



# Vulnerability and its discontents: the past, present, and future of climate change vulnerability research

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## Abstract

The concept of vulnerability is well established in the climate change literature, underpinning significant research effort. The ability of vulnerability research to capture the complexities of climate-society dynamics has been increasingly questioned, however. In this paper, we identify, characterize, and evaluate concerns over the use of vulnerability approaches in the climate change field based on a review of peer-reviewed articles published since 1990 ( $n = 587$ ). Seven concerns are identified: neglect of social drivers, promotion of a static understanding of human-environment interactions, vagueness about the concept of vulnerability, neglect of cross-scale interactions, passive and negative framing, limited influence on decision-making, and limited collaboration across disciplines. Examining each concern against trends in the literature, we find some of these concerns weakly justified, but others pose valid challenges to vulnerability research. Efforts to revitalize vulnerability research are needed, with priority areas including developing the next generation of empirical studies, catalyzing collaboration across disciplines to leverage and build on the strengths of divergent intellectual traditions involved in vulnerability research, and linking research to the practical realities of decision-making.

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## 1 Introduction

Vulnerability denotes susceptibility to harm and is derived from the Latin *vulnerare*, meaning “to wound.” While the concept of vulnerability is variously applied in different fields and disciplines, vulnerability research is generally concerned with identifying and understanding factors that put people and places at risk and which reduce the ability to respond to threats (Cutter 2003). In the climate change field, vulnerability research has sought to identify where, how, and why human systems are affected by changes in the climate, with such work growing rapidly over the last decade (McDowell et al. 2016; Räsänen et al. 2016; Wang et al. 2014) and building upon seminal studies in the natural hazards field in the 1970s and 80s (Hewitt 1983; Hewitt and Burton 1971; Liverman 1990; Timmerman 1981). Pioneering work in the 1990s incorporated vulnerability approaches from this work into a climate change context (Adger 1999a; Bohle et al. 1994; Downing 1991; Liverman 1990), and by the early- to mid-2000s, there was a well-established body of scholarship focusing on vulnerability, as well as being a central focus of global research programs and vulnerability reduction efforts of governments and international organizations. Politically, vulnerability is mentioned in the original text of the UNFCCC, has underpinned discussion over the allocation of financial support, and has been used to inform differential obligation of Parties to the Convention (Klein 2009; Hinkel 2011).

Vulnerability research remains prominent in the climate change field, but has come under increasing scrutiny in recent years, with some questioning the ability of vulnerability approaches to capture the complexities of climate-society dynamics. Alternative approaches have been promoted to replace vulnerability (Brown 2016; Weichselgartner and Kelman 2015) and some have argued that researchers should avoid using vulnerability approaches altogether (Cameron 2012; Haalboom and Natcher 2012; Hall and Sanders 2015). In many instances, excitement, interest, and funding for climate change research has shifted from vulnerability to resilience. These developments bring diverse perspectives on the social and ecological conditions that mediate climate-related risks, but they also raise questions about the future of vulnerability research. Since the publication of a number of landmark papers over a decade ago (Adger 2006; Füssel and Klein 2006; Gallopin 2006; Smit and Wandel 2006), however, few have examined conceptual and methodological grand challenges facing vulnerability research or reviewed and evaluated concerns that have been raised.

In this article, we identify, characterize, and evaluate concerns over the use of vulnerability approaches in human dimensions of climate change research, based on a review of 587 articles published since 1990 that report on, critique, and/or comment on vulnerability research. Thirty-nine percent of reviewed articles ( $n = 226$ ) document at least one concern around the use of vulnerability approaches, and from this we, identify seven concerns. We evaluate each concern in light of the literature and the conceptual underpinnings of vulnerability research, focusing on high-level considerations surrounding the concepts used in vulnerability research, methodology, and the presentation of empirical findings, recognizing that such considerations will differ by the context in which vulnerability research takes place (e.g., sector, region, scale). We use this review to examine the future of vulnerability research, identifying key directions and needs for future work.

## 2 Methodology

This paper is based on a systematic review and evaluation of climate change vulnerability research. By “vulnerability research,” we are referring to studies which seek to understand the

factors that create or attenuate susceptibility to harm in a human system in response to the effects of climate change. A diversity of approaches to assessing vulnerability exist, including modeling-based outcome or biophysical vulnerability approaches rooted in the natural sciences, contextual or social vulnerability approaches rooted in the social sciences and humanities, and integrative approaches which combined elements of both (Bennett et al. 2016; Burton et al. 2002; O'Brien et al. 2007).

We employed a multi-stage review approach within Web of Knowledge (WOK) to identify relevant peer-reviewed articles focusing on vulnerability, building upon Berrang-Ford et al. (2015). We began by performing a review in WOK using the topic search terms “climate change” and “vulnerability,” retrieving 7311 hits (the original dataset). We then applied a three-step procedure to sample papers from this original dataset to create a manageable number of papers while also maintaining the scope of the review to capture all relevant articles. The process sought to capture a diversity of article types, including theoretical, empirical, methodological, and review papers.

Firstly, we selected those peer-reviewed articles captured in WOK’s “ESI Top Papers,” where “highly cited” and “hot papers” were selected to capture the most influential papers on the basis of citation metrics. This process retrieved 215 articles, with the title and abstract of each screened for inclusion as having to focus on vulnerability in the context of the human dimensions of climate change. For empirical, theoretical, and methodological articles to be included, they had to focus on elements of exposure, sensitivity, and adaptive capacity (or associated synonyms), consistent with McDowell et al. (2016); those articles framed as vulnerability research but only focusing on biophysical factors or superficially treating sensitivity and/or adaptive capacity were excluded. We also sought to capture work reviewing and evaluating vulnerability research, including articles which had a substantive focus on critiquing or commenting on the state of vulnerability research. Selected articles were published between January 1, 1990 and December 31, 2016. This first stage resulted in 65 articles being selected for full reading, with excluded articles primarily focusing on vulnerability of natural systems.

Secondly, we focused on “review articles” in the original dataset, with the intention of capturing papers that review the state of the field, capture key critiques, and outline research gaps. Of the 495 review articles, 121 met the inclusion criteria (and were additional to those selected in step 1) and were retained for full review.

Thirdly, we searched the top 5 journals publishing human dimensions of climate change research, (as identified by Wang et al. (2014)), using the topic search terms “vulnerability” or “resilience” in WOK for each journal. We added the resilience search term to also capture articles critiquing vulnerability or proposing alternative approaches, and within the search, only documented papers not already captured in steps 1–2. The journals selected were as follows: *Global Environmental Change* ( $n = 395$  articles matching search terms, of which 124 retained for evaluation as meeting the inclusion criteria), *Climatic Change* ( $n = 390$ , 97), *Climate Research* ( $n = 100$ , 21), *Natural Hazards* ( $n = 728$ , 22), and *Mitigation and Adaptation Strategies for Global Change* ( $n = 136$ , 31). We also included five journals documented in steps 1 and 2 as having papers commenting on and critically engaging with vulnerability approaches: *Progress in Human Geography* ( $n = 28$  articles matching search terms, 11 retained for evaluation as meeting the inclusion criteria), *Annals of Association of American Geographers* ( $n = 59$ , 8), *Climate Policy* ( $n = 53$ , 7), *Wiley Interdisciplinary Reviews-Climate Change* ( $n = 65$ , 9), and *the Geographical Journal* ( $n = 56$ , 8).

Steps 1–3 retained a total of 524 articles which were read in full. References cited by all articles were also checked to identify additional work not documented by the search

procedures. An additional 63 articles were documented this way, leading to a total of 587 articles for review.

A framework for collecting and evaluating qualitative data on each article was developed building on McLeman et al. (2014) and Ford et al. (2015a, b). This involved each paper being read independently by two of the authors (“the reviewers”), with key components of the paper recorded and summarized in a word document structured by a set of standardized questions. The questions were open-ended and focused on documenting the nature of the study in question (region, date, type of article), definition of vulnerability and approaches used, findings, comments/critiques on vulnerability approaches documented, and proposal of alternative approaches to vulnerability. Evaluation focused on identifying and characterizing concerns on the use of vulnerability approaches that have emerged in the literature, where a “concern” captures instances where negative statements were made on the use of vulnerability approaches, methods, concepts, and/or terminology. Statements had to address epistemological and/or ontological considerations specific to vulnerability approaches to be classed as a concern; for example, challenges in recruiting enough interviewees or an absence of data were noted in many papers but reflect broader challenges not specific to vulnerability research and were thus not included. Seven concerns were repeatedly noted across articles by the reviewers, discussed among the author team, and form the corpus of concerns addressed here; concerns noted in fewer than ten papers were not included. Secondly, all papers were then re-read and evaluated according to the seven concerns, whereby evidence supporting and countering the concern was documented, and perspectives of the use of vulnerability approaches documented. We structure our presentation of results by profiling each concern and then engaging with it, with concerns ordered by the number of mentions per concern in reviewed articles (Table 1). We acknowledge that we do not capture all the vulnerability literature, noting that we reached saturation with the articles reviewed, whereby no new insights were emerging in the final papers read.

## 3 Results

### 3.1 Concern #1: vulnerability research privileges climatic factors over social

The most common concern directed to vulnerability research, documented in 117 articles, is the privileging of climatic factors over the social context, where it is argued that vulnerability research focuses primarily on estimating vulnerability directly attributable to climate change. These “outcome” or “biophysical” approaches to vulnerability guided much early work and have been critiqued as overlooking the non-climatic drivers of vulnerability and neglecting the complex dynamics of human-environment interactions (Eakin et al. 2014; Hinkel 2011; O’Brien et al. 2007). This concern is most frequently referenced in empirical research to justify a focus on social factors in the vulnerability study in question, although some recent articles also argue that the privileging of climatic factors is a reason to abandon vulnerability approaches (Cameron 2012; Haalboom and Natcher 2012; Sejersen 2015). Among the papers reviewed, however, research has advanced well beyond a one-dimensional focus on climate in assessing vulnerability, with a rich and well-developed literature viewing vulnerability as a state or condition embedded in socioeconomic processes. These “contextual” or “starting point” approaches are mainstream in contemporary work (Jurgilevich et al. 2017; e.g., McDowell et al. 2016; Räsänen et al. 2016), draw upon a long history of theoretical work

**Table 1** Concerns on the use of vulnerability approaches documented in the peer-reviewed scholarship

Concern	Nature of concern	Evidence to support concern	Opportunities for addressing concerns
Concern #1: vulnerability research privileges climatic factors over social	Non-climatic factors creating vulnerability overlooked.	Limited. Well-developed literature focusing on non-climatic drivers of vulnerability.	- Re-engage with foundational research on vulnerability
Concern #2: vulnerability research promotes a static understanding of human-environment interactions	Dynamic, continually evolving nature of vulnerability not captured.	Well supported. Research neglects how vulnerability is produced and evolves over time.	- Longitudinal study design - Vulnerability monitoring - Scenario planning
Concern #3: vulnerability is a vague concept	Diversity of definitions and approaches to assessing vulnerability creates confusion.	Partly supported. Precise meaning of vulnerability contested, but attempts have been made to define key terms and approaches.	- Build awareness of the diverse approaches that exist - Be explicit about the concepts used
Concern #4: vulnerability research neglects cross-scale interactions	Overreliance on community case studies downplays broader determinants of vulnerability.	Supported. Cross-scale dynamics and interactions often neglected.	- Meta-analyses to identify broad determinants of vulnerability - Regional and local case studies
Concern #5: vulnerability research brings a passive and negative framing	Vulnerability approaches paint affected peoples as passive victims.	Limited. Vulnerability approaches do not a priori denote a negative focus.	- Careful use of vulnerability terminology
Concern #6: Vulnerability research has had limited influence on decision-making	Vulnerability research has had limited policy uptake.	Unclear. Absence of studies evaluating whether vulnerability research is informing decision-making.	- Examine the success and failure of vulnerability research in affecting decision choices
Concern #7: vulnerability research takes place in disciplinary silos	Limited collaboration across disciplines provides incomplete understanding.	Supported. Research combining quantitative and qualitative approaches within an integrated methodology remain rare.	- Targeted funding calls to promote collaboration. - Cross-disciplinary networking

(Blaikie 1985; e.g., Hewitt 1983; Watts 1983), and are among the most cited in the field (Adger 2006, e.g., 1999a; Schröter et al. 2005; Smit and Wandel 2006; Turner et al. 2003); interestingly, many of these articles are not cited in studies arguing for abandoning the use of vulnerability approaches.

### 3.2 Concern #2: vulnerability research promotes a static understanding of human-environment interactions

Conceptual work describes vulnerability as inherently dynamic, influenced by socioeconomic and climatic conditions and processes operating over different spatial-temporal scales, along with internal system dynamics associated with feedbacks and thresholds (Eakin and Lemos 2006; Leichenko et al. 2010; Smit and Wandel 2006; Turner et al. 2003). Vulnerability outcomes are constantly changing between vulnerability and adaptability, in which small changes in climate or society may have a large impact and vice versa. The ability of vulnerability research to capture these dynamics has been questioned, with such concerns first

profiled in 1993 (Watts and Bohle 1993) and documented in 81 articles reviewed. Many components of this critique are supported in the scholarship, with vulnerability research primarily focusing on the current state of vulnerability, neglecting how vulnerability is produced and evolves over time, and is largely descriptive in nature (Magnan et al. 2016; Fawcett et al. 2017). Some have therefore favored the use of resilience approaches, arguing that resilience provides a stronger conceptual and analytical basis for capturing socio-ecological dynamics (Engle et al. 2014; Nelson et al. 2007). Others have cautioned vulnerability researchers to temper their recommendations for decision makers until these complex dynamics are better captured (Dilling et al. 2015).

### 3.3 Concern #3: vulnerability is a vague concept

Concern over a lack of conceptual clarity and vagueness on what vulnerability is was first noted in the mid-1990s (Cutter 1996) and is articulated in 68 reviewed articles. Writing over a decade ago, Janssen and Ostrom (2006) identified a “Babylonian confusion” of definitions, methodologies, and approaches to vulnerability, reflecting how different disciplines have independently defined and studied vulnerability (Cutter 1996). Vulnerability remains a contested concept, with a plethora of alternative and sometimes competing definitions and approaches, each focusing on different dimensions of vulnerability while sidestepping others, and advocating different policy positions. Several papers argued that such confusion hampers understanding and learning and constrains the potential for comparative analysis and meta-synthesis. Attempts have been made to clarify vulnerability definitions and approaches, with articles teasing out dominant themes in vulnerability research, developing glossaries of key terms, and creating integrative frameworks (Adger 2006; Burton et al. 2002; O’Brien et al. 2007; Turner et al. 2003). While there still remains little consensus about its precise meaning—and the success of studies seeking to bring clarity to vulnerability research is debatable—there is agreement that vulnerability denotes susceptibility to harm, and is composed of exposure, sensitivity, and adaptive capacity. Moreover, some view the diversity of vulnerability research as indicative of strength and vitality, bringing multiple perspectives on potential vulnerability trajectories (Adger 2006; Preston et al. 2011; Ford et al. 2015a, b). In this view, rather than striving for a unified approach to vulnerability, researchers should be aware of the diverse approaches that exist, and be explicit about the concepts they use.

### 3.4 Concern #4: vulnerability research neglects cross-scale interactions

Community-based case studies have long been promoted as the scale of analysis for vulnerability research, helping to develop a rich understanding of how human and biophysical stresses interact to affect vulnerability in specific places (Cutter 1996; Hewitt 1983; Smit and Wandel 2006; Turner et al. 2003). While central to vulnerability research, 56 of the articles reviewed express concern that vulnerability neglects cross-scale interactions. It has been argued that an overreliance on community-based case studies limits the ability to form generalizations (Bennett et al. 2016; Birkenholtz 2012); that emphasis on the individual and specific is drawing attention away from broader sociopolitical determinants of vulnerability (Bennett et al. 2016; Birkenholtz 2012; Ingalls and Stedman 2016; Keskitalo 2009); and that case studies downplay understanding of cross-scale interactions and teleconnections, risking potential policy irrelevance and/or promotion of maladaptive practices (Adger et al. 2009; Birkenholtz 2012; Cameron 2012; Eakin et al. 2009; Leichenko et al. 2010). These concerns

are evident in some of the studies we reviewed. For instance, of the 324 papers in the review profiling case studies, 130 (40%) focus on the local level, 49 (15%) were cross-scale, and 145 (45%) focus on the non-local (i.e., regional or national). While the role of cross-scale dynamics and interactions in affecting local vulnerability is the least considered in the studies reviewed, they have nevertheless been long acknowledged and interwoven in the vulnerability literature (Adger 1999a; e.g., Bohle et al. 1994; Kelly and Adger 2000; Räsänen et al. 2016; Turner et al. 2003). A parallel focus on how community-level response to change affects other communities, regions, or ecosystems, directly or through feedback with larger level processes is largely absent (Adger et al. 2009; Eakin et al. 2009; Snorek et al. 2014; Turner 2010).

### 3.5 Concern #5: vulnerability research brings a passive and negative framing

Fifty of the reviewed articles expressed concern that vulnerability research is disempowering and paints affected peoples as passive victims. First documented in the early 2000s (Barnett and Adger 2003), there was spike in articles presenting this concern in 2013 and 2016. This critique centers on the tendency in vulnerability research to focus on the negative impacts of climate change (Bene et al. 2016, 2014; Bennett et al. 2016). The labeling of populations or regions as “vulnerable” by external actors has also been problematized (Barnett and Adger 2003). In the context of research with Indigenous peoples, it has been noted that the vulnerability label may hinder efforts to gain greater autonomy by focusing on the negative, can result in victimization, and promotes external interventions that reflect non-Indigenous worldviews and notions of progress (Bates 2007; Cameron 2012; Haalboom and Natcher 2012; Hall and Sanders 2015). A focus on the harmful impacts of climate change is a characteristic of many of the vulnerability articles reviewed, but other arguments on the passive/negative framing have less support. In vernacular usage, “vulnerability” captures the condition of being vulnerable and is associated with harm and susceptibility. In scientific usage, vulnerability is an approach for understanding the dynamics and drivers of change, central to which is a focus on concepts such as entitlements, coping, and adaptive capacity (Adger 1999b; Sen 1981; Turner et al. 2003). Vulnerability approaches thus do not a priori denote a negative focus but rather seek to understand the social and ecological conditions and processes that shape risk. This distinction is rarely made in studies critiquing vulnerability terminology, where vulnerability research is often conflated with the labeling of populations or regions as being “vulnerable.” Ribot (2011) further challenges concerns over terminology, acknowledging that “words matter” but arguing that while people are not passive in the face of change, many people are in fact victims of circumstance, and vulnerability captures the underlying drivers of exclusion, marginalization, disempowerment, and inequality (Cannon and Muller-Mahn 2010; Gronlund 2014; Leach and Scoones 2013; Luna 2014; Wolf 2015).

### 3.6 Concern #6: vulnerability research has had limited influence on decision-making

Vulnerability research takes place in a diversity of decision contexts, with the aim of identifying opportunities for adaptation, assessing funding needs, developing fundamental scientific understanding, and/or identifying areas for further research (Smit et al. 1999; Moss et al. 2013). The effectiveness of vulnerability research in informing decision-making for risk reduction is specifically questioned in 44 articles reviewed. From a political science perspective, it has been argued that vulnerability research has had limited policy uptake due to a superficial treatment of institutions and politics (Birkenholtz 2012; Wellstead et al. 2013;

Wise et al. 2014). Wellstead et al. (2013) argue that governance is treated in rational-functional terms in vulnerability research, with recommendations to enhance adaptive capacity rarely examining actual implementation processes. Others note how a focus on overcoming barriers to adaptive capacity—a common focus in empirical vulnerability articles—have “reduced complex and highly dynamic decision-making processes into simplified [and] static statements about why current outcomes are ‘incorrect’” (Biesbroek et al. 2015). Thus, recommendations for vulnerability reduction in some instances are infeasible or impossible to implement in light of decision-making realities, lie outside the mandate of organizations at whom proposed adaptations are targeted (Bunce et al. 2010; Keskitalo 2009, 2010), or are not conducted at a scale appropriate for relevant decision-making contexts (Miller and Bowen 2013).

### 3.7 Concern #7: vulnerability research takes place in disciplinary silos

Despite the purported strengths of vulnerability research in integrating climatic and non-climatic factors, 41 articles reviewed argue that studies continue to view vulnerability from a specific disciplinary specialization, epistemologically framed by the social, engineering, health, or biophysical sciences (Ford et al. 2015; McDowell et al. 2016; Singh et al. 2017). Each approach contributes unique understanding, with a strong disciplinary base important for knowledge generation, varying by context. For example, studies on infrastructural vulnerability that seek to influence design guidelines require engineering-based technical information on the vulnerability of specific infrastructural assets and performance under different climate scenarios. “Siloed” thinking, however, risks providing incomplete understanding on vulnerability (Castree et al. 2014; Murphy 2011); for the previous example, the effectiveness of infrastructural vulnerability assessments depends also on an understanding of decision-making and governance structures and not just technical information.

This review documents that qualitative and quantitative focused vulnerability studies are typically disengaged from each other. This is particularly notable for modeling of future climate scenarios, where vulnerability concepts have substantial potential to contribute to the development of pathways and scenarios that are more nuanced and better integrate social dynamics. When vulnerability research has employed quantitative methods, it has typically done so through social surveys of perceptions and experiences with climate change, or via the creation of indices and indicators (Jurgilevich et al. 2017; McDowell et al. 2016). Much vulnerability research considers future climate projections and historic data to compliment local observations of climate change, but studies operationalizing vulnerability quantitatively or integrating vulnerability into climate change modeling beyond crude pathways models remain rare. We found few papers that included vulnerability approaches and climate modeling within an integrated methodology, or that attempted to quantify the dynamics of vulnerability empirically. Among papers that do employ quantitative modeling of climatic and social factors, sociodemographic variables are typically treated as covariates of changing climate rather than factors that dynamically interact with (and effect modify) climate impacts. This is despite a long-standing qualitative and theoretical recognition that climate impacts will interact with—not just be additive to—existing social dynamics. It is notably difficult to integrate (primarily local) vulnerability factors with (primarily global or regional) climate modeling, yet this is the type of research that is both lacking and being called for in the literature. There is promise and potential in emerging efforts to use locally important environmental factors identified through vulnerable research to inform selection of more specific variables for



climate projections, and in exploring the interaction of social and weather variables in local contexts (Jankowska et al. 2012; Huang et al. 2015; MacVicar et al. 2017).

## 4 Discussion

This article identifies, characterizes, and evaluates concerns over the use of vulnerability approaches in climate change research. As researchers who have been actively engaged in vulnerability research since the early 2000s, we were motivated to write the paper after being consistently challenged and asked to justify our use of vulnerability approaches. With limited scholarship identifying or engaging with the various discontents of vulnerability, we found ourselves (and our students) questioning the utility and appropriateness of using vulnerability approaches. Based on the review, we find some of the seven concerns weakly justified, but others pose valid challenges to vulnerability research. We feel, however, that these challenges are related more to how the concept of vulnerability has been operationalized rather than fundamental shortcomings of vulnerability research per se. In the discussion, we identify challenges and opportunities for vulnerability research in the face of these concerns.

Addressing the first challenge area requires a new generation of empirical studies. Conceptual understanding of vulnerability is generally well-developed—albeit with the need for enhanced conceptualization of how vulnerability is produced and evolves over time—but empirical studies typically do not advance beyond a generalized understanding of current or future exposure, sensitivity, and/or adaptive capacity. Priorities for future work include the following:

- *Methodological development*: new methodologies offer the potential for vulnerability research to better capture the dynamics of human-environment relationships, feedbacks, and cross-scale applications of findings (concern #2, 6, and 7). Longitudinal study design and vulnerability monitoring, for instance, involve repeat observation of human-environment interactions over extended periods of time (Archer et al. 2017; Fawcett et al. 2017, 2018). Longitudinal methods are commonplace in the biophysical and health sciences, but there are few examples in vulnerability research. Community-based monitoring, involving local people to collect data on a problem or outcome on a regular basis, can be used to examine vulnerability processes over time. Scenario planning, commonly employed in the sustainability literature (Oteros-Rozas et al. 2015), can be used to expand current understandings of vulnerability by including future climate change scenarios and socioeconomic projections to examine vulnerability in the future (Shaw et al. 2009) (Flynn et al. 2018). Taken together, these and other advancements in methodologies can move current vulnerability research from static assessments of risks and responses, to capture the processes that influence how people experience and respond to changing conditions and how these evolve over time.
- *Collaborating on future scenarios modeling*: there is significant potential for vulnerability research to inform future scenarios work that is currently dominated by quantitative climate modeling, where there are still substantial challenges to integration of non-climatic social drivers (Birkmann et al. 2015; Hallegatte et al. 2011). While there have been efforts to consider social drivers across scales and to downscale Shared Socioeconomic Pathways, climate data (primarily temporally variant except at broad scales, and typically available regionally/globally) are often poorly aligned with available social data

(primarily spatially variant except over long time scales, and typically highly local). The result has been siloization of research to advantage either climate or social drivers—but not both—within methodological approaches, at the expense of meaningful consideration of the importance that their interactions play in driving vulnerability (concern #1). Opportunities for better integration of vulnerability approaches into quantitative modeling are numerous, yet require meaningful collaboration across disciplines (concern #7). Impacts research that focuses on estimating associations between meteorological variation and incidence of disease, for example, rarely model non-climatic factors as interacting (or effect modifying) variables. Doing so would significantly alter our understanding of changing risk, our ability to project impacts, and opportunities for identifying and modeling adaptation options. Appropriate understanding of vulnerability dynamics is in many cases well developed but often poorly diffused to relevant disciplines outside of vulnerability (concern #3). Similarly, vulnerability research has limited engagement in the ways in which climate change affects local weather and environmental variance, typically assuming that local weather variables are direct and reasonable proxies for climatic variables changing over time. Infusion of lessons and insights from vulnerability on the ways in which social systems mediate relationships with weather and climate will be critical in the development of better future projections.

- *Re-imagining case studies*: community-based case studies will continue to be central to vulnerability research, but new approaches to the use of case study findings are required (concern #2 and 4). In particular, there is a need for meta-analyses which draw upon multiple case studies to identify broad determinants of vulnerability and vulnerability processes across scales and sectors; this has already begun in some highly researched areas (Ford et al. 2010; Lopez-i-Gelats et al. 2016; Tucker et al. 2015). There is a need for case studies at the regional and national scale to compliment the community-focused work that has dominated to-date, with nested case studies proposed as one way to identify determinants of vulnerability at multiple scales (concern #4) (Adger et al. 2009; Keskitalo 2010).
- *Learning from past research*: foundational work on vulnerability from the twentieth century has often been overlooked in contemporary thinking, but there is much to learn by re-engaging with this scholarship. Methodologically, a greater focus on the long-term historic processes creating vulnerability is essential for developing a richer understanding of the dynamics that shape vulnerability, representing a set of completed historical experiments on climate-society interactions (concern #1, 2, and 3) (McLeman et al. 2007; McLeman 2011; Nelson et al. 2016). Such temporal analogues were characteristic of early work in the field (Glantz 1988, 1990), but have not been widely utilized in research from the last decade.

Multi-year funding will be needed to catalyze the next generation of empirical vulnerability studies, and methodologies based on longitudinal assessment and real-time monitoring will require considerable commitment from participants and researchers. Making use of big data offers opportunities for managing such challenges (Ford et al. 2010), although inevitably, it will not be possible to utilize such methodologies in all regions globally. Selecting specific locations or regions that are representative of broader socio-ecological systems for rolling out next-generation empirical studies can help manage the breadth-depth trade-off and develop new insights that can be scaled up (e.g., guided by archetypes of vulnerability (e.g., Sietz et al., 2017)).

The second challenge area concerns how vulnerability research is designed. On the one hand, there is a need for greater collaboration across disciplines (concern #7). Such collaboration can happen in a variety of ways and may be (i) *interdisciplinary*, involving working across disciplines to provide an integrated outcome, involving the co-design of projects and integration of multiple methods to address shared objectives, and is particularly important for capturing the dynamic nature of vulnerability, identifying vulnerability thresholds, and systems modeling of vulnerability; (ii) *multidisciplinary*, where research teams work towards a common goal drawing on knowledge from different disciplines but staying within their boundaries, and is important for studies focusing on specific sectors and which seek to operationalize vulnerability quantitatively or integrate vulnerability into climate change modeling beyond crude pathways models; or (iii) *transdisciplinary*, involving transcending academic boundaries and incorporating different ways of knowing into vulnerability research (e.g., indigenous/local knowledge) and engaging in how knowledge is used, and is particularly important for studies taking place in cross-cultural contexts and where projects have strong focus on informing decision-making.

While the importance of working across boundaries is recognized and promoted with vulnerability research (e.g., PROVIA, Future Earth, EU Horizon 2020), many collaborations struggle to truly bridge the disciplines (Brown et al. 2015; Murphy 2011), with fundamental challenges reflecting the different ways in which vulnerability is defined and approached in different disciplines, and how research is funded (concern #3). Targeted funding calls are important to promoting collaboration across disciplines, along with a need for researchers to be aware of the diverse approaches to assessing vulnerability that exist. Practical “bottom-up” actions to catalyze collaboration and networking are also required, through for instance, workshops, project exchanges, web-based platforms, the development of communities of practice, and mentorship (Ford et al. 2015; Pittman et al. 2016) (Turner et al. 2016). We also recognize that discipline-based climate change research is still critical to vulnerability research, bringing multiple perspectives on potential vulnerability trajectories (Adger 2006; Ford et al. 2015).

Related to collaboration across disciplines, emphasis on linking research to the practical realities of decision-making is essential if future vulnerability research is to have enhanced impact (concern #6). While knowledge co-production and the creation of usable science are widely promoted in vulnerability research, few of the studies we reviewed actually examined the success or the failure of vulnerability assessments in affecting decision choices, documenting the needs and perspectives of knowledge users, or characterizing the context in which the information was applied.

By engaging with the seven discontents on vulnerability, we are confident that vulnerability research continues to have a strong future. Vulnerability research leads us to ask critical questions such as why people and places are vulnerable (or not); direct attention to local agency, power, and scale; emphasize dynamic and complex interactions between climate change and society; and draw upon a rich and varied intellectual history. If vulnerability research is to regain the influence it had in the first decade of the twenty-first century, however, it will need to rediscover its dynamism. The challenge areas proposed here illustrate broad developments needed to strengthen vulnerability research and enhance its relevance to researchers, practitioners, governments, and communities. It is up to the vulnerability community to meet the challenge.

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