviewed studies performed well on the timeliness attribute of usable science, with only 13% ($n = 35$) demonstrating evidence that they were conducted to provide timely information in response to stakeholder needs. Such studies were first documented in 2003, and since 2009 studies conducted in response to stakeholder concerns have been slightly increasing as a proportion of studies conducted in a given year. These studies are most common in North America (26% of studies in region, $n = 21$). Studies did better with regard to providing information for decision-making processes or events (26%, $n = 70$). Studies with a focus on this aspect of timeliness first register in 1997 and aside from small peaks in 2005 and 2006 remained relatively stable as a proportion of studies in a given year. Interestingly, North America is not a leader in studies with this focus. Instead, the Pacific Islands

(35% of studies in region, $n = 14$), Middle East (33% of studies in region, $n = 3$), and Western Europe (30% of studies in region, $n = 6$) rank highest with regards to providing timely information for decision-making processes or events.

3.8. The vulnerability scholarship has made limited progress in addressing critiques

Community-level vulnerability studies with a significant focus on linkages between human and ecological systems are rare, representing only 13% ($n = 36$) of the sample. Studies in Africa (21% of studies in region, $n = 11$), the Pacific Islands (20% of studies in region, $n = 8$), and North America (18% of studies in region, $n = 14$) place the greatest emphasis on interlinked socio-ecological systems. Conversely, no studies with this focus have been conducted in Central/Eastern Asia, the Middle East, and Eastern Europe. Overall, efforts to addressing this critique remain low across the sample.

Eleven percent ($n = 29$) of the studies reviewed provide evidence of attention to researcher/subject power dynamics, a key tenet of ethical community-based vulnerability research (e.g. Sherman *et al* 2012). Studies in rural areas are more likely to address these issues. For example, researchers working with remote indigenous communities in Australia anticipating and accounting for the ways in which their presence might affect community members (Bardsley and Wiseman 2012). Studies with this focus are first recorded in 2006, and are consistently limited thereafter. Assessments in North America (20% of studies in region, $n = 16$) have been most likely to attend to researcher/subject power dynamics. Similarly, critical interpretation of key terms (e.g. Indigenous, vulnerability) is limited, evident in only 15% ($n = 41$) of studies reviewed.

While it is reasonable to expect that many of the impacts of climate change will be negative, only 15% ($n = 42$) of the studies reviewed explicitly considered potential positive impacts (e.g. expanded agricultural opportunities). Western Europe is a strong leader in this area (40% of studies in region, $n = 8$), while other regions lag behind significantly.

3.9. The majority of studies identify incidences of high vulnerability, with calls for adaptation policies widely documented

The reviewed articles reveal several broad insights about the nature of vulnerability at the community-level. For example, socio-economic and political factors were identified as the main driver of vulnerability in 63% ($n = 172$) of studies, while climate variability and/or change were the main driver in 21% ($n = 58$) of studies. High vulnerability, where the effects of climatic change lead to marked declines in wellbeing, was identified unequivocally in about a third of the community-level case studies reviewed.

Conversely, ~4% of case studies reported unambiguously low vulnerability. However, these vulnerability statistics only represent cases where vulnerability was determined to be the same within or across communities. Although not quantified, high vulnerability was cited among some group or sector in about another third of the articles reviewed, implying high vulnerability in about two-thirds of sample. In evidence of widespread sensitivity to the effects of climate change, 82% ($n = 225$) of the studies identified a need for adaptation policies to manage the effects of climate change. See supplementary materials for complete results table.

4. Discussion

Since the mid-2000s, there has been a rapid increase in publishing on community-level vulnerability assessments, contributing to a growing understanding of the pathways through which climate change affects human systems at the local level. Studies have diversified significantly over the last decade in terms of the risks studied, although the scholarship continues to be dominated by academics from developed countries, is geographically limited, and retains a strong focus on rural regions. Furthermore, comparing the empirical community-level studies reviewed here to the scholarship theorizing climate change vulnerability, it is evident that there are still critical gaps in understanding of vulnerability at the community-level.

Firstly, while there is increasing focus on the human factors that determine vulnerability, not all recent community-level assessments have kept pace with this evolution in conceptual thinking. Moreover, many studies continue to utilize 1st generation approaches to vulnerability assessment, and tokenism is prevalent in a relatively large proportion of studies vis-à-vis the socio-economic/political dimensions of vulnerability. And while issues related to scale do register in many studies, they rarely receive sustained, critical attention in assessments, consistent with claims that vulnerability studies preference local drivers of vulnerability (Adger *et al* 2008).

Secondly, methods used in assessments generally reflect a trend towards efforts to incorporate and evaluate local experiences of climate change, and to develop metrics of vulnerability that are realistic for local circumstances and, in some cases, transferable to other contexts. But this observation has limitations: a fifth of studies lack the type of local/participatory involvement widely regarded as fundamental for cogent vulnerability assessments. This is especially true of assessments evaluating the health effects of increasing temperatures in urban areas and studies of vulnerability to sea level rise. As well, the use of analog methods, longitudinal study designs, and real time monitoring is relatively uncommon, highlighting a focus on short-term case studies aimed at providing a

snapshot of vulnerability in specific contexts. Moreover, modeling of climate and social change in studies is uncommon, limiting efforts to understanding future vulnerability. Notwithstanding, the conceptual and methodological aspects of most community-level vulnerability assessments reflect the best practices prevailing at the time of their publication.

Thirdly, the community-level vulnerability research shows significant shortcomings with respect to usability. In particular, a wide gap exists between stated objectives to inform decision-making, and the uptake of approaches having a strong bearing on the relevance of vulnerability research for decision-making. In particular, limited involvement of stakeholders in co-developing research objectives suggests a potential gap between the issues being evaluated by researchers and those of interest to decision makers. And limited involvement of stakeholders in evaluating study results may reduce the extent to which the research is trusted and valued. The greatest emphasis in the scholarship is on providing timely information to support formal decision-making activities, but the limited integration of other key principles of usable science may hinder knowledge translation. This study highlights a pressing need for more robust linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions.

Finally, the results of this review largely confirm the veracity of critiques levied at the community-level vulnerability scholarship. There is growing consensus among environmental change researchers that treating communities as separate from their ecological context can lead to research that overlooks critical socio-ecological interdependencies, and subsequently recommendations for reducing vulnerability that are not mindful of the effects remedial actions have on social groups *and* ecosystems. In addition to adversely affecting biodiversity and ecological integrity (Pateron *et al* 2008, Turner *et al* 2010), unintended ecological degradation may eventually feedback to erode the ecosystem services that underpin human wellbeing (a form of mal-adaptation). The paucity of attention to these dynamics in the scholarship is concerning, and expanded engagement with social and ecological interdependencies is essential going forward. Because many terms in the vulnerability scholarship are boundary objects (i.e. concepts that are viewed or used differently among groups), the lack of studies critically interpreting key terminology is also problematic, and compounds usability concerns. Greater precision in the use of key terms will benefit knowledge sharing among and across scholarly and policy communities. Greater attention to research/subject power dynamics must also occur, as power asymmetries are often significant and, if not carefully considered, can strongly influence research findings and lead to harmful legacy effects in study communities. Finally, given that 'a large fraction of anthropogenic climate change

resulting from CO₂ emissions is irreversible on a multi-century to millennial time scale' (IPCC 2013), it is essential that understanding adverse impacts be complimented by recognition of the potential for new opportunities.

5. Conclusion

The study highlights several opportunities for improving the community-level vulnerability scholarship. These include promoting a greater diversity of author and institutional involvement; conducting assessments in areas currently underrepresented in the literature; aiming for fidelity to contemporary best practices and/or charting out new trajectories in conceptual and methodological thinking; improving linkages between the practice of community-level assessments and efforts to develop and implement vulnerability-reducing interventions; and attending to the critiques of the vulnerability scholarship through more integrative, community-engaged assessments. The importance of community-level vulnerability research is only increasing given projected changes in the climate system and the persistence of widespread socio-economic inequities. Addressing the gaps and research needs identified in this review is an important step in navigating the challenges and opportunities ahead.

Acknowledgments

This project was supported by funding from the Social Sciences and Humanities Research Council of Canada (SSHRC), Natural Sciences and Engineering Research Council of Canada (NSERC), Canadian Institute of Health Research (CIHR), Fonds de Recherche du Québec-Société et Culture (FRQSC), and Arctic Net.

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