Focus Article

The dynamics of vulnerability: why adapting to climate variability will not always prepare us for climate change

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Recent reports and scholarship suggest that adapting to current climate variability may represent a 'no regrets' strategy for adapting to climate change. Addressing 'adaptation deficits' and other approaches that target existing vulnerabilities are helpful for responding to current climate variability, but we argue that they may not be sufficient for adapting to climate change. Through a review and unique synthesis of the natural hazards and climate adaptation literatures, we identify why the dynamics of vulnerability matter for adaptation efforts. We draw on vulnerability theory and the natural hazards and climate adaptation literatures to outline how adaptation to climate variability, combined with the shifting societal landscape can sometimes lead to unintended consequences and increased vulnerability. Moreover, we argue that public perceptions of risk associated with current climate variability do not necessarily position communities to adapt to the impacts from climate change. We suggest that decision makers faced with adapting to climate change must consider the dynamics of vulnerability in a connected system—how choices made in one part of the system might impact other valued outcomes or even create new vulnerabilities. We conclude by suggesting the need for greater engagement with various publics on the tradeoffs involved in adaptation action and for improving communication about the complicated nature of the dynamics of vulnerability.

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INTRODUCTION

Reducing vulnerability and, therefore, negative outcomes from climate stressors and weather-related disasters have been a persistent topic in disaster risk management discussions. One of the prominent views that has emerged in recent years from convergence of the disaster risk reduction and climate change adaptation literatures is that if we could adapt better to present climate variability and extremes—i.e., address the 'adaptation deficit'—we could significantly reduce the impacts of future climate change.[1–3] The concept has been specifically applied within the water sector,[4] it partly drove the logic behind the Intergovernmental Panel on Climate Change (IPCC) report 'Managing

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the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation' (SREX), and is discussed in the most recent Working Group II volume of the Intergovernmental Panel on Climate Change Report (IPCC AR5 WGII; Refs 3, 5)

A decade ago, when adaptation was still a peripheral component of climate policy, scholars began the difficult work of grappling with the complex dynamics of vulnerability by accounting for risks that may be experienced at different timescales, by different populations, or in different sectors or parts of a system.[1,6–9] Since then, climate adaptation research has moved far beyond a 'taboo' topic[10] and is rapidly growing.[11] Furthermore, in the time since many of the studies of the dynamics of vulnerability were first conducted, the notions of 'low regrets' and even no regrets measures, many of which are aimed at existing climate variability, have gained currency in policy circles as a means of approaching adaptation in the face of future climate uncertainty.[3,5]

There are several slightly varying definitions for no/low regrets options: according to the SREX report they are 'decisions that have net benefits over the entire range of anticipated future climate and associated impacts'(Ref 3, p. 56). In another report they are actions 'worthwhile in their own right, independent of climate considerations' (Ref 12, p. 67). This framing may result in actions that do not 'perform optimally in any particular scenario' but are perceived to provide net benefits given the large uncertainties about future climate (Ref 3, p. 56). Lempert and colleagues have developed the 'robust decision-making strategy' to identify options that are maximally insensitive to uncertainties, including uncertainties in future climate scenarios.[13,14] Wilby and Dessai advanced a framework for selecting low regrets options as those that 'reduce vulnerability under the present climate regime, whilst being socially acceptable, technically and economically feasible given the prevailing regulatory environment' (Ref 15, p. 182). Hallegatte has refined the concept to hypothesize varying levels of no/low regrets actions depending on how the action might be supposed to perform under various climate scenarios.[16] Finally, as some authors have clarified, no/low regrets does not necessarily mean low cost or no opportunity costs.[15,17,18] Table 1 summarizes the types of adaptive actions suggested to be no/low regrets from two recent IPCC assessments (SREX, IPCC AR5 WGII)—the degree to which these reflect actual implementation examples varies from source to source. Some are hypothetical examples whereas in other cases, the actions have actually been taken by communities and thus may be perceived at least at the outset as no/low regrets.

In this Focus Article, we argue that there is a need to revisit the claim that adapting to current variability will automatically lead to reducing vulnerability to climate change. While such actions indeed may be no regrets in terms of addressing well-known vulnerabilities in our current climate, there is no guarantee that these decisions will be sufficient for reducing vulnerability or building resilience to climate change. It is possible of course that current adaptations may build future resilience, but we simply do not yet have the evidence for either of these claims to be made with confidence. There are at least three reasons that we felt this review was warranted: (1) there is a growing emphasis in the last decade on merging development, disaster risk reduction, and climate change adaptation practice and the no regrets strategy has been advanced as a practical way of integrating these fields, (2) no regrets rhetoric has been widely applied as a basis for policy and planning efforts, despite the fact that there has been little empirical examination or measurement of such efforts to actually test whether no regrets strategies provide the 'win-win' outcomes with respect to climate change that are claimed, and (3) there was a push to complexify the dynamics of vulnerability in the early- to mid-2000s, though this literature appears to have been largely excluded from no regrets argumentation. Given the increase in attention to adaptation in the policy realm at multiple scales, we argue for a more nuanced approach to adaptation policy recommendations, with more emphasis on the complex dynamics of vulnerability and the need for a flexible, learning approach rather than the simplified solution that the term 'no regrets' implies. Indeed, the challenge of adaptation is not solvable by any one approach, and transparency and nuance is essential in dialogs about policy choices with respect to climate change.

This article reviews selected literature across natural hazards and climate adaptation fields to explain why the dynamics of vulnerability matter for climate adaptation, and how these dynamics challenge the notion of no/low regret actions. We begin by reviewing the arguments for why adapting to climate variability is a step toward adapting to climate change. We summarize the existing recommendations for actions in these circumstances. We then review the changing context for vulnerability and arguments for why it is difficult to anticipate how actions taken to reduce vulnerability to current climate variability will affect vulnerability to future climate change. We conclude with a call for more discerning and transparent examination of risks, uncertainty, and tradeoffs in adaptation decision making.

TABLE 1 | Summary of No/Low Regrets Examples and Discussions in IPCC 2012 and IPCC 2014

Low Regrets Cited in IPCC 2012 (SREX) Report	
No/Low Regrets Element	**Description**
• Early warning systems • Risk communication between decision makers and local citizens • Sustainable land management including land use planning • Ecosystem management and restoration	SPM (from chapter 6)—'most commonly cited measures' that the SREX reviewed)—stated that they also provide 'co-benefits; help address other development goals, such as improvements in livelihoods, human well-being, and biodiversity conservation; and help minimize the scope for maladaptation'
• Improvements to health surveillance, water supply, sanitation, and irrigation, and drainage systems • Climate proofing of infrastructure • Development and enforcement of building codes • Better education and awareness	SPM citing: [5.3.1, 5.3.3, 6.3.1, 6.5.1, 6.5.2] See also Case Studies 9.2.11 and 9.2.14, and assessment in Section 7.4.3.
• Chapter 1: Learning examples: single- and double-loop learning processes. • Chapter 6: better forecasting and warning systems, use of climate information to better manage agriculture in drought-prone regions, flood proofing of homesteads, or interventions to ensure up-to-date climatic design information for engineering projects	Section 9.2 provides examples of single- and double-loop learning processes. Enhancing public health response capacity, augmenting early warning systems, and applying known strategies for protecting health from the threat of extreme heat in new settings—had demonstrable impacts on heat related mortality, quickly shifting a region's coping range with regard to extreme heat (Section 9.2.1).
• Disaster preparation	Countries have started to adopt 'no or low regrets' strategies that generate short-term benefits as well as help to prepare for projected changes in disaster risks, even when robust information is not available (see Section 6.3.1). Included in these 'no or low regrets' strategies are ecosystem-based strategies that not only help reduce current vulnerabilities and exposure to hazards under a range of climatic conditions, but also produce other co-benefits such as improved livelihoods and poverty reduction that help reduce vulnerability to projected changes in climate.
Addressing the underlying drivers of vulnerability as one of the most effective 'low or no regrets' measures	An approach to managing disaster risk in the context of a changing climate highlights that disaster risk management efforts should seek to develop partnerships to tackle vulnerability drivers by focusing on approaches that promote more socially just and economic systems; forge partnerships to ensure the rights and entitlements of people to access basic services, productive assets, and common property resources; empower communities and local authorities to influence the decisions of national governments, NGOs, and international and private sector organizations and to promote accountability and transparency; and promote environmentally sensitive development. (see Figure 6–3 and Table 6–5 in FAQ 6.1). Such underlying drivers of vulnerability include inequitable development; poverty; declining ecosystems; lack of access to power, basic services, and land; and weak governance.

TABLE 1 | Continued

Low Regrets Cited in IPCC 2012 (SREX) Report	
No/Low Regrets Element	**Description**
• Addressing the underlying drivers of disaster risk	Section 6.5.2 lists following headings: 1. Applying technological and infrastructure-based approaches (mostly hard infrastructure discussion and tech) 2. Human development and vulnerability reduction (low evidence base, but some indication that social safety nets, cash transfer payments etc. are working in some areas to reduce poverty) 3. Investing in natural capital and ecosystem-based adaptation (potential, low evidence base)—discussion of mangroves and coastal vegetation helping to blunt the effect of coastal storm surge Such actions are effective irrespective of projected changes in extremes of weather or climate (see Section 6.5.2).
Low regrets cited in IPCC AR5 WGII • Changes in land use planning; • Sustainable land management; • Ecosystem management; • Improvements in health surveillance, water supplies, and drainage systems; • Development and enforcement of building codes; • Better education and awareness.	AR5 Chapter 1 referencing the SREX SPM, 5.3,1, 5.3.43, 6.3.1, 6.5.1, 6.5.2, 7.4.3 and Case Studies 9.2.11, 9.2.14

METHODS

We conducted an extensive literature review on vulnerability from our different disciplinary perspectives, focusing on the fields of climate adaptation and natural hazards. Our goal was to focus specifically on a subset of literature that could support or refute the claim that adapting to current climate variability would reduce vulnerability to future climate change, and to understand how that claim has been measured and tested in the field (for a literature review on 'no regrets' more broadly see Preston and colleagues[19]). We searched for key words related to vulnerability in academic search engines, and included articles focused on vulnerability to climate variability or climate change using the key words: vulnerability, climate, indicators, and dynamics. We then narrowed down our list of articles to target those that specifically focused on dynamics of vulnerability, or no/low regrets. This focused sample included over 150 articles, book chapters, and reports primarily over the past three decades.

In addition, we searched the electronic versions (using the document reader program's search function) of the 2012 SREX report and all chapters of the new 2014 IPCC AR5 WGII report for all mentions of no or low regrets to reveal the most recent assessment of the concept as represented in the literature as reviewed by a large team of experts on climate change adaptation (in the case of the AR5) and hazards (in the case of SREX) and reviewed all of the supporting literature for no and low regrets actions included in these reports.

We then integrated arguments from this body of literature to develop a synthesis of how adapting to climate variability has been advanced as an argument, and reviewed reasons from the literature about how the dynamics of vulnerability make simple prescriptions about no/low regrets actions problematic.

RESULTS AND DISCUSSION

Why Adapting to Existing Climate Variability Has Been Advanced as an Argument to Adapt to Climate Change

Several threads of reasoning have driven a focus on climate variability as a locus for adaptive action instead of future climate as predicted by climate models. Schipper and Pelling state that 'a number of scholars agree that, for all practical purposes, such as policy design, the distinction between natural variability (including extreme events) and incremental variability due to climate change is trivial, and hence responding to existing variability will initiate the necessary actions to respond to climate change' (Ref 20, p. 29). Furthermore, it is asserted, 'actions taken today to reduce vulnerability—actions which have been justified for a long time—will increase resilience and security by providing a buffer against vulnerability to future consequences of climate change'(Ref 21, p. 15). The argument is also made that climate change projections themselves are uncertain, particularly at the scales which they would be of use to decision makers.[15,22] Progress on reducing the uncertainty of projections is by no means guaranteed, and therefore, adaptation strategies that rely on 'top down' climate projections may be waiting for improvement in science that is slow to come or reflect unrealistic assumptions about the kinds of information climate science can provide. Wilby and Dessai suggest that focusing on existing climate variability offers a more practical and reliable way to reduce vulnerability to climate.[15]

As Dovers states, implementing well-developed proposals to manage climate variability may get us 'halfway to a believable adaptation response without having to think too hard' rather than facing a 'disturbing blank canvas' as we would if we tried to discern among adaptation choices for climate change in an uncertain future (Ref 23, p. 4–5). Furthermore, he argues, extremely vulnerable populations are not likely to be concerned with reducing their vulnerabilities to future climate change when their existing vulnerability is so acute, therefore, it makes sense to focus on existing vulnerability to climate variability.[23]

It is also argued that reducing the vulnerability of the poor specifically with respect to disasters and extreme events, will improve outcomes in the long run for climate change. The argument is that existing climate variability is disproportionately hard on the already vulnerable, can exacerbate existing inequality, and can create a cycle of vulnerability. Therefore, if we address existing vulnerability to extreme events, we can at least prevent some of the poverty traps that are created by repeated exposure to extreme events.[17]

Finally, in regions where climate change is a polarizing and politically challenging issue (e.g., Ref 24), engaging the public and decision makers to respond to current climate variability may be the only practical way to discuss action to reduce climate vulnerability. Here, the argument goes, some dialog around climate is better than none, and actions to reduce vulnerability to existing climate extremes is a place to start.

Why It Is Difficult to Anticipate that Adapting to Current Climate Variability Will Reduce Vulnerability to Future Climate Change

Vulnerability to climate can be conceptualized as a function of exposure ('conditions of the natural and built environment that position a system to be affected' by climate), sensitivity ('the degree to which a system is affected' by climate stressors), and adaptive capacity ('the ability of a system to modify its features and behaviors to better manage' climate) (Ref 25, p. 3). Reducing vulnerability means addressing at least one, and sometimes two or all three of these components. Adaptation can be considered successful if it avoids harm in the short term and does not undermine the capability for responding to harm in the future,[26] although empirical literature operationalizing or evaluating what constitutes successful adaptation is rare.[11,27,28] Vulnerability can also change over time, and the 'landscape of risk' itself can shift in unpredictable ways, including changes in chronic stresses and cumulated effects of more frequent events.[29] Belliveau et al.[30] expand the notion of vulnerability to include dynamic feedbacks from adaptations to one set of risks, which in turn may expose the system to other risks that either were not present before or to which the system was less sensitive.

While we do not yet have much experience of how adaptations have performed in actual climate change, we do have over 60 years of study of hazards mitigation and its outcomes. Global loss of life from extreme events has decreased over the past 50 years[31] stemming from, e.g., stronger building codes, early warning systems, zoning, protective structures, water diversions, and retaining mechanisms, food storage, and transportation systems, and so on. However, economic losses have dramatically increased, independent of hazard occurrence, because of increasing wealth in many areas, growing population, human migration patterns, and other societal changes.[32–36]

It is clear, then, that the societal context in which climate is experienced changes over time and can dramatically affect vulnerability. Population and demographic trends, advances in technology, or changes in institutions, attitudes, or behaviors[9,32,33] shape the exposure, sensitivity, and adaptive capacity of societies and systems. Direct and indirect linkages between changes in population and vulnerability have been recognized.[32,34] In the most basic sense, changes in the location and concentration of human settlements directly shape vulnerability, making populations or assets more or less exposed to weather- and climate-related hazards. Changes in urbanization patterns, including concentration of high-value development, can result in increasing economic losses even when the number and intensity of extreme weather or climate events has not changed over time.[35–37]

Therefore, we cannot assume that response to a particular physical stress at a particular point in time will still be effective as the societal landscape changes. This is not to say that such measures do not have value, but rather that we need to think of adapting as a dynamic, iterative process.

Why Adaptations to Climate Variability Can Increase Vulnerability

Adaptations to current climate variability change the context for vulnerability and can even introduce new sources of vulnerability into the system. They can also introduce sources of resilience, as argued in the no/low regrets literature cited above. In the next section, we give examples that illustrate how adaptations to climate variability can change each of the components of vulnerability: exposure, sensitivity, and adaptive capacity.

Adaptations to Climate Variability Change Exposure and Sensitivity

Especially over the past century, as engineering skills and technologies have advanced, structural responses to natural hazards have become common. While effective in many cases at reducing losses, structural responses can also increase the exposure of people to extreme events, leading to increased vulnerability. For example, land in the floodplain is increasingly occupied and developed as flood protection structures are built.[38,39] The influx and growth of development in what, but for the presence of the protective structures, is a hazardous location has become known as the 'levee effect.'[40,41] Protective structures serve to reduce the vulnerability of the population within a certain range of flooding. However, given 'fat tails' of natural event distributions, a more intense event is likely to eventually overwhelm the protective structure, exposing a much greater population to disaster than would have been there if the structure were not in place. In fact, flood losses have continued to increase in the United States and elsewhere[42,43] in the presence of both protective structures and insurance programs, leading some analysts to question the efficacy of these policies.[31,39,44] The key dynamic at play in the levee effect is not that the hazard changes, but that the adaptation itself draws more people and assets into harm's way. On the positive side, the population has use of a desirable area that would otherwise be uninhabitable in the absence of the protective structure.[44]

Similar to the levee effect, technological and social systems developed to cope with recurrent climate variability can in some cases increase vulnerability by creating the potential for catastrophic failure.[45,46] An example of this phenomenon is the suppression of smaller wildfires in the United States which has paved the way for larger, catastrophic wildfires. Simultaneously, more Americans seek the amenities of living in the wildland–urban interface, leading to rapid increases in the population at risk.[47] Highly technical systems place more emphasis on sophisticated control and management, and expose adaptations to the failure mode known as 'normal accidents'[48] where small mishaps or failures propagate through tightly coupled systems to cause widespread and/or catastrophic failures. Cases of 'controlled floods' gone awry below reservoirs designed to reduce both flood and drought illustrate the potential for loss in such finely tuned systems.[49,50]

Institutions can help in mediating the impacts of climate-related hazards.[51,52] This can include both formal (e.g., local government, laws, and regulations) and informal (e.g., customs and cultural norms) institutions, although the two are intertwined. Institutions ultimately determine how resources are distributed within societies and, depending upon how equitable those distributions are, can serve either to improve or worsen levels of collective or individual vulnerability.[7] For example, it has been argued that the U.S. National Flood Insurance Program (NFIP) may have the perverse effect of increasing vulnerability to flood events through the underestimation of risk and inability to effectively encourage home-owners living in flood-plains to maintain their insurance coverage.[39,53,54] The subsidization of flood and crop insurance, while intended to enhance the ability to cope with environmental hazards, may increase exposure to the perils of flood damage and crop failure.[55] Given these examples, it is difficult to say with certainty whether policies undertaken to address current vulnerability to extreme weather and climate may better position societies or systems to respond to future climate change.

Adaptations Change Adaptive Capacity

The logic behind no/low regrets adaptation, especially the recommendation to better adapt to current, well-known variability rather than to future, uncertain change, raises the question of trade-offs between robustness and flexibility[56] and between uncertainty and commitment to adaptation.[16] Essentially, the 'adapt better to current climate' prescription calls for robustness now, ignoring the potential loss of future flexibility. Yet, the literature stresses the importance of flexibility—the ability to change when conditions warrant—as a key indicator of adaptive effectiveness.[57] Adaptations to short-term variability may reduce flexibility to respond to future hazards by precluding options, expending scarce adaptive resources, and locking systems into path-dependent policies.

Adaptations that not only fail to reduce vulnerability but actually also increase it are referred to as 'maladaptations'(Refs 58, p. 990; 59). Barnett and O'Neill[60] identify several means by which maladaptation can occur in the context of climate change. For example, an adaptation that 'commit[s] capital and institutions to trajectories that are difficult to change in the future' might lead to 'decreased flexibility to respond to unforeseen changes in climatic, environmental, economic and social conditions'(Ref 60, p. 211). They argue that building a desalination plant that relies on carbon-based electricity is an example of a maladaptation because it locks in dependency on an energy-intensive water source that increases greenhouse gas emissions, which will exacerbate drought, the very condition that the plant was intended to relieve. It has been argued that past societies such as the Maya or the Viking colonists in Greenland were maladapted because their centers of population grew through overexploitation of local resources; they found themselves unable to cope with extreme climate fluctuations and ultimately collapsed.[59] Trajectories of maladaptation based on current patterns of adaptation to variability have been identified among subsistence communities in the Solomon Islands and Iqaluit, Nunavut.[61,62]

Individual and institutional risk perceptions are important factors mediating a system's adaptive capacity as they affect the tendency to take precautionary measures and to support adaptation policies. While the influences on behavior are complex, risk perception does matter in determining how individuals respond to climate change.[63–65] Moreover, risk perception can suffer either attenuation or amplification,[66] resulting in under- or over-investment in adaptation.[67] In disaster management and planning, many stakeholders anchor their risk perceptions in present-day hazards. In a study of Australian drought and bush fire vulnerability, Preston et al.[68] showed that stakeholders maintained their established perceptions of present-day risk even when they were presented with climate change scenarios and additional sources of information. Similar to other hazards, drought vulnerability studies often evaluate risks and responses based on historical observations and present-day environmental and social characteristics.[69] Incorporating climate change into analysis of drought vulnerability requires shifting the focus to future risks, which in turn requires analysis of exposure, sensitivity, and adaptive capacity over time.[70,71]

Dessai and Sims[72] examined risk perceptions and behavioral changes of water users in the United Kingdom, finding a lack of congruity between people's concerns about the risks of climate change and recognition of warmer, drier summers, and their willingness to accept measures to mitigate the impacts of climate change that would impinge on their finances or current practices. If we link the concepts of responding to climate change with how we respond to climate variability, we may find perceptions do not serve to achieve sufficient adaptive behavior.

Furthermore, natural hazards research suggests that techniques designed to cope with disasters do not necessarily build the necessary adaptive capacity for climate change. Coping can be defined as the less comprehensive 'adjustments people make to deal with existing weather stressors' (Ref 25, p. 3). This can be distinguished from true adaptation, which is 'long-term or fundamental changes people make to systematically reduce potential harm (or take advantage of opportunities) from changing weather stressors' (Ref 25, p. 2). As Handmer et al.[73] suggest, the goals and incentives for emergency managers and others tasked with preparing for and helping society cope with disasters do not necessarily support addressing the underlying vulnerabilities that create potential for disaster in the first place. For example, emergency responses such as evacuation, while effective in saving lives in a disaster, do not necessarily address underlying maladaptations, such as having populations living in a flood zone. Handmer et al.[73] suggest that emergency management may delay effective adaptation, as its very short-term effectiveness masks the signal that provokes societies into making more fundamental structural changes.

Climate Change Is Projected to Produce Different *Exposures* than Existing Climate Variability

As assessed by the IPCC, climate variability itself has begun to change and is expected to continue to change in the future as greenhouse gases accumulate in the atmosphere.[74] Changes may occur in the means, ranges, frequency, or timing of climate variables such as precipitation or extreme heat.[75] Atmospheric science theory and modeling indicate that changes across distributions of climate variables will not be linear; extremes may change more and faster than shifts in means suggest.[3,76,77] Evidence for shifts in extremes is emerging in some areas, but is contested and certainly not uniform.[3,78,25,79] As Naess et al. suggest, these changes present 'largely unpredictable challenges' especially at the local level (Ref 80, p. 125). Water engineers are taught the concept of stationarity, meaning that 'natural systems fluctuate within an unchanging envelope of variability'[81]; (e.g., in the water sector, allocation strategies as well as drought plans are based on drought of record). If adaptation strategies are targeted at current or recent climate variability, they may not be well suited for future climate change, as has been suggested for water resource management.[81]

In addition, a newer interpretation of thresholds in climate change has emerged around the theme of tipping points or tipping elements in the Earth system.[82–84] In this case, the threat is not shifts in climate variability, or even the frequency and severity of extremes; it is a matter of switching to a fundamentally different climate state. In this case, human systems will have to consider more transformational change to cope with the new suite of climate and weather-related hazards.[85–87] For example, Orlove has suggested that adaptation strategies currently being promoted for glacier-fed villages in the Andes are unsuitable to a future lacking glaciers.[88]

Adjustments to Other Stressors Can Lead to Increased *Sensitivity* to Existing Climate Variability

Finally, climate is only one of many stressors that cause people to adapt.[89] Addressing one source of vulnerability, or a particular stressor, specific to a particular time, place, system, sector, or stimulus, may not be effective in reducing vulnerability to other factors.[90] Moreover, one set of adaptations may reduce certain vulnerabilities, while exposing other parts of the system to other sources of vulnerability, to which there is a greater degree of sensitivity or less adaptive capacity.[30,91] For example, grape-growers in British Columbia adapted to changing consumer demands by replacing low-quality, winter-hardy grape varieties with higher-quality varieties that were particularly sensitive to cold weather.[30] In another case, charcoal production in Ghana was used as an adaptive strategy to supplement farming and fishing livelihoods, which had become increasingly threatened by changes in climate. It was discovered, however, that shifting to charcoal production increased vulnerability at longer time horizons through increased forest extraction and resource degradation.[89] In a third example, intensified planting of cash crops as an adaptation to land scarcity and uncertain markets in Bolivia heightened sensitivity to climate-related stressors, such as frost events, variable precipitation, and frequent hail storms, all of which could increase under future conditions of climate change.[26,92]

The Problem of Identifying No Regrets

Relying on adaptation to existing climate vulnerability as a no/low regrets strategy is problematic as well because of limitations in our ability to fully measure and understand dimensions of vulnerability across space, time, and potentially affected people.[89,93,94] Drawing the boundary for analysis at too short of a timescale, too narrow of a population group, too isolated a portion of a system or sector, or too small of a spatial scale can result in failure to anticipate where vulnerability may be created through adaptive action. For example, case studies in Peru and Northeast Brazil demonstrated that climate forecasts intended to alleviate the effects of drought in those regions during El Niño events actually exacerbated conditions for some of the poorest workers and farmers as higher capacity organizations on which the poor depend, such as banks and employers, protected themselves from the clarified risk.[95] In India, vulnerability of agricultural producers to climate variability was made uneven due to trade liberalization policies, which benefitted some farmers, while bankrupting others.[96] Indeed, as Preston et al.[19] suggest, 'whose regret' is being considered is not always clear, and not every stakeholder is likely to have the same view about what would constitute decisions they would or would not regret.[24] These challenges to the identification of no/low regrets can also apply to measures aimed at coping with current climate variability, although we would argue that existing hazards research does offer some insight into the outcomes of adaptation to current climate.

As Preston et al.[19] also suggest, heuristics have a useful place, but a more robust critique and engagement is necessary in order to make the concept of low/now regrets usable for practitioners of adaptation. While it may appear that no/low regrets strategies empower stakeholders to act in the face of uncertainty, they may instead create an overly optimistic sense of efficacy, by implying that adaptation is easy, cheap and will do the whole job of positioning us well for climate change.[97]

The Dynamics of Vulnerability and Moving Forward

Adapting to current climate variability is necessary and has been essential for the success of human populations. Furthermore, there is certainly room for improvement in infrastructure, governance arrangements, behavior, and other mechanisms to respond to existing climate variability. However, the dynamic nature of vulnerability across time and space suggests that efforts to adapt to climate change by better adapting to current climate variability may not be as effective as some of the discourse on adaptation implies. Adaptation decisions can have unintended consequences both for the system in question and for people or ecosystems who are connected directly or indirectly to the outcomes of actions. Emerging vulnerabilities created by changes in the system may not be evident by examining the system only at a current time slice—some vulnerabilities created by past decisions may only be revealed after more time has passed. This problem is unavoidable in practice—one is always looking at the state of the system from a particular point in time with an uncertain future ahead. We therefore cannot assume that the vulnerability of the system as a whole is reduced by any particular action to address climate variability. Rather, we might do better to envision vulnerability as a dynamic construct that is constantly shifting as decisions are made and environmental and social conditions change. The challenges raised in this article point to the need for, at the least, a critical evaluation of any no regrets prescription, and perhaps even a rethinking of research and practice with respect to adaptive actions.

Researchers and practitioners should recognize that any measure of vulnerability is both tentative and likely to quickly become anachronistic. The adaptation literature has recently emphasized concepts such as resilience and sustainability, but we should also incorporate forward-looking notions of risk trade-offs, the possibility for unintended consequences, flexibility and malleability of adaptation choices, and path dependencies when developing frameworks for adaptation research and practice. Thinking of the provision of water, energy, food, shelter, recreation, and livelihoods as interrelated, integrated goals may help to anticipate how changes in one part of the system may affect another critical part. The dynamics of vulnerability also remind us that climate change is but one stressor in a complex suite of stressors and moving goals, and that efforts to reduce vulnerability in the system overall must consider how these stressors interact.[9]

Rather than thinking that the ultimate goal of producing knowledge is to find the best policy prescription that will stand the test of time, or even that will produce 'no regrets,' researchers and practitioners alike may need to consider policy actions as experiments with uncertain outcomes that need to be revisited on an ongoing basis—and communicate them to stakeholders as such. Learning is an essential adaptation process[3] but even more important is changing how decisions about risk are framed by decision makers for various publics. As uncertainty increases, and the dynamics of vulnerability become more difficult to anticipate, policy outcomes will be more uncertain as well. Rather than seeking the ever-elusive certainty of climate predictions or promises of failsafe policy prescriptions, decision makers could engage with various publics as to what is known and unknown about their state of risk exposure and the efficacy of various adaptation alternatives, and set expectations that policies will need to be evaluated and revisited on an ongoing basis.

As Verweij et al.[98] suggest, 'success' in adaptation requires engaging multiple value orientations, and devising 'clumsy solutions' which will be satisfactory, if not optimal, across various worldviews. Yet, doing so will require thinking outside of the confinements of 'status quo' or 'business as usual' approaches to dealing with climate risks that may be perpetuated by reliance on no regrets strategies alone. Mechanisms are lacking to encourage various publics to contemplate risks and trade-offs across longer time scales, and to counteract the path dependency created by existing but ineffective policy processes in order to forge new opportunity spaces (e.g., Ref 99). Developing roadmaps for how communities can systematically evaluate their own vulnerabilities in linked systems, engage in open dialog and anticipate how various decisions along a path may affect overall vulnerabilities would appear to be a fruitful avenue for exploration.

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